Of Kinship and Wealth; An Agent-Based Model of Rural and Urban Migration

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Abstract

With the rapid urbanization of societies of the last half century, the United Nations projects that 68% of the world's population will live in urban areas by 2050. Policy-makers should quickly adapt to this demographic shift especially concentrated in the developing world. Existing literature finds that employment and economic opportunity, and desire for kinship are the main motivators for individuals to migrate. With the purpose of exploring the role of these migration motivators, we use an agent-based model to simulate an environment where each agent maximizes her utility by locating the region with the highest probability of obtaining a profitable job and which hosts neighbors that are similar to herself. We find employment availability to be the most salient factor driving internal migration being that in our model it is the primary determinant of an agent's potential utility in a region. Wage and kinship do not drive an agent to migrate if not accompanied by a possibility of employment.

Keywords:· Migration· Urbanization· Unemployment· Counterurbanization· Auto-Segregation· Intra-migration · Agent-Based-Model · Rural

Introduction

Since the Nineteen-Sixties, the world has undergone an enormous demographic transition, as the global population began to trend toward urban centers rather than rural agrarian settings. In 2007, moreover, for the first time in world history, the global urban population superseded the rural. (Ritchie, et al.). Likewise, The United Nations Department of Economic and Social Affairs projects a hike in the urbanization rate reaching 68% by 2050. (2018 Revision of World Urbanization Prospects). This unprecedented demographic shift leaves no small challenge to the world's policy makers. Being that much of this increase is within the second and third worlds, policy makers are now tasked with managing this influx of urban migrants with high unemployment rates and lack of effective facilities. (Todaro, Economic Development, 348-349). Despite this however, there remains a distinct trend or counter-urbanization in certain locales, where individuals have been enticed to "de-urbanize" and move out to the suburbs or the countryside. (Schultz), (Bell, et al.). These patterns are thus dynamic and intricate, and the outcome of these trends of urban and rural migration may belie similarly unpredictable ramifications. Therefore, we have crafted an Agent-Based Model designed to explore the role of kinship and job-seeking in the emergent decisions of urban-rural and rural-urban migrants. Based on the literature, we understand the opportunity for employment, the wages of said employment, and proximity to kin to be the fundamental driving factors of intranational migration. Therefore, in our model, we intuitively expect to find agents to be driven to migrate by the need to find employment, but we also predict that some agents may be willing to endure an occupation that pays lower wages than alternative options provided they are pleased and satisfied with those agents geographically near to them and the social interactions they yield. In so doing we may surmise the precise motivations and externalities of individuals which policy makers can manipulate through proper policy levers and incentives to maximize the potential for economic growth that comes through urbanization and migration, while minimizing the infrastructural risks of urban migration.

Literature Review

Our model is predominantly concerned with the driving factors of urban migration and the salience thereof in determining a migrant's decision to relocate. Extensive qualitative and quantitative research has been produced examining such indicators. Demographers such as Everett Lee and Douglas Massey identify key "push-and-pull" factors of international and inter-regional migration, foremost being employment seeking and economic opportunity, but also note the importance of familial ties and similar cultural or personal rationales. (Lee, 53-55), (Massey, et al., 434-435). For the purpose of model simplicity, however, in order to facilitate the emergence of new trends and behaviors, these motivations can be broadly classified as economic incentive and familial ties.

Bearing this in mind, the economic sub-component used within our model is conceptually and functionally inspired by the 1969 benchmark Model of Labor Migration by development economist Michael Todaro. Todaro argued that the economic drive for an individual to migrate from a rural region into an urban region can be expressed in terms of probability of acquiring a job in the urban region, and the expected wage of the individual within that region. Todaro thus suggests that since a potential migrant's decision whether or not to relocate is based on what she expects to earn. Intuitively, we observe this in the real world, particularly in developing countries; an increase in the rate of urbanization despite climbing unemployment. (Todaro, *Model of Labor Migration*, 140-144.)This notion of expectation, rather than certainty of gain is correspondingly reflected in our model, as a migrant is enticed to relocate to a new region based on what she expects to gain, yet external factors, such as high unemployment rates or low demand for her labor may still prohibit her from employment despite her expectations

