A Theoretical Model of the Individual-Decision Making Processes for Refugees

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ABSTRACT

There exists contemporarily over 70 million people forced into displacement, which is historically the highest the world has seen, making aid for humanitarian crises more necessary than ever. This paper aims at a formulation for a basic theoretical model, within the Agent-Based Modelling (ABM) framework, that can be used in to make predictions about refugee migration-decision making processes. Some of the models existing are reviewed, serving as a reference for assumptions and choices made in the model presented here. Following which the model is described in the form of a cost-benefit evaluation problem along with the assumptions it makes. The model has no explicit analytic solution but can be employed by way of computerized simulations. Owing to a dearth of the requisite data to run simulations, the model was not simulated within this paper. Extensions to the model are discussed, as well as the challenges associated with modelling phenomena using ABMs.

INTRODUCTION

The Syrian Civil War, solely between 2011 and 2014, has displaced more than 3 million civilians including internally displaced persons. Individuals displaced by the conflict flee to neighboring regions within Syria or to Turkey, Jordan, Iraq or even further abroad.[1] Within Syria, attempts at refugee aid and assistance have attempted to be politically neutral amidst major political turmoil. Concerns of a post-Assad Syria are also expressed exhaustively by different protection agencies and bodies that anticipate further turmoil.[2] Since 2014, U.S led-coalition units have been conducting systematic strikes to the Islamic State of Iraq and Greater Syria (ISIS), while Russia, concerned about a post-Assad Syria, aims to deter Assad's opposition in an effort to keep the situation from adverse proliferation.[3] Of late other countries and states have been involved in the conflict, either directly or through external aid. Consequently, the humanitarian crisis resulting has been catastrophic with at least 350,000 people killed and around 12 million displaced from their homes. Several regional armed groups such as militants, rebels along with participating global powers with sometimes contradictory motives have complicated the situation further, the brunt of which is borne by civilians.

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[1] Connable, Ben. From Negative to Positive Stability: How the Syrian Refugee Crisis Can Improve Jordan's Outlook. RAND Corporation, National Defense Research Institute Santa Monica United States, 2015.

[2] Reynolds, Matthew A. "The Current Plight of Palestine Refugees in Syria." *Proceedings of the ASIL Annual Meeting*. Vol. 107. Cambridge University Press, 2013.

[3] Alkaff, Syed Huzaifah Bin Othman. "Syria." *Counter Terrorist Trends and Analyses* 8.1 (2015): 87-91.

In Africa, more than two-thirds of the countries south of the Sahara have either seen acute humanitarian crises originate or act as a final destination for refugees.[4] Within these crises women and children are the most vulnerable in addition to internally displaced individuals that are highly susceptible to attack by armed groups. The violence produced in the crises plaguing sub-Saharan Africa has had several adverse implications for the health and livelihood of the population. These outcomes are primarily due to the disruption in livelihoods and work, reduced expenditure on health resulting from budget allocations towards the conflicts, and poor infrastructure at refugee camps.

According to the 1951 Refugee Convention, a refugee is "someone who is unable or unwilling to return to their country of origin owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group, or political opinion."[5] Contemporarily, the world clocks in million of refugees and there exists a dearth of models and information that predict refugee movements. While there does exist predictive models on migration, few can be used to predict involuntary and forced migration.[6]

Given this proliferation of migration and displacement within and out of the Syrian Arab Republic, predictive research on refugee movements is necessary to mitigate adversities on the front of this humanitarian crisis. Individuals faced with challenging and potentially life threatening societal situation will often migrate to regions with a promise of better living conditions.[7] These adverse living conditions can arise from social, political, natural, anthropogenic or economic circumstances. A means of accounting for these complexities and heterogeneity among individuals comes from complex systems theory and the methods of agent or individual-based modelling.

A SHORT NOTE ON COMPLEX SYSTEMS THEORY AND AGENT-BASED MODELLING

Complex systems are characterized by dynamic systems harboring individual heterogeneity, non-linearity, stochasticity and emergence.[8] Agent-based modelling is an approach drawing on the theory of complex systems which is used to investigate emergent trends arising from individual behavior, accounting for heterogeneity. Owing to the importance of heterogeneity to the modelling process, it becomes paramount to know what influences individual decisions, in this context of forced migration. Agent or Individual-Based Models provide a robust framework for the modelling of situations that are characterized by their complexity and heterogeneity.

