

Decision-Making in Agent-Based Models of Migration: State of the Art and Challenges

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Introduction

- The paper reviews agent-based models (ABM) of human migration with respect to their decision-making rules
- The most prominent behavioral theories used as decision rules are **the random utility theory**, as implemented in the discrete choice model, and the **theory of planned behavior**
- Two challenges that hamper the widespread use of ABM in the study of migration and, more broadly, demography and the social sciences
 - the choice and the operationalization of a behavioral theory (decision making and social interaction)
 - the selection of empirical evidence to validate the model
- Review shows that agent-based modelling is still in its infancy with regard to migration

Some Background

- For decades, the literature was dominated by the gravity model, which posits that the volume of migration between two locations increases with population sizes in each location and decreases with geographical distance between the locations
 - The spatial interaction models that evolved from the gravity model incorporated additional determinants of migration and historical migration patterns that were considered to have long-term effects
- The level of migration between two locations may be related to
 - push factors in the location of origin
 - pull factors in the location of destination, and
 - intervening factors between the two locations
- However, the level of migration is ultimately the outcome of **individual actions**
 - But: Spatial interaction models do not capture individual actions; instead, they **summarize the outcome of these actions**

Some Background 2

- Microsimulation models take the individual as the unit of analysis and allow researchers to differentiate between **individual characteristics and idiosyncrasies**
- Although most microsimulation models refer to individual decisions, they are **not** “very explicit and detailed about the path economic subjects follow to reach a decision”
- In **agent-based modelling**, the focus is on individual agents, their decision processes, their interaction with other agents, and the effects of that interaction on decision processes
 - **Individualistic modeling, more flexible, more malleable**

Some Background 3: Why ABM?

- The only method that allows for the explicit modelling of social interaction and the social networks that result from it
 - This represents a huge opportunity for modelling migration, as networks shape the migration decision, and especially the destination choice
- Information on migration options and job market opportunities is transmitted through these networks

What is an agent?

- Agents are discrete entities that are autonomous and capable of making decisions using procedures or rules
 - Autonomous means that they can act independently
 - Other agents may influence their decisions, however
- Agents have goals, at least implicitly
- The aim of an agent-based model is to **uncover** causal mechanisms
- ABMs and microsimulations both lack equations which govern the overall social structure on the macrolevel
 - Structures at the macrolevel **emerge** from actions and interactions at the microlevel

Six Types of Models

- The first type **makes no or minimal use of decision theory**
 - The main purpose of the models in this category is to show that the interaction between individuals using simple behavioral rules can generate complex patterns at the population level
- The second type of model **uses microeconomic expected utility theory** to explain the choices people make between discrete alternatives
- The third type of model is based on a **theory of action derived from social psychology**
- The fourth type **uses heuristics**
- The fifth type is **loosely based on decision theory and relies more heavily on direct observation**
- The last type **relies exclusively on direct observations**

Evaluation Criteria

- Eight criteria to reflect both the various aspects of empirical migration decision-making and the requirements for computational modeling
 - 1. The theory should allow for the **possibility that there is a gap between desires or intentions and actual behavior**
 - 2. The theory should **take into account social influence**
 - It has often been shown that migrants are influenced by the choices of others and that they depend on others for help
 - 3. The theory should allow for **uncertainty**
 - 4. The theory should be able to **situate the migration decision in the life course and to relate it to other demographic events and changes in goals**

Evaluation Criteria 2

- Eight criteria to reflect both the various aspects of empirical migration decision-making and the requirements for computational modeling, continued ...
 - 5. The theory should **allow for the time it takes to plan a migration**
 - 6. The decision rules laid out in the theory should be **based on decision theory and empirical evidence**
 - 7. The theory should **be as simple as possible and as complex as necessary**
 - 8. The theory should **be falsifiable in principle**
 - If the model outcomes at an aggregated level are **not** in line with empirical observations, the assumed decision behavior is ***unlikely*** to describe the actual data-generating process.

Model 1: Minimalist

- The aim of minimalist models is usually to show how *macro*-outcomes can be “grown” from very simple *micro*-level rules and thus to show which **minimal assumptions are necessary to generate the observed outcomes**
- The great advantage of minimalist behavioral models is their **simplicity**, but the empirical relevance of the decision rules employed in these models is questionable
- Example: Migration and the resulting economic agglomeration in space
 - Agents in this model are active Brownian particles that have two different internal states (employed and unemployed)
 - Employed agents generate a field around themselves, the force of which depends on the wage
 - This field attracts unemployed agents who move towards it.