Functionally for our model, moreover, we implement a migrant's desire for kinship, or family or "homophily" as implied in the literature, through a computationally similar approach to that taken by Thomas Schelling. In his benchmark work *Dynamic Models of Segregation,* Schelling simulated how the self-choice and self-organization of individuals in a free society can emerge as de-facto gentrification or segregation, insofar as people, or agents, consistently seek to surround themselves with persons similar to themselves, and demonstrated that such factors are salient weights on one's choice of migration destination. (Schelling). Schelling's simulation was predominantly concerned with segregation and how it is derived from voluntary migrations albeit, and though any auto-segregation or gentrification is beyond the scope of our model's core focus, Schelling's findings are supported by much of the existent literature, such as Benenson and Omer's case study that quantitatively identifies Schelling-esque migratory choices and patterns in Urban areas in Israel, (Benenson, Omer)., and similar findings in the work of Portugali. (Portugali). As such, we find it feasible that a similar computational framework driving agent choice can be adopted as a sub-component of our model, replicating an agent's preference to relocate to locations in closer proximity to agents similar to herself, through modeling "kinship" or homophily as an indicatory factor in an agent's decision to migrate.

With respect to Agent-Based computational research into migratory patterns, there currently exist models of case-specific examples such as the Syrian War Migration Model (Hébert et al.), and more generally exploratory computational models such as Ana Klabunde's *Model of Circular Migration.* Klabunde's simulation, additionally, adds credibility to our deductions from the literature that migration is not concrete, and that migrants continue to migrate seeking out greener pastures, or, as in the case of our model, higher utility, that may come with geographic relocation. (Klabunde). Moreover, as noted by Ronald Skeldon in his work *International Migration, Internal Migration, Mobility and Urbanization*, migrants indeed migrate frequently, and that these "inter-regional" migrations are, due to economic constraints, across relatively short distances, of "regions." (Skeldon, 3-4). Fittingly, therefore, our model focuses in on this particular phenomena, the frequent, short-distance employment seeking migrations, and likewise is to our knowledge the first generalized agent-based model exploring the relationship between kinship and wealth as driving factors of urban migration.

Methodology

In order to explore the dynamics of migration between regions and aid policy makers, one needs to understand the underlying behaviors and decision-making processes of individual persons. Thus, as people are diverse and heterogeneous, agent-based modeling is uniquely suited to explore our research query, as Agent-Based Modeling enables us to depict individual heterogeneity through agents' decision-making processes (N. Gilbert, Ch 1). The value of this method is the ability to observe the underlying interactions between agents that comprise group dynamics, further integrated into a broader computational model. In the context of the current research, we examine individuals as our central unit of analysis with the purpose of understanding the role of kinship, job opportunities and wage in the decisions of urban-rural migrants. The current approach allows us to closely observe agents' interactions with one another and with the geographical and social environment. By focusing our research on individual decision-makers—(agents), we can with high granularity, identify and observe the most salient factors driving an agent's perception of higher utility in a different region. This focus renders our research question uniquely suited to agent-based modeling and bottom-up simulative prediction, ideal for revealing unexpected emergent behaviors otherwise unobservable with formal, top-down traditional statistical modeling.

The urban-rural intra-migration model is mainly exploratory in nature, created to see the dynamics of agents given particular settings not fitted to any specific country. Built in Netlogo, our model allows the user to adjust sliders to simulate different levels of economic development, urban-rural employment disparity and expected wages by region. The model simulates an environment where each agent maximizes her utility by locating the region with the highest probability of obtaining a profitable job and which hosts neighbors that are similar to herself. Agents then decide to migrate to this region if they deem its utility high enough to justify the inconvenience of migrating from their current region.

The environment consists of two types of regions, rural and urban. The modeler can choose between an environment with one rural region and one urban region, or an environment with multiple regions of the two types. The number of agents to be initialized on the environment can also be specified with a slider. Likewise, the average number of jobs and wage for each region type are normally distributed and can be adjusted with mean and standard deviation sliders. All patches' attributes within the same region will correspondingly have the same values. Agents' attributes, in turn, include color, which represents their job status, and similarity threshold, which determines the desired level of similar agents in their neighborhood to maximize their utility. This similarity threshold can likewise be adjusted by the modeler with a slider. Once employed in a given region, agents then change their color to yellow, whereas unemployed agents are colored red.