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[4] Kalipeni, Ezekiel, and Joseph Oppong. "The refugee crisis in Africa and implications for health and disease: a political ecology approach." *Social Science & Medicine* 46.12 (1998): 1637-1653.

[5]UNHCR 2010. "Convention and Protocol. Relating to the Status of Stateless Refugees". http://www.unhcr. org/uk/3b66c2aa10.

[6] Suleimenova, Diana, David Bell, and Derek Groen. "Towards an automated framework for agent-based simulation of refugee movements." *Simulation Conference (WSC), 2017 Winter*. IEEE, 2017.

[7] Hébert, Guillaume Arnoux, Liliana Perez, and Saeed Harati. "An Agent-Based Model to Identify Migration Pathways of Refugees: The Case of Syria." *Agent-Based Models and Complexity Science in the Age of Geospatial Big Data*. Springer, Cham, 2018. 45-58.

[8] Tang, Wenwu. "Simulating complex adaptive geographic systems: A geographically aware intelligent agent approach." *Cartography and Geographic Information Science* 35.4 (2008): 239-263.

AGENT-BASED MODELS AND THEIR ASSOCIATED CHALLENGES

Migration decisions, especially ones in the context of war torn regions is complex to model, and not to mention, aren't mutually exclusive, for example; the presence of other migrants and their decision also play factor to an individual's decisions. Individuals dynamically interact with other agents on the pretext of some rules giving rise to complex trends that emerge at a macro levels.[9] In the realm of migration modelling, statistical models still predominate the field as the method of agent-based modelling is still relatively new in its application to processes like migration. Conflict related or forced migration also draws from theories proposed by sociologists, psychologists and political scientists.[10] However, studies and models on forced migration are only a handful, owing primarily to challenges in deciding the assumptions and choice of decision making rules. Additionally, the fact that models of this nature can't be traditionally analyzed poses another challenge. The subsequent or prior consideration to making models of this nature is empirical data that will fit, which too is lacking.[11] Following this section, the aims and questions of this paper will be laid out followed by discussion of some of the existing models and literature on migration decisions.

AIMS AND QUESTIONS

The questions of interest to this paper lies in the investigation of refugee decisions, that are of a forced nature out of areas with acute civil and humanitarian conflicts, specifically areas such as the Syrian Arab Republic. The aim of this paper is solely to evaluate decision making theory and applying it to an agent-based model. The aim of the model is to provide a simple set of rules that govern an individual's decision to migrate to a particular region or stay in the home location and to build a basic theoretical framework by which one can address problems of this nature. The model presented here is not an attempt at an exhaustive framework but rather a simple model focused on one facet of this complex phenomena.

LITERATURE REVIEW

An agent-based decision model of migration, embedded in the life course: Model description in ODD+D format[12]

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[9] Epstein, Joshua M. Generative social science: Studies in agent-based computational modeling. Princeton University Press, 2006.

[10] Sokolowski, John A., and Catherine M. Banks. "A methodology for environment and agent development to model population displacement." *Proceedings of the 2014 symposium on agent directed simulation*. Society for Computer Simulation International, 2014.

[11] Hébert, Guillaume Arnoux, Liliana Perez, and Saeed Harati. "An Agent-Based Model to Identify Migration Pathways of Refugees: The Case of Syria." *Agent-Based Models and Complexity Science in the Age of Geospatial Big Data*. Springer, Cham, 2018. 45-58.

[12] Klabunde, Anna, et al. An agent-based decision model of migration, embedded in the life course-model description in ODD+ D format. No. WP-2015-002. Max Planck Institute for Demographic Research, Rostock, Germany, 2015.

