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# Defining Practical Guidelines for Evaluating Long-term, Smallholder Decision-making in Developing Countries

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Australian Centre for International Agricultural Research

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# Defining Practical Guidelines for Evaluating Long-term, Smallholder Decision-making in Developing Countries

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# 1 Defining practical guidelines: the problem

## *1.1 Introduction*

Upon developing a new agricultural technology, national agricultural research services (NARSs) and international agricultural research centres (IARCs) need to determine whether the innovation will provide long-term, sustainable benefits to their targeted stakeholders, usually smallholder farmers in developing countries. To determine this, researchers employ private investment analysis to assess the net benefits to smallholders of adopting the new technology. Private investment analysis often concludes that investments with distant future benefits, such as resource conservation, pasture improvement and livestock breeding programs, are not profitable because the short-term costs outweigh the long-run benefits. Yet, it is not uncommon to find smallholders making long-term investments of this type. This apparent contradiction between investment analysis and investment behaviour suggests there may be flaws in the methods used to assess private investment decisions in such contexts.

The problem with the standard method of investment analysis is that it may not properly account for how smallholders in developing countries value their own (non-monetary) labour and capital costs and how they value future outcomes. In standard investment analysis, non-monetary benefits and costs are converted into monetary (cash) terms using a seemingly appropriate measure, such as market wage or rental rate. In developing countries, however, the opportunity costs of labour and capital, such as bullocks or tractors, may be near zero, unobservable, or simply difficult to estimate due to the presence of imperfect or failed labour and capital markets. Opportunity costs may also vary significantly through the year due to the seasonality of production. Using costs associated with a harvest period may not be appropriate for the off-season. Furthermore, in these circumstances a premium is placed on cash since market imperfections make cash a scarce commodity. In this context, using the market wage or rental rate for non-monetary costs and putting a cash value on these inputs may overestimate the costs of projects. Additionally, by assuming that all activities can be directly converted to cash assumes that the value of these activities may be discounted in a manner similar to cash, which for standard analysis is done using the interest rate on borrowed funds. However, given the premium placed on cash in these economies, such an assumption may be incorrect. Future outcomes from these activities may need to be evaluated using an alternative method.

In valuing future outcomes, discounting is used to convert future costs and benefits into present values. The discounting of future values is done using the opportunity cost of cash, the return on alternative investment, or preferences in the timing of personal consumption (Perrin 1972). The appropriate method to use depends on assumptions about the functioning of markets and individual behaviour. Often the opportunity cost of cash is taken to be appropriate and the actual discount rate used is the interest rate on borrowed funds. This approach implies an assumption of perfect credit markets. However, rural credit markets in developing countries often do not function properly. The interest rates on savings, if saving with a bank is even possible, are often substantially lower than the interest rates on borrowed funds, which are often extremely high. The disparity between savings and borrowing rates is a clear indication of the imperfection in rural credit markets. Furthermore, smallholders are often limited in both the level and time horizon over which they can borrow, even at prevailing interest rates. Therefore, while discounting at the cost of credit may be reasonable in situations where financial markets work well, it is likely to be misleading in rural areas of

developing countries where such markets are limited or absent. If the high rates charged on farmers' borrowing are used in discounting, few long-term investments will appear profitable.

If an inappropriate method for evaluating smallholder investment is employed, then the wrong technologies may be selected for promotion. Researchers run the risk of two significant errors, which are highlighted in Figure 1. Type I errors occur if a project is rejected that would have been profitable to smallholders. Type II errors occur when projects are accepted and smallholder adoption encouraged even though the projects will not prove profitable. These errors lead to costly misallocation of limited resources for NARSs and IARCs and potentially also for their smallholder clients. The objective of private investment analysis for research planning is to predict smallholder behaviour accurately by minimising the possibility of type I and type II errors. For projects with short-term costs but long-term benefits, such as those noted above, the standard private investment analysis system of converting values to cash and discounting using local interest rates on borrowing is likely to result in type I errors.

**Figure 1. Errors in project selection.**

| ***Technology selection*** | ***Technology profitable*** | |
|---|---|---|
| | *Yes* | *No* |
| *Accepted* | ✓ | **Type II error** |
| *Rejected* | **Type I error** | ✓ |

The flaws in the standard analysis suggest that there is room to improve the analysis and reduce the possibility of errors. Yet there are no comprehensive guidelines on how better to deal with these issues. For example, a publication by the International Maize and Wheat Improvement Center (CIMMYT 1988) discusses problems in valuing the opportunity cost of labour but not discounting, while McConnell and Dillon (1997) discuss the relevance of 'subjective' interest rates but do not attempt to estimate these and all their subsequent examples use a standard 10 per cent interest rate. Determining an appropriate rate for discounting is the more difficult issue, so we turn now to this problem.

### *1.2 Discounting*

The problem of market failure in identifying the appropriate rate to use in discounting is not confined to private investment analysis; the same applies in public project appraisal. For example, in one of the texts that helped to standardise the way projects are appraised around the world, Dasgupta, Sen and Marglin (1972) noted the problem of capital market imperfection. It is worth quoting directly from their discussion, even though the context is slightly different:

> In fact, the problem with this approach lies much deeper than the multiplicity of market rates of interest. For this approach assumes a rational, calculating basis for

> individual decisions on saving and borrowing, a basis that remains, after many years of econometric research, a hypothesis supported more by the preconceptions of the its authors than by empirical observations. The reasons for these preconceptions are not hard to find. The whole structure of welfare economics, which traces its intellectual ancestry to Adam Smith, requires the assumption of a rational, calculating 'economic man' to justify market outcomes. So intertemporal rationality must be assumed to justify the rate of capital accumulation dictated by market forces in a capitalist economy. … Actually, observable data no more support the notion of rationality, calculation and planning in individual decisions as saving and borrowing than they do the contrary hypothesis.
>
> The viewpoint taken here is that the customary treatment of intertemporal choice, which permits one to infer the social rate of discount from rates of interest that individuals earn on what they save or pay for what they borrow, is a misplaced application of the theory of consumer choice. (Dasgupta et al. 1972, p. 158)

These authors argue that the reason for differential weighting of consumption at different times occurs only because of the diminishing marginal utility of consumption in any one time period in conjunction with the expectation that per capita consumption will rise over time. After dismissing the capital market as a reliable source of information on the appropriate weights for valuing future consumption, they examine other ways of determining the social discount rate, reaching the conclusion that policy-makers must determine this parameter by making an implicit or explicit value judgment. Noting the extreme difficulty in making such a judgment, they conclude their discussion as follows:

> Benefit–cost analysis can sharpen the focus of policy makers' intervention in project evaluation, but it cannot as yet reduce this process to a routine that, once set in motion by appropriate value judgements on the part of those politically responsible and accountable, would—like the universe of the deists—run its course without further interference from the top. (Dasgupta et al. 1972)

It might be better if those routinely undertaking project appraisals gave more attention to this warning than they appear to do. Although the context is different, the conclusion should also cause those undertaking private investment analysis of the kinds that are the focus of this study to pause and ponder before they automatically adopt the cost of borrowing as the appropriate rate of discount.

Perhaps one reason for this seemingly careless disregard on the caution urged by Dasgupta, Sen and Marglin is that most project appraisals for major international development agencies such as the World Bank are conducted using a slightly different, but supposedly equivalent, method developed by Little and Mirrlees (1974). They substitute the accounting rate of interest (ARI) for the social rate that Dasgupta, Sen and Marglin use. The ARI is that rate which ensures that all mutually compatible projects whose present social value is positive, and only those, are undertaken. Moreover, the rate should be set so that the projects so chosen collectively use just the amount of investment funds allocated, no more or less (Squire and van der Tak 1975). In other words, the ARI is simply a device for rationing funds across projects. That, of course, begs the question of how much should be allocated to project investment. Little and Mirrlees do not sound the same warnings about the choice of discount rate, claiming that the accounting rate can be more objectively estimated.

In considering the relevance of the debate outlined above to private investment appraisal in smallholder agriculture, it should first be noted that the project appraisal methods discussed depend on the assumption that each project is small relative to the size of the national economy. The equivalent may not necessarily be the case in smallholder agriculture where an investment in, say, land development, may substantially influence household income and welfare. In other words, a method of appraisal for smallholder investment should be applicable to both marginal and non-marginal investments. That seems to imply that private investment appraisal should be done in a whole farm-household context, comparing with and without investment scenarios. Only in this way can potential impacts of household welfare be properly appreciated.

The project appraisal literature provides some insights into establishing a theoretical basis for valuing future outcomes in smallholder agriculture and developing methods for improving the evaluation of smallholder investment decisions. As the remarks of Dasgupta et al. (1972) quoted above suggest, this task is not likely to be easy and requires careful consideration.

### *1.3 Initial steps: feasibility and dominance analysis*

Before continuing, it is appropriate here to suggest that some initial steps be taken before conducting formal private investment analysis. In particular, we suggest that two steps be taken before embarking on further analysis. First, the *feasibility* of the innovation should be considered and second the *dominance* of the potential innovation should be considered.

For the *feasibility analysis*, the first step is to use all the information available to budget out, for a range of representative farm-households, whether the uptake of innovation is likely to be feasible. For example, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) proposed the use of a toolbar technology for smallholders. In evaluating the technology they found technical and credit infeasibilities—the oxen were found to be too weak at the end of the dry season to break the ground, and lending limits on institutional credit were set less than the cost of the toolbar. Given this was the case, the innovation was clearly not feasible and further analysis unnecessary. This stage of analysis then involves, *inter alia*: 1) assessing what cash can be generated by farmers and how much might be spared for investment; 2) what credit is available at what costs and with what limits on access and use; and 3) how much labour could be made available without unacceptable losses in income or food production etc. A number of proposed innovations are likely to be ruled out in this process. Thus, a careful feasibility-testing phase may avoid at least the worst errors that may be made by research organisations in promoting technologies that will not work.

There is much more that could be done to develop better methods for feasibility testing of innovations. It is apparent that the process should be a continuing one as research on some particular prospective innovation is developed and refined. The testing should be an integral part of on-farm testing that is incorporated into farming systems research programs. Too often, we suspect, the provision of free or subsidised inputs from the research station to farmers participating in on-farm trials may mask constraints that would otherwise be apparent. Yet the practice of supplying inputs or other help is usually considered necessary by researchers to secure farmer cooperation. Moreover, there may be great variability in the population of farmers and it may be difficult to assess what is possible and what is not for certain farmers. Some may have relatively abundant labour and others may be short of family labour, and the same applies to cash and other resources. Clearly, undertaking effective feasibility testing is complex and outside the scope of this paper. It is, however, something that we believe deserves more attention in future than it has received in the past.

The second step, *dominance analysis*, comes for those prospective innovations that pass the feasibility test. In this step, we want to test whether a future for the farm with the innovation would dominate—in a household welfare sense—a future without that innovation. Where there may be alternative innovations or alternative ways of implementing a particular innovation, we want to know whether some options are clearly better than others in terms of their impacts on household welfare. Doing this requires examining how the consumption patterns of adopting households would be changed over time after recourse to labour capitalisation, borrowing and repayment etc. Clear dominance occurs when the household is, or could be, better off in every time period, present and future. Only if there are losses in immediate welfare to obtain future gains in welfare do we even need to think about formal evaluation methods such as discounting. In some cases, certain innovations may be clearly dominant so that further analysis is unnecessary.