Existing research done with multiple regression analysis has empirically demonstrated that employed individuals are less likely to migrate to seek work than those who are unemployed, even if the expected wages are higher, as they are encumbered with the loss in wage or environmental factors that they could incur in the moving process. (DaVanzo, 511-512). Thus reflective of the literature, in our model, an agent decides to migrate if any of the other regions' utility is 1.5 times greater than the utility of the agent's current location. This is to represent such expense of migrating to a different region. This cost is not always exclusively monetary in nature. When individuals relocate, they abandon long-established interpersonal relationships, professional networks, and a life-style they are familiar with. They also have to invest time and effort to adapt to the new location. If the utility of her current location is equal to that of a different location, the agent will prefer to stay rather than taking the risk of migrating.

Each patch has a utility attribute, which is separately modified by each agent according to whether her similarity threshold is met. Each region's utility (U) attribute is expressed with equation 1 as follows;

$$U_i = W_i * V_i \tag{1}$$

where W is the wage of region i and V is the vacancies available. Vacancies are determined by the difference between the number of jobs and the number of agents in region i. If the number of agents in region i is greater than the number of available jobs, the value of vacancies is zero. The utility for each agent is updated based on whether the similarity threshold is met or not. If the threshold is met, the utility is increased by a certain weight (w) or a salience level as shown in equation (2) . Similar principle applies when the threshold is not met, where the utility decreases by a certain weight (w), presented in equation (3).

$$U_{ai} = U_i * (1 + w) \tag{2}$$
$$U_{ai} = U_i * (1 - w) \tag{3}$$

Where Uai is an adjusted utility after similarity threshold, Ui is a utility before adjustment, w is a weight or a similarity salience level.

Once the agent has considered each of the regions in the environment and decided to move or stay as specified before, she updates her job status to yellow (employed) if there are vacancies in the destination point, or turns red if otherwise.

Given unequal opportunities for different individuals, the model considers only a half of the population to make their decisions at the initialization stage. This could be explained due to the nature of individuals' constraints that restrict them from immediate decision making, such as financial, social and environmental. Thus, the model only considers half of the aggregate at a time. The process is continued iteratively every 5 ticks, once the first half is finished with decision making, another half comes in. Figure 1 below summarizes the overall process of an agent during one tick.

At a model setup, there is a regional wage and number of jobs that form a basis for agent Utility. The social aspect of the model is added in the next stage, where agent examines her environment and determines whether the similarity threshold is met. If the case is positive, she finds the location that yields the highest possible utility incorporating the positive similarity threshold. If the highest utility available exceeds current utility by 1.5, the agent migrates. Otherwise, she stays. If the similarity threshold is not met in the utility with the highest possible utility, the agent might still decide to migrate if that utility is 1.5 times higher than the current utility.

