Household resource allocations in response to risks and returns in a communal area of western Zimbabwe

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Abstract

A household production model is constructed in the context of a subsistence economy, influenced by fluctuating rainfall, increasing populations, and relationships to the natural resource base. Households are modelled as attempting to optimally allocate their resources among four sectors: agriculture, woodlands (with wood and non-wood sub-sectors), livestock and urban. Simulations show that, although welfare decreases over the 50-year simulation period, the resource base appears to be able to sustain the increased pressure. Data to feed the model are limited, implying further research is needed on: resources expended by households by sector, perceptions of risk, and differentiation within and among households according to gender and wealth. Despite data limitations, results show the importance of considering that households may allocate resources between multiple sectors, as these options may buffer their welfare from rainfall shocks and increasing population pressures. © 2000 Elsevier Science B.V. All rights reserved.

1. Introduction

Many households in Zimbabwe depend on the natural resource base, in the context of fluctuating rainfall, changing economic conditions, and increasing populations. However, the behaviour of these households, as they seek to maintain and/or improve their livelihoods in response to risks and returns, is not well understood. Bradley and Dewees (1993), for example, point out that:

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A typical approach to assessing household allocation decisions in the economics literature revolves around household production models. Cavendish (1997) reviews this approach in the context of Zimbabwean households, and notes the difficulties in solving for the optimal household solution in the context of multiple resource uses in a dynamic, risky environment over time. His approach is to simplify the model to a point where it may be solved by ignoring dynamics and risk. In contrast, our approach is to attempt to capture more reality by including risk and dynamics over time, but at the cost of constructing a simulation, instead of an optimisation, model.

In this paper a stylised model of human behaviour, with linkages to the ecological system, is constructed. In essence, the model simulates resource allocation behaviour by communal households. The paper outlines a model of how rural households within and adjacent to Mzola State Forest in the Lupane district, Matabeleland northwestern Zimbabwe, allocate their household resources among crop production, raising livestock, urban employment and gathering products from woodlands in response to risks associated with each sector, and changes in variables such as rainfall, human populations, and employment opportunities. The effort exerted by households in each sector is linked to their expectation of the value that they may obtain from each sector. In addition, whether the resource base may sustain the household activities is modelled.

The model developed in this paper should be regarded as a ‘scoping model’ in that its purpose is to provide a general method for modelling household allocation decisions and a framework for generating specific research questions, rather than to generate accurate simulated scenarios. As will become evident in the following presentation, there are large data gaps where expert opinion was used in order to simulate scenarios.

The paper proceeds as follows. In the next section, background information regarding the socio-economic and biophysical characteristics of the study region, along with characterisations of the modelled sectors, are reviewed. Next the model and the methods used in the simulations are presented. The results are then presented and discussed, followed by our conclusions and recommendations for further research.

2. Background

2.1. Bio-physical

The Lupane district falls within Natural Region IV, the largest (14.7 million ha) of the five natural regions into which Zimbabwe is divided. With a mean rainfall of 650 mm per annum, this region is subject to periodic seasonal droughts and extreme dry spells during the rainy season.

Two main vegetation types cover Mzola State Forest and surrounding communal areas: mopane (Colophospermum mopane) woodland and Baikiaea–Schinziophyton–Pterocarpus woodland. In addition, there are grasslands in the drainage lines (dambos). Dambos are the focus of both crop production and livestock grazing. They are also the main areas from which thatching grass is collected, yet form a small proportion (<10%) of the total land area. Baikiaea–Schinziophyton–Pterocarpus woodlands on leached, drought susceptible Kalahari sands cover a major portion of the study area, followed by Colophospermum mopane woodlands on more clay-rich soils.

2.2. Socio-economic

Our model is based on households within and adjacent to the Mzola State Forest. In 1997, there were 1225 households in the communal area adjacent to Mzola State Forest and about 500 ‘squatter’ households within the State Forest. The combined areas of the communal lands and the State Forest occupy 136 000 ha. The communal area lies within the Lupane district that has a total population of 94 800 people, with a population density of 12.28 people/km² and a population growth rate of 3.09% per annum (Central Statistical Office, 1992).

