# 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
- 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 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**

# Some Background 2

- 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
- **But**: Spatial interaction models do ***not*** capture individual actions; instead, they **summarize the outcome of these actions**

# Some Background 3

- 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 4: 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

- 1. **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
- 2. **uses microeconomic expected utility theory** to explain the choices people make between discrete alternatives
- 3. is based on a **theory of action derived from social psychology**
- 4. **uses heuristics**
- 5. is **loosely based on decision theory and relies more heavily on direct observation**
- 6. **relies exclusively on direct observations**

# Evaluation Criteria: 1-4

- 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: 5-8

- 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**
- Great advantage: 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**
  - **Control Variable**: location choice
  - **State Variables:** employment status and location
  - **Utility**: the consumption opportunities and the amenities at the location, the evaluation of which will differ between individuals
  - **Expectation**: formed in the first period, during which individuals correctly predict—given some stochastic influence—their employment probabilities, income, search costs, and migration costs
  - **Optimal decision rules:** 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*
- **Example:**
  - 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**

# 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
  - 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 determine which behavioral rules produce certain facts on the macrolevel
  - E.g., the distribution of people across the three locations and the distribution of wealth across individuals

# 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**: 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 (*not transferrable*)
  - **That is:** ***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
- An 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**

# Modeling Decision Making: 4 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

Theory of planned behavior: a **theory** that links one's beliefs and **behavior.** The concept was proposed by Icek Ajzen to improve on the predictive power of the **theory** of reasoned action by including perceived behavioral control. (Wikipedia)

# 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

# My Conclusions

- A good, comprehensive literature review that categorizes the six types of models insightfully
- Provides information on agent-based modeling, especially towards the field of computational social sciences
- Agent-based modeling and multiagent simulations can be of great benefits to this field, but their design and implementations require thoughtful considerations
- Rational agents (using utility maximization) are more for prescriptive modeling or simulation
- Bounded rational agents or BDI agents (using the theory of planned behavior) are more for descriptive modeling or simulation for more truthful analysis