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Savings and technology choice for risk averse farmers

Donna Brennan†

Farmers in developing countries have limited opportunities for borrowing to even out variability associated with risky farm income, but they can save. A dynamic programming model of savings is presented in the current paper which examines optimal savings strategies for farmers, using a case study of integrated rice-shrimp farms in Vietnam. It is shown that when savings are accounted for, the expected utility ranking of different risky farm choices may not differ that much between farmers with different levels of risk aversion.

1. Introduction

There is a large volume of literature dealing with farmer risk aversion. This includes studies that measure attitudes to risky outcomes (e.g. Moscardi and de Janvry 1977; Binswanger 1980; Antle 1987), those that evaluate risky farm management choices using commonly accepted assumptions about the nature of farmers' attitudes to risk (e.g. Newberry and Stiglitz 1981; Lambert and McCarl 1985; Goetz 1993) and those that rank farm income choices without imposing assumptions about the nature of preferences to risk (e.g. Patten *et al*. 1988; Pandey 1990; Cacho *et al*. 1999). One aspect that these approaches have in common is that they refer to variation or uncertainty in annual income, with the underlying implication that the farmer gains his/her utility from income rather than from consumption.

The literature on farm financial management applies the tools developed in financial economics to analyse risky choices for sophisticated (developed country) farm managers. For example, Barry *et al*. (1981) and Collins (1985) examine farmers' choices over a portfolio of risky activities, where opportunities for borrowing to acquire more productive assets is accounted for. While this approach recognises the farmer's ability to borrow against assets to expand production choices, the focus on a single period outlook (the model performs a mean-variance test on returns to assets in the next period) still implies that farmers are myopic. In contrast, Collins and Karp (1995)

† REAP Research, North Perth, WA, Australia.

propose a lifetime choice model where farmers are risk neutral but make decisions over a long term planning horizon and only care about variations in annual income if they affect the net wealth position of the farm. This representation implies that the farmer has flexibility to draw down and accumulate cash against his/her net wealth position and so can manage stochastic cash flows. This is a reasonable approximation for farmers in developed economies.

In developing countries, farmers do not have access to these types of financial management tools. In many cases, formal credit is only available for farm working capital and on a crop-seasonal basis, and informal credit is so expensive that long term loans for consumption are not feasible.[1] Hardaker *et al.* (1997) argue that in such cases (i.e. where capital markets are inadequate) then maximising the present value of expected income or the expected wealth of a farm enterprise (as in the agricultural finance literature) is not appropriate. They suggest that the problem should be analysed by maximising the discounted sum of utilities derived from the variable income stream.

Even though farmers in developing countries cannot readily access loans to supplement consumption in years of low cash income, they can choose to accumulate liquid assets in periods of high production as a safety net for bad production years. Thus, the decision-making problem is somewhere in between the Collins and Karp (1995) 'borrow and save' model, and the Hardaker *et al.* (1997) 'consumption equals current income' approach.

An alternative approach is presented in the current paper which takes an uncertain cash income stream and examines optimal savings strategies for farmers with different levels of risk aversion. Unlike the Collins and Karp (1995) model, the opportunity for inter-temporal consumption smoothing is one-sided, because borrowing is impossible or prohibitively expensive. This means that the decision-making problem cannot be represented by simple analytical models, but the numerical solution techniques that have been employed to examine the problem of commodity storage (e.g. Williams and Wright 1991) can be adapted to solve for optimal savings strategies.

In the present paper, a case study of a farming system that has recently been widely adopted in the Mekong Delta of Vietnam is used to evaluate risky choices for two different savings strategies. The consumption stream that occurs when farmers employ an optimal savings strategy is compared with the case where no savings are used. If the ability to save is ignored when evaluating the risky farm choices then the widespread adoption of a risky

[1] For example, in the case study area examined in the present paper, interest rates paid on informal credit were 7–8 per cent per month (Brennan *et al.* 1999).

farming practice, shrimp farming, that has been observed in the Mekong Delta seems inconsistent with commonly held views about the risk averse attitudes of semi-subsistence farmers. In contrast, when savings are considered, the adoption of the risky farming activity is consistent with a high degree of curvature in the farmer's utility function.