The size of households in communal areas in Zimbabwe is an important factor determining the

availability of labour that can be directed to the crop, livestock, woodland product or urban employment sectors. Average size of household is 6.2 persons in the communal area adjacent to Mzola State Forest (Gwaai Working Group, 1997). There is a somewhat larger mean household size amongst households within the State Forest. Polygamous households are fairly common in the area. In two villages within the communal areas adjacent to the State forest (Bimba 1 and Bimba 2) approximately 20% of the households were headed by women (Gwaai Working Group, 1997). Mean household income per year in well-wooded areas of Zimbabwe was ZS2495 in 1994 (c. US$300) (Campbell and Mangono, 1994). Cavendish (1997) reports an average income of ZS3528 in 1993/94 (c. US$500) including in-kind income from woodland products (see also Clarke et al., 1996).

Human settlements in the study area are concentrated within 3–4 km of rivers and dambos. These concentrations enable easier access to water, better grazing and arable soils. Thus, dambos and nearby woodlands are likely to feel the greatest pressure from increasing population.

2.3. Characterisations of modelled sectors

2.3.1. Livestock

Livestock play many roles within the farming system and household economy (Campbell et al., 2000), and people invest in livestock as a form of savings and an indication of wealth. Herds consist of both cattle and goats, with the ratio between these two depending on wealth and rainfall. In dry times, there is a shift from cattle to goats, which are more tolerant of drought (Steinfeld, 1988). Livestock units (LU), equivalent to 500 kg liveweight, are a standard measure for a species mix to determine the pressure on a given grazing area. On average, households in the study area own 4 LU.2

2.3.2. Crops

Agricultural land per household in the communal area is thought to be 3 ha, while holdings in the State Forest average 9 ha. Weighting these amounts by population yields an average of 4.7 ha per household. Households typically cultivate crops in gardens on dambos as well as in dryland systems on sandy soils away from dambo margins. Pearl millet (Pennisetum) and two Sorghum types (for seed and sweet stems) are commonly intercropped with pumpkins and melons (Citrullus lanatus) in dryland systems. Maize (Zea mays) is cultivated during high rainfall years, but it is a risky crop in the region due to the drought susceptible soils and uncertain rainfall. Sweet potatoes (Ipomoea batatas), peanuts (Arachis hypogoea), beans (Vigna sp.), bambara groundnuts (Vigna subterranea) and okra (Hibiscus esculentus) are cultivated on the more fertile soils of dambos or dambo margins. Edible greens are collected from cultivated crops (e.g. pumpkin shoots) as well as from ‘weeds’ within fields (e.g. Cleome gynandra, Amaranthus).

Uncertain rainfall greatly increases the risk for cash crops, particularly in dryland farming systems where farmers attempt to grow maize, rather than more drought-tolerant sorghum and pearl millet. As a result, there is increased reliance on livestock production, with nearly 80% of livestock in Zimbabwe grazing in Natural Regions III–V, where rainfall is lowest (GFA, 1987).

2.3.3. Woodland use: wood and non-wood sectors

Woodlands provide ‘green social security’, the last safety net for poor rural households during drought or periods of economic depression and high urban unemployment. One indication of this is the rapid rise in numbers of people marketing wood carvings, basketry and other gathered products (mopane caterpillars, wild fruits such as Strychnos cocculoides, fuelwood and thatching grass) in western Zimbabwe (Braedt and Gunda, 1988; Hobane, 1994, 1995; Matose et al., 1997). Woodlands also provide a major source of low-cost housing materials, fuel, household utensils, medicines, farm implements, products for processing or storage of crops (grain stamping mortars, winnowing trays, granaries) and dietary supple-

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ments. Campbell et al. (1991), for example, record woodland trees as the source of 96% of domestic utensils, 98% of agricultural tools and 94% of rope and cord.

