Individual motivations and network effects as underlying mechanisms in migration rates: a theoretical Agent Based Model

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Topic

Empirical research on international migration has observed the so-called pioneers and followers behavior in migration rates in communities of origin. This pattern follows an S-shape curve, similar to the diffuse or innovation models, in which migration grows slowly until it reaches a critical juncture point, after which the prevalence stabilizes. Previous studies have approached the analysis of the pioneers-followers phenomenon in relation to the selectivity of migrants across the different stages of the migration process. Lindstrom and López (2010) found that pioneer Latin American migrants to the US were characterized by having a higher socioeconomic status make them better able to take on the risks of migration at an earlier stage compared to those that migrate later. Moreover, other scholars, both empirically and theoretically, have argued for including the crucial role of networks as a mechanism that decreases migration costs and helps to sustain flows over time (Massey et al. 1993; Munshi 2003). There is a scarcity of studies explaining the role of migrant networks in the formation of the pioneers-followers macro-pattern from a bottom-up approach. Moreover, existing studies are usually more interested in the end state than the dynamics over time (Klabunde and Willekens 2016).

In this paper we aim to model the micro behavior corresponding to the decision to migrate and to describe how individual motivations and migrant networks affect migration rates over time. We use Agent-Based Models (ABM) to model individual micro-behavior, migration costs, and different levels of decision-making (household and individual) and migrant networks (household and community).

Theoretical framework

Theory is a key component in ABM because agents' decision-making has an underlying theoretical reasoning. Our framework consists of four components: i) the identification of the so-called pioneers and followers macro-pattern in migration rates in population of origin by Lindstrom and López (2010); ii) the role of a somewhat planned behavior

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in the decision-making process involving a differentiation between intention and actual migration (Ajzen 1985; Klabunde et al. 2015, 2017); iii) the acknowledgment of migration as an individual endeavour, but also embedded in households strategy of risk diversification; iv) finally, the role of migrant networks, that is strong and weak ties in explaining sustained migration flows as a cumulative causation mechanism (Massey et al. 1993; Liu 2013).

The pioneers and followers macro-pattern follows an S-shape curve, similar to the diffuse or innovation models, in which migration grows slowly until it reaches a critical juncture point, after which the rate stabilizes. Lindstrom and López (2010) identified three development stages of migration. In the pioneer stage, a slow increase of migration rate is present, driven by individual migration. Therefore, individuals with higher economic resources will migrate. In the second stage, take-off, migration rates accelerate due to the influence of migrant networks. Here, migration becomes a social phenomenon where individual decision-making is assisted by migrant networks produced by previous pioneer migrants. Both intention and ability to migrate are affected. Finally, in the stabilization or mature stage, migration rates stabilize when agents with the intention and ability to move have already done so.

Drawing on the relationship between attitudes and behavior from the Theory of Planned Behavior (Ajzen 1985), Klabunde et al. (2017) separated the decision to migrate into three states: intention, planning, and preparation. By this, the authors acknowledge that the desire to move internationally does not necessarily translate into migration, and that the process between intention and migration is not necessarily immediate. Each of the states within the migration decision entails different mechanisms that triggers the transition to the next state. In their model, Klabunde et al. (2017) determine the intention to migrate by one's assessment about the potential outcomes (benefits and costs) of the behaviour or attitude, social norms, and one's own ability to mobilize resources.

Drawing on the New Economic of Labor Migration (NELM) theory, Lucas and Stark in Lucas and Stark (1985) suggest that migration could be part of a family adaptation strategy to reduce vulnerability under economic shocks. Migration should thus be understood as a risk aversion behavior, where the household rationally decides to send some of its members to places where the labor market has different characteristics (non-correlated labor markets). Migrants would be assisted during the preparation of their migration to new destinations or under unemployment periods while overseas. This idea of co-insurance is in line with the NELM theory, in which the migration itself is motivated by risk aversion at the household-level. Determinants of migration are thus linked and framed within a risk management context that is mutually beneficial to migrants and households.

Migrant networks can be a determining factor when explaining sustaining migration flows over time. Massey et al. (1993) argue that while economic differential and household risk diversification strategies may be determinants of migration, the development of migrant networks can act as structural factors that explain why migration systems persist. Migrant networks, defined as strong (family) and weak (e.g. community and friendship) ties with migrants may help to reduce migration costs Liu (2013). Having family with migratory experience may be capitalized in terms of acquiring information about labour opportunities at destination, or by reducing arrival costs such as housing.

Methods

In this paper we use an agent-based model (ABM) to model migration as a micro-decision making process to explain the role of individual and migrant networks on migration rates over time. ABMs pre-suppose rules of behaviour and verify whether these micro-based rules can explain macroscopic regularities Billari et al. (2006). ABM are useful because we are interested in understanding under what conditions a specific pattern in migration rates emerges, that is, the so-called pioneers and followers S-shape curve.

