Exploring the impacts of cash transfers on household resilience in Amazon estuary region of Brazil--an agent-based simulation

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Abstract

Small farm households in the Brazilian Amazon estuary region are facing increasing changes that include more extreme floods or droughts and market oscillations. These changes have led scientists to explore the vulnerability of coupled human-environment systems, to provide a base for decision-making by households and policy makers. Government cash transfer programs, such as old age pensions or child education subsidies, often play an important role in household livelihoods, leading to a variety of outcomes and impacts on their vulnerability. To further interpret the influences of such programs on household livelihoods and vulnerability, this study utilizes an agent-based simulation to investigate various patterns of household behaviors in response to government cash transfer programs.

An agent-based model is designed based on Chayanov's farm theory, which is a tradeoff between income generation and leisure time, as a foundation for household decision making. Results from a household survey are used to inform model design and parameterization while guiding simulation analysis. Early results indicate that there are varying degrees of household dependency on cash transfers. Factors such as education level and household labor and land assets were found to be significant in influencing household dependency on cash transfers in the short and long term.

Background and Relevance

In the Brazilian Amazon estuary region, households must adapt to a dynamic environment that includes years with extreme flood or drought events. Besides such extreme events, the environmental risks also include the increasing variation of river levels and precipitation that has been observed in both scientific evidence and farmers' perceptions (Pinho, Marengo, & Smith, 2014). These changes have led scientists and decision makers to assess the vulnerability of coupled human-environment systems. Not solely due to being exposed to such hazards, vulnerability is also determined by the resilience of the human system, which offers options and flexibility to cope with or adapt to changes and risks (Turner & Kasperson, 2003). Even when exposed to the same disturbances and risks, humans with different characteristics will experience varying impacts that trigger adaptations resulting in varied vulnerability (IPCC, 2012, p. 7). To sufficiently reduce vulnerability to these extreme and non-extreme weather or climate events, it is essential to investigate the resilience and adaptive capacity of the human side in this coupled system.

The resilience and vulnerability of human systems in this region have been largely influenced by government cash transfer programs. These programs, including old age pensions or child education subsidies, play an important role in influencing household livelihood strategies and activities. The impact of these programs on economic growth and labor allocation, such as its multiplier effect on income and less labor endowment, has been studied (Barrientos, 2012; Bertrand, 2003; Boone, Covarrubias, Davis, & Winters, 2013; Sadoulet, Janvry, & Davis, 2001), but its role in shaping household resilience needs further study and is important for exploring the vulnerability of these communities in the face of a changing environment.

To simulate human-environment dynamics, agent-based models (ABM) have been proved as a favorable tool (Deadman, Robinson, Moran, & Brondizio, 2004; Parker, Berger, & Manson, 2001; Robinson, Brown, & Currie, 2009; Schreinemachers & Berger, 2006, 2011). An ABM is a computerized simulation consisting of a number of decision makers that interact with a spatially explicit landscape and with one another through prescribed rules (Farmer & Foley, 2009; Parker, 2012). This paper reports on the ongoing effort to develop an ABM of coupled human-environment dynamics in Amazon estuary region of Brazil. From previous analysis of the household survey data, household livelihoods are found to be significantly influenced by education, land assets, demographic stages, and their strategy choices—here we define a livelihood strategy in terms of how much a household relies on cash transfer in the total income. This ABM can serve as a tool to explore the importance of these factors in the household livelihood dynamics that emerge from the examination of survey data, and to further assess the impact of cash transfer programs on household vulnerability to change.

Aims: Using a social survey and an ABM, we answer the following questions: (1) among small farm households, who are more likely to become dependent on cash transfers? (2) How are cash transfers and the consequences attenuated or amplified to household resilience differently? (3) What can be done to increase resilience and thus reduce vulnerability to change?

Importance of the study: By answering the above questions we are able to (1) identify who are more vulnerable, furthermore, what makes them vulnerable; (2) investigate different impacts from government cash transfer programs on household resilience; and (3) design a more effective policy for vulnerability reduction.

Methods and Data

This study utilizes household surveys and ABM to explore the dynamic of this coupled human and natural system.