Like feasibility analysis, there are many practical and applied issues in dominance analysis that require more consideration. We conceive it as a process that starts with a careful documentation of the inputs and outputs associated with uptake of the proposed innovation, and a similarly careful examination of the opportunities for farm households to use financial, labour and other markets. For the simplest case of 'with versus without' a proposed innovation, the analysis would involve examining whether the available market opportunities could be used to make the household better off in each period. Of course, it would be necessary to think about how variability between farms is to be dealt with, and there is also the vexed question of risk to be considered (which we largely ignore). While in theory it might be possible to extend the type of dominance we have in mind to some form of stochastic dominance, we think it more likely that some simpler, more heuristic rules would meet the case. Again, however, this is a topic that needs to be left for future work.

### *1.4 Outline*

As noted, the objective of this paper is to establish a theoretical basis for valuing future outcomes in smallholder agriculture in developing countries and to consider methods for improving the evaluation of smallholder investment decisions. Towards this end, we start by examining how smallholders make long-term investment decisions. As a basis for understanding this decision, in section 2 a model is presented for understanding smallholder decision-making when markets are functioning perfectly. As part of this discussion, simulations of household behaviour are presented. Section 3 begins with a discussion of the market imperfections that tend to exist in rural areas of developing economies and how these imperfections influence smallholder decision-making. A model is then presented which considers smallholder investment decisions in the presence of market imperfections. In section 4, evidence in support of the proposed approach is presented based on information gathered from a case study done in the Philippines. Based on the earlier model and the case study, in section 5 some suggestions are offered to improve smallholder investment analysis. Section 6 presents conclusions.

## 2 Smallholder investment decisions under perfect markets

### *2.1 The model under perfect markets*

The first step in understanding smallholder investment in activities with future outcomes is to consider the investment decision when markets function perfectly. Towards this end, a

mathematical model of investment behaviour is presented in Appendix 1. The first model in the appendix focuses on investment decisions when markets operate perfectly and relates to the case of household investment in land improvement. This section begins with an overview of that model. While household land improvement will be used as the example for this study, the results are applicable to other long-term investments.

Consider a smallholder household that receives utility from food, cash goods and leisure and seeks to maximise utility from these commodities over two periods. Utility is maximised subject to cash income, production technology and labour time constraints in each period. The household uses cash to buy cash goods, food (if necessary), and labour (if desired). The household receives cash if it sells some of its agricultural production (food) or sells its labour at a prevailing market rate. Assuming the credit market functions perfectly, the household can shift cash from one period to the other by saving or borrowing at the market interest rate. In addition to the cash constraint, the household is also constrained by the agricultural production technology that is available. Agricultural output depends on the amount of labour dedicated to production and a fixed amount of land. Furthermore, the household is able to enhance agricultural production in the second period by investing in land improvement in the first period. Productivity gains depend on the amount of labour invested in land improvement. Finally, the household is constrained by the total time available in each period. Total family labour can be allocated to leisure or productive activities including agricultural production, land improvement and the labour market. As shown in Appendix 1, these three sets of constraints (cash, production technology and labour time) can be written as a single constraint in each period. The following equations then represent the household's maximisation problem:

$$\underset{X_a^t X_c^t X_l^t L_a^t L_I B}{Max} \; U\left(X_a^1, X_c^1, X_l^1\right) + \beta U\left(X_a^2, X_c^2, X_l^2\right)$$

subject to:

$$p_c X_c^1 = p_a\left(Q(L_a^1, H) - X_a^1\right) - w\left(L_a^1 + L_I - T + X_l^1\right) + B$$

$$p_c X_c^2 = p_a\left(A\left(L_I\right)Q(L_a^2, H) - X_a^2\right) - w\left(L_a^2 - T + X_l^2\right) - (1 + r)B$$

where: $X_a^t$ = food consumed in period *t,* $t = 1, 2$

$X_c^t$ = cash goods consumed in period $t$

$X_l^t$ = leisure consumed in period $t$

$\beta$ = discount factor for utility

$p_a$ = price of food

$p_c$ = price of cash goods

$w$ = market wage

$L_a^t$ = total labour input in agricultural production in period $t$

$L_I$ = labour invested in land improvement in period 1

$T$ = total household labour available

$B$ = amount of money borrowed if positive, or saved if negative, in period 1

$r$ = interest rate on cash

$Q(L_a^1, H)$ = production function for period 1 where $H$ is the available land

$A(L_I)Q(L_a^2, H)$ = production function for period 2 where $H$ is the available land and $A(L_I)$ represents the land improvement technology

As noted in section 1, Dasgupta et al. (1972) argue that the differential weighting of consumption at different times occurs because of the diminishing marginal utility of consumption in any one time period in conjunction with the expectation that per capita consumption will rise over time. A further consideration that might affect the weighting of future utility is the uncertainty associated with receiving utility. To factor these into a model would lead to unnecessary complications. Instead, a discount factor for utility, $\beta$, is included in the model to show that households weight consumption differently over different periods. This does not imply, however, that households are necessarily time impatient, but rather that there are factors that may lead households to weighting utility differently in different periods.

The first-order conditions for the optimal solution to the utility maximisation problem can be used to explore household investment in land improvement (see Appendix 1 for details). Manipulating the first-order conditions yields the following equation:

$$w = \frac{1}{(1+r)}\left( p_a \frac{\partial A(L_I)}{\partial L_I} Q(L_a^2, H) \right)$$

This result indicates that investment in land improvement occurs provided that the discounted (by the market interest rate) marginal value of land improvement is greater than the market wage. At the optimal solution, households invest to the point at which the market wage is equated to the discounted marginal value of land improvement. Investment in land improvements is discounted by the cash interest rate, which in these circumstances is the opportunity cost of capital. Based on this equation the following can be noted:

1. The higher the market wage in period 1, the lower the labour investment in land improvement.
2. The higher the cash interest rate, the lower the labour investment in land improvement.
3. The higher the price of agricultural output, the greater the labour investment in land improvement.
4. The greater the productivity gains from labour investment in land improvements, the higher the investment.

Since labour markets are assumed to function perfectly, household labour can readily be converted to cash via agricultural production or wage labour. Investment in these activities will occur until the value of the marginal product of labour is equal to the market wage. If the household wishes to shift cash from one period to the other it can do so at a given interest rate. Any activity with a future benefit, such as land improvement, must then be discounted by the interest rate since generating cash using labour is the alternative investment opportunity. Of course, this assumes that the credit market functions perfectly, which requires the following conditions: no barriers to entry; no participant can influence the interest rate; transactions are costless to complete; information is widely and freely available; credit services are homogenous; no distorting taxes exist; and investment opportunities are perfectly divisible (Robison and Barry 1996).

To further understand the results of the model, manipulating the first-order condition yields the following relationship for leisure across the two periods:

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_l^1} = (1+r)\beta \frac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_l^2}$$

These results indicate that households chooses a level of leisure in each period that weights the marginal utilities of leisure across the two periods by the relationship between the discount factor and the market interest rate. This same relationship holds for the consumption of food and cash goods. Consumption across the two periods is dependent on the relative weighting of utility and the ability to shift cash across the two periods through the market interest rate.

Finally, we can consider the relationship between the consumption of leisure and the use of labour from the following relationship:

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_l^1} \frac{1}{\lambda_c^1} = p_a \frac{\partial Q(L_a^1, H)}{\partial L_a^1} = w$$

This equation shows the standard production relationship where the value of the marginal product of labour is equal to the wage rate. It also shows the relationship of both the wage and the value of marginal product to leisure. Households equate the marginal utility of leisure weighted by the reciprocal of the cash constraint (the price of consuming leisure instead of working) to the value of the marginal product of labour and so to the wage rate.

### *2.2 Simulations with perfect markets*

To further explore the private investment decision and the factors that influence this decision, simulations were run based on the mathematical model presented above. To run these simulations, functional forms and parameters had to be determined as well as specific values for constraints and initial values. Tables 1a, 1b and 1c provide details on the model specification. The model was kept as simple as possible to aid transparency. The data values used were chosen to give solutions that were plausible for a smallholder household with limited land and capital. However, neither the model nor the values chosen is intended to represent any particular situation. Rather we are concerned to note how the model solutions change in response to changed specifications. It would obviously be desirable to extend the model to some real farm-households, but this was too demanding a task to be undertaken with time and funds available for this pilot project.

**Table 1a. Functions.**

| | ***Function*** | ***Specification in simulation*** |
|---|---|---|
| Utility function | $U\left(X_a^t, X_c^t, X_l^t\right)\ t = 1, 2$ | Stone-Geary function |
| Production on unimproved land, period 1 | $Q(L_a^1, H)$ | 75 units of labour input/ha ➔ 1 tonne of output/ha |
| Improvement in land productivity | $A\left(L_I\right)$ | 46 units of labour input/ ha ➔ improves land |
| Production on unimproved land, period 2 | $Q(L_a^2, H)$ | 75 units of labour input/ha ➔ 1 tonne of output/ha |
| Production on improved land, period 2 | $A\left(L_I\right)Q(L_a^2, H)$ | 75 units of labour input/ha ➔ 1.5 tonne of output/ha |

**Table 1b. Starting values and constraints used in calculating base result.**

| | ***Variable*** | ***Unit*** | ***Initial value*** | ***Constraint*** |
|---|---|---|---|---|
| Household food needs | $X_a^t$ in period $t = 1, 2$ | t | 0.52 | >0.5 |
| Leisure | $X_l^t$ in period $t = 1, 2$ | units | 22 | >20 |
| Cash | $X_c^t$ in period $t = 1, 2$ | $ | 35 | >30 |
| Land area | $H$ | ha | 1.5 | <1.5 |
| Total family labour | $T$ | units | 250 | <250 |
| Borrowing | $B$ | $ | 0 | <100 |
| Saving | $-B$ | $ | 0 | <100 |

**Table 1c. Parameters.**

| | ***Parameter*** | ***Unit*** | ***Value*** |
|---|---|---|---|
| Price of grain sold/bought | $p_a$ | $/t | 100 |
| Price of hired/sold labour | $w$ | $/unit | 1 |
| Utility discount factor | $\beta$ | % p.a.[a] | 0.95 |
| Interest on credit/savings | $r$ | % p.a.[a] | 5 |

[a] % p.a. = percentage per annum

Note: there is no price of cash since cash is measured in monetary terms.

The utility function used is the Stone-Geary function which is additive in logs and includes minimal values for each consumption item. The household is assumed to require minimal quantities of food (0.5 tonnes), cash goods ($30) and leisure (20 units) in each period. Agricultural production is modelled as a Leontief production technology in which a fixed quantity of labour per hectare (75 units/ha) yields a specific level of output (1 tonne/ha for unimproved land). A lower quantity of labour employed yields proportionately less output. Improving land by investing labour time in period 1 shifts the productivity of the land in period 2. A certain amount of labour time (46 units/ha) is required to improve one hectare of land. If land is not improved then productivity does not change and the food production technology is the same in period 2 as in period 1. If land is improved then a given amount of labour input (75 units/ha) yields a higher level of output (1.5 tonnes/ha) than for unimproved land. The specification of agricultural production is then assumed to be linear, which is done to simplify the problem. The drawback of this specification is that it tends to lead to discreet changes in behaviour. That is, changes in parameters can lead to dramatic shifts in household activities. While this is unlikely to reflect reality exactly, the model is useful in evaluating the role of particular parameters on household behaviour, which, as stated above, is the purpose of this research.

Households are assumed to have 1.5 hectares of land and to be constrained by that fixed quantity of land. Initially they are assumed to have no improved land but can improve all the land that they own using labour. The household has 250 units of labour available for agricultural production, wage labour, improving land and leisure. Assuming markets function perfectly, the selling and buying price of grain are the same as are the buying and selling wage rates for labour. The discount factor for utility is set at 0.95 and the interest on credit/savings at 5% per annum.