The outline of this paper is as follows. First, a brief description of the farming systems used in the case study region is provided. The farm cash income prospects from different farming practices are then evaluated using a model that first estimates optimal savings strategies that maximise expected utility from consumption. Expected utility results from the dynamic (with savings) model are compared to the expected utility that is calculated from the underlying cash income stream when no savings are assumed.

2. The risky farming problem

The case study described in the present paper is an example of an extremely risky choice. Traditionally, farmers in the coastal areas of the Mekong Delta have been limited to farming in the wet season because naturally occurring saline intrusion in the dry season precludes irrigation. In the 'rice-shrimp' farming system, the farmers flood their fields with this saline water and raise shrimp in the dry season. Wet season rice is an important crop for meeting rice subsistence needs, and any surplus is sold for cash. However, income from shrimp production is, on average, the most important source of cash, comprising 60–65 per cent of household income, with the remainder coming from surplus rice sales, wet season cash crops and off-farm employment (Brennan *et al.* 2000).

There has been widespread adoption of shrimp farming in the saline affected agricultural lands of the Mekong Delta in recent years. For example, in a survey of 32 hamlets in Soc Trang and Bac Lieu Provinces in 1997, Brennan *et al.* (1999) found that 98 per cent of traditional rice growing farms now practiced some form of shrimp production. While there is anecdotal evidence to suggest that rice monoculture farms have better rice yields (Tran *et al.* 1999), more recent scientific research failed to find any evidence that the inundation of salty water in the rice-shrimp cycle affected rice yields (Phong *et al.* 2002). Rice monoculture farms also engage in other wet season cash crops and sell surplus labour off the farm where possible, hence the main difference between the rice-shrimp and rice-only farming systems is the larger but risky cash income from dry season shrimp activities.

The main source of risk is in the shrimp farming operation because cash outlays are relatively large and there is a high probability of total crop failure. On the other hand, if survival rates are high, the income realised is an order of magnitude better than the income of the rice crop. The nature of risk

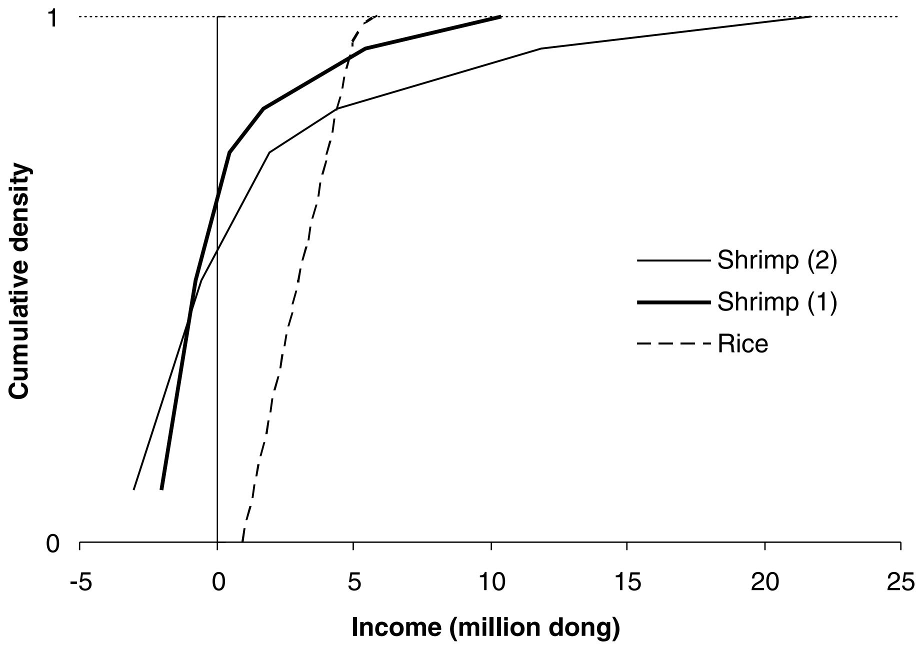

Figure 1 Income risk for rice and shrimp production. Source: Simulated from typical farm characteristics reported by Brennan *et al*. (1999). Two shrimp values representing different shrimp stocking rates (postlarvae per square metre in parenthesis).

is illustrated in Figure 1, using observed yield and survival data for rice and shrimp, and representative cost structures.[2] This allows illustration of the key components affecting income risk. There is, in fact, considerable variation in shrimp farming practices on farms in the region which also affects cost and incomes from shrimp production (Brennan *et al.* 2000). However, it is believed that much of the variation in survival is caused by endemic disease, for which the farmer has no technology to control.[3] The effect of this 'exogenous' variation in survival on income from shrimp farming is illustrated in the schedules for two different stocking rates in Figure 1.