Patterns observed from the household survey: A household survey was conducted to capture household livelihoods in Abaetetuba, the Amazon estuary region of Brazil

(1°43’4” S and 48°52’58”W). Information including livelihood income, size of cash transfer, education, family size, and size of household assets were collected. The heterogeneity of household characteristics and their strategy choices are extracted from survey and are demonstrated in Figure 1. Households with higher education level and larger assets are more likely to generate adequate livelihood income, and are grouped in a “less-dependent on cash transfer” strategy. Households that have lower education and smaller assets are more likely to choose a “highly-dependent on cash transfer” strategy, with lower livelihood income. Between these two types of households, some households are following a “moderately-dependent” strategy, with a modest income and medium size asset. Seen from a snapshot—a static questionnaire – of household livelihood status, the diversities in strategy choices and household conditions are further explored in ABM to explain the dynamics of household livelihoods and resilience. We compare the model results with this pattern to further evaluate the ABM.

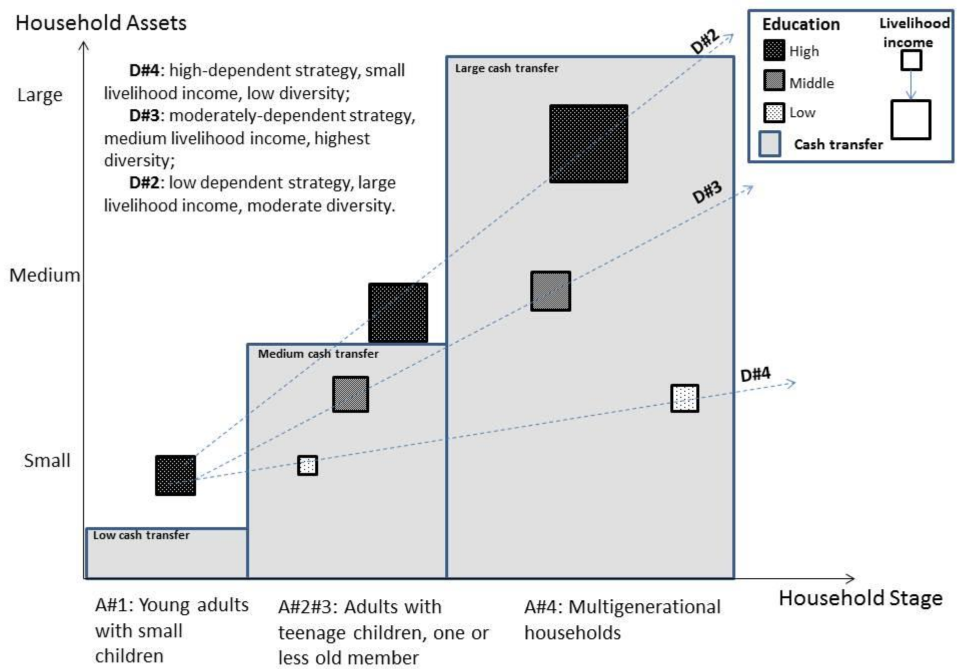

Figure 1 Heterogeneity of household characteristics and their strategies

Agent-based simulation: The model then is constructed to represent the households, focusing on their responses to different cash transfers given variability across household characteristics. The current model is an updated version of MARIA (Cabrera, Deadman, Brondizio, & Pinedo-Vasquez, 2010), which is written in Java using the RePast multi agent simulation platform (http://repast.sourceforge.net/). Built on well-established MARIA, we extended the human decision making in respect to cash transfer programs and calibrated employment probability, with no other change to MARIA’s original environmental module.

Human agents: There are two parts to the human decision making rules in this version:

(1) *Decision-making*: We use Chayanov's theory as a foundation (Chayanov, 1966; Ellis, 1996) to form and explain a small farming household's behavior and patterns that have emerged from the survey. Households face two opposing objectives: an income objective which requires labor input, and a work-avoidance objective which conflicts with income generation. Three sources contribute to income: government cash transfer, income from agriculture and agro-forestry which is environmental income, and salary from off-farming activities. Therefore, the utility function is constituted by total household income and leisure, as follows:

$$U = \left[\text{cashT} + \text{f}_{\text{agri}}(L_a) + f_{\text{wage}}(L_w)\right]^{\alpha} \times \left(L - L_{agri} - L_{wage}\right)^{\beta}$$

$$\alpha + \beta = 1$$ **Equation 1**

Where cashT is the amount of cash transfer a household receives[1], α is household weight of income as utility, and β is the weight for leisure time in utility. The sum of α and β equals 1. The total labor a household has is L_{max}, of which L_a is used for agricultural production, L_w is allocated for employment, and the rest of labor is for leisure. Households, following the above utility function, are optimal agents with constraints from labor and land input. They maximize the total utility by allocating labor into different income activities and leisure sections. Parameters of utility preferences (α, β) are set to be 0.8 and 0.2, and will later be obtained from the survey.