This paper includes a description and results for a migration agent-based model formulated on theories of planned behavior. The model includes microsimulations of demographic events and decisions made in an agent-based context, with the end goal of the model being to forecast then when and where factors of migration decisions taken by individuals. Also accounted for are external event pressures such as policy, climate change, war, diplomatic relations etcetera. Various life events of individual agents are also stochastically included in the model, thus delineating it into two important segments; a demographic simulation of events and a life event simulation, that ultimately leads agents to make migration related decisions.

The model is described by the authors in the ODD + D format.[13]A description of the model is as follows:

- Entities, state variables and scales: Model includes individuals organized into households as well as the home country or country of origin and the host country. Network theory is also employed for individuals in the home or host country as well as across.
- Entities, state variables and parameters are characterized by the following attributes; gender, marital status, children, income, location, household membership, time in current stage, migration stage, capital, number of household members among other characteristics.
- Exogenous drivers/factors in decisions: These include the random life events of an individual's life that influence migration related decisions such as income, marital status, death, children, child birth etcetera. Policy in the model is assumed to be constant and is akin to the feasibility of emigration.
- Space in the model is via a spatial arrangement of households and individuals on a grid. Households or individuals by virtue of being located on a grid form networks with those within some proximity of themselves.
- A process overview and chronology of the model (continuous time) moves from birth, deaths, marriage, divorces, retirement, to migration, roughly speaking. This process makes up the life events of individuals which is in part dictated by the microsimulation of demographic processes.
- Agents also consume and save on a daily basis and receive an income on a monthly basis, if they are part of the labor force.

The model accounts for the fact that migration decisions can't be mutually exclusive of one another, which has been shown across several different studies. The decision to migrate is influenced not only by individual factors but also by the actions of previous migrants, hence their decisions are correlated with one another.

Decision aspects of the model are based on the Theory of Planned Behavior (TBT), which states that decisions are made in two stages at least.[14] A stage that involves individuals establishing their attitudes, social norms and perceived behavior. Then in the next stage a behavioral intention is formed, where based on the level of control over action or simply put, feasibility of the action, the behavior translates into an action.

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[13] B. Mu¨ller, F. Bohn, G. Dreßler, J. Groeneveld, C. Klassert, R. Martin, M. Schlu¨ter, J. Schulze, H. Weise, and N. Schwarz. Describing human decisions in agent-based models ODD + D, an extension of the ODD protocol. Environmental Modelling & Software, 48(0):37 – 48, 2013.

[14] I. Ajzen. The theory of planned behavior. Organizational behavior and human decision processes, 50(2):179–211, 1991.

The main migration model is given by the following equation:

$$probm_{i,t} = 1/1 + exp(-1/pb_t),\ pb_t > 0$$

The above equation stating that if the household's capital exceeds migration costs, the agent will attempt migration or else the agent is in the last stage of the decision making process where the probability of successful migration is given as the above equation.
No results from this model have been obtained in this paper as this paper serves as an exploration of how one could possibly go about designing an anger-based model for migration and migration related decisions.

Decision-Making in Agent-Based Models of Migration: State of the Art and Challenges[15]

Here agent-based models of migration are reviewed with focus on the decision-making rules adopted by the various models. The most used theories being the theories of random utility in discrete choice models, and the theory of planned behavior. Additionally, two key challenges in the development of an ABM of such a nature are discussed.

A history of models of this nature is first presented, where initial literature on the matter was predominantly occupied by the gravity model. The model posits that volumes of migration between two locations would see increases with increased population sizes in either location and would see a decrease consequent of an increased distance between the two locations. Many models evolved from the gravity model, such as the spatial interaction model, and others all aimed at making predictions on migration flows at some future period. Models then evolved to points where individuals were taken as the unit of observation and microsimulations of individual behavior allowed for heterogeneity among individuals. Further decision-making models began to employ theories of behavior as well as attributing locations with attractiveness and feasibility constraints etcetera. Contemporarily, models have proliferated in their degrees of complexity especially since the earlier gravity model of migration. Now, with the introduction of agent-based models (ABMs) the focus is entirely on individuals, their behaviors and individual decision-making processes including attention to detail by way of continuous time simulations. Agent-based models allow for nonlinear trends resulting from individual versus aggregate population level trends. Social networks and interactions also factor into agent-based models and have influence over the resulting trends.