The production economics of the farm household is treated very simply. It is assumed that the only variable input to shrimp farming is shrimp seedstock

[2] Data used in the present analysis was derived from a survey of 212 farms in Gia Rai district of Bac Lieu province in 1997. These data are reported in Brennan *et al*. (1999), and Brennan *et al*. (2000).

[3] Biotechnologists have developed sophisticated testing technologies to check for the presence of white spot but such technology is out of the reach of farmers and hatchery operators in Vietnam at present.

(postlarvae or PL).[4] Income from shrimp production is equal to revenue less stocking costs, where yield depends on the stocking rate and the random survival of the shrimp. Annual income is defined by a stable component (which is made up of off-farm income and wet season rice production[5]) and an unstable component, which is income from shrimp production. In order to emphasise the difference between the 'with' and 'without' savings models of expected utility, the focus of the analysis is on savings as the decision variable. The analysis is conducted for different shrimp stocking rates to illustrate how increased (multiplicative) risk affects optimal savings, and how, as the degree of risk varies, so does the effect of ignoring potential savings strategies. Algebraically, the annual income ($\tilde{Y}$) derived from farm household activities is given by Equation 1.

$$\tilde{Y} = K \cdot (P\varphi - C) + O \tag{1}$$

where K is stocking rate, number of postlarave per 1 ha of pond, P is price per individual shrimp harvested, φ is random survival (number harvested as a proportion of number stocked), C is the cost of stocking, per postlarvae, and O is net income from other sources.

3. Managing consumption risk using savings

The purpose of this present exposition is to illustrate savings strategies under conditions of zero expected growth in income. Thus, the literature on risky choices in the context of stage of life (e.g. Hardaker *et al.* 1997) is ignored. The model presented in the current paper ignores life cycle issues by presenting an infinite planning horizon, which implies that utility derived from bequests to future generations is equivalent to the utility that would be derived by the current decision-maker if she were to live forever. This allows for the solution to be a savings rule dependent on beginning of year cash funds, applicable for all years.

The annual income ($\tilde{Y}$) derived from the farm household activities was described in Equation 1. Consumption in any period t is determined by the identity:

[4] While farmers in neighbouring regions have begun to use more sophisticated technology (e.g. supplementary feeding) and appear to have had better success with shrimp farming, there is no conclusive evidence on the nutritional requirements for shrimp in these extensive farming systems. For farmers in the remote district of Gia Rai, investment in shrimp can almost be likened to a lottery. The analysis presented in the current paper uses data on shrimp costs and survival from a field survey of farms in Gia Rai.

[5] Because the rice crop is irrigated, yield is quite stable and the contribution of farming in rice yield to variation in farm income is relatively unimportant.

$$C_t = \tilde{Y}_t + (1+g)\cdot S_{t-1} - S_t; \qquad S_t \geq 0;\ C_t \geq 0 \tag{2}$$

where $\tilde{Y}_t$ is cash income in period t, S_{t-1} is savings carried into the year, S_t is savings carried out of the year, and g is the potential return on savings.

The farm decision-making problem can be specified as choosing a set of savings decisions for t = 1 to ∞ to maximise the expected value of utility, V, defined as:

$$\text{Max V} = \text{E}\left[\sum_{t=1}^{\infty}(1+r)^{t-1}U(X_t, S_t, \tilde{Y}_t)\right]; \qquad S_t \geq 0 \tag{3}$$

where r is a discount factor reflecting farmer's rate of time preference (which may be different from g, the return on saving) and X is the state variable defined as:

$$X_t = S_{t-1} \quad \text{for } t > 1, \tag{4}$$

and X_1 is the farmers opening cash level. The utility function, U, is represented by a constant relative risk aversion model, based on a power function:

$$U = \frac{1}{1-R}C^{1-R} \tag{5}$$

The effect of the risk parameter R on the shape of the utility function, for the range of parameter values R used in the present study, is illustrated in Figure 2.