(2) *Probability of employment in a household*: The significant role of education in rural livelihoods and land use changes has been widely studied (Ellis & Bahiigwa, 2003; Godoy, Groff, & O'Neill, 1998). The limited availability of job opportunities excludes households without particular skills or education. Therefore we apply a binomial logistic regression to estimate a household's probability of having employment: the independent variables that we choose are household head age (hage), household head education (hedu), and average education level of female members (avewomenedu). Furthermore, we use a linear regression to estimate the relation between size of salary and these variables. The reasons for choosing these three variables include: they are not correlated to each other and are highly correlated with other factors (Dou et al, unpublished).

The logistic regression is:

$$\log\left[\frac{p}{(1-p)}\right] = \beta_1 \bullet hage + \beta_2 \bullet hedu + \beta_3 \bullet avewomenedu + a$$ **Equation 2**

Where β is the log likelihood of independent variables, and p is the probability of employment. If any family member has an off-farming job, there is

[1] Due to the relatively small size of children education subsidy, we only consider pension in this simulation. However, with proved relation between higher education and school subsidy, we can assume that higher education quality at young generation in the region is largely caused by this program.

employment of this household. The cash transfer program-- Bolsa Familia--child school subsidies, will increase the education quality thus produce a larger employment probability.

Environment context: The environmental module is same as the original MARIA. Households interact with a theoretical binomial landscape: water, and land cells that evolve with land use history and land cover transition rules. The rules of land cover transition are derived from previous research in this region (Brondízio, 2008). Land cells are 5 m × 5 m rectangle grids and are classified from remote sensing images. They can be converted by agents to grow acai, agriculture, or stay as forest. Land cells affect household decision based on the following two aspects: (1) the fertility of soil determines crop yield, and (2) the distance to houses and water impacts agent's land use decisions, such as land cells close to houses are more likely to be developed earlier than land cells further away.

Results

Model construction: We implemented 15 household agents, who belong to the first stage in Figure 1, and run a 40-year simulation to generate the demographic dynamics. Their land holding sizes, education levels, and demographic structures are obtained from the distribution of households in group 1 in the survey results. Commodity prices are set constant. The initial capital endowments for households are the same. We run each setting 15 times to lower the randomness.

Preliminary results include household employment probability and size of household salary that are based on factors such as age and education, as summarized in Table 1. The probability of household overall employment is significantly related to husband education and average female education. Low husband education leads to a low employment probability of 0.2; this probability steadily increases to 0.7 when education rises to 16 years, equivalent to university diploma. Meanwhile, the average female education level also has an impact on employment probability: when the husband's education is the same, the increase of average female education will enhance the probability of employment; and the impact is bigger when the husband's education is higher. Salary size wise, it is husband age and education that matters.

Table 1 Summary of logistic and linear regression

	binomial logistic—probability of employment			linear regression—size of salary		
	Coefficient-β	p-value		Coefficient-β	p-value	
hage	-0.014	0.120		76.1	0.007	**
hedu	0.148	0.000	***	316.8	0.000	***
AveWomenEdu	0.064	0.013	*	83.9	0.232	
(Intercept)	-1.463	0.001	***	3238.0	0.016	*

For logistic regression: Null deviance: 536.67 on 463 degrees of freedom; Residual deviance: 500.69 on 460 degrees of freedom; AIC: 508.69;
Linear regression: Residual standard error: 3398 on 119 degrees of freedom; Multiple R-squared: 0.151, Adjusted R-squared: 0.129; F-statistic: 7.03 on 3 and 119 DF, P-value: 0.000.

Spatial patterns of land use changes: Snapshots of land cover and land use changes are captured at each model run. Here we present a snapshot at step No.20 of one simulation as an example in Figure 2. Agents first decide their labor allocation to different activities based on non-spatial factors, and then allocate their labor into a spatial context. Four types of land uses are simulated and shown by different colors in Figure 2: original forest, acai patches, crop gardens, and fallow parcels. Among all emerged land use patterns, the circular pattern of land uses is worth noting. This effect is a result of agent working habit which is not being modeled explicitly. Households cultivate land cells closer to their dwelling first and then expand to further distance, hence there shows the circles of land uses.