Based on this specification, the optimal solution to the household's utility maximisation model was determined. The results of the base model, along with a number of other runs, are presented in Table 2. In the first period, the household sells 14% of its productive labour to obtain income, uses 13% of productive labour to improve approximately 30% of land and uses 73% of productive labour to produce grain. The selling of labour suggests that the household has excess labour (as we intended in formulating the model) and the marginal benefit of allocating more labour to land improvement or to production would be less than the market wage. The benefits of the investment in land come in the second period when agricultural output increases by 50% on the land that was improved (0.44 ha) and revenue increases by the same percentage (since prices are fixed). Part of this second period windfall in income is brought to the first period through the credit market. The household borrows a substantial amount of cash (15% of cash consumed) against the expectation of this future income allowing the household to consume more commodities in the first period. In the second period, the household sells a substantial quantity of labour while still using most of its productive labour on agricultural production.

The remaining runs in Table 2 examine how changes in a number of parameters change the results of the base model. The primary aim of this exercise is to determine how changes in these factors influence the investment in land improvements. Runs I and II show the effects of a change in the price of grain (food). A 20% rise in the price of grain increases investment in land improvement because it enhances the return to investment by increasing the value of grain production in period 2. For that particular increase, the household improves all the land at that food price and uses hired labour and borrows more cash to make the investment. Correspondingly, a decrease in the price of food reduces investment in land improvement.

**Table 2: Response of smallholder investment to changes in model parameters**

| | | unit | | grain price ($) | | labour price ($) | | labour/ha required for land improvement (units) | | labour/ha required for crop production on unimproved land (units) | | labour/ha required for crop production on improved land (units) | | interest rate (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 100 to 110 | 100 to 90 | 1 to 1.10 | 1 to 0.90 | 46 to 44 | 46 to 50 | 75 to 60 | 75 to 90 | 75 to 60 | 75 to 90 | 5 to 10 | 5 to 0 |
| Run number | | | base | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| *Year 1* | Crop-Unimproved land | ha | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| | Land improved | ha | 0.44 | 1.50 | | | 1.50 | 1.50 | | | 1.50 | 1.50 | | 0.06 | 1.05 |
| | Hire labour | units | | 35.51 | | | 33.24 | 27.55 | | | 49.54 | 34.57 | | | 3.22 |
| | Sell Labour | units | 20.71 | | 45.18 | 42.31 | | | 38.13 | 54.15 | | | 38.59 | 37.19 | |
| | Buy grain | t | | | | | | | | | | | | | |
| | Sell grain | t | 0.72 | 0.73 | 0.67 | 0.66 | 0.73 | 0.70 | 0.70 | 0.63 | 0.74 | 0.66 | 0.70 | 0.74 | 0.68 |
| | Borrow | $ | 15.98 | 69.21 | | 1.78 | 61.46 | 64.86 | | | 81.20 | 81.22 | | | 51.01 |
| | Save | $ | | | 3.14 | | | | | 1.09 | | | 0.14 | 0.09 | |
| | Eat grain | t | 0.78 | 0.77 | 0.83 | 0.84 | 0.77 | 0.80 | 0.80 | 0.87 | 0.76 | 0.84 | 0.80 | 0.76 | 0.82 |
| | Leisure | units | 96.73 | 104.01 | 92.32 | 95.19 | 101.74 | 99.05 | 99.37 | 105.85 | 95.54 | 103.07 | 98.91 | 97.42 | 92.25 |
| | Cash | $ | 108.71 | 113.99 | 102.17 | 114.80 | 104.50 | 106.93 | 107.84 | 115.77 | 105.58 | 113.08 | 108.77 | 110.64 | 116.10 |
| *Year 2* | Crop-Unimproved land | ha | 1.06 | | 1.50 | 1.50 | | | 1.50 | 1.50 | | | 1.50 | 1.44 | 0.45 |
| | Crop-Improved land | ha | 0.44 | 1.50 | | | 1.50 | 1.50 | | | 1.50 | 1.50 | | 0.06 | 1.05 |
| | Hire labour | units | | | | | | | | | | | | | |
| | Sell Labour | units | 37.41 | 30.20 | 43.19 | 42.48 | 30.51 | 38.28 | 39.39 | 52.81 | 41.91 | 56.93 | 38.34 | 35.16 | 37.99 |
| | Buy grain | units | | | | | | | | | | | | | |
| | Sell grain | t | 0.90 | 1.46 | 0.67 | 0.67 | 1.46 | 1.41 | 0.69 | 0.63 | 1.49 | 1.41 | 0.71 | 0.73 | 1.22 |
| | Eat grain | t | 0.81 | 0.79 | 0.83 | 0.83 | 0.79 | 0.84 | 0.81 | 0.87 | 0.76 | 0.84 | 0.79 | 0.80 | 0.81 |
| | Leisure | units | 100.09 | 107.30 | 94.31 | 95.02 | 106.99 | 99.22 | 98.11 | 107.19 | 95.59 | 103.07 | 99.16 | 102.34 | 99.51 |
| | Cash | $ | 110.99 | 118.34 | 106.54 | 111.60 | 109.09 | 111.26 | 108.24 | 116.57 | 105.58 | 113.07 | 109.08 | 108.61 | 108.62 |

Runs III and IV examine the effects of changes in the wage rate. In the base run, the household is selling labour to obtain cash. A rise in the wage increases the return to selling labour, raising the opportunity cost of land improvement, and thus leads to a reduction in investments with future returns. Furthermore, the household ceases to borrow much cash since cash is available through the labour market. On the other hand, a 10% reduction in the wage rate leads the household to shift from selling to hiring labour and to improve all the land in the first period, since this investment leads to a higher return than selling labour. Note also that borrowing is much higher than in the base run since the household is bringing the returns to investment forward and using the cash to hire labour.

As runs V and VI show, the model is extremely sensitive to changes in the labour required for land improvement. All other things being equal, if the labour requirement for land improvement is greater than 49 then no land is improved and if it is 44 or less then all land is improved. The sensitivity to this parameter is the result of the linear specification of the model. When the labour requirements for land improvement are low (<45) then the household expands borrowing and hires labour to improve land. When the labour requirements for land improvement are high (>49) then the household ceases borrowing and sells more labour.

Runs VII and VIII and IX and X show, respectively, the effects of changing the labour requirements for food production on unimproved and improved land. A reduction in the labour requirement for crop production on unimproved land, all other parameters remaining the same, decreases investment in improved land because the benefits of improving the land are lower. Correspondingly, increasing the labour requirement for production on improved land has the same effect. Similarly, an increase in the labour requirements for production on unimproved land or a decrease in the labour requirements for production on improved land increases the investment in land improvement. The results show that the relative labour requirements for production on unimproved and improved land affect the investment decision. If the returns to land improvement can be enhanced then investment is more likely.

Finally, runs XI and XII examine land investment when the interest rate rises, keeping the discount factor unchanged at 0.95. Recall that in the base run, households borrow funds to bring forward the returns to land improvement. The results indicate that even a moderate rise in the interest rate leads to a substantial reduction in land investment, limits borrowing and induces a small amount of savings. When the interest rate is higher than the discount factor, then savings begin to occur since the return to savings is greater than the discounting of utility in the second period. A reduction of the interest rate (run XII) has the opposite effect of increasing borrowing and land improvement. Credit plays an important role in investment.

The model and the simulations suggest that investment analysis, while influenced by a number of factors, is relatively straightforward when markets function well. The household acts as a price taker and makes decisions based on market prices. The wage rate, price of crops, labour requirements for production and land improvement, influence on productivity of land improvements and interest rates all influence the smallholder investment decision. With sufficient information on prices, the production technology and future returns to investment, evaluating the investment decision follows standard procedures of using market rates for wages and interest rates for discounting.

# 3 Smallholder investment decisions in the presence of imperfect markets

## *3.1 Market imperfections and smallholder agriculture*

The previous section examined the household's investment decision in the presence of perfect markets. In this section, the household's investment decision when markets are imperfect is examined. The two markets considered most important in the context of private investment analysis for smallholders are the labour market and the credit market. Before discussing these specific market failures, the functioning of markets in rural areas of developing countries is discussed.

While many economic models assume that markets function perfectly, smallholders in developing countries typically operate in an environment that is characterised by market failures in both product and factor markets. While markets may not exist at all, it is typically the case that the market exists in some form. However, the market might fail for a particular household because of the wide price margins between the selling and buying price of products and inputs, including labour. Sadoulet and de Janvry (1995) identify the following factors that influence the margin between the buying and selling price:

1. *Transaction costs*. If local infrastructure is poor and markets far away, then transportation costs can be high. Local monopoly power can create high marketing margins. Imperfect information can result in high search and recruitment costs for hired labour. Limited incentives can require employers to supervise hired labour. Each of these costs of transactions influences buying and selling costs.

2. *Shallow local markets*. If local markets are shallow it implies a high negative correlation between household supply and effective prices. If the harvest is good then the price is low as most households in the local market also have a good harvest. If there is a drought then prices are high but output low. Even with changes in the price, the household may stay self-sufficient.

3. *Price risk and risk aversion*. The greater the level of price risk and the higher the risk aversion, the wider the effective price band. This is because the certainty equivalent for the selling price is lower than the expected selling price and the certainty equivalent for the buying price is higher than the expected price.

One of the key features of market imperfections is that they are contagious—a failure in one sector is likely to lead to imperfections in other sectors (Ray 1998). For example, credit market failure may lead households to be cash poor and to seek opportunities to earn cash beyond what might be normally desirable. Resources are then diverted to compensate for failure of the credit market. The more flexible markets then tend to adjust to compensate for the failings of other markets, implying further market imperfections.

In such a context—where there are one and more market imperfections—it is difficult to evaluate household behaviour because they are responding to constraints in markets rather than simply to relative market prices. The values of products and inputs are not necessarily equal to the observable market prices, but are idiosyncratic, depending on the constraints and conditions of the particular household. Below we explore how this influences investment decisions.

*3.2 Investment decisions in the presence of labour market failure*

While rural smallholder households in developing countries may at certain times of the year sell labour, in general, such households are assumed to have excess labour and labour is assumed to be underemployed. Rural households would then be willing to sell labour at a reasonable market wage if labour opportunities were available. In this section, labour market failure is added to the model and households are assumed to be unable to sell labour (and thus have surplus labour). Including labour market failure in the model requires an adjustment to the constraints presented for the perfect market case. Since the household is assumed to have surplus labour then it will not hire labour at the market wage and all productive labour will come from the household. Details of how this is done are presented in Appendix 1, section A1.2. The household cash constraints can be rewritten as follows:

$$\text{Period 1: } p_c X_c^1 = p_a\left(Q(T - L_I - X_l^1, H) - X_a^1\right) + B$$

$$\text{Period 2: } p_c X_c^2 = p_a\left(A\left(L_I\right)Q(T - X_l^2, H) - X_a^2\right) - (1+r)B$$

With labour market failure, the cash constraint excludes any buying or selling of labour. The household then maximises utility subject to this set of constraints.

Using the first-order conditions for the optimal solution, the following equation—which represents the factors influencing the land improvement decision—can be derived as follows:

$$p_a \frac{\partial Q(L_a^1, H)}{\partial L_a^1} = \frac{1}{(1+r)}\left(p_a \frac{\partial A(L_I)}{\partial L_I} Q(L_a^2, H)\right)$$

These results can be contrasted to those presented for the perfect market scenario. Those results indicated that investment in land improvement would occur provided the discounted marginal value of land improvements is greater than the market wage. In this case, household investment in land improvement is related to the value of the marginal product of labour. Households equate the value of the marginal product of labour in food production to the discounted (by the market interest rate) value of the marginal product of labour in land improvement. Because the household has surplus labour, the value of the marginal product of labour in food production is less than the market wage (if there is a market wage). If the market did function then the household would sell labour and the value of the marginal product of labour would be higher since less labour would be used in agricultural production. The conclusion is that when labour markets do not function properly and households have surplus labour then households are more likely to invest in land improvements.