Model 2: Microeconomic Expected Utility Maximization

- No agent-to-agent interactions
- Example:
 - The potential migrants in the model perform **finite horizon and discrete time expected utility maximization with rational expectations**
 - The **control variable** is the location choice
 - The **state variables** are employment status and location
 - **Utility** is derived from the consumption opportunities and the amenities at the location, the evaluation of which will differ between individuals (apart from the initial location, this is the only point of heterogeneity)
 - The **expectation** is formed in the first period, during which individuals correctly predict—given some stochastic influence—their employment probabilities, income, search costs, and migration costs
 - The **optimal decision rules** are derived by backward induction using a dynamic programming algorithm

Model 3: Psycho-Social and Cognitive Models

- These models allow for the inclusion of a **large number of the features considered relevant for the migration decision**
 - especially the distinction between desired and actual behavior, but also social influence, the role of uncertainty, and the treatment of migration together with other life events.
- The **empirical relevance** of the theory of planned behavior for a behavior with similar far-reaching and uncertain consequences has been shown
- However, psycho-social decision theories tend to be **complex** and can be criticized for being **arbitrary** as they theoretically allow for the inclusion of an infinite number of decisive factors and beliefs
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Model 3: Psycho-Social and Cognitive Models, Examples

- Theory of planned behavior
 - Individuals form **attitudes towards a certain behavior** (in this case, migration), which are defined as **evaluations of different outcomes of the action**, weighted by their **subjective probability of occurrence**
- Maslow's motivation theory
 - theory of the hierarchy of needs; e.g., migration is influenced stepwise by income, safety, and social needs

Model 4: Heuristics without Direct Empirical Correspondence

- A heuristic is “a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods”
 - Thresholds, triggers
- Like minimalist models, heuristics tend to be simple and easily falsifiable and to allow for social influence
- Accounting for uncertainty or other demographic is easier in heuristics than in minimalist models
- Nevertheless, heuristics are limited, since, by definition, they stop being heuristics once the decision rule becomes more complex
 - In reality, the migration decision is almost certain to be complex

Model 5: Based on Decision Theory and Direct Observation

- The aim of combining decision theories with other empirical rules is to combine the **rigor of a decision theory** with the **empirical accuracy of observational rules**
- While this works to some extent, it comes at a cost, as the decision rules are ***no*** longer easily falsifiable
 - The fact that stylized facts can be reproduced with a mixture of a theory and empirical rules does not increase the empirical weight of the theory.
 - These types of models can be interesting case studies, but their generalizability is limited

Model 5: Based on Decision Theory and Direct Observation, Example

- In the baseline version of a model, migration propensities and destination choice are influenced by
 - the location of an individual's family members,
 - the total number of migrants at a destination,
 - whether the individual receives remittances,
 - the individual's assets,
 - the availability of jobs at the destination, and
 - the individual's income
- The aim was to distinguish between different theories of remittances by determining *which* behavioral rules produce certain stylized facts on the macrolevel
 - such as the distribution of people across the three locations and the distribution of wealth across individuals
- The study found that **no behavioral rule in isolation is able to reproduce all of the stylized facts at the same time**

Model 6: Purely Empirical, Observational Rules Without Mention of a Theory

- The determinants of migration are estimated from data through statistical and econometric analysis, or they are taken from expert or stakeholder interviews
- Big advantage of empirical rules is their empirical accuracy
- Disadvantages are
 - lack of guidance on which factors to include; potentially, anything could be included which is statistically significant.
 - But this makes for overly complex decision rules with little meaning.
 - **Of course the problem is that the more variables that are included, the better a behavior can be explained in one particular situation, but the less generalizable the explanation is, and the less likely it is to be of value in a different situation**

Model 6: Purely Empirical, Observational Rules Without Mention of a Theory, Example

- One studied climate-induced migration and distinguished between intentions and behavior
- According to this model, the individual's intention to migrate is influenced by crop yield, gender, age, assets, migration experience, risk attitude, and social network, linked together in a logistic regression
- Intentions are converted to behavior by drawing a random value from a standard uniform distribution
 - If the random number is smaller than the probability of developing an intention to migrate, the individual migrates; otherwise, the individual stays
- This method implies that the proportion of people migrating is the same as the proportion developing an intention to migrate

Modeling Decision Making

- Four key questions:
 - How expectations are formed and how information is gathered to form expectations
 - Rational? Local? Greedy? Temporal?
 - How alternatives are evaluated and how one alternative is selected
 - Thresholds, ranking, logical regression
 - How to determine the complexity of the model describing the decision process
 - Deliberate cognitive actions? Multiple steps? Planned behavior? Multiple checkboxes?
 - At what level of detail a migration network should be modeled
 - What is transmitted through a network?
 - Are networks exogenous (emergent?) or endogenous (factors?) to the model?

Challenges

- Challenge 1: Which decision theory should be chosen?
 - Utility maximization or the theory of planned behavior
- Challenge 2: What is the role of empirical data?
 - Sensitivity study for estimation and validation
 - Statistical meta-model

Conclusions: Important Issues

- Disciplinary barriers that currently exist should be removed
- Modeling of social networks in ABMs should take advantage of recent developments in social network research
- It is time to bridge the divide between microsimulation and agent-based modelling
- An innovative and systematic approach is required to validate ABMs
- ABMs of migration should position the migration decision in the human life course and use up-to-date life-history modelling techniques to describe how migration is intertwined with other life events
- There is a need for more applications of ABM in migration research