Six different models are then distinguished and evaluated based on eight criteria that the authors determine necessary for empirical migration and decision-making trends as well as computational requirements. The six models include purposes of:

i. Showing that simple interactions between individuals can generate complex social outcomes.
ii. Use of microeconomic theories of expected utility to explain choices, among discrete alternatives.
iii. Using theories of action derived from social psychology to explain decisions.
iv. Use of heuristics or learning and outcomes from information acquisition and processing at individual levels.
v. Based on decision theory and reliant of direct observation.

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[15] Klabunde, Anna, and Frans Willekens. "Decision-making in agent-based models of migration: state of the art and challenges." *European Journal of Population* 32.1 (2016): 73-97.

vi. Wholly reliant on direct observation.

Modelling decision-making is then looked at. With theoretically almost infinite ways to model decision-making, four are discussed here. Chronologically it follows that the first question is how expectations are formed based on the information acquired and processed. Next the choice of alternatives are evaluated and one selected. Third, the level or degree of complexity of decision-making factors and variables is chosen. And, finally at what level of detail should the migration network follow. The last element including how networks may influence the model as well as what exogenous or endogenous variables they may possess. Thus, this serves as a sort of prescribed format for modelers to follow in the pursuit of building an agent-based model of this nature.

Two challenges for agent-based modelers are discussed and are as follows:

i. Choice of Decision Theory: Although different disciplines usually adopt different decision theories, for example economists using utility theories of decision or other social scientist employing cognitive models, many do not employ a single decision theory at all. Instead, a cocktail of different decision theories are employed and thus an 'arbitrary' cohort of behavioral rules follows. The paper suggest that one decision theory should be employed by modelers, especially when models aren't based on empirical data and thus have flexibility with what they want to employ.
ii. Role of Empirical Data: In the ABMs reviewed by the paper, the use of empirical data varies from none to an considerably large amount. Empirical data may be used for estimation and validation purposes and overall to draw parallels between observations and simulations. Estimation is used to determine future values of dependent variables and validation to match model outcomes to what is actually observed. The challenge here comes from what empirical data can be used by the modeler for, either for estimation, validation or sensitivity analysis.

An Agent-Based Model to Identify Migration Pathways of Refugees: The Case of Syria[16]

The model presented in this paper generates refugees as agents who have discrete choices with where they can migrate to. Here the study uses a dynamic approach in their modelling of the decisions leading up to migration as well as the choice of destination and path taken too. The model is rooted in complex systems theory and makes use of an agent-based modelling framework to simulate the dynamic nature of migration. The model takes data inputs in the form of population data, road, rails and other GIS data including airports, political territories, elevation, ethnicities etcetera. A key input to the model that speak of the severity of conflict in regions where potential migrants are present. Once individuals make the decision to depart, several factors play a role in their choice of destination and subsequently where to seek refuge and ultimately whether to stay or return. Time steps in the model move as 1-month time steps. Conflict zones are are present as 20km wide areas around cities wherein death toll data exists. A conflict score is given by the following formula:

$$C(t) = 1/2[C(t-1) + D(t)] \ ;$$

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[16] Hébert, Guillaume Arnoux, Liliana Perez, and Saeed Harati. "An Agent-Based Model to Identify Migration Pathways of Refugees: The Case of Syria." *Agent-Based Models and Complexity Science in the Age of Geospatial Big Data*. Springer, Cham, 2018. 45-58.

where C(t) is the perceived conflict score of a zone at month t, D(t) is the danger score at moth t. The equation follows that we get $C(t) = D(t)$ for t = 1.

The results of the model show some similarities to observations made by the UNHCR in terms of new refugees annually as well as their distribution across Jordan, Iraq, Lebanon and Turkey. Differences in model predictions and actual observed outcomes are attributed by the modelers to a lack of spatial data available, especially on the spatial distribution of ethnicities.