Another interesting aspect of this result is the fact that it is the value of the marginal product of food crop production that determines land investment. This is due to the fact that agricultural production is now the alternative mechanism for obtaining cash, which is done by selling surplus food crop. The household is still examining the trade-off between cash produced now and future cash but it is doing so based on the alternative to selling labour.

To explore the effect of labour market failure on the investment decision, further simulations were run and are presented in Table 3. Run XIII examines a situation in which transaction costs lead to a difference between the selling and buying price of labour. For this simulation, the selling price of labour is reduced by 10% (to 0.9) and the buying price is increased by 10% (to 1.1). Note that this run is similar to run IV in which the labour price was reduced by

10% for both buying and selling labour. In that case, the household shifts from selling to buying labour and improves all the land, borrowing a substantial amount of funds to finance the investment. In this run, because of the labour price band, the household ceases selling labour but does not hire labour. Borrowing and investment increase but not to the degree as would occur without the labour price band. To pursue this further, run V is rerun but in the presence of the labour market price band. In run V, the reduction in labour requirement for land improvement (to 44) led the household to stop selling labour and to hire labour to improve land. Run XIV shows the results of the same simulation but with a labour price band. While the reduction in labour requirement induces the household to stop selling labour, the price for hiring labour is too great and the household does not improve all land. These runs show how a price band creates a situation in which the household may neither sell nor buy labour so that the shadow value of labour, lying somewhere in the price band, is used to decide the optimal use of labour. Run XV represents the more extreme situation in which there is complete labour market failure. When complete labour market failure is included—meaning households can no longer either sell or buy labour—the results indicate that households spend more time on leisure, more time on agricultural production and invest more in land improvements. As noted above, this is because the value of labour is now lower and the returns to land improvement sufficiently high. Decisions are made based on the shadow value of labour, which is related to labour's marginal productivity in other activities and the marginal utility of leisure. The functioning of the labour market thus plays an important role in the investment decision.

### *3.3 Investment decisions in the presence of credit market failure*

The requirements for perfect capital markets are fairly stringent and even in developed countries perfect capital markets are unlikely to exist. Rates of return on savings rarely equal the rate for borrowing because of transaction costs, market information is often limited, and there are significant barriers to entry which allow participants to influence price. Credit markets can also completely fail, meaning households are unable to borrow or are limited in the quantity or length of time for which they can borrow. In this section, we examine credit market failure.

Ray (1998) notes two primary features of credit markets that make them problematic. First, monitoring the use of a loan is often very difficult and a loan taken for one stated purpose may be used for another. This can create a situation where the borrower defaults, even if they intended to repay. A second problem is that of strategic default where a borrower could repay but chooses not to do so. If an individual defaults it is difficult to know the reason. Information and enforcement are both problems. To ensure repayment requires either a legal system which penalises default or some informal mechanism for punishing defaulters. Given the weakness of the legal system in most developing countries, especially in rural and remote areas, informal mechanisms are often employed to ensure repayment, such as threats to advance no future loans. The less effective the threats of punishment, the more constrained the credit market. Even if informal mechanisms can be used to ensure payments for some loans, it is more difficult to use such mechanisms for long-term loans. Short-term loans, such as for crop inputs, are easier to monitor since the time period is short, and easier to enforce since collection requires a single payment. Long-term loans, which may be required for long-term investments, are more difficult to monitor due the length of the period and the greater enforcement requirements. {See hard copy for corrections to Table 3.}

**Table 3: Effects of labour and credit market failure on smallholder investment decision-making**

| | | unit | | Labour market | | | Credit market | | Alternative investment | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Imperfection sell=0.9 buy=1.1 | Imperfection & land imp.=44 | Market failure | Market failure | Failure & discount rate=0% | Savings interest=20% | Savings & yield imp. land=1.6 |
| Run number | | | base | XIII | XIV | XV | XVI | XVII | XVIII | XIX |
| *Year 1* | Crop-Unimproved land | ha | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| | Land improved | ha | 0.44 | 0.92 | 1.02 | 1.03 | 0.09 | 0.21 | | 1.50 |
| | Hire labour | units | | | | | | | | 18.32 |
| | Sell Labour | units | 20.71 | | | | 35.64 | 32.00 | 43.37 | |
| | Buy grain | t | | | | | | | | |
| | Sell grain | t | 0.72 | 0.72 | 0.71 | 0.77 | 0.72 | 0.74 | 0.76 | 0.73 |
| | Borrow | $ | 15.98 | 36.11 | 38.00 | 25.33 | | | | 52.56 |
| | Save | $ | | | | | | | 15.35 | |
| | Eat grain | t | 0.78 | 0.78 | 0.79 | 0.73 | 0.78 | 0.76 | 0.74 | 0.77 |
| | Leisure | units | 96.73 | 95.15 | 92.76 | 89.91 | 97.83 | 95.95 | 94.13 | 86.82 |
| | Cash | $ | 108.71 | 107.82 | 108.78 | 102.43 | 107.20 | 105.72 | 103.80 | 107.26 |
| *Year 2* | Crop-Unimproved land | ha | 1.06 | 0.58 | 0.48 | 0.47 | 1.41 | 1.29 | 1.50 | |
| | Crop-Improved land | ha | 0.44 | 0.92 | 1.02 | 1.03 | 0.09 | 0.21 | | 1.50 |
| | Hire labour | units | | | | | | | | |
| | Sell Labour | units | 37.41 | 31.06 | 30.01 | | 36.94 | 35.15 | 31.91 | 29.28 |
| | Buy grain | units | | | | | | | | |
| | Sell grain | t | 0.90 | 1.18 | 1.22 | 1.29 | 0.74 | 0.77 | 0.65 | 1.51 |
| | Eat grain | t | 0.81 | 0.78 | 0.79 | 0.73 | 0.81 | 0.83 | 0.85 | 0.89 |
| | Leisure | units | 100.09 | 106.44 | 107.49 | 137.50 | 100.56 | 102.35 | 105.59 | 108.22 |
| | Cash | $ | 110.99 | 107.79 | 108.76 | 102.33 | 110.82 | 112.60 | 114.91 | 117.39 |

Recognising the problems with credit markets, in many developing countries it has been fashionable to provide institutional credit at subsidised interest rates to farmers and other rural borrowers. The problem with this strategy is that demand for cheap credit nearly always outstrips supply so that some form of rationing has to be imposed by the lending agency. Usually that means that the available funds go to the richer and more influential farmers, leaving smallholders, who are the focus of our concern in this report, with recourse only to traditional money lenders. They typically lend at high interest rates for short periods only and often in only small amounts.

To explore the issue of credit market failure in detail, some revisions of the model presented above are required. In this case, households are assumed to be unable to borrow or save. While this is a strong assumption, it is assumed for two reasons. First, while credit is often available in rural developing countries, at least from informal sources, it is usually for short-term purposes, and long-term projects with future benefits are less likely to be financed. Secondly, complete credit market failure provides insights into the investment decision in general. Details of the changes to the model are presented in Appendix 1, section A1.3. Using the perfect competition model as the base, credit market failure is included by altering the cash constraints as follows:

$$\text{Period 1: } p_c X_c^1 = p_a\left(Q(L_a^1, H) - X_a^1\right) - w\left(L_a^1 + L_I - T + X_l^1\right)$$

$$\text{Period 2: } p_c X_c^2 = p_a\left(A\left(L_I\right)Q(L_a^2, H) - X_a^2\right) - w\left(L_a^2 - T + X_l^2\right)$$

Borrowing is removed as an option for the household.

The utility maximisation problem remains the same with the household maximising utility subject to these cash constraints. Since households can no longer move cash between periods through the credit market there is no clear relationship between the cash in each period. The only way to shift cash between periods is through land improvement (since cash is obtained through agricultural production) and that only goes in one direction (from period 1 to period 2). Using the first-order conditions for a maximum, the land investment decision can be written as follows:

$$w = \frac{\lambda_c^2}{\lambda_c^1}\left(p_a \frac{\partial A(L_I)}{\partial L_I} Q(L_a^2, H)\right)$$

where $\lambda_c^1$ and $\lambda_c^2$ are, respectively, the Lagrange multipliers associated with the first and second period cash constraints. These conditions suggest that land will be improved provided the wage received in period 1 is less than the value of the marginal product of labour for land improvement multiplied by the relative value of the Lagrange multipliers of the cash constraints—the higher the ratio of the Lagrange multipliers, the higher the investment in land improvements. To get an idea of the value of this ratio, any of the first-order conditions related to the consumption commodities can be used. As an example, the first-order conditions with respect to leisure for each period can be used and the following relationship can be derived:

$$\frac{\lambda_c^2}{\lambda_c^1} = \frac{\beta \dfrac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_l^2}}{\dfrac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_l^1}}$$

This relationship shows that the relative value of the Lagrange multipliers is directly related to the ratio of marginal utilities across periods. It suggests that, when credit markets fail and borrowing or saving are not possible, then investment in land improvement is not related to the interest rate but to the marginal utilities of commodities across time. Taken together, these equations suggest that land improvement will occur if the wage rate is less than the value of the marginal product of labour for land improvement discounted by the household's weighting of utility now versus the future. If labour is particularly inexpensive, as is likely the case if labour markets are imperfect and households have surplus labour, then investment in land improvements is likely to occur.

While this would be the case for complete credit market failure, it is a rather extreme position in that it assumes it is not possible to use some mechanism to transfer cash from the current period to the next. In the current form of the model, the only way to shift resources is through labour investment in land improvements. However, in a real world situation, if cash were available, there would most likely be some method of shifting cash forward at least at a low rate (possibly less than zero if there is inflation). Investment projects that shift income to the future should be evaluated using by the internal rate of return (IRR). In perfect markets, any project with an IRR that is higher than the market interest rate on borrowed funds should be accepted. In imperfect markets, such as where there is a wedge or band between the borrowing and savings rates, the rule for which projects should be implemented will be different. Like the labour allocation decision, it will be the shadow value of cash that will determine investment which uses cash, with the exact shadow value in the presence of credit market imperfections idiosyncratic, and thus depending on the constraints and conditions of the particular household. Any investment project that requires cash that has an IRR in excess of the shadow value of cash should be accepted.

To explore these issues further, Table 3 presents simulations that include changes in the interest rate and discount factor. Run XVI shows the optimal solution when the credit market fails (no borrowing or saving is possible.) In the base run, the household borrows cash to bring forward the financial returns to land improvement. Without access to credit, the household is unable to borrow against the future and cannot obtain the future benefits of land improvement. The household reduces land improvement and expands the selling of labour in order to buy cash goods and to compensate for credit market failure. The household uses the perfectly functioning labour market to compensate for failure in the credit market to maintain a certain level of cash goods consumption.

Run XVII examines the effect of equal weighting of utility across time (a discount factor of 1.0) when credit markets do not function. This simulation is done to examine whether the household's weighting of utility influences the land improvement decision in the presence of credit market failure (as proposed above). The results indicate that when a household discount future utility less, the household is more likely to invest in land improvements. The household's weighting of future utility matters in the land investment decision is independent of the market interest rate.