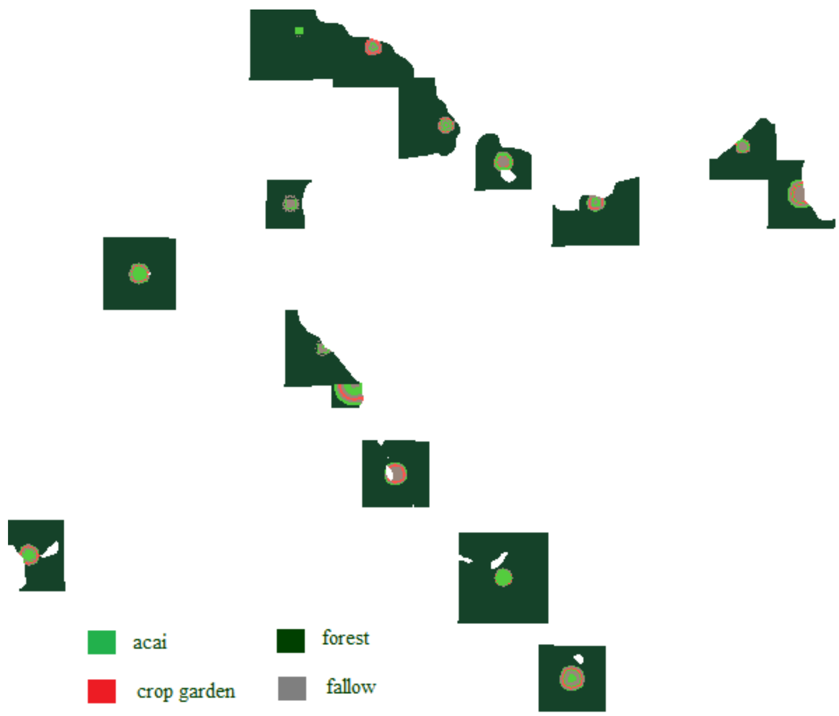

Figure 2 Spatial Land use changes (No.20 step in one simulation)

Trajectories of household livelihood and dependency on cash transfer: to examine the dynamics of household livelihood, we choose the simulation when pension payment is 20 reais, which is scaled as the price of commodities in the model, as shown in Figure 3. Size of dots is correlated with dependency of cash transfer in each time step. Same as the pattern that we see in Figure 1, households show different growth temporal trajectories and higher dependency on cash transfer, the lower the capital assets they have. One other observation that we can make from this figure is that after households start receiving cash transfers (around tick 16), the inequality of capital becomes bigger.

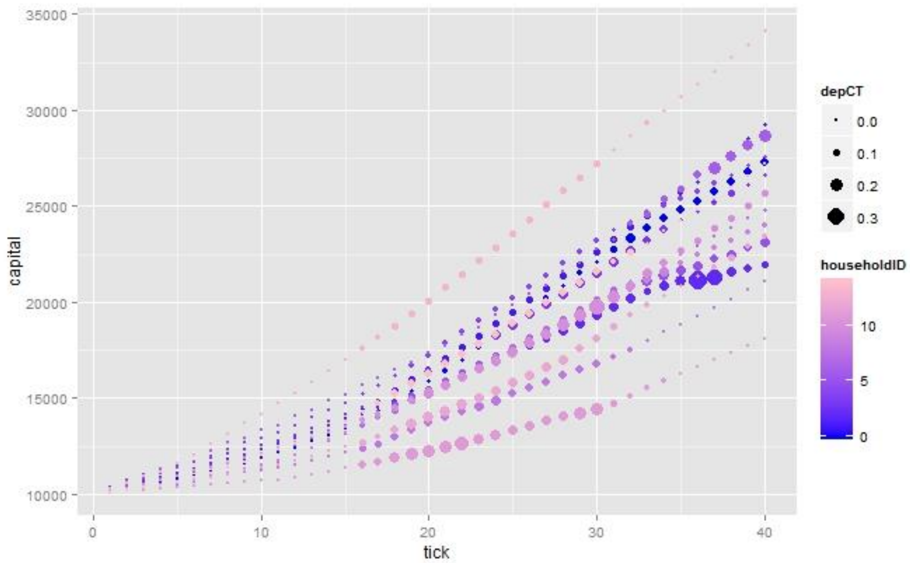

Figure 3 Household livelihood trajectory and dependency on cash transfer

Further analysis is ongoing. We now present the comparison of factors and income in an arbitrary classification, as shown in Table 2. The top household (ID.13), with a highest average income and lowest dependence on cash transfer, has the largest land holding and labor assets as well as high education levels in both husband and female sections. On the contrary, the bottom household, with the lowest income and highest dependency, has the smallest labor asset and a relatively small land holding; the husband education ranks lowest as well.