Making use of the recursive functional for infinite-stage dynamic programming problems, problem (3) can be written as:

$$V^*(S) = \max(E[U(X, S, Y) + (1+r)\cdot V^*(S)]) \tag{6}$$

Optimal savings are affected by the shape of the utility function, or degree of risk aversion; the shape of the probability distribution of annual cash income; and the decision-maker's discount rate. There are a number of methods for solving this problem. For example, an approach that has been used to evaluate similar commodity storage problems is to estimate the optimal strategy (or its dual) as a smooth function of the state variable (e.g. Williams and Wright 1991; Gardner and Lopez 1996), where the expected future marginal value of storage is estimated as a function of the amount stored. An alternative approach is to calculate a discrete set of state/choice pairs using a general purpose dynamic programming algorithm. This approach is applied here. The basic parameters used in the model are shown in Table 1.

4. Discount rates

The choice of discount rate used in analysing decisions made by developing country farmers is often influenced by the argument that the very poor have a

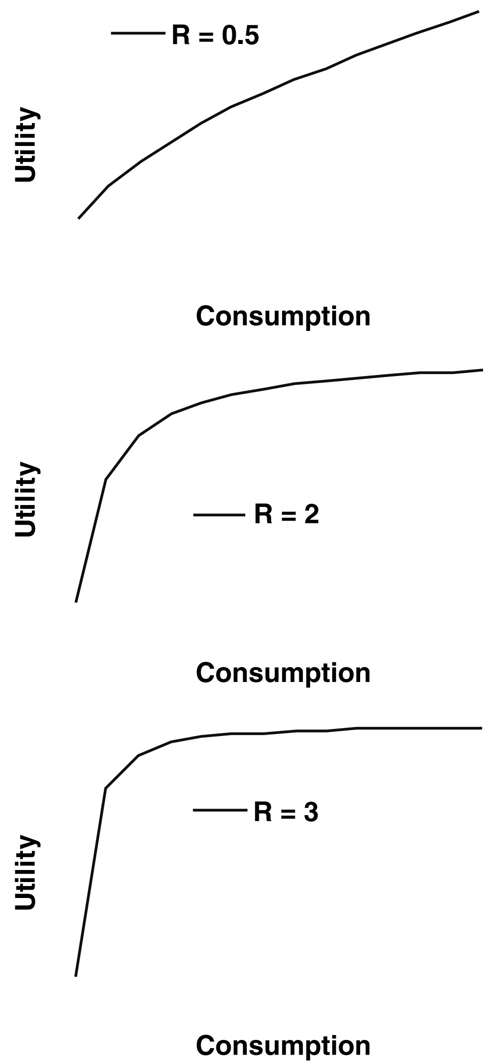

Figure 2 Illustration of effect of risk parameter R on curvature of utility function.

high rate of time preference for current consumption. However, in this model a preference for avoiding low current consumption is reflected in the utility function for the 'risk averse' farmer. Consequently, a discount rate typical of social discount rates used in public investment analysis is used. It is assumed that farmers do not invest their savings in interest bearing accounts and that returns to savings are zero.[6] The effect of varying the discount rate and the return on savings is illustrated in a later section.

[6] Brennan *et al.* (1999) observed that farmers held savings in the form of cash and gold.

Table 1 Assumptions used in the farm production model

Item and units	Value
Shrimp price dong per kg	100,000
Cost of postlarvae dong per postlarvae (PL)	100
Average weight of harvested shrimp grams	30
Expected yield kg per postlarvae stocked per square metre	33
Income from shrimp production million dong per postlarvae stocked per square metre	4.3
Other household income (million dong per farm)	1, 2, 3
Risk parameter R	0.5, 2, 3

Assumed one ha of shrimp growing area per farm. 1 AUD is equivalent to about 8,500 dong.