The model does not offer an alternative investment option to land improvement other than through the savings market. Saving is used as a proxy for an alternative investment of cash. To see the effect of changing the return to an alternative cash investment, the model is run (run XVIII) using a higher interest rate on savings (20%). Increasing this rate provides a better alternative to land improvement and land improvement drops dramatically. Thus, when there is a higher return to investment through savings or another alternative, that activity will be selected. Examining this further, in run XIX the return to land improvement is increased so that the benefit to yield of investing in land increases to 1.6 tonnes/hectare while keeping the return to saving at 20%. With this return to land improvement the household no longer chooses to save. Investment in land improvement, especially when such an investment can be translated easily into cash through product markets, will depend on the rate of return of alternative investments.

### *3.4 Investment decisions in the presence of market imperfections*

We have shown that in the presence of market imperfections the household investment decision in land improvements is not as straightforward as is often presumed. Market failures and imperfections alter household decision-making and limit the usefulness of market rates for labour and cash in evaluating smallholder investment. This has a number of implications for smallholder investment analysis. We now discuss these implications—first looking at failures in the labour and credit markets, then the difficult issue of investment decisions in the presence of multiple market failures.

For the labour market, the implications of our analysis are relatively straightforward. In the presence of labour market failure, the value of household labour is less than the market wage in labour-surplus households. In this context, household labour used for land investment or other activities with future outcomes should not be valued at the market wage. Instead, the value of labour should be measured against the alternative use of labour at the particular time of investment. If labour requirements for investment are flexible—that is, labour can be used at any particular time of year—the appropriate labour value will be the lowest value for the year.

Analysis of the credit market is more complicated. Under imperfect credit markets, such as a wedge between borrowing and savings rates, the shadow value of cash differs from the market rates and depends on the use of cash in investment and consumption as well as the ability to obtain cash through product and labour markets. If cash is generally available to the household, the shadow value is more likely to be near the savings rate, while if it is scarce, as is likely the case for smallholder agriculture, the shadow value is likely to be near the borrowing rate. This implies that the appropriate rate for discounting in cash-scarce situations would be at, or near, the borrowing rate. This assumes, however, that both labour and agricultural products are easily converted to cash as reflected in the model presented in section 3.3. In the simulations, this is apparent in the increase in labour-selling when credit markets fail. The household is compensating for the inability to obtain cash through the credit market by using other markets. The ability to convert other activities, particularly labour activities, into cash is critical in determining how to evaluate future outcomes.

Although we have evaluated labour and credit markets independently, for reasons noted above, it is likely that neither market will function perfectly. The next issue that needs to be considered is how to evaluate farmer decision-making in the presence of multiple market failures, in particular when labour market failure is added to credit market failure. As noted, if labour markets fail, it is the shadow value of labour that needs to be used in evaluating labour

rather than the market wage. While the shadow value of labour can be converted into a cash equivalent value, it may be the case that actual labour cannot be converted to cash. For example, suppose a household is using labour to produce food for home consumption (and the market for food is imperfect). There is clearly a value to this activity that can be measured in the utility received from consumption of food. However, there is no cash received from that activity. If labour activity cannot be converted to actual cash (as opposed to a cash equivalent), then it would be inappropriate to discount the returns to labour over time using a cash rate. Instead, valuing of labour activity across time would be related to the weighting of utility in different time periods along with the returns to alternative labour activities and leisure in each period.

While we have focused on pure market failure, in real rural economies markets do function in some limited form. Although this is the case, the results hold even in situations in which markets partially fail. For example, smallholder households may be able to use labour for a certain amount of agricultural production that has a cash return and work off-farm to earn cash. However, there may be limits in the amount of labour that can be provided for these activities. Households cannot optimally allocate work across activities and thus may work to the maximum possible on these activities and still have surplus labour. The credit market is very similar in this respect. Households may have access to credit for certain lengths of time (usually only a few months) and for certain purposes (such as the purchase of agricultural inputs) but may not be able to obtain credit for any purpose and may still be constrained. These partial failures still limit household behaviour and make standard private investment analysis inappropriate. Conducting investment analysis requires understanding these market limitations and assessing their impact on smallholder decision-making.

## 4 Evidence in support of the approach: a case study

### *4.1 Case study approach*

The model and simulations indicate that the functioning of labour and capital markets can have a significant effect on smallholder investment decision-making. They also indicate that the ability to buy and sell labour and to obtain credit (and save) will influence the level of on-farm investment. Our analysis leads us to formulate two hypotheses about smallholder investment behaviour. The first hypothesis is that labour market failure can lead to smallholder on-farm investment beyond what would be expected using standard investment analysis. The second hypothesis is that if there is labour and credit market failure, it is inappropriate to use market wage rates when valuing labour and market interest rates when estimating discount rates. To test these hypotheses we use a case study approach to provide initial indications as to:

1. whether or not *a priori* perceptions about the role of market failure as modelled are consistent with actual smallholder decision-making processes; and

2. whether or not market failures do lead to higher than expected on-farm investment.

The case that is used for this research is investment in conservation farming technologies among smallholders in the Philippines. This case is chosen because of the long-term nature of conservation technologies and the variability of adoption in the highlands of the Philippines. This study does not attempt to highlight the factors that influence the adoption of conservation farming technologies, which have been discussed by Lapar and Pandey (1999) and Lapar et al. (1999). Instead we seek to obtain information on the hypotheses discussed above.

### *4.2 Case study results*

Semi-structured surveys of 23 farmers in two regions of the Philippines, the districts of Batangas and Cebu City, were undertaken to collect information on the functioning of labour and credit markets and the factors that influence smallholder investment decisions. These regions were chosen for the case study based on *ex ante* information that markets in Batangas tended to be fairly limited while those in Cebu City were previously limited but are now more developed (although in both locations markets were far from perfect.) A detailed discussion of the surveys is provided in Appendix 2. As expected, evidence from the survey suggests that there are substantial imperfections in the labour and credit markets in both areas.

Twelve smallholder households were interviewed in two villages (*baranguay*) in the Batangas region—2.5 hours drive from Manila (including 1 hour of dirt road). All farmers in this area grow upland (highland, rainfall-dependent) rice intercropped with maize. Only one farmer was able to sell excess rice, all the others having to buy extra rice to satisfy basic household requirements. Most farmers either owned or managed livestock (cattle and pigs) which were used as a form of savings and to generate cash that could be used to purchase rice. Within these villages, labour markets did not exist and there was no buying or selling of local labour. Off-farm employment opportunities were limited to seasonal day labour in nearby towns. There was minimal access to credit in these areas and no credit had been obtained for any short- or long-term investment in on-farm activities.

Smallholders, while aware of declining soil fertility, have minimal understanding of how to alleviate the problem and believe that they are not in a secure enough financial position to attempt changes or take land out of production. Lack of credit and information appear to be discouraging the adoption of conservation technologies, even though there is available labour that could be used for this purpose. Based on responses to questions in the semi-structured interviews it seemed that, with the provision of appropriate information, some smallholders would be prepared to invest labour resources if there were reasonably assured long-term benefits.

The conclusion that can be drawn from the investigations in these two Batangas villages is that there is failure in both the capital and labour markets. There also appears to be a labour surplus, suggesting that labour should not be valued at the market wage. Furthermore, given the inability to translate labour into cash, investment of labour should not use the market interest rate on cash or even the shadow value of cash but rather farmers' weighting of future outcomes (which is obviously very difficult to measure.) Under these conditions, one question to consider is why there has not been more capitalisation of labour into land improvements. There are a number of possible reasons. The interviews seemed to suggest that farmers did not have proper information to judge the value of land improvements, indicating a missing market for information. Some concern was also expressed about the high opportunity cost, in terms of food production, of the land conservation measures known to farmers. When the question was put to smallholders in Batangas as to whether or not they would be willing to sacrifice a proportion of their land if it could alleviate soil fertility decline, nine of the 12 said that they would.

Eleven smallholders were selected from four *baranguay* in the province of Cebu City. All villages had sealed road access and were not more than 1.5 hours from Cebu City (the second biggest city in the Philippines). Each village had a history of government and non-government agency (NGO) support going back 20 years and recent assistance had been provided by a World Bank project now administered by the Cebu City Hillyland Resources Management and Development Commission (CCHRMDC). The land was more steeply sloping than in the Batangas district and the soil more of a reddy-brown than the deep chocolate-coloured soil in

Batangas. All smallholders produced cash and tree crops as well as maize for home consumption.

The present situation in Batangas may well be similar to the situation in Cebu in the 1980s. At that time, smallholders in Cebu were caught in a monoculture cropping regime (maize) and were experiencing rapidly decreasing productivity due to soil fertility decline. The situation became so critical that farmers knew they had to make changes, but it was only through intercession by the government and NGOs that smallholders were able to adopt new agricultural technologies. Smallholders at the Cebu sites received information and credit assistance to construct hedgerows and contour banks on their sloping land. The activities that were proposed by extension agencies tended to be labour-intensive and require minimal amounts of cash. The fact that farmers adopted these land improvements suggests that, at least at 20 years ago, households had surplus labour and limited cash. NGOs and government agencies, by promoting these activities, at least implicitly, assumed this was the case. Standard private investment analysis would not have necessarily have come to the conclusion that the conservation technology was worthwhile if market wage rates were used to value labour and market interest rates were used to discount the future.

Conditions in Cebu have changed, however, and if new land improvement technologies were suggested now, the situation may well be different. While access to credit remains limited, there is more access to short-term credit. In the labour market, there are now additional sources of on-farm and off-farm income. While markets still do not function perfectly, it may now be more appropriate to use market rates to evaluate investment decisions. Careful analysis still needs to be conducted to obtain an accurate understanding of the credit and labour markets, but it is clear that the situation has changed in the last 20 years and the errors created by using market rates have been reduced.

Results from the case study support *a priori* perceptions that there are clear market failures in the case study regions. Additionally, the view by the majority of Batangas smallholders that they would adopt labour-intensive land improvements and the evidence of adoption by Cebu smallholders of labour-intensive land improvements suggest that the functioning of labour and credit markets influences this decision. These observations are consistent with the model's predictions that surplus labour will lead to greater adoption of labour-intensive land improvement. Furthermore, given that conservation technologies require short-term costs for long-term benefits, this suggests that either the benefits from conservation are exceptionally higher or that farmers do not discount the future at the high level found in local credit markets.

## 5 Evaluating smallholder investment: some guidelines

### *5.1 Developing guidelines*

The model presented in section 3 noted the problem that market failure presents in evaluating smallholder decision-making with respect to long-term investment. In section 4, a case study of two regions in the Philippines was presented. In the less developed region of Batangas, markets are found to be extremely limiting, while in Cebu, markets have developed further but remain imperfect. Additionally, farmers with surplus labour and limited cash were found to invest in labour-intensive land improvements when provided with appropriate information and initial capital. While the case study focuses on only two regions in one developing country, both the development economics literature and the first-hand experience of the authors suggests that similar circumstances would be found throughout rural areas of developing countries. Furthermore, it is in these very areas—where markets function poorly

and smallholders are marginalised—where NARSs and IARCs are most likely to promote new technologies (in an attempt to improve economic welfare in these areas).

The question then becomes one of how to adequately determine whether an innovation will be beneficial to smallholders—that is, how to adequately conduct private investment analysis to minimise the possibility of type I and type II errors. Researchers have three choices when evaluating potential interventions. First, they can ignore the presence of market imperfections and conduct private investment analysis as if markets function. Second, researchers can recognise that markets do not function perfectly and develop 'rules of thumb' for dealing with the issue. Third, they can investigate the functioning of markets in conjunction with studies of the returns to the innovation to determine how to evaluate labour and the future. Each of these is discussed below.