We focused on developing a working model of migration decision-making that contained both individual motivations and migrant networks, as well as the different states individuals could move to. Drawing on the TPB and previous ABM migration modelling efforts, we separated the migration decision into three different states, namely: potential, intention, and migration (**figure 1**). By this, we wanted to differentiate between the mechanisms underlying the desire to migrate and the ones influencing the ability to do so. We added networks between agents that could be later transformed into migrant networks, when agents' contacts acquired migration experience. Agents' decision-making about migration was influenced by the presence of migrant networks which had a positive influence on the intention to migrate and on reducing migration costs. Our model considers that the intention to migrate can emerge at the individual and household level. This allows us to incorporate the possibility of external shocks that increased households' vulnerability and account for migration as a family strategy. Moreover, networks between agents are defined both at household (strong ties) and community levels (weak ties), and their effects on the migration decision-making is also different. Simulation starts with a number of household and potential migrant agents (persons) that are randomly ordered. Persons are socially connected by household membership and physically connected by community membership. Income is assigned to each person based on the Colombian income household survey distribution. Each simulation is run 300 time steps, which represent 25 years (1 timestep = 1 month). In each time step, all persons state is updated based on a set of functions that determine their intention and ability to migrate. Model outputs are defined in relation to the indicator generating the macro-pattern of interest, that is, migration rates. Therefore, the main outputs are the rates of potential, intention, and migrants over the 300 months simulated.

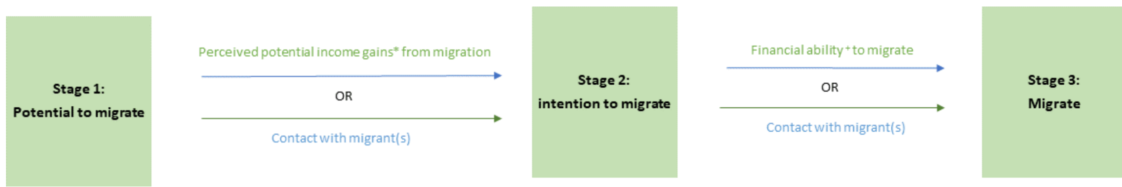

Figure 1: Decision-making model – three stages

The decision model

The model consists of a number of update functions that regulate state transitions for households and persons. The model uses a series of parameters (e.g. migration cost), but at this point the only parameter drawn from empirical data is the Colombian income distribution, which is taken from the 2016 Colombian household survey. **Table 1** presents all the model parameters, with a brief description of where they are applied.

Table 1: Parameters

	Description
vuln_th	Vulnerability threshold. Used in update_potentialHH to define whether household changes to intention.
n	Total population
n_hh	Total population of households
p_contact	Proportion/Probability of community contact. Used in setup to define the size of person's community network.
inc	Income gain loss ratio threshold. Used in update_potential! to define perceived probability of income gain.
cost	Migration cost. Used in update_intention! to define ability to migrate.
nmig	Number of migrants. Used in run to set a default number of migrants before simulation starts.
seed	Random seed. Used in run to define different random seeds in all numbers generated randomly.
empInc	Empirical income distribution. Used in setup to set person's income.
weights	frequency weights. Used in setup to define income weights.

Households can shift from a *potential* to *intention* state. The underlying idea of household state shifts is to acknowledge that individual migration may be influenced by a person's family. We implement the model so that it evaluates the vulnerability of each household. If a household's vulnerability is higher than the vulnerability threshold parameter, then the household will shift to the intention state. In turn, a household in the intention state will pick a random household member who will change its status to intention to migrate.

Persons can shift from potential to intention, and from intention to migration, as described in **figure 1**. In addition to state changes driven by vulnerability changes at the household-level, individuals can shift their state to intention motivated by individual interest. The model regulates individuals' transition from potential to intention state. The shift is motivated by the ratio between the perceived income gains versus losses being greater than an income threshold parameter. Including a ratio instead of a direct income gain perception intends to consider risk aversion among persons (Czaika 2015; Castro et al. 2016). Individuals with low risk aversion behavior will be more likely to become interested in migration. For instance, if the perceived probability of income gain and loss for a particular person is a 40% and 30%, respectively, the ratio will be 1.33. This means that the person perceives that the potential for income gains are 33 per cent higher than income losses. In addition to this rational calculation, persons having migrant networks, that is contacts with migration experience, will be positively influenced to become interested in becoming migrants themselves.

Expected results.

Table 2 presents the results for the exploration of the parameter space using an orthogonal approach. We selected a set of two points for the following parameters: random seed, probability of contact, vulnerability threshold, income threshold, and cost. The last four columns depict the proportion of agents that have migrated at time points 1, 35, 75, and 300.

Our model uses random generated numbers in several components such as in the decision model (changing influence of migrant networks) or the simulations setup (random gains and losses). In this preliminary stage, we run our simulations on two different seeds to how randomness affects our results (in a next stage we plan to run at least 5-10 random replicates). We observe that results are not largely influenced by changes in the random seed being used. In fact, the proportion of agents that have changed status to migrant is similar for the two different seeds chosen.