5. Optimal savings and dynamically optimal consumption

The GPDP algorithm (Kennedy 1986) was used to estimate optimal savings as a function of the state variable, X_t. Results are illustrated in Figure 3. The more risk averse farmer is likely to save more for any given level of cash availability because of the greater disutility from reduced consumption. However, it can be seen that even the less risk averse farmer will also save to smooth consumption, although the propensity to save is less.

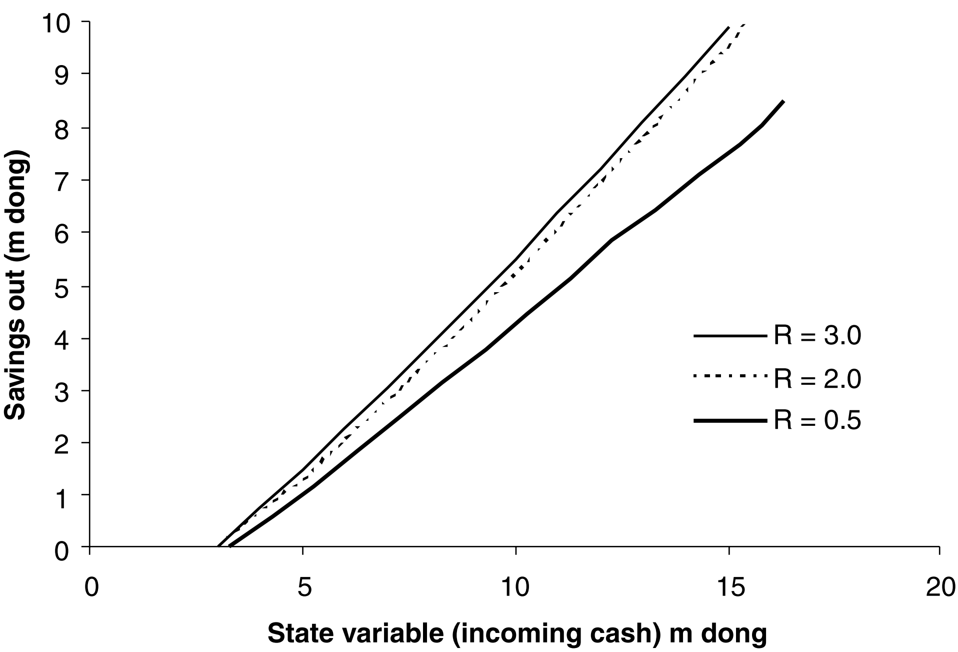

Figure 3 Optimal savings for different risk parameters, where stocking rate is 1 postlarvae per square metre.

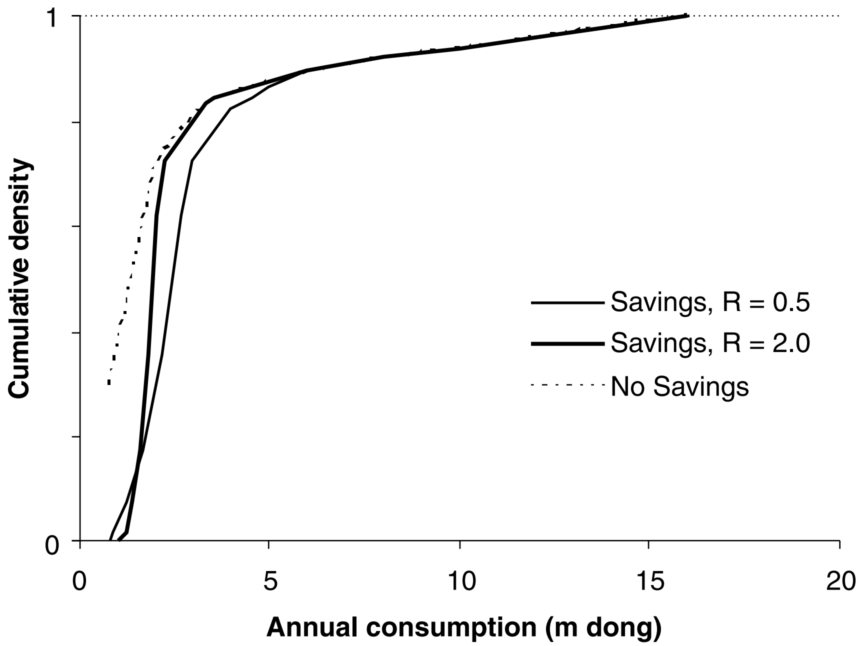

Figure 4 Dynamically optimal consumption pattern for different risk parameters, compared to the "no savings" model.