Household wood consumption rates for fuel and construction have been relatively well studied in Zimbabwe and are reviewed by Campbell and Mangono (1994). Median fuelwood consumption for cooking is 4.5 tonnes/household per year, to which must be added wood use for other activities (beer brewing (0.2 tonnes), brick burning (0.4 tonnes) and special occasions (0.7 tonnes)), giving a total of 5.8 tonnes/household per year for fuelwood and 2 tonnes/household per year for construction timber. In well-wooded communal areas, such as this study area, women spend 9 h/week gathering fuelwood in the dry season and 3 h/week during the wet season (Campbell and Mangono, 1994). By comparison, the time men spend collecting construction timber is negligible (8.2 h per trip every 2–4 years).

Wild foods (fruits, edible greens, mushrooms, insects) are gathered by women and children, and are an important seasonal activity for poorer households. Starchy staple diets are frequently deficient in nicotinic acid, vitamin C, calcium and riboflavin, protein and caloric values. Bush foods gathered from woodlands of the study area are valuable dietary supplements providing nutrients deficient in the starchy staple diet of local people. Particularly important are nicotinic acid from wild spinach, vitamin C from a range of wild fruits, and protein from *Sclerocarya birrea* and *Schinziophyton rautanenii* seeds and edible insects. Favoured wild fruit-bearing trees such as *Strychnos cocculoides* are frequently maintained in agricultural fields (see Chivaura-Mususa et al., 2000).

Although values from wild foods will decline with severe reduction in tree cover or with species specific over-exploitation, woodland systems are very resilient to wild food gathering (McGregor 1995). For this reason, in the model that follows, we assume that the share of household effort in gathering wood and non-wood products will not be directly affected by population growth. A greater potential effect on woodlands may occur as they are cleared for crop production, which results in a decline of woodlands for both gathering and livestock grazing.

2.3.4. Urban sector

The urban sector is included in the model as returns to households from remittances are significant, especially in times of low rainfall. Most people in rural areas rely to a certain extent on remittances from the cities. In return, agricultural foodstuffs are frequently returned to the city. However, returns from the urban sector are quite risky since employment opportunities are difficult to secure and these opportunities are influenced by shocks to the macro-economy. Also, employees might use their wages to maintain a household in the city and not send money back to their rural family.

Although a high level of urbanisation (5% per year) is a general trend in Africa (Huntley et al., 1989), urban migration is strongly influenced by the availability of urban employment. Between 1977 and 1993, the proportion of Zimbabwe’s total population employed in the formal sector dropped from 15.6 to 11.6% (Bond, 1996). Between 1985 and 1993, real wages dropped by 35% (Bond, 1996). Decreasing wages and reduced opportunities for employment imply that more people may be relying on communal areas for their livelihood. Government subsidies to communal agriculture through drought relief and the provision of seed, fertiliser and tillage have provided an additional incentive for people to remain in, or move to rural areas (Bond, 1996).

3. The model

In order to characterise the response of households to changes in environmental and economic conditions, a stylised household decision model was constructed. The general structure of the model is shown in Fig. 1. Circles and squares represent variables in the models, while arrows represent interrelationships between variables. Types of variables are differentiated as squares and circles, with squares representing state variables that may accumulate values or be drawn down. Hollow arrows are differentiated from solid arrows in that hollow arrows represent flows to state variables. Variables with lighter perimeters represent variables that are used in a number of sectors.
Fig. 1. Structure of the household model
The model functions to allocate household ‘effort’ to five activities or sectors, in response to the returns from these sectors and the associated risks. The sectors used are crops, livestock, urban, woodland non-wood, and woodland wood. Another component of the model includes a household utility sector. Households are shown to derive their utility from the five sectors of the economy, thus in this sector the total returns to the household are calculated. Also included is a physical inputs component that tracks quantities of natural resources being drawn from the natural resource base and a rainfall sector taken from the ecological model (Gambiza et al., 2000).