Table 2 Livelihood and factors among households

	top	group 1	group2	group 3	bottom
Household ID	13	0,1,4,6,14	3,7,9,10	5, 12	11
Average income	603	450	382	331	202
Average livelihood income	576	398	352	305	186
Land holding size	3649	1104	2650	1168	1569
Husband education	5	5.285	4.25	6.5	3.5
Female education	6.18	7.78	6.95	5.51	6.78
labour	11.18	8.21	7.89	7.23	4.45
Average dep. on cash transfer	0.039	0.041	0.061	0.067	0.074

Non-linear impacts from cash transfer on household livelihood: we compare the influence on household livelihood with different sizes of payment to design a more effective cash transfer program. We set the unit of pension program for each eligible member to increase from 0 to 100, with a 20 division. Average household capital at each step in each simulation is shown in Figure 4, in which the size of dots is represented by the total amount of cash transfer households get. From Figure 4 we can see that there is higher capital accumulation when cash transfer payment becomes higher. Furthermore, the gap of capital between each payment setting becomes bigger across time. However, each year's livelihood income (exclude cash transfer) is becoming smaller when increasing the payment, especially when the payment is increasing from 20-40 and from 60-80, though the rate is not significant.

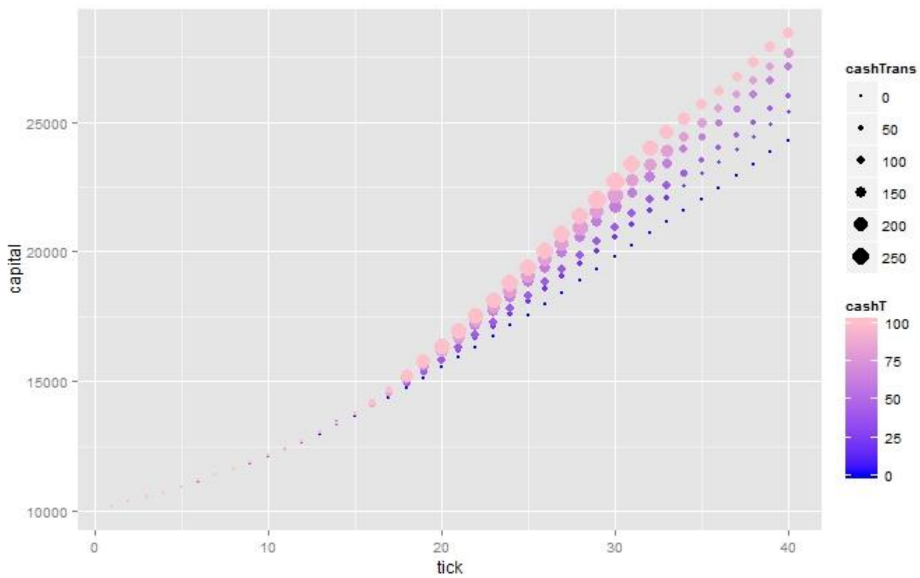

Figure 4 Average household capital under different pension payments

Conclusions

Preliminary simulation results demonstrate the heterogeneous nature of livelihood dynamic trajectories in response to household conditions and to cash transfers. The emerged pattern is consistent with the findings from the survey data. Factors in household conditions including education quality, land holding size, labor asset, and cash transfer size are significant in household strategy choice and their development paths. In general, households with higher education, larger land size, and more labor endowment are more likely to become less-dependent on cash transfer and to accumulate wealth. However, there is no positive sign found between the size of cash transfer and net income growth. We can conclude that adequate cash transfer has a positive impact on household livelihood thus can enhance household resilience and reduce vulnerability to uncertain changes. In the future, more livelihood options such as fishing and shrimping will be integrated in the model. These two activities are associated with household spatial access to floodplain and river, which are restricted from households who live on upland. The accessibility to different land types is another crucial factor to identify vulnerable households and to investigate their dynamics.

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