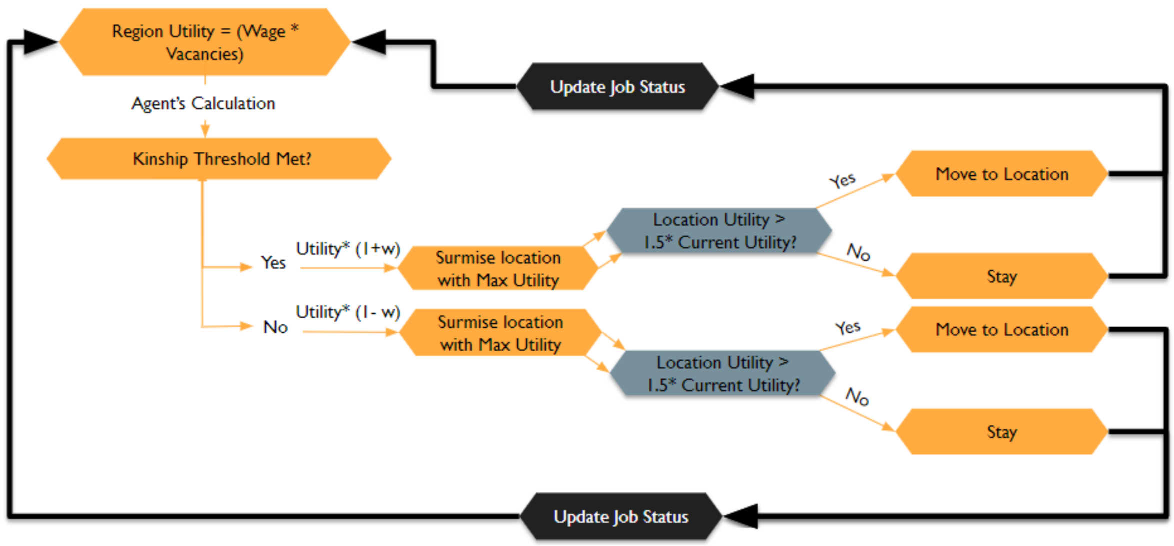

Figure 1, Model Architecture

Model Implementation

Baseline

The Baseline model setup represents a small community comprised of 70 individual agents, each seeking to maximize her utility. The environment is divided into two main regions, namely urban and rural. For the sake of simplicity of the model, we assume that every single agent has the same similarity requirement threshold of 50%. The model setup is designed to loosely represent a developing country, however it is not fitted for any one country in particular. For this reason, the assumption of income disparity between urban and rural areas still holds. The number of jobs in urban and rural regions is set at 35 and 28 respectively, thus an unemployment level equals 10%.

As a comparison, the real world unemployment rates for developing countries vary from 0.1 % (Qatar) to 46.10 % (Congo), (Trading Economics, 2019). For simplicity's sake in our model however, we set 10% as our baseline, which is close to the unemployment rates of developing countries such as Mongolia, Colombia and Iran, but this number could easily be adjusted by the modeler to emulate different countries. To keep the model deterministic in the Baseline run, we set standard deviation of jobs and wages in regions at zero. Finally, the wages are set at 20 and 15 for urban and rural regions correspondingly. The numbers are taken rather arbitrarily, representing an income gap of 25% between the two regions. The weight by which utility is modified (as shown in equation 2 and 3) when evaluating similarity threshold satisfaction is set at 20% or 0.2.

The Baseline yields interesting results. Given that the number of jobs in urban regions exceeds that of rural, the employment rate in the urban region appears to be higher consistently across 500 runs (Figure 1). Figure 2 below shows a phase portrait between the number of agents that moved between the two regions and the number of agents that have met the threshold of similarity.

The first stages of the simulation demonstrate that the number of agents which migrate from region to region follow the same trajectory as the number of turtles whose similarity threshold has been met. Intuitively, as people are attracted to others similar to themselves the graph exhibits an upwardly sloped line. However, about halfway through the model, agents move regardless of the similarity threshold until the model finally reaches its equilibrium and agents stop migrating. Since people maximize their utility at a new location, they have no incentives to move towards a different region. As only half of the agents make decisions at a time, the model reaches its equilibrium at a slower pace.

Figures 3 and 4 show phase portraits of Employment and Utility in the two existing regions. As we can see, both graphs exhibit almost identical behavior, where the only difference is that the utility level in an urban region is about twice as high relative to a rural region. Utility increases as employment increases, which confirms the definition of utility mentioned in the Methodology section above.

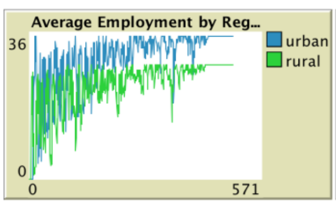

Figure 1

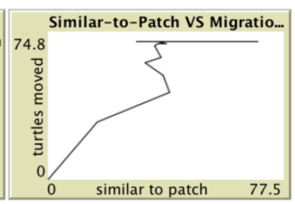

Figure 2

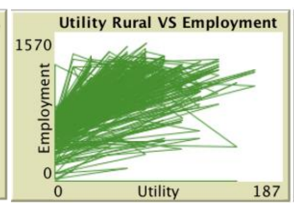

Figure 3

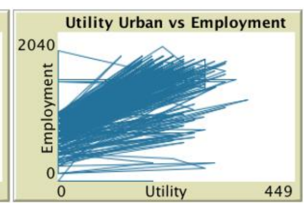

Figure 4

Scenario 1- Seeking Kinship

What happens if every agent has a higher requirement for the similarity threshold in order to maximize her utility? The second scenario drives percent similar wanted slider to 80%. Such situation corresponds to the individuals which prefer to be in homogeneous societies, surrounded by a vast majority of similar people. On top of that, we assume that once similarity threshold is met, it adds 40% to the current utility level and subtracts 40% if the threshold is not met. In other words, the salience of similarity is doubled.