### *5.2 Assume markets function*

If analysts assume markets function properly then they will need to determine market rates for the costs of labour and other inputs and for the opportunity cost of capital. Wage rates are often difficult to identify except in periods of high labour use, and therefore labour demand, such as during the harvest period (even then payment may be made in product rather than cash). The wage rate during such periods represents the opportunity cost of labour during certain seasons and not necessarily the value of labour during other periods of the year. Generally, the value of labour is likely to be less than this amount. Unless the long-term investment happens to require labour during the peak seasons, then that wage rate may be inappropriate and is likely to overestimate labour costs. Whether this is a problem depends largely on how important labour is in the investment. If substantial amounts of labour are required, as is often the case with conservation technologies, then the costs of the innovation may be substantially overestimated, making the project appear unprofitable and leading to a type I error. If the labour requirements are a minimal component of investment, such as may be the case with livestock breeding, then the likelihood of error may be less important.

Assuming markets function properly suggests that the local interest rate on borrowed funds adequately reflects farmers' opportunity cost of cash. It also assumes that all activities can be translated into cash and should be treated, in terms of future outcomes, the same as cash. The local market for short-term credit often exceeds 50% and can be as high as 200%, suggesting a $100 investment would have to have at least a $150 return in one year to make it a worthwhile investment. While possibly reflecting the value of cash, for reasons stated above, such rates are not likely to reflect the return to investment of labour or other inputs, such as oxen, the value of which are not easily converted to cash. The cash rate on short-term credit does not necessarily reflect smallholders' long-term view of the future. Using the cash rate on short-term credit is therefore likely to be an overestimate of the discount rate (and therefore an underestimate of the discount factor.) If the investment is longer term, such as land improvement or the planting of trees, then future benefits are likely to be dramatically discounted, leading to an underestimate of the present value of future benefits and a type I error.

Under the assumption of perfect markets, the types of projects that are likely to be rejected when they should be accepted are those with a high level of family labour input and with distant benefits.

### *5.3 Rules of thumb*

A second approach that can be taken for private investment analysis is to recognise that markets in rural areas of developing countries do not function properly and to address the problem by developing 'rules of thumb'. For example, an analyst may realise that the wage rate at the harvest period is an overestimate of the opportunity cost of labour. Instead of using that rate, the analyst decides to use, for example, 50% of that wage rate. A similar rule would be used to calculate a rate for discounting the future. This can be an arbitrary rate, such as 10%, implying that all people discount the future at about that rate. A rule of thumb is then a practical, albeit unscientific, method of dealing with the problem. It recognises the direction of bias of assuming that markets function perfectly and attempts to compensate for this by reassigning values. The effectiveness of this depends largely on how correctly the rules are able to reflect reality. If there is some evidence that the marginal productivity of labour is around 50% in the off-peak labour demand season, then a 50% rule for wage labour may be appropriate. If research shows that people generally discount the future at 10%, then this may be a reasonable approximation. The risk of error depends on the confidence in the developed rules. If the rules underestimate labour costs or the discount rate then there is a risk of type II error, and if they still overestimate the costs and rate, there remains a risk of type I errors (although probably less of a risk than assuming markets function perfectly). One mechanism to minimise the risk is to do a sensitivity analysis on the rules of thumb. If the results of the analysis are not very sensitive to the rules, then the assumption may not be overly important. If the results are sensitive then the rules must be carefully considered.

### *5.4 Investigate functioning of markets*

The third and recommended approach is for researchers to investigate the functioning of markets in the relevant regions when conducting private investment analysis. In the process of conducting private investment analysis, researchers must collect information on the inputs required for the investment, the outputs, and an appropriate set of prices. The input–output information is often initially collected on experiment stations and then using pilot sites in which smallholders are selected to test the innovation in the field. As part of the evaluation process, researchers can use rapid rural appraisal techniques to evaluate the functioning of markets and how smallholders evaluate present versus future benefits. Given the heterogeneity of communities, as noted in the difference between Batangas and Cebu in the Philippines, it would be necessary to study each region where an innovation is being considered independently or to identify a type of region in which an innovation might be appropriate. In such an appraisal the following information would be required:

1. *Labour market*. Information must be collected on how the labour market functions. This information should include not only information on whether the market functions at all, but the timing of labour market demand (if the market functions) and the value of labour in the off-peak season. The valuation of the labour market should depend on the labour requirements of the innovation. If labour requirements are flexible, then labour should be valued at its minimal value for the year. If labour is required at a certain period in time then it should be valued at that time. This logic holds true for other inputs in addition to labour. For example, the market for animal services may also be thin or non-existent and valuing such services at market value during peak seasons may be inappropriate. To facilitate this process, farm-household models that use mathematical programming might be employed to generate information on the shadow prices of resources such as labour in different seasons.

2. *Credit market*. Information should be collected on the functioning of both the formal and informal credit markets. Questions should be asked on both the time horizon and the level of availability of credit. Credit may be available but it may be available for only short-term investment. Furthermore, access to some credit does not necessarily indicate access to further credit at the same interest rate since credit may be rationed. A household that is able to get a loan of, for example, $100 at a certain interest rate but is unable to secure more funds at that same rate is still credit-constrained if it is rationing that limits the amount of loans. A clear understanding of the details of this market is needed to evaluate the appropriateness of using the local interest rate on borrowing as a discount rate.

3. *Alternative investment*. Information should be collected on the alternative forms of investment available to farmers. With labour or cash available, it needs to be clear what actions smallholders might take, if any, to shift the value of those commodities to future periods. This is particularly important in the likely event that credit markets do not function perfectly. Care should be taken to distinguish the independent uses of labour, cash and other inputs. If non-cash inputs cannot be easily converted to cash, then they must be valued in their potential for investment independently of cash.

4. *Smallholders' valuation of present versus future outcomes.* In addition to understanding the functioning of markets and investment strategies, having direct information on smallholders' weighting of the future outcomes is important. While adequately evaluating how smallholders weight the future is difficult, it can provide insights into their decision-making. The problem is that assessing their views of the future by asking hypothetical questions does not necessarily reflect what they would do in an actual situation. Hypothetical questions can, however, provide insight into the process that they may use in making such decisions. Furthermore, if farmers have undertaken investments in the past, those can be used to determine how they might make future investments. Such information can help determine the appropriate use in private investment analysis of information collected about labour markets, credit markets and alternative investments.

The use and value of the above information is largely dependent on the innovation that is under consideration. The above information must be used in conjunction with the information that is normally collected on an innovation. With this information, private investment analysis will more accurately predict smallholder adoption of innovations and minimise the risk of type I and type II errors.

## 6 Conclusions

The purpose of this paper is to determine the appropriate method of conducting private investment analysis in rural areas of developing countries where market imperfections are widespread. The reason for this investigation is that standard private investment analysis of innovations developed by NARSs and IARCs is likely to reject innovations that require substantial short-run labour inputs and investments that have long-term rather than short-term benefits. Such rejections contradict the fact that smallholders often do make such investments. In this paper, we offer the basis of a method of conducting private investment analysis that recognises market failure and reduces the likelihood of inaccurately predicting farmer adoption or non-adoption of innovations. Namely, we suggest that in addition to collecting the standard information necessary for private investment analysis, such as information on the

inputs and outputs of an innovation, researchers should obtain information on the context in which the innovation will be promoted. The cost of this methodology is the additional information that must be collected beyond what is standard. This cost will be justifiable if there are significant benefits to reducing the probability of prediction errors. NARSs and IARCs will then face a trade-off between the additional costs of obtaining adequate information and the benefit of reducing those errors. The proposed methodology is problematic in that it is difficult to operationalise because of the complexity associated with determining shadow values. As noted in the introduction, it is possible to avoid these complications by conducting feasibility analysis and dominance analysis as first steps. By taking a step-wise approach, the difficult issue of determining shadow values can be avoided.

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## Appendix 1. Modelling long-term smallholder decision-making

The purpose of this appendix is to present a detailed mathematical model that provides the basis for understanding smallholders' decision-making. The model discussed in this appendix builds on the basic model presented in chapter 2 of Singh et al. (1986) and forms the basis for the discussion in sections 2 and 3 of this paper. The first step in understanding smallholder investment in activities with future outcomes is to consider the investment decision when markets function perfectly. Standard investment analysis is based on this assumption and this is the logical starting point for the discussion. Following this discussion, the model is adjusted to consider labour and credit market failures.

### *A1.1 Perfect markets*

Consider a smallholder household that seeks to maximise utility over two periods based on the additive utility function:

$$U\left(X_a^1, X_c^1, X_l^1\right) + \beta U\left(X_a^2, X_c^2, X_l^2\right)$$

where the commodities that provide utility ($U$) to the household in periods $t = 1, 2$ are food that is an agricultural staple $\left(X_a^t\right)$, cash goods $\left(X_c^t\right)$, and leisure $\left(X_l^t\right)$ and utility in period 2 is discounted by a discount factor $\beta$. Utility is maximised subject to a cash constraint in each period:

*Cash constraint period 1*: $$p_c X_c^1 = p_a\left(Q^1 - X_a^1\right) - w\left(L_a^1 + L_I - F^1\right) + B \qquad (1a)$$

*Cash constraint period 2*: $$p_c X_c^2 = p_a\left(Q^2 - X_a^2\right) - w\left(L_a^2 - F^2\right) - (1+r)B \qquad (1b)$$

where $p_a$ and $p_c$ are, respectively, the price of the agricultural commodity and the price of cash goods, $Q^t$ is the household's production of the agricultural commodity in period $t$ (so $Q^t - X_a^t$ is marketed surplus), $w$ is the market wage, $L_a^t$ is the total labour input in agricultural production in period $t$, $L_I$ is labour invested in land improvement in period 1, $F^t$ is family labour used for productive purposes in period $t$ (so $L_a^1 + L_I - F^1$, if positive is hired labour in period 1 and, if negative, labour sold off-farm in period 1, and $L_a^2 - F^2$ is similarly defined for period 2), $B$ is the amount of money borrowed if positive, or saved if negative, and $r$ is the interest rate on cash. These cash constraints represent all the cash flows in each period.

The household also faces a time constraint, $T$, in each period, which represents the total stock of time available to the household for all activities. The household allocates its labour for productive purposes $F^t$ or receives utility from leisure $X_l^t$ subject to the constraints:

*Time constraint period 1* $$X_l^1 + F^1 = T \qquad (2a)$$

*Time constraint period 2* $$X_l^2 + F^2 = T \qquad (2b)$$

Additionally, agricultural production in each period is constrained by the available technology. Production is considered a function of labour use and a fixed quantity of household land, $H$, and follows the normal assumptions of a production function.

Furthermore, in period 1 the household can choose to use labour $L_I$ to improve the land. Land improvement in period 1 improves agricultural production in the period 2 based on the improvement technology embodied in the function $A\left(L_I\right)$ where $\frac{\partial A(L_I)}{\partial L_I} > 0$ and $\frac{\partial^2 A(L_I)}{\partial L_I^{\,2}} < 0$. The production constraint for each period is then:

*Production constraint period 1* $$Q^1 = Q(L_a^1, H) \qquad (3a)$$

*Production constraint period 2* $$Q^2 = A\left(L_I\right)Q(L_a^2, H) \qquad (3b)$$

Other constraints include minimal levels for a number of variables. For example, presumably the household could not survive without a minimal amount of food, certain cash goods and leisure (such as sleep). By not explicitly defining those constraints, we are assuming that there are no conditions under which these constraints will be binding and the solution to the maximisation problem presented below is an interior solution. Furthermore, the equalities placed on the above constraints assumes that they are binding.

