Proceedings of the 2021 Winter Simulation Conference
S. Kim, B. Feng, K. Smith, S. Masoud, Z. Zheng, C. Szabo and M. Loper, eds.

MODELING MULTI-LEVEL PATTERNS OF ENVIRONMENTAL MIGRATION IN BANGLADESH: AN AGENT-BASED APPROACH

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ABSTRACT

Environmental change interacts with population migration in complex ways that depend on interactions between impacts on individual households and on communities. These coupled individual-collective dynamics make agent-based simulations useful for studying environmental migration. We present an original agent-based model that simulates environment-migration dynamics in terms of the impacts of natural hazards on labor markets in rural communities, with households deciding whether to migrate based on maximizing their expected income. We use a pattern-oriented approach that seeks to reproduce observed patterns of environmentally-driven migration in Bangladesh. The model is parameterized with empirical data and unknown parameters are calibrated to reproduce the observed patterns. This model can reproduce these patterns, but only for a narrow range of parameters. Future work will compare income-maximizing decisions to psychologically complex decision heuristics that include non-economic considerations.

1 INTRODUCTION

Agent-based models (ABMs) are a promising approach to studying environmental migration. ABMs are powerful in representing dynamics between individual-scale and collective or community-scale phenomena, and to incorporate psychological and sociologically complex decision processes (Thober et al. 2018). Here, we present an original ABM of internal environmental migration from rural villages in Bangladesh in which agents make decisions to maximize their household's expected utility in the form of annual income. This work investigates whether an agent-based simulation of local labor markets can reproduce the two key patterns of environmental migration observed by Gray and Mueller (2012) in Bangladesh. The model allows both community-level and household-level dynamics to influence livelihood and migration decisions. This model also serves as a starting point for future investigations into interactions among environmental, social, and behavioral influences on migration.

2 MODEL DESIGN

2.1 Patterns of Migration

We use a pattern-oriented approach to developing and validating our ABM. Gray and Mueller (2012) identified two distinct patterns of internal from rural Bangladeshi villages:

- Pattern 1: As the proportion of a community impacted by environmental shock increases, rates of migration initially decrease below the baseline levels, but then increase, especially above a threshold where approximately 20% of the community is impacted. This shows that individual migration decisions are strongly influenced in a non-linear manner by community-level impacts.

- Pattern 2: Households that are directly impacted by environmental shock are less likely to migrate. Migration is costly, and affected households may wish to migrate but lack the means to do so.

These patterns serve as the key patterns that this ABM aims to reproduce at the community level (Pattern 1) and the household level (Pattern 2).

2.2 Model Structure and Entities

Our ABM simulates household decisions whether to migrate under environmental stress. We use the model to study relationships between environmental stress and changing livelihood opportunities with regard to their impact on mobility patterns. A complete description of the model based on the ODD protocol and model code are available online (Best 2021). This model has entities representing *individuals*, *households*, and *communities*.

3 RESULTS

To calibrate uncertain parameters in the model, we used a pattern-oriented approach to calibration (Grimm et al. 2005). We used Latin hypercube sampling to cover a wide parameter space for 100 unique combinations of cost of migration and migration utility. We then ran the model 20 times for each parameter combination and otherwise the same initialization of a test community with 100 households and 700 individuals, and compared model results to each of our patterns of interest. Each model was run for 20 steps (20 years). This allowed us to identify values of the parameters that could successfully generate the patterns. We assessed the successful parameter combinations by aggregating the results of each of the 20 runs for each combination and using a binary variable to indicate whether or not the model satisfied each pattern for that combination of migration utility and cost of migration. We then ran the model 960 times using a combination of parameter values from the calibration for which both patterns are predicted to be reproduced. We ran 120 batches of simulations, where each batch ran the at varying levels of community environmental impact between 0 (no impact) and 1 (the entire community is impacted). Of these 120 batches, we aggregate the results to assess the patterns.

4 DISCUSSION

Results from this calibration show that the model is able to reproduce both patterns with varying rates of success. Pattern 2 is reproduced with a high rate of success across the bottom half of the parameter space. In contrast, Pattern 1 was only reproduced inconsistently. While the majority of model runs with varying parameter combinations were able to reproduce an increase in migration with increasing scale of environmental impact, the initial decline in migration followed by an increase at an approximately 20% threshold was more difficult to reproduce, which could indicate that the processes that generate the non-linear aspects of Pattern 1 are less fully captured within the current model dynamics.

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