The results yield different behavior in Figure 6 compared to the Baseline. Even though the number of agents with a satisfied similarity threshold is zero, people continuously move to other regions. That means that homophily does not play the most salient role in the decision-making process even if the weight was increased to 0.4 (compared to 0.2 in the Baseline), affecting the utility by 40%.

On the contrary, agents choose to migrate based on the employment possibilities of a region shown in Figures 7 and 8.

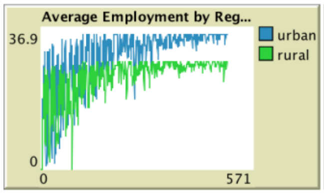

Figure 5

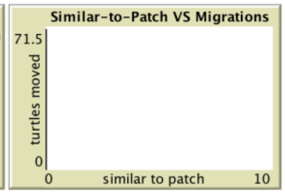

Figure 6

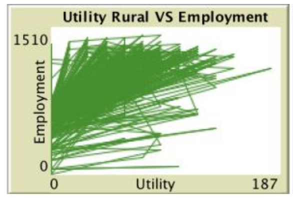

Figure 7

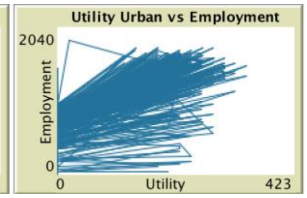

Figure 8

Scenario 2. Rural Boom

In this scenario, we assume there is an industrial boom in a rural part of a country which results in higher wages. We set urban wages at 25 and rural at 35. However, in order to test the salience of the wages, we keep the job levels as it is (35 in urban and 28 in rural). We also set the similarity threshold and weight at 50% and 0.2 respectively identical to the Baseline.

Figure 9 shows the employment rate by region. As we can see, towards the end of the simulation, the number of employed agents in each region remains constant with no variation. Figure 10 shows that in the earlier stages of the analysis, regardless of the increasing number of agents with a satisfied similarity threshold, individuals would not move between the regions as the utility remains below the threshold of the migration. However in the latter stages, agents start migrating even if the number of agents with a satisfied similarity threshold remains constant.

This scenario shows a higher salience of the availability of jobs and wage levels compared to the threshold for similarity. Even if individuals satisfy the homophily condition, they do not yet migrate to other regions. Given an exceeding number of jobs in the urban region, but an increased wages in rural areas, it takes some time to decide whether agents want to stay in urban regions or move towards increased wages. However, Figure 9 demonstrates that most agents remain within an urban area even if the wages are higher in rural region. Therefore we can conclude that intuitively, wages are only relevant if there is availability of jobs, therefore vacancy remains as the most salient factor in individual migration decision-making process.

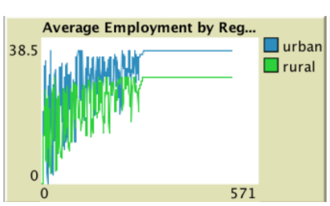

Figure 9

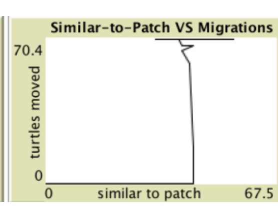

Figure 10

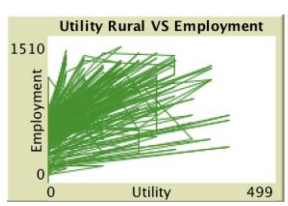

Figure 11

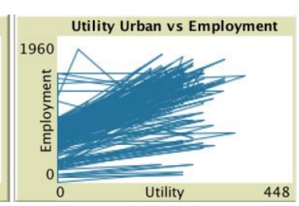

Figure 12

Scenario 3: Multiple Regions

For our last scenario, we consider a different environmental setup. We introduce multiple regions of each type. Attributes of regions of the same type are normally distributed and defined by mean and standard deviation sliders. For consistency, we maintain the Baseline wage and similarity sliders unchanged. Urban and rural mean wages are set at 20 and 15 respectively. The similarity threshold is 50% and the weight is 0.2. We do increase the standard deviation to 1 so that regions of the same type are not completely homogenous. Urban and rural mean jobs are set at 20 and 15 respectively.