INDIVIDUAL BASED MODEL PRETEXT

Individual migration decisions are of a complex nature, often involving both economic and non-economic factors.[17] The decision to migrate involves the assessment of all available information on multiple facets, which may also involve weights and other considerations. In this there may very well be information overload as well as imperfect information, contrary to traditional neo-classical theories. When modelling these decisions in an agent-based manner, agents interact with one another as well as their environment leading to changes in the global dynamics.[18]

Despite this model being an attempted departure from the standard neoclassical paradigm, a number of assumptions are to be made. The assumptions are built from other models attempting at a similar understanding as well as theories such as refugee and trauma theory.[19] The model presents itself as a cost-benefit problem, wherein the difference between the benefits derived from emigration against the cost of leaving home are focal to the decision problem. Several studies have indicated the strong presence and importance of network effects in migration.[20] A variable has been included that states the effect of the number of known individuals on expected wages in the host region. The expected wages of the host region for an individual i is an essential variable in this model and others studying similar systems.[21] Separate weights on the home and new location have been included to serve as a measure of conflict in the region, thus acting as a limiting factor on expected wages and the difference between wages at home and transition costs respectively. Another important consideration, illustrated by many, is an individual preference factor for the home location.[22] This constant, unique to an individual i, can, owing to the value assigned, outweigh the benefits of migrating from home to the host region and is an important factor in individual migrant decisions.

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[17] Baláž, Vladimir, Allan M. Williams, and Elena Fifeková. "Migration decision making as complex choice: eliciting decision weights under conditions of imperfect and complex information through experimental methods." Population, Space and Place 22.1 (2016): 36-53.

[18] Oremland, Matthew Scott. Techniques for mathematical analysis and optimization of agent-based models. Diss. Virginia Tech, 2014.

[19] George, Miriam. "A theoretical understanding of refugee trauma." *Clinical Social Work Journal* 38.4 (2010): 379-387.

[20] McKenzie, David, and Hillel Rapoport. "Network effects and the dynamics of migration and inequality: theory and evidence from Mexico." *Journal of development Economics* 84.1 (2007): 1-24.

[21] Kennan, John, and James R. Walker. "The effect of expected income on individual migration decisions." *Econometrica* 79.1 (2011): 211-251.

[22] Abu El-Haj, Thea Renda. "" I was born here, but my home, it's not here": Educating for democratic citizenship in an era of transnational migration and global conflict." *Harvard Educational Review* 77.3 (2007): 285-316.

Lastly, there is an **Ω** value that specifies any negative/positive shock to transition costs which may come by way of changes in policy, changes in conflict etcetera.

Several assumptions are made for this simplified model; however, much scope exists for extensions to be made.[23] Firstly, we will assume that an individual faces a binary choice, in that, they can choose whether or not to migrate from the home location h to a region r. The decision to migrate comes form the simple cost-benefit difference given in u_i. A negative outcome resulting in the individual choosing not to migrate and a positive outcome resulting in migration to region r. The agent makes a decision in two stages primarily. The first stage involves the agent realizing values to their own variables including age, conflict scores, home preference etcetera. The second stage involves the individual cost-benefit consideration. Secondly, we assume that knowing individuals in a region r leads to increases in expected wages due to some network effects.[24] Thirdly, we assume, for the time being, that individual's spatial characteristics with respect to other agents and regions/ home don't factor into this decision. Additionally, temporal aspects do not factor in as well, and the decision is made at one discrete point in time. Fourth, for this version of the model, agents or collectives of agents do not exhibit learning capabilities. Fifth, we assume that environmental factors, other than distance, such as the climate and weather conditions, terrain, altitude etcetera do not factor into the transition
costs consideration. Lastly, we assume that the regions in $\vec{r}$ are located in the same country/state and are thus proximate to the home location. This leads a lack of any stark differences in expected wages, conflict scores, etcetera. Thus, the choice that agents are making are of a local nature.

Agent-based models lack a rigorous mathematical formulation, making rational mathematical approaches and standard analysis problematic.[25] Consequently, optimization and solving becomes equally problematic and misleading should one get it wrong. Optimizations for agent-based models could be done by way of multiple simulations of **k** agents, model reduction methods, and the conversion of systems into discrete difference equations. For this model, the decision has been put into the form of a difference equation. However, the most appropriate means of obtaining a result or trends comes from a simulation of the model on a computerized software.