All five sectors of the economy are similar in that their respective functions are shown to allocate shares of household resources depending on the variables of rainfall, and risks and returns of a given sector. Variables beginning with \( m \) are parameters that represent marginal utilities associated with variables. All sectors except for the urban and woodlands non-wood products sectors are shown to be directly influenced by population. The woodlands non-wood products sector is assumed to not be directly affected by population because, as discussed above, their production is believed to be quite resilient to population pressures. Similarly, the urban sector is assumed to not be directly affected by population. Despite the fact that the urban and woodlands non-wood sectors are not shown to be directly affected by population, the model does account for indirect effects. As population pressures degrade natural resources, returns decline thereby attracting more resources to the urban sector. The woodland wood products function is shown to have a biomass variable to account for growth dynamics of the woodland over time.

A number of theoretical approaches for modelling household behaviour could be used. For this model, we adopt random utility theory, as it is quite flexible, allowing us to include large numbers of diverse considerations within the Stella framework. This theory supposes that individuals choose from alternatives based on the utility associated with these alternatives. However, the utilities arising from these alternatives are not known with certainty to the analyst. This uncertainty causes a random element to be associated with household decisions and may be addressed with a model that produces probabilities of investment in each sector. We interpret these probabilities as shares of resources devoted to each sector. Thus, we employ the random utility structure as a method of apportioning the household resources.

The five sectors are assumed to capture all of the household’s ‘effort’. Thus the shares of effort must total unity. The modelling approach chosen to meet this need, while capturing the interactions described above, is centred on a multinomial logistic function. If the utility arising from effort allocated to each sector \( i \) is represented as:

\[
U_i = (\text{Returns, Risk, Environmental}) \tag{1}
\]

then the share of resources devoted to sector \( i \) is:

\[
S_i = \exp(U_i) / \sum \exp(U_i) \tag{2}
\]

where \( i = 1\ldots5 \).

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3 We use of the term “effort”, as we do not have the data necessary to allocate distinct factors of production (i.e. land, labour, capital and management) amongst sectors. Therefore, effort may be interpreted as an amalgamation of household resources. Of the components that may make up household effort, labour resources have been identified as the primary variable input into production decisions in the context of smallholder Zimbabwean economies (Campbell et al., 1997). An important exception, addressed in a latter section, may be the presence of capital in the livestock sector.

4 Non-wood resources are not included in the physical inputs sector as it is assumed that this resource is relatively resilient.

5 The random utility theoretical foundation of the model is described below.

6 Angelson (1999) reviews several models of the household in the context of development issues.

7 See Greene (1993) for details on the use of the multinomial logit model in econometrics.

8 Environmental represents a vector of variables, described above as important exogenous factors including rainfall, population, and woodland biomass. As described above, all sectors do not have all environmental factors explicitly modelled. More detail is presented in a later section.
The multinomial logit approach employs utility functions and maintains the ordinal nature associated with economic utility theory. Thus, the model is based on shares of effort in the activities, but returns and risks are classified in terms of utility. This utility is not directly convertible to income or monetary units. However, changes in the utility received by households over time can be tracked. Accordingly, the model in Fig. 1 shows a sub-model (the household utility sector) that totals the sectors’ returns and records their flows over time. These amounts may also be accumulated and discounted to compare net present values of alternative scenarios.

It could be possible to identify the parameters on each element of the utility functions through a detailed econometric analysis of the shares that households invest in these activities and the returns and risks they face. In a simple financial analysis the household would ‘invest’ resources to the point where the marginal returns from these activities are equated between sectors and periods over time. However, several activities that communal households expend effort on do not have market values. For example, collection of non-wood products from the communal forest is a significant household activity, especially in drought years, but attempts to value these products in conventional economic terms have been difficult. Furthermore, given the limited role of cash in the communal economies of the region, strictly using returns in monetary units would probably not accurately reflect the value of these resources to the household. Accordingly, data for econometric estimations of return functions from the various sectors are not available. The approach taken in this paper was to construct a simple model by calibrating the parameters on the variables affecting utilities, according to knowledge about the local community and their responses to changes in rainfall, and population numbers.