Scenario 3 results in complete urbanization. Given that the average jobs for urban regions is higher, rural regions' utilities are never high enough to attract agents. There are enough urban regions to prevent rural regions from ever maximizing the utility of any agent. As observed in figure 13, all agents immediately migrate to urban regions and only move within regions of this type. Similar to the Baseline, throughout most of the simulation run the number of agents who migrate also meet their similarity threshold. Eventually, nevertheless, agents migrate even when they don't satisfy their percent similarity threshold, until an equilibrium is reached and agents stop migrating as evidenced by figure 14. Figure 15 captures all agents migrating towards urban regions only, with employment in rural regions at zero. Accordingly, utility in urban regions reaches a maximum value, but employment levels keep changing given that agents continue to migrate to other urban regions.

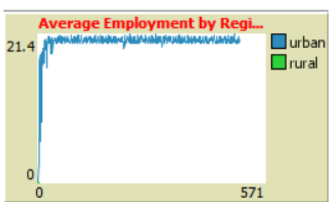

Figure 13

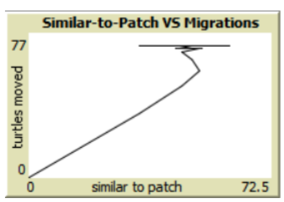

Figure 14

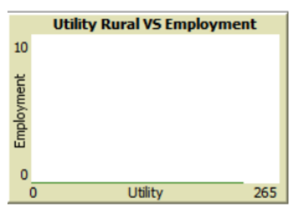

Figure 15

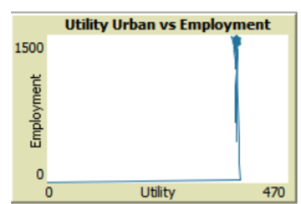

Figure 16

Figure 17 captures the emergence of collective behavior where agents migrate in clusters to the regions with highest utilities. In our model, when agents are evaluating the potential utility of moving to a different region, they consider the vacancies of the region at a specific point in time. Yet, they do not consider which other agents are simultaneously making the same decision. This results in movement in masses and in some level of unemployment in the regions with highest utilities due to the sudden increase in the regions' populations.

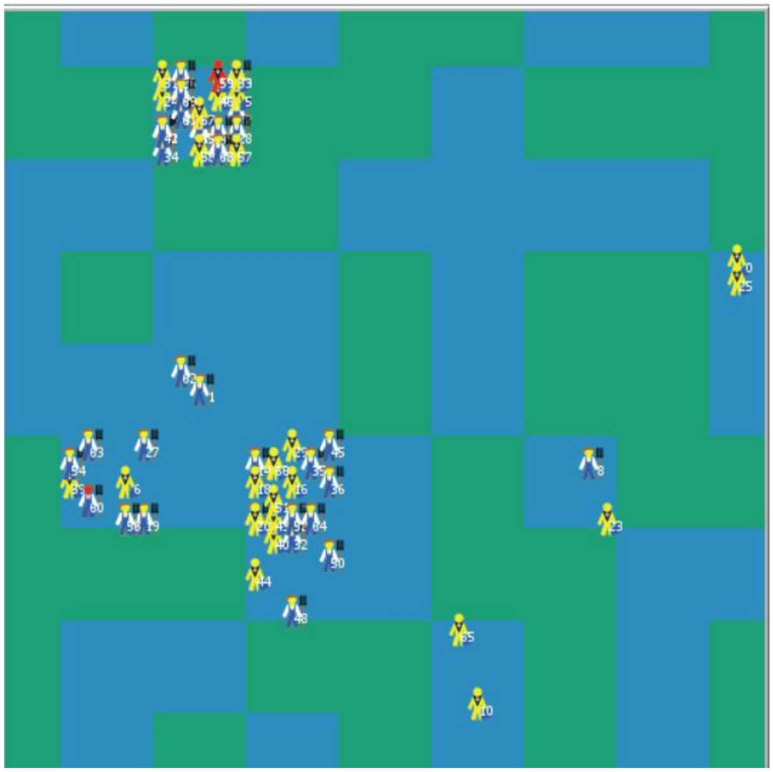

Figure 17

Internal Validation/Results

In order to validate the above mentioned results, we conduct a Global Sensitivity Analysis varying all input variables in order to test the robustness of the model and see what drives the output variable the most. Figure 18 below provides Pooled OLS summary statistics of three models.