Results indicate that different household vulnerability thresholds (0.2 and 0.6) played a slight role in migration rates over time. As expected, a higher vulnerability threshold reduced the share of persons in an intention state. This effect was small and in some cases nonexistent with regard to the total share of migrants (see lines 3 and 4 from table 1). This means that under certain conditions, vulnerability does not seem to play a significant role in the shape of migration rates over time. For instance, we found that under lower levels of interaction between agents at the community-level (0.2), vulnerability played a greater role in the total share of migrants produced by the model.

Changing the probability of contact plays an important role. Holding everything else constant, a shift in the probability of contact from 0.2 to 0.8 increases the final proportion of total migrants from 37% to 51%. The probability of contact between agents represents whether agents interact with all the population versus only some of them. Hence, the higher the probability of contact between agents, the greater the size of the potential community of interaction and, in turn, the effect of migrant networks at the community-level.

We examine the role of risk aversion on migrant decision-making using income threshold. This threshold is the probability of income gain over the probability of income loss, both generated randomly in our model. A higher figure indicates a more risk averse attitude where individuals would only migrate when there is a greater certainty they will gain income relative to the likelihood of losing income. We used two thresholds, 1.5 and 2.5, in our model. At a threshold of 1.5, agents will migrate if the probability of income gain is 50% more likely as the potential income loss. Keeping all other parameters constant, a threshold of 1.5 results in 37% of individuals migrating at the final timepoint whereas a higher threshold of 2.5 reduces the proportion of migrants to 18%. However, note that the effect of increasing the income threshold is null when the probability of contact is kept at 0.8 (and the cost 500 USD), that is comparing lines 3 and 7 in table 2.

We inputted migration cost as a parameter in the model, setting cost at a low of 500 USD or a high of 2500 USD to explore the difference in migration decision. Unsurprisingly, lower migration costs result in a larger proportion of migrants compared to higher migration costs, 37% (line 1) and 30% (line 9) respectively. Increasing the probability of contacts from 0.2 to 0.8 increased the proportion of migrants at both cost points, but the difference between the effect of low versus high costs remains similar, 52% vs 47%.

Table 2: Orthogonal sensitivity analysis

seed	cost	inc th	pc contact	vul th	mig 1	mig 35	mig 75	mig end
42	500	1.5	0.2	0.2	0.001	0.270	0.318	0.373
42	500	1.5	0.2	0.6	0.001	0.244	0.287	0.348
42	500	1.5	0.8	0.2	0.001	0.442	0.480	0.516
42	500	1.5	0.8	0.6	0.001	0.440	0.480	0.516
42	500	2.5	0.2	0.2	0.001	0.164	0.174	0.182
42	500	2.5	0.2	0.6	0.001	0.123	0.131	0.143
42	500	2.5	0.8	0.2	0.001	0.294	0.464	0.516
42	500	2.5	0.8	0.6	0.001	0.204	0.453	0.516
42	2500	1.5	0.2	0.2	0.000	0.034	0.188	0.306
42	2500	1.5	0.2	0.6	0.000	0.028	0.158	0.279
42	2500	1.5	0.8	0.2	0.000	0.034	0.215	0.468
42	2500	1.5	0.8	0.6	0.000	0.028	0.184	0.462
42	2500	2.5	0.2	0.2	0.000	0.017	0.122	0.173
42	2500	2.5	0.2	0.6	0.000	0.012	0.092	0.131
42	2500	2.5	0.8	0.2	0.000	0.017	0.132	0.453
42	2500	2.5	0.8	0.6	0.000	0.012	0.099	0.445
50	500	1.5	0.2	0.2	0.003	0.272	0.315	0.373

50	500	1.5	0.2	0.6	0.000	0.253	0.290	0.343
50	500	1.5	0.8	0.2	0.003	0.431	0.461	0.516
50	500	1.5	0.8	0.6	0.000	0.426	0.461	0.516
50	500	2.5	0.2	0.2	0.003	0.179	0.190	0.206
50	500	2.5	0.2	0.6	0.000	0.145	0.153	0.170
50	500	2.5	0.8	0.2	0.003	0.280	0.451	0.516
50	500	2.5	0.8	0.6	0.000	0.221	0.443	0.516
50	2500	1.5	0.2	0.2	0.000	0.030	0.181	0.305
50	2500	1.5	0.2	0.6	0.000	0.023	0.159	0.283
50	2500	1.5	0.8	0.2	0.000	0.031	0.202	0.454
50	2500	1.5	0.8	0.6	0.000	0.024	0.179	0.453
50	2500	2.5	0.2	0.2	0.000	0.025	0.134	0.188
50	2500	2.5	0.2	0.6	0.000	0.017	0.107	0.151
50	2500	2.5	0.8	0.2	0.000	0.026	0.139	0.441
50	2500	2.5	0.8	0.6	0.000	0.017	0.111	0.434

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