4. Model calibration

In order to calibrate the model, known information regarding returns received, effort allocated, risks, population, rainfall, and biomass were collected.

4.1. Returns and effort

A study in Chivi communal area (Natural region IV) found the following sources of wealth: crops (33%), remittances (13%), off-farm income (48%) and livestock income (7%) (GFA, 1987). By contrast, in Chilimanzi, crop sales represent 50% of income, livestock products 6%, urban remittances 13% and off-farm income 32% (Steinfeld, 1988). For the purposes of our study, we also need information about percentages of household income derived from sectors, such as non-wood woodland products, that do not necessarily have market values. For this reason we chose to use data presented by Cavendish (1997), which come from Shindi Ward in Southern Zimbabwe. Cavendish (1997) does not break down income according to the sectors that we have identified. However, personal communications with Cavendish provided the breakdown required. Five percent of the household income was found to come from miscellaneous activities not captured by the above sectors. This 5% was allocated, proportionally according to sector size, amongst the modelled sectors.

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9 While we are aware of the great cultural importance of some woodland localities for traditional religious purposes such as rainmaking ceremonies (e.g. Hot Springs Working Group, 1995), we have not included non-use values in calibrating the model.

10 Cavendish (1997) does not break down income according to the sectors that we have identified. However, personal communications with Cavendish provided the breakdown required. Five percent of the household income was found to come from miscellaneous activities not captured by the above sectors. This 5% was allocated, proportionally according to sector size, amongst the modelled sectors.
percent of household income from each sector is compiled in Fig. 2. Data regarding effort allocated between sectors are not available. However, if we assume that households allocate effort among activities in proportion to the returns that they receive, then the income percentages may also be used as proxies for effort expended.11

4.2. Risk

Unfortunately, there have been no explicit studies done on the risk perceptions of Zimbabwean households associated with these economic sectors. Although no data are available on household perceptions of risk or on how these vary between wealthier and poorer households, the risks associated with different options are known locally. In part, these are related to the nutrient poor, drought susceptible sandy soils in this area and the risks this poses for crop production and pastoralists. Droughts and patchy rainfall also pose a risk for more ephemeral gathered resources, particularly wild spinach and edible caterpillars. In an economy where formal employment options have historically been declining, seeking work in urban areas may also be a risky option. Under risky circumstances, therefore, woody gathered products are a mainstay providing a resilient, risk-free backup if sustainably used. Considering these and other attributes of the sectors, estimates by experts at the workshop suggested the following risk factors associated with the model’s sectors, based on the number of years in a decade in which the sector will fail to produce the average returns received in non-failure years: urban, 4; crops, 2; livestock, 1; non-wood, 0.5; and wood, 0.

4.3. Population, rainfall, and biomass

The human population of the Lupane district was known to grow at 3% per year (Gwaai Working Group, 1997). Although the average rainfall in the region is approximately 650 mm/year, the income data from Cavendish were collected during 1993/94 in an area where rainfall was 523.5 mm. Accordingly, the model was calibrated assuming this rainfall amount. Standing biomass was assumed to be 30 tonnes per hectare (Frost, 1996).

4.4. Specification of model equations

Given the above information, the equations of the model in any given period were specified as:

\[ U_c = \alpha_c + \beta_c (\text{return crop} \times \text{rainfall}) \]
\[ + \beta_{c2}(\text{risk crop}) + \beta_{c3}(\text{population}) \]  
(3)

\[ U_u = \alpha_u + \beta_{u1}(\text{return urban} \times \text{rainfall}) \]
\[ + \beta_{u2}(\text{risk urban}) \]  
(4)

\[ U_n = \alpha_n + \beta_{n1}(\text{return non-wood} \times \text{rainfall}) \]
\[ + \beta_{n2}(\text{risk non-wood}) \]  
(5)