There are several ways in which this model can be extended, some of those ways are given as follows:

- Additional network effects could be included into the model.
- More regions could be added to the model, including other countries.
- Policy and macroeconomic decision effects on transition costs and shock variables.
- Climate factors could increasingly play a role to transition costs and challenges, and thus could be included.

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[23] Varian, Hal R. "How to build an economic model in your spare time." *The American Economist* 41.2 (1997): 3-10.

[24] Klabunde, Anna, et al. An agent-based decision model of migration, embedded in the life course-model description in ODD+ D format. No. WP-2015-002. Max Planck Institute for Demographic Research, Rostock, Germany, 2015.

[25] Oremland, Matthew Scott. Techniques for mathematical analysis and optimization of agent-based models. Diss. Virginia Tech, 2014.

ASSUMPTIONS

This model makes several assumptions, which are given as follows:

- We assume that the decision to migrate is solely an individual decision. Thus, the presence of a household or any union of individuals is irrelevant to the model.
- The decision theory is loosely based on the Theory of Planned Behavior, wherein the decision to migrate is primarily made in two stages, one where the attitudes, beliefs, and expectations of the individual are decided.[26] Following this, the decision problem is put forth and decisions made on the existing individual information from the first step.
- An implicit assumption made is that the regions, that is, the home and the host region, are all within the Syrian Arab Republic. Hence, the difference between regions will not be as pronounced as if perhaps other countries were included as host regions. Thus, this looks at migration within Syria itself.
- We assume that climate does not play a factor into the individuals decision making process, despite a heap of literature cumulating the effects of conflicts in the middle east as well as climate change to the migration decision making problem.
- For now, the conflict scores assigned to the regions are arbitrary and not based on data from the regions themselves as done by Klabunde and Anna (2016) in their model.
- Additionally, for now, the only other individual phenomena affecting the decisions of potential migrants is how many individuals they know in the host region. The decisions of other potential migrants themselves does not play factor in an individuals' migration decision. It does play a factor indirectly in that, individuals present in the host region known to the potential migrant are assumed to have made the migration decision prior, on the same basis.

INDIVIDUAL/AGENT BASED MODEL

This section presents a basic formulation for an individual based model that solely looks at the decision to migrate.

Agents: $k \geq 1$ individual agents.

Agent strategies include $\vec{r}$ regions, however the model only allows for a choice between the home location h and an alternative region r. If an agent moves from the home location to the new region, the new region r will update as the new home location h.

Utility: An individual's utility is given by the following equation, acting in the manner of a cost/ benefit function:

$$\mathbf{u_i} = (\mathbf{n_{ri}} + (\mathbf{ew_{ri}})\mathbf{p_{ri}}) - \alpha_\mathbf{i}((\mathbf{w_{hi}} - \mathbf{c_{ri}})\mathbf{p_{hi}}) \pm \mathbf{\Omega}$$

n_{ri} = network effect of the number of known individuals in region r
$e\,w_{ri}$ = expected wages in region r

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[26] B. Mu¨ller, F. Bohn, G. Dreßler, J. Groeneveld, C. Klassert, R. Martin, M. Schlu¨ter, J. Schulze, H. Weise, and N. Schwarz. Describing human decisions in agent-based models ODD + D, an extension of the ODD protocol. Environmental Modelling & Software, 48(0):37 – 48, 2013.

p_r = conflict weight in region r
α_i = home preference constant
w_{hi} = wage at home location h
c_{ri} = transition cost from home h to region r
p_{hi} = conflict weight at home location h, which may affect transition states
Ω = negative/positive shock to transition

Expected Wages: The expected wages for an individual i at region r is given below:

$$\mathbf{ew_{ri} = m_r + I(P_i, w_{hi})}$$

m_r = mean wage rate at region r
$I(P_i, w_{hi})$ = individual productivity function
P_i = individual i's productivity factor
w_{hi} = wage at home location h