Following the procedure presented in Singh et al. 1986, the three sets of households constraints can be collapsed into a single cash constraint by substituting the time constraints (equations 2a and 2b) and production constraints (equations 3a and 3b) into the cash constraints (equations 1a and 1b). The household problem is to maximise utility by choosing the level of each consumption commodity in each period, the amount of labour allocated in each period and the amount of borrowing subject to the cash constraints as follows:

$$\underset{X_a^t X_c^t X_l^t L_a^t L_I B}{Max} \; U\left(X_a^1, X_c^1, X_l^1\right) + \beta U\left(X_a^2, X_c^2, X_l^2\right)$$

subject to:

$$p_c X_c^1 = p_a\left(Q(L_a^1, H) - X_a^1\right) - w\left(L_a^1 + L_I - T + X_l^1\right) + B$$

$$p_c X_c^2 = p_a\left(A\left(L_I\right)Q(L_a^2, H) - X_a^2\right) - w\left(L_a^2 - T + X_l^2\right) - (1+r)B$$

Defining $\lambda_c^1$ as the Lagrange multiplier associated with the first period cash constraint and $\lambda_c^2$ as the Lagrange multiplier associated with the second period cash constraint, the following first-order conditions for a maximum are obtained:

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_a^1} - \lambda_c^1 p_a = 0 \qquad (4a) \qquad \beta\frac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_a^2} - \lambda_c^2 p_a = 0 \qquad (4b)$$

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_c^1} - \lambda_c^1 p_c = 0 \qquad (5a) \qquad \beta\frac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_c^2} - \lambda_c^2 p_c = 0 \qquad (5b)$$

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_l^1} - \lambda_c^1 w = 0 \qquad (6a) \qquad \beta\frac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_l^2} - \lambda_c^2 w = 0 \qquad (6b)$$

$$\lambda_c^1\left(p_a\frac{\partial Q(L_a^1,H)}{\partial L_a^1}-w\right)=0 \qquad (7a) \qquad \lambda_c^2\left(p_aA\left(L_I\right)\frac{\partial Q(L_a^2,H)}{\partial L_a^2}-w\right)=0 \qquad (7b)$$

$$-\lambda_c^1 w+\lambda_c^2\left(p_a\frac{\partial A(L_I)}{\partial L_I}Q(L_a^2,H)\right)=0 \qquad (8)$$

$$\lambda_c^1-\lambda_c^2(1+r)=0 \qquad (9)$$

$$p_cX_c^1=p_a\left(Q(L_a^1,H)-X_a^1\right)-w\left(L_a^1+L_I-T+X_l^1\right)+B \qquad (10)$$

$$p_cX_c^2=p_a\left(A\left(L_I\right)Q(L_a^2,H)-X_a^2\right)-w\left(L_a^2-T+X_l^2\right)-(1+r)B \qquad (11)$$

The first-order conditions can be divided into three sets. Equations 4a–6b represent the household's consumption decision. In each case, there is a trade-off between utility from each commodity and the cost of that commodity weighted by the Lagrange multiplier of the appropriate cash constraint. Combined with equations 10 and 11 (the cash constraints and first-order conditions associated with the derivatives of the Lagrange multiplier), these equations form the basis for a system of Marshallian demand functions (Silberberg 1990).

Equations 7a–8 represent the production decision. Assuming the cash constraint is binding (and thus $\lambda_c^t > 0$), equations 7a and 7b note the standard profit maximising result that labour will be allocated until the value of the marginal product of labour is equal to the market wage. Equation 8 shows the trade-off between investing in land improvement, measured by the first term in the equation, and the returns to that improvement, represented by the second term. The fact that the consumption decision (equations 4a–6) and production decision (equations 7a–8) can be easily identified in the first-order condition is not surprising. As has been noted in the household economics literature (see Singh et al. 1986), when markets function perfectly household behaviour can be modelled as a recursive system. That is, it can be shown the household behaves as if it maximises the value of its income subject to its production constraint and then maximises utility subject to its cash income. This is known as the principle of separability.

Equation 9, not surprisingly, suggests that savings or borrowing will depend on the cash constraints in each period and the market interest rate. The household will shift cash from one period to the other to equalise the value of cash in each period. This depends on the cash constraint in each period as well as the market interest rate on cash.

To explore household investment in land improvement further (equation 9), which shows the relationship between the shadow values of the two cash constraints, can be used to substitute for either Lagrange multiplier. Substituting equation 9 into equation 8 yields

$$w=\frac{1}{(1+r)}\left(p_a\frac{\partial A(L_I)}{\partial L_I}Q(L_a^2,H)\right) \qquad (8')$$

At the optimal solution, households invest to where the market wage is equated to the discounted marginal value of land improvement.

To further understand the results, we can substitute equation 9 into any of the consumption results (equations 4a–4b, 5a–5b, or 6a–6b) to show the consumption relationship across the two periods. For example, substituting equation 9 into equation 6a and manipulating that equation and equation 6b yields the following result:

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_l^1} = (1+r)\beta \frac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_l^2} \qquad (6')$$

These results indicate that households choose a level of leisure in each period that weights the marginal utilities of leisure across the two periods by the relationship between the discount factor and the market interest rate. This same relationship holds for the consumption of food and cash goods.

Finally, we can consider the relationship between the consumption of leisure and the use of labour. From equations 6a and 7a the following relationships can be noted

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_l^1} \frac{1}{\lambda_c^1} = p_a \frac{\partial Q(L_a^1, H)}{\partial L_a^1} = w \qquad (7a')$$

This equation shows the standard production relationship where the value of the marginal product of labour is equal to the wage. It also shows the relationship of both the wage and the value of marginal product to leisure. Households equate the marginal utility of leisure weighted by the reciprocal of the cash constraint (the price of consuming leisure instead of working) to the value of the marginal product of labour and the wage.

*A1.2 Labour market failure*

In this section, labour market failure is added to the model and households are assumed to be unable to sell labour (and thus have surplus labour). To include the fact that households cannot sell labour requires an adjustment to the constraints. First, since the household is assumed to have surplus labour, it will not hire labour at the market wage and all productive labour will come from the household. The following then hold true:

*Labour use period 1* $\qquad L_a^1 + L_I - F^1 = 0 \qquad (12a)$

*Labour use period 2* $\qquad L_a^2 - F^2 = 0 \qquad (12b)$

Substituting equations 12a and 12b into the time constraints (equations 2a and 2b) yields the following time constraints:

*Time constraint period 1* $\qquad X_l^1 + L_a^1 + L_I = T \qquad (13a)$

*Time constraint period 2* $\qquad X_l^2 + L_a^2 = T \qquad (13b)$

Since the household neither sells nor buys labour, the labour market no longer enters the cash constraint (equations 1a and 1b). Furthermore, substituting the time constraints (equations 13a and 13b) for labour for agricultural production ($L_a^1$ and $L_a^2$) into the cash constraint yields the following constraints on cash:

*Cash constraint period 1* $\qquad p_c X_c^1 = p_a\left(Q(T - L_I - X_l^1, H) - X_a^1\right) + B \qquad (14a)$

*Cash constraint period 2* $$p_c X_c^2 = p_a\left(A\left(L_I\right)Q(T - X_l^2, H) - X_a^2\right) - (1+r)B \quad (14b)$$

The utility maximisation problem remains the same with the household maximising utility subject to the cash constraints (equations 14a and 14b). The first-order conditions for an optimum are as follows:

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_a^1} - \lambda_c^1 p_a = 0 \quad (15a) \qquad \beta\frac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_a^2} - \lambda_c^2 p_a = 0 \quad (15b)$$

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_c^1} - \lambda_c^1 p_c = 0 \quad (16a) \qquad \beta\frac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_c^2} - \lambda_c^2 p_c = 0 \quad (16b)$$

$$\frac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_l^1} - \lambda_c^1 p_a \frac{\partial Q(L_a^1, H)}{\partial L_a^1} = 0 \quad (17a)$$

$$\beta\frac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_l^2} - \lambda_c^2 p_a A\left(L_I\right)\frac{\partial Q(L_a^2, H)}{\partial L_a^2} = 0 \quad (17b)$$

$$\lambda_c^1 p_a \frac{\partial Q(L_a^1, H)}{\partial L_a^1} - \lambda_c^2\left(p_a \frac{\partial A(L_I)}{\partial L_I} Q(L_a^2, H)\right) = 0 \quad (18)$$

$$\lambda_c^1 - \lambda_c^2(1+r) = 0 \quad (19)$$

$$p_c X_c^1 = p_a\left(Q(T - L_I - X_l^1, H) - X_a^1\right) + B \quad (20)$$

$$p_c X_c^2 = p_a\left(A\left(L_I\right)Q(T - X_l^2, H) - X_a^2\right) - (1+r)B \quad (21)$$

One significant difference between this set of first-order conditions and those presented for the perfect market scenario is that there is no longer clear separability between the household's consumption and profit maximisation decisions. This result is clear in equations 17a and 17b. The marginal utility of leisure is now equated with value of the marginal product of labour multiplied by the shadow value of the cash constraint. The reason this is the case is that now the only means for the household to gain access to cash is through agricultural production. Under perfect market conditions the household equates leisure to the wage rate times the shadow value of the cash constraint and the wage is equated with the value of the marginal product of labour. However, in the case of labour market failure and surplus labour the household produces more output and the value of the marginal product of labour will be less and lower than the market wage.

To explore the decision regarding investment in land improvement (equation 19) is substituted into equation 18 to get the following result:

$$p_a \frac{\partial Q(L_a^1, H)}{\partial L_a^1} = \frac{1}{(1+r)}\left( p_a \frac{\partial A(L_I)}{\partial L_I} Q(L_a^2, H) \right) \qquad (18')$$

The results presented in equation 18' can be contrasted to those presented in equation 8'. In this case, we find that household investment in land improvement is related to the value of the marginal product of labour. Households equate the value of the marginal product of labour in food production to the discounted (by the market interest rate) value of the marginal product of labour in land improvement.

*A1.3 Credit market failure*

In this section, rural households are assumed to lack cash and therefore wish to borrow but are unable to borrow due to credit market failure. Using the perfect competition model as the base, we include credit market failure by altering the cash constraints (equations 1a and 1b with the substitution of the time and production constraints) as follows:

*Cash constraint period 1* $$p_c X_c^1 = p_a\left(Q(L_a^1, H) - X_a^1\right) - w\left(L_a^1 + L_I - T + X_l^1\right) \qquad (22a)$$

*Cash constraint period 2* $$p_c X_c^2 = p_a\left(A\left(L_I\right)Q(L_a^2, H) - X_a^2\right) - w\left(L_a^2 - T + X_l^2\right) \qquad (22b)$$

Borrowing is simply removed as an option for households.

The utility maximisation problem remains the same with the household maximising utility subject to the cash constraints (equations 22a and 22b). The first-order conditions for an optimum are the same as for perfect markets (equations 4–11). The only changes are the deletion of equation 9 as part of the first-order conditions (since there is no borrowing) and the change in the first-order conditions that represent the cash constraint (from equations 10 and 11 to 22a and 22b).