\[ U_w = \alpha_w + \beta_{w1}(\text{return wood} \times \text{rainfall}) \]
\[ + \beta_{w2}(\text{risk wood}) + \beta_{w3}(\text{population}) \]
\[ + \beta_{w4}(\text{biomass}) \]  
(6)

\[ U_l = \alpha_l + \beta_{l1}(\text{return livestock} \times \text{rainfall}) \]
\[ + \beta_{l2}(\text{risk livestock}) + \beta_{l3}(\text{population}) \]  
(7)

where: \( U \) is utility derived from each sector; \( \alpha \) is constant for each sector equation; \( \beta \) is marginal utility associated with the variables; ‘return’ is return associated with each sector (normalised with crops = 1) (superscripts: c, crop; u, urban; n, non-wood; w, wood; l, livestock); rainfall = \( \ln(\text{rainfall})/\ln(650) \) where annual rainfall (rain,) is generated over time by the rainfall sub-model, and 650 is the mean annual rainfall in mm; ‘risk’ is risk factor associated with each sector (urban, 4; crops, 2; livestock, 1; non-wood, 0.5; and wood, 0); population = 1 – (1450/households,) where households, is the total number of households in the study area at a given point in time with a

11 A maximising firm would attempt to get the same ratio of value of output per value of input in each sector. If not, returns could be increased by re-allocating household resources. Problems with this assumption are considered in the final section.
starting value of 1450 and forecast to increase by 3% per year; ‘biomass’ is total wood biomass per hectare, estimated at a starting value of 30 tonnes.

The model is solved to allocate shares among sectors by employing these utility equations in Eq. (2).

4.5. Solving for model coefficients

Given the above equations, the model was calibrated on a spreadsheet by searching for marginal utilities that caused the logistic function to distribute incomes, according to the data presented in Fig. 2. Because there was no a priori reason to believe that the marginal utilities for a given variable would be different across sectors, values were used that were constant across sectors. After marginal utilities that caused the model to approximate the actual income shares were found, finer calibration was done by adding constants. The resulting marginal utilities and constants were: \( \beta_{(0.1)} = 2; \beta_{(0.2)} = -0.01; \beta_{(0.3)} = 1; \beta_{(w)} = 0.001; a_{(c,w)} = 0; a_{(0)} = 0.4; a_{(u)} = 0.2; a_{(l)} = 0.2. \)

With these parameters, the model was run over a 50-year period in the presence of rainfall variation and increasing population numbers. These simulations were assessed using knowledge of the local communities’ response to significant rainfall shocks and changes in ecological conditions. As will be described in the next section, the model seems to reflect local knowledge of sectoral changes in response to the exogenous factors modelled.

5. Results

Fig. 3 shows how sector shares change over time in response to increases in population and fluctuating rainfall. In the figure, crops are shown to be most responsive to rainfall variations. As rainfall decreases, households shift their efforts from crop production to gathering woodland products and seeking returns in the urban sector. Efforts in livestock production are relatively stable unless there is a marked change in rainfall, such as a severe drought. This is because livestock are more resilient to drought than crops. In response to increasing populations, land pressures are felt in the crops, livestock and wood sectors, causing decreasing shares, while urban and non-wood sector shares increase.

Although the data in Fig. 3 show how resource allocations may change over time, they do not
show how the welfare of households are changing and potential effects of increasing use levels on the resource base. Fig. 4 shows the flows of resources used by households from the landbase, and resulting wealth flows over time. In general, welfare per household is shown to decrease over time with increasing pressures on the land base. However, the resource use levels appear to be sustainable over the period of the simulation. In order to calculate land pressures, average numbers of resources used by households were projected over time, given expected changes in sector shares. Livestock units have increased to approximately 19,000 for all households over the 50-year simulation period. The stocking rate recommended by the national extension for the area is 8 ha per LU, but this rate applies for beef production. For a multi-purpose herd, twice as many animals can be carried. Given that the size of the area is 136,000 ha, the area could probably sustain 34,000 LU, which is well above the numbers predicted by the end of the simulation period. Crop area increases to approximately 24,000 ha by the end of the simulation period, which makes up about 18% of the study area. Wood collection totals approximately 36,000 tonnes per year by the end of the period that appears sustainable considering an annual production of 0.75 tonnes/ha per year (Grundy et al., 1993) and 91,800 ha of woodland, giving a total annual growth of 68,800 tonnes.