The effect of these optimal savings patterns on the probability distribution of consumption is shown in Figure 4. Compared with the consumption pattern that would occur if the farmer did not save; the introduction of savings leads to a rightward shift in the cumulative distribution function, with a reduction in the frequency of very low consumption. The effect of the degree of risk aversion on the probability distribution of consumption is that the more risk averse farmer has a steeper probability distribution of consumption, with a reduction in the frequencies of very low consumption and very high consumption. This is the result of a higher propensity to save.

5.1 Effect of discount rate

The effect of discount rate on the optimal level of savings is illustrated in Figure 5. A high discount rate creates a disincentive to save, as expected. The effect of allowing a return on savings was also analysed and has the expected effect of increasing the marginal propensity to save. Just as varying the time preference and returns to savings affected the optimal level of savings for different risk aversion coefficients, they also affected the simulated probability distribution of consumption patterns and expected utility. However, sensitivity analysis on the ranking of technology options (presented below)

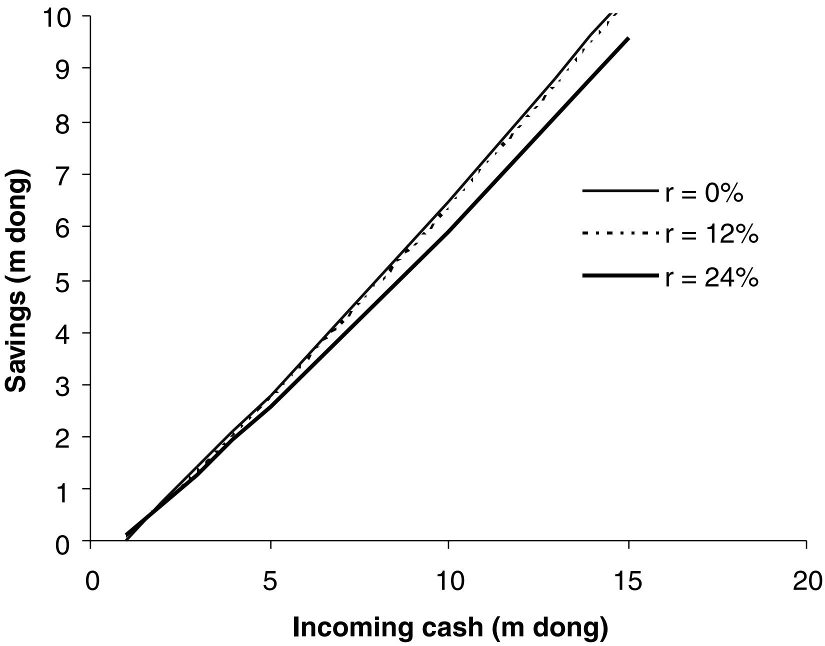

Figure 5 Effect of discount rate on savings, for R = 2.

revealed that the calculated rankings were robust to a wide range of assumptions about discount rates.

6. Impact of the dynamic model on interpretations concerning optimal technology

Expected utility analysis is often used to examine the type of technology that would be preferred by farmers with different risk attitudes. These analyses are usually based on converting a given probability distribution on cash income to an expected utility measure (e.g. Fraser 1992). It is demonstrated in the present paper that such an analysis is misleading if there is no accounting for the ability to use savings to even out the consumption stream. In this section, expected utility analysis is used to rank three technologies, using both the 'with savings' and 'without savings' approaches. The three technologies are: no stocking, stocking at 1 PL per m^2, and stocking at 2 PL per m^2 (the most risky case). Analysis was conducted for a range of risk parameters and results are shown in Table 2. Also shown is expected annual cash income ($\tilde{Y}$) and the coefficient of variation (c.v.) in income for each technology.