Since households can no longer move cash between periods through the credit market, there is no clear relationship between the cash constraints in each period. The only way to shift resources between periods is through land improvement (since cash is obtained through agricultural production) and that only goes in one direction (from period 1 to period 2). The condition for land improvement can be re-written as follows:

$$w = \frac{\lambda_c^2}{\lambda_c^1}\left( p_a \frac{\partial A(L_I)}{\partial L_I} Q(L_a^2, H) \right) \qquad (8'')$$

Land will be improved provided the wage received in period 1 is less than the value of the marginal product of labour for land improvement multiplied by the relative value of the Lagrange multipliers of the cash constraints. The higher the ratio of the Lagrange multipliers, the higher the investment in land improvements. To get an idea of the value of this ratio, any of the first-order conditions related to the consumption commodities can be used. From equations 6a and 6b the following relationship can be derived:

$$\frac{\lambda_c^2}{\lambda_c^1} = \frac{\beta \dfrac{\partial U\left(X_a^2, X_c^2, X_l^2\right)}{\partial X_l^2}}{\dfrac{\partial U\left(X_a^1, X_c^1, X_l^1\right)}{\partial X_l^1}} \qquad (6'')$$

This relationship shows that the relationship between the Lagrange multipliers is directly related to the ratio of marginal utilities across periods.

## Appendix 2: The case study

*A2.1 Survey structure*

For the case study, semi-structured interviews of 23 smallholders in the Batangas and Cebu City regions of the Philippines were undertaken to elicit the required information. Smallholders range from those involved in subsistence agriculture (without the ability to sell or hire labour or obtain credit) to those who have market access for cash crops and access to credit. All smallholders were, or have been, faced with decisions regarding long-term sustainability of farming activities and were making decisions based on their particular social, physical and economic constraints. Selected respondents were both adopters and non-adopters of conservation farming technologies. The interviews considered each individual's attitudes to on-farm and off-farm investment decision-making—how much is undertaken, why and what factors influence the level of investment. The following information was elicited in order to construct a picture of the smallholder decision-making process:

1. Labour
    - Alternative uses for labour. Including on-farm production, selling labour off-farm, or using labour for land improvement.
    - Use of hired or exchange labour. (Exchange labour is the use of neighbours to help with specific activities on-farm. Neighbours will help with the required activity, such as weeding or harvesting, with the understanding that they will in turn be helped when necessary. The only costs are incurred from the supply of meals during the workday.)
    - Functioning of the labour market. Whether or not there is a labour market and if so, how does it function and what are its limitations.
2. Credit and investment in activities with future outcomes, particularly land improvements.
    - Availability and uses of credit in the short term or long term. Household access to different types of credit and how they use credit.
    - Level of savings and mechanism for savings. If households have the opportunity to save and decide to save, how do they do it.
    - Functioning of the credit market. Determine whether or not there is a credit market and if so, how does it function and what are its limitations.
    - Investment in activities with future outcomes and the role of the credit market in the decision. What long-term investment opportunities are available, are they investing in these activities and the influences on this decision-making process.
3. Other
    - Land use; cropping and livestock systems.
    - Community, social and political structures and responsibilities.
    - Other issues considered important by the respondents.

The semi-structured interviews were used as a preliminary means of determining whether or not the model includes all relevant decision-making variables. It was undertaken after initial model formulation and, therefore, was also a means of identifying other important elements of smallholder decision-making that should be included. The information about each of the case study regions is noted below. This forms the basis for the discussion in section 4.

*A2.2 Batangas district*

Smallholders from two villages (*baranguay*) were surveyed in the Batangas region—2.5 hours drive from Manila (including 1 hour of dirt road). Twelve smallholders from the districts of Tuban and Arumahan within the village of Lemery were interviewed. All farmers in this area grow upland (highland, rainfall-dependent) rice intercropped with maize. Only one farmer was able to sell excess rice, all the others having to buy extra rice to satisfy basic household requirements. Most farmers also either owned or managed livestock (cattle and pigs) which were used as a form of savings and to generate cash. The sample of farmers at this site was mainly limited to older farmers (10 out of 12 were over 45) as the younger ones were forced to seek day jobs in the larger towns. The older farmers either had greater assets or access to remittances from children living and working in Manila.

A transition from a purely subsistence rice production to a potentially more profitable cash crop was generally perceived to be too risky by the farmers interviewed. Even though fertility decline was regarded as a major problem (75% of smallholders regarded it as a problem) smallholders did not know what the solution is, or were not convinced the construction of hedgerows or contour banks would both solve the problem and maintain food security in the short term. Some smallholders did believe that fallowing would help and none was actually implementing a crop rotation system as they all believed that they could not afford to leave land out of production; family basic food needs were seen as too great. Smallholders believed that they are locked into declining rice yields and would have to depend increasingly on off-farm income and remittances.

*Labour market*

Of the 12 smallholders interviewed, nine believed that, if they were confident that the technology to be implemented was going to improve fertility, they would have enough labour available to undertake the activity. Two of the three who said they wouldn't were semi-retired smallholders who relied on others to do their labouring. Only one farmer believed he would not have time. Likewise, when asked about the availability of off-farm work, those who received remittances from children working in Manila were less prepared to seek extra income than those without access to remittances. Most farmers interviewed also managed livestock (cattle and pigs). This responsibility kept them from searching for jobs that took them away from the village. One farmer (aged 30 who also worked as a carpenter) believed that the cattle management required him to stay on the farm. However, after further questioning he admitted that if he were offered 200 pesos per day to work off-farm he would consider leaving his wife in charge of the livestock (an average casual day wage rate is approximately 175 pesos per day). Only three of the 12 smallholders had worked off-farm although another three said that they would if they could find work.

These smallholders did not have the ability to pay for hired labour. When labour was required to help with particular labour-intensive on-farm activities they used exchange labour. Farmers only paid cash for rice milling (specialised equipment) and coconut harvesting (specialised labour). No smallholder paid for assistance with the rice crop and no smallholder was paid for on-farm assistance given to others in the village. The only means of obtaining income was from casual work outside the village, either in the construction or transport industries or on lowland farms. Off-farm labour is seasonal (construction and lowland farm work is not available in the wet season) and hence on-farm activities designed to alleviate soil fertility decline must also take into account seasonal labour availability.

*Credit market*

No farmer had ever borrowed money for the purpose of investing in on-farm activities. Only two had ever borrowed from a bank and that was to cover medical expenses and purchase of a 'jeepney' (local passenger transport) for use by a son. Each smallholder stated 'lack of collateral' as the reason both formal (banks) and informal (farmer coops) lending institutions had not been contacted. On the other hand, all farmers had either borrowed or lent money to neighbours on interest-free terms. The purpose of borrowing was for the purchase of basic necessities or health costs.

The nearest bank was in Lemery and not accessible to smallholders in these villages. Two farmers who had considered borrowing from the bank decided against applying because of the fear of not being able to repay and the length of time and bureaucracy required to obtain loan approval. Farmers believe they do not have access to credit.

*Other information*

These villages are remote and have had minimal access to government extension services. Traditional rice varieties are used with seed carried over from one crop to the next. It is only in the past 12 months, when this area has become an important upland rice study area, that new varieties have been considered and tested. Only one smallholder has actively tried to obtain new varieties and test different fertiliser rates on his own land. There is a lack of understanding concerning the use of hedgerows, contour banks, trees and legumes for soil conservation and hence fertility continues to decline.

While six of the twelve respondents used and maintained hedgerows, two of these were not sure why they were there. They had been constructed before these smallholders acquired control of the parcel of land and were used mainly to grow cattle feed. Only one of the respondents had used fallow in order to influence soil fertility, and three had planted trees. Trees were planted in non-arable land and not specifically for erosion control.

*A2.3 Cebu district*

Eleven smallholders were selected from four *baranguay,* Gabun, Aalaon, Taptap and Tabunan, in the province of Cebu City. All villages had sealed road access and were not more than 1.5 hours from Cebu City (the second biggest city in the Philippines). Each village had a history of government and NGO support going back 20 years. Recent assistance has been provided by a World Bank project now administered by the Cebu City Hillyland Resources Management and Development Commission (CCHRMDC). The land was more steeply sloping than Batangas and the soil more of a reddy-brown colour than the deep chocolate colour in Batangas. All smallholders produced cash and tree crops as well as maize for home consumption.

Buyers of produce (crops and livestock) were diverse. As well as traders regularly passing through the village there was a weekly market where all produce could be sold. There was also regular transport (daily) available into Cebu City if smallholders wished to sell in the larger markets. Unlike in Batangas, functioning produce markets were accessible.

*Labour market*

The labour market in this area is significantly more developed than in Batangas. All smallholders hire labour for necessary farming activities rather than using exchange labour. The only occasion that exchange labour has been used was when NGOs were encouraging the construction of contour banks and hedgerows (in the 1980s). All smallholders received off-farm income but, unlike in Batangas where smallholders depended on remittances and casual

labour away from the village, smallholders were able to receive income from transport, home production, forest wardens, farmer training and retailing. While maize was produced for household consumption, all farmers produced cash crops, ranging from flowers to tree crops (mangoes) and vegetables (tomatoes, beans, broccoli etc). As in Batangas, however, (nine of the eleven) smallholders interviewed believed that they had labour available that could be used if required to undertake further proven conservation farming practices. Labour was not believed to be the limiting constraint in the adoption of alternative activities; it was rather capital, availability of inputs and in some cases water. Only one smallholder considered labour to be a constraint. This respondent owned 3.25 hectares (the most land of any smallholder) and although he had constructed contours with the help of government programs, he was relying on fallowing for maintaining fertility. He fallowed half his land every year.

*Credit market*

The credit market in Cebu was more developed than in Batangas. Smallholders here did not depend on neighbours for short-term borrowing or support but rather used the farmer cooperative and local shops. Three respondents had borrowed from banks but none had borrowed for on-farm investment purposes. All smallholders received credit from local input providers at average interest rates of 5% per month (equivalent to 80% per annum). This was used to purchase both food and fertiliser and seed to be repaid after harvest. Smallholders were not prepared to approach banks for longer-term or large-scale borrowing, even though capital and equipment were regarded as limiting the ability to change or develop farming activities. Only three respondents had borrowed from neighbours but ten of the eleven had received credit from the farmer cooperative and/or shop.

*Other information*

A major difference between this site and Batangas is the influence of both government and NGO support, especially during the 1980s. Soil erosion and fertility decline were major problems, with farmers growing continuous maize crops without fallow and without other rotation crops on particularly sloping land. The availability of new technology and assistance in constructing hedgerows and contour banks plus the close proximity of a large urban market were major factors in the development of smallholder cash crop farming systems. Farmers had seen productivity decline as a major problem but knew of no alternative technology to both provide food security and conserve the soil. Both tenants and landowners embraced the new technology, spending the required labour resources to construct the necessary infrastructure (the most recent contour banks constructed were in 1996, where it took four family members two weeks to build the banks on a 1 hectare parcel of land). While some banks have been flattened, these have been substituted with fallow, which is regarded as a more efficient (but more costly) method of improving soil fertility.

Land tenure is still major issue in this region, with only three of the respondents owning all of their land. Of the other eight, four were tenants only and four worked both owned and tenanted land. Tenant farmers tended to be less likely to make long-term investments than did owners. One tenant, in particular, who had made significant improvements over a 30-year period was very concerned about being forced to start afresh on land that would be redistributed to him by a government land tenure reform program. He wished to stay where he was but the landowner had the power to force him to accept new land.

Of the eleven respondents in this area, four had constructed hedgerows and contour banks of their own volition after observing the technology on neighbouring farms. All smallholders had continued to maintain these structures and seven had constructed extra hedgerows and banks without government or NGO support. Smallholders in the early 1980s were trapped in a poverty cycle and faced with a continuing decline in yields. At that time, without access to

off-farm income sources, farmers were forced to make changes to their activity types and farming practices. While labour was available, assistance with information and capital made the transition possible. Even with greater access to markets, information and short-term credit now, the interviewed farmers believed that labour (apart from during peak sowing, weeding and harvesting times) could be made available if further longer-term soil conservation activities were deemed appropriate.