6. Discussion

This paper presents a framework for considering how households may allocate their resources among activities in response to varying rainfall and increasing populations over time. Although some data are available to provide a basis for simulations, the major contribution of this paper is not in its empirical results, but in identifying a framework and the accompanying data needs for addressing household allocation issues with future research. Furthermore, the intent of the modelling exercise is not to construct the ‘correct’ model of human behaviour. Rather, our intent is to outline how a model of human behaviour can be integrated into a model of ecological–economic interactions. The model here could be developed with more elaborate feedback, perhaps including links to the macro-economy that effect remittances as members of communal households move to urban areas in search of employment. Links between...
population growth, livestock rearing and cropland use could also be established, perhaps using some form of Ricardian rent model to describe how added population pressure would push individuals to the extensive margin and increase the risk of cropping. Conceptually, the choices of the household could then be modelled to affect the ecological system through changes in biomass, cropped area or other factors. This would provide an integrated model of the human system and the ecological system. There are many avenues by which one could proceed, given the basic structure of modelling communal household behaviour in the context of the changing ecosystem.

With respect to the existing model structure, one key area where data are needed includes amounts of effort expended by households among sectors. In the above model, effort is taken as an aggregate measure of resources allocated among sectors. Tracking resource allocations of land, labour and capital separately, in response to returns to each factor of production, would provide more insights into the behaviour of households. Furthermore, contrary to our assumptions in this paper, it is quite possible that households fail to equate the values of effort to return ratios among sectors that we are able to measure. Other factors such as status from holding cattle or cultural values of collecting woodland products are not being captured. Nonetheless, if effort is accurately recorded, then the model will be in a better position to capture the random utility elements that we are not able to explain.

A further area where research could aid in specifying the model relates to risk perceptions by households. Risk factors associated with the various economic sectors were largely based on expert opinion. To our knowledge, there have been no systematic studies of household risk perceptions among rural households in Zimbabwe.

Extensions to the above model could also warrant further research. Specifically, the macro-economy could be explicitly modelled within the urban sector to better assess effects on households of such policies as the recently introduced economic structural adjustment policies. Similarly, modelling of the agricultural sector could also be refined to attempt to depict decisions between maize and sorghum, and between cattle and goats. Furthermore, effects of alternative land tenure policies could be modelled by altering returns according to different scenarios. Likewise, technological change could be introduced over time as it influences relationships between household inputs and outputs.

Finally, refinements to the assumption of a household as a homogenous decision making unit could be added. Household behaviour could vary significantly according to wealth levels. Data regarding households could be collected among different wealth classes in order to model the actions of each class separately. Furthermore, household decisions and available resources could be broken down by age and/or gender to capture inter-household dynamics.

The above types of data would ideally be collected in a number of regions of the country. This would allow a better understanding of how robust the model is between regions, and provide information regarding the extent to which the model needs to be re-calibrated for the differing environmental and social situations found in the communal areas.

While the current simulations are based on limited data, they nonetheless show the importance of considering multiple sector responses of households as they respond to their changing environments. The existence of multiple sectors provides households with important opportunities to buffer their welfare from rainfall shocks and increasing population pressures. In the absence of explicit accounting of these types of opportunities, estimates of welfare changes are likely to overestimate the losses and gains of welfare to households.

In essence, the above model is a step in the direction of treating households as mini-economies in themselves. In macro-economic studies, computable general equilibrium models are increasingly being used to attempt to understand workings of interrelated sectors of economies. Similarly, if we are to gain a better understanding of household allocation decisions over time, we will have to search for tools that can accommodate the complexities of multiple sectors in dynamic environments.
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