The first column of results shows the expected utility calculated for the 'with' and 'without' savings cases, where the risk aversion parameter is 0.5. At this almost-neutral preference set, the effect of ignoring savings does not

Table 2 Preferred options under risk: with and without savings

Stocking rate	Coefficient of relative risk aversion R: Mean Y (C.V.)	Model	Calculated expected utility: 0.5	2	3
0	2 (0)	(No risk)	2.83	−0.50	−0.13
1	4.3 (93%)	With Savings	3.90	−0.29	−0.05
		Without Savings	3.78	−0.47	−0.16
2	8.3 (98%)	With Savings	4.72	−0.24	−0.04
		Without Savings	4.34	−257.70	−128788.00
Implied ranking of technologies (stocking rates)					
		With Savings	2 > 1 > 0	2 > 1 > 0	2 > 1 > 0
		Without Savings	2 > 1 > 0	1 > 0 > 2	0 > 1 > 2

alter the conclusion regarding the desirability of adopting the highest stocking rate which has a much higher return but higher risk than the other options.

The two other columns show results for more risk averse farmers (R = 2, 3). These degrees of curvature in the utility function are plausible for poor farmers because bad years impose extreme hardship. If expected utility were calculated based on the cash income (rather than smoothed consumption) stream, it would be concluded that a farmer with a risk aversion coefficient of 2 would prefer to adopt a stocking strategy of 1 postlarvae per square metre. The farmer would rank no stocking (the risk free option) ahead of the most risky (high) stocking option. In contrast, if we allow for the fact that the farmer can save in good years in order to stabilise consumption, the conclusion is different. By following an optimal savings strategy, the farmer can maximise utility by adopting the highest, and most risky, stocking strategy.

Similarly perverse conclusions are drawn for the risk aversion coefficient of 3, if savings are ignored. As shown in table 2, if expected utility is calculated from annual cash income, it would be concluded that the farmer would not adopt shrimp farming at all, because the high variance is weighted heavily. In contrast, if an optimal savings strategy is followed along with a high stocking rate, the resulting consumption pattern gives the highest level of utility compared to the other stocking options. In fact, technologies are ranked in order of expected income, because the variance can be sufficiently dampened by savings.

In the context of the above analysis, the widespread adoption of shrimp farming in the region can either be explained by fairly neutral attitudes to risk, or could be interpreted as being consistent with a high degree of curvature in the utility function, where farmers adopt savings to dampen the variability in consumption. Because these farmers are very poor it is not very plausible that utility functions would be almost linear in consumption, as implied by the R = 0.5 scenario. In contrast, it has been observed in the field that farmers adopting these risky farming practices do actively save significant amounts of liquid assets as a strategy for managing risk.

7. Conclusion

Regardless of whether farmers in developing countries are risk averse or not, the models of farm financial management that have been applied to consider risky farm choices in developed countries are not relevant because they assume that farmers can borrow or save to smooth variability in annual returns. However, an alternative method that has been proposed for the imperfect capital markets case – that of weighting cash income streams using expected utility analysis, while ignoring the ability of farmers to accumulate assets during bountiful years to smooth consumption in lean years – is also misleading.

The analysis presented in the current paper demonstrated that it is reasonable for a risk averse rational farmer to adopt a risky farming practice if that farmer can save. The consumption pattern resulting from an optimal savings strategy is much more stable than the underlying income stream. For the case study presently examined, this meant that the expected utility ranking was always higher for the risky choices that had higher mean returns, even for very risk averse farmers. These results contradict the rankings that would be made by estimating expected utility derived from consumption while ignoring savings. The likelihood that the two types of models lead to different results is higher when there is a greater risk, and a higher level of risk aversion.

The method used here to analyse alternative stochastic income streams could be applied to other similar problems, and the availability of the generic GPDP software used in the present study means that the task of estimating optimal storage strategies is relatively straightforward. The approach can be used to evaluate income profiles for a range of technology choices and the model presented in this paper analyses the case where savings is the only method for inter-temporal consumption smoothing. With the addition of another state variable, the model could be extended to consider other means of transferring assets through time, such as storing physical assets like water or fodder or mining the natural resources on the farm.

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