Subscript-Based Geospatial Migration Dynamics

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Introduction

Overland immigration to and through Europe caused significant political tension within the European Union and its neighbors between 2013 and 2015. Rather than adopting a unified European approach, many countries chose to adopt independent national policies. Some of these policies further aggravated the political and humanitarian situation, and demonstrated that Europe was largely unprepared for this migration event. While migration numbers have now fallen (and new routes are developing), recent work on climate and conflict-related migration (Zinkina and Korotayev, 2014) indicates future population displacements are likely. To be better prepared for such a situation, an exploratory model that shows effects and interactions of national and continental migration and asylum policies, both temporally and spatially, may be useful.

Model

To capture the geospatial aspects of migration, we implemented our model as a simple stock-flow structure for each country, and then subscripted this structure across all 37 considered European countries. By exploiting vector operations, we created flows between neighboring countries. The stock-flow structure is causally equivalent to a Limits to Growth archetype with a reinforcing and a balancing feedback loop. The main driver of the model is *country attractiveness*, which consists of *residence* and *transit attractiveness*. We proxied these two attributes through a variety of factors, including GDP per capita, democracy rating, population, and migrant population already in-country. These factors are taken from recent surveys among migrants (IAB BAMF SOEP, 2016). Geospatial attributes such as terrain, ground transportation quality and neighboring countries also affect attractiveness of a country.

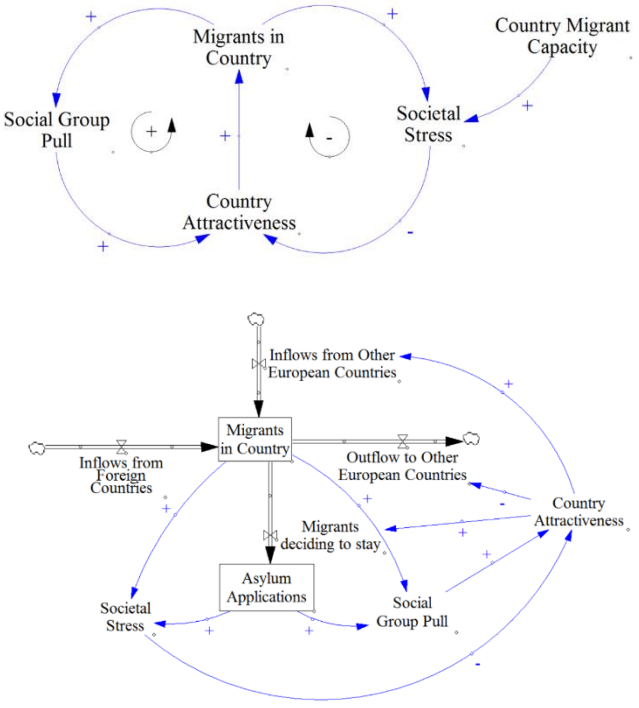

Figure 1: Causal loop diagram and stock-flow structure

The flows between neighboring countries conserve mass – if 100 migrants leave country A, then a total of 100 migrants must enter A's neighbors B, C and D. The transiting migrants are distributed using the

attractiveness of the neighboring countries, ensuring the most attractive neighboring country receives the most, and the least attractive neighboring country the least migrants.

Policy Examples

A base case for model behavior was created using historical migration data (UNHCR, 2017). Migrants entered Europe through Greece and to a lesser extent through Spain and Italy, and then proceeded to slowly flow towards Central and Northern Europe without major obstructions apart from time and terrain.

Additionally, we implemented three exemplary national migration policies. By temporarily deactivating the flow between two neighboring countries, we could effectively create a border wall between them. This measure was taken by Hungary in 2015 to protect its borders with its neighbors Serbia and Croatia. We found that the number of migrants in Hungary decreases, while the number in Serbia rises, with a corresponding increase in societal stress as migrants are blocked from continuing their journey.

Austria instead chose to load migrants onto busses at the Austro-Hungarian border, and transport them directly to the Austro-German border. We implemented this as a *de facto* direct border between Hungary and Germany, and found that migrant numbers in Austria dropped dramatically, but Hungary was almost completely unaffected.

In late 2015, Germany declared a "Refugees Welcome" policy, making the country a prime destination for migrants. We implemented this as an artificial decrease in national societal stress, and found that Germany received many migrants as a result. In a final step, we combined all three policies in one model run, and found that the separate measures combined plausibly over space and time to flow even more migrants towards Germany.

Conclusion

Based on the tested individual and combined policies, we believe the presented model structure may be useful for exploring the temporal and spatial interactions of diverse national migration policies. By applying advanced subscripting to a simple stock-flow structure, we were able to achieve complex geospatial interactions with little effort.

The model is not without flaws. Various aspects of modern migration policy, such as deportations or forced relocation are not considered. Similarly, government policies are exogenous, which is unlikely to reflect reality. We are currently developing the presented methodology further using additional subscript layers to account for migrant country of origin and further migration mechanisms, and extending the model size to cover more countries.

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