The network effect of the number of known individuals in region r of any individual i is given by the following function:

$$\mathbf{n_{ri}(n, ew_{ri})}$$

n = number of known individuals
ew_{ri} = expected wages in region r

Transition costs from the home location h to the region r is given by the following function:

$$\mathbf{c_{ri}(d_r, a_i)}$$

d_r = distance to region r from the home location h
a_i = age of individual i

Thus, we can further expand upon the individual equation to give:

$$\mathbf{u_i = (n_{ri}(n, ew_{ri}) + (m_r + I(P_i, w_{hi}))p_{ri}) - \alpha_i((w_{hi} - c_{ri}(d_r, a_i))p_{hi}) \pm \Omega}$$

We can write the decision problem as follows:

$$\mathbf{V_i = max_r(u_i)}$$

SOLUTIONS TO THE AGENT-BASED MODEL

Agent-based modelling is a method that lacks any rigorous mathematical framework. Thus, there isn't any standard solution to an agent-based model. These models consist of individual agents that act upon some locally updated rules, different for each agent, and the cumulative results in some global emergent trends. Stochasticity is characteristic and key for most agent-based models, and owing to this, standard mathematical approaches are rendered intractable.

Oremland (2014) proposed several ways to approach the optimization and solving of agent-based models ranging from difference equations to simulations using special software etcetera.[27] The most appropriate solution for the agent-based model proposed in this paper is by way of a computerized simulation. For this, data would be needed on several facets of the individual decision-making process such as wages, mean wage in the host region, number of known individuals, conflict scores, location distances etcetera. The UNHCR and the Humanitarian Data Exchange (HDE) are the predominant sources present on data involving refugees, especially for The Syrian Arab Republic. However, no dataset of the required nature exists where even values for the variables of interest can be arbitrarily determined. The bulk of the datasets lend themselves to analysis of a GIS nature, primarily tabulating the influx or outflux of refugees into and out of several refugee camps. In general, the amount of data available on Syrian refugees of an individual nature are scarce. Thus, a simulation of the model is not possible until the requisite data becomes available.

CONCLUSION AND DISCUSSION

Agent-based models lend themselves well as a predictive tool for individual decision making. Especially in the case of Syria, predictive models can be of great use for predicting where potential migrants might emigrate to. To entities like the United Nations and others, that seek to minimize damage on the front of the ongoing humanitarian crisis, models of a predictive nature could serve as more than useful. Although no solution or means of optimization was proposed, the aim of this paper was to provide a model based on existing theory on the individual decision to migrate. The next step in furthering the model and its testing will come by way of a computerized simulation. However, for this to be done, datasets will need to be collected in such a manner that we can extract the requisite variables for input into the model. A means to test the soundness of the model would simply be to run a simulation and compare actual migrations flows of individuals with their simulated outcomes. Again, this would require individual level data as well as spatial data of the same cohort of individuals.

Another further step that can be taken is to relax some of the assumptions made and to then proceed with a computerized simulation. Firstly, we can relax the assumption of this being a solely individual decision, thus involving the household. Decisions at a household versus at an individual level are bound to be different and will introduce and added layer of complexity to the model, but will also take it a step closer to the reality of these situations. The assumption that climatic factors don't play influence can also be relaxed as the climate is a robust factor in decisions of a migratory nature across the world. Lastly, the assumption of only within state migration can be dropped and host countries outside borders included. This will too drastically change the outcomes of the models, as host regions abroad have starkly different opportunities and variables associated with them.

The decision to migrate is a key component in the life of a refugee but is not the only facet entailed therein. Several models including those of an individual-based nature as well as traditional analytic models have been proposed over the years. These models have looked at aspects ranging from the spatial flow of migration to the challenges faced by cohorts of refugees such as unregistered

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[27] Oremland, Matthew Scott. Techniques for mathematical analysis and optimization of agent-based models. Diss. Virginia Tech, 2014.

refugees.[28] Models of such a nature have been important to the entities that are stakeholders in these processes, such as concerned nation states and government bodies. The model presented in this paper, although loosely within the context of the Syrian humanitarian crisis, aims at serving as a basic theoretical framework for problems of a similar nature. It can be extended to incorporate additional theories in the context of migration decision making as well as other metrics such as those from network theory.

[28] Groen, Derek. "Simulating refugee movements: Where would you go?." (2016).