Regression Results

	Dependent variable:		
	Turtles moved (1)	utility urban (2)	utility rural (3)
Employment urban	0.885*** (0.064)	9.439*** (0.879)	-1.630*** (0.363)
Employment rural	0.593*** (0.078)	-1.954** (0.954)	3.992*** (0.505)
Similar to patch true		-0.482* (0.260)	-0.160 (0.125)
Mean Jobs Urban		-0.756 (1.450)	
Mean Wage Urban	0.040 (0.206)	6.038*** (2.266)	
Mean Jobs Rural			1.254 (0.867)
Mean Wage Rural	-0.454* (0.266)		4.126*** (1.403)
`%-similar-wanted`	0.126 (0.083)		
Constant	27.351*** (7.051)	-145.830** (69.765)	-93.689*** (32.671)
Observations	1,000	1,000	1,000
R2	0.468	0.235	0.133
Adjusted R2	0.466	0.231	0.128
Residual Std. Error (df = 994)	12.816	140.807	67.420
F Statistic (df = 5; 994)	175.193***	60.905***	30.434***
Note:	*p<0.1; **p<0.05; ***p<0.01		

Figure 18

The first model considers the number of agents that crossed the borders between the regions as a dependent variable. As a specification, we include employment and wages by region type as well as the percent similar wanted value determined through a slider at a model setup. Employment in both regions appear to be highly significant at a 1% significance level with a positive sign, which implies that the higher is employment in a given region, the higher the number of people crossing borders between the two regions. However the magnitude of the urban employment is higher due to a higher number of jobs in urban region at a model setup stage. Interestingly, confirming Scenario 2, the number wages are not significant in this model. Finally, percent similar wanted is not significant either, which suggests that the results of Scenario 1 are confirmed.

The second model's dependent variable is Utility by region type. Both employments by region type are strongly significant, yet with different signs. Urban employment is positive and strong in magnitude, which suggests that it is the main driver of urban utility. Unlike urban employment, the higher the rural employment, the lower the urban utility as more people are inclined towards moving into a rural region. In this model, we introduce the variable being the number of people which met a threshold of similarity. The variable is negatively correlated with the output variable and is significant at a 10% level. The interpretation of this variable is quite ambiguous as the output variable measures the number of border crossings which does not consider the direction of the movement. Finally, urban wage is highly significant with a positive sign and a high magnitude, suggesting that it appears important, yet to a lesser extent compared to the employment level.

The third model focuses on the utility of a rural region. In a similar fashion, both employment variables are highly significant at 1% level, with reversed signs, indicating that the more people are employed in an urban region, the less is utility in a rural region. The similarity variable is no longer significant in this model. However, mean wage in rural region is indeed significant and at a higher magnitude, which is quite surprising given that agents seemed to prioritize availability of jobs as opposed to the level of wages.

Overall, the regression outputs confirm the previous findings stating that employment in a given region appears to be the most salient factor in both utility and border crossing. The goodness of fit decreased with every model, which can be justified as a poor fit of the data via nonlinear patterns of behavior and a lack of explanatory variables adding to an omitted variable bias.

Discussion and Future Research

What motivates individual inclinations towards migration? We approach this problem with an agent-based model focusing on the micro-level dynamics that yield complex nonlinear behavior at group and system scales. Given that in our model the utility of a region is primarily determined by the number of jobs available, employment availability looks to be the most salient factor driving internal migration. Though employed and unemployed agents alike prefer being among "their own," they are willing to migrate to regions where neighbors have differing characteristics to their own if they can achieve more profitable employment in so doing. Additionally, if agents do not perceive an opportunity to enjoy high wages (job availability), they will not give importance to increasing wages. This is intuitive, as there is little utility of higher wages if the agent's likelihood of obtaining that position is low.

Due to the ongoing movement of agents, the composition of regions constantly changes, thus agents' utility calculation is continuously updated, resulting in high migration. At this point, our model assumes that migratory agents vacate their respective regions and arrive at their new locations at the same point in time in spite of their distance from the previous location. This results in a competition for jobs if agents arrive at the new location simultaneously. Thus, despite job vacancies at the time of the utility calculation being high enough to warrant an individual to migrate, she runs the risk of being unemployed once she arrives at the chosen location in this instance. Consequently, agents' simultaneous calculation of the location with the highest utility does not prove to be the most effective strategy for agents to maximize their utility. This is reflected in the emergence of clusters of individuals that migrate together between high-utility regions expecting to maximize their utility and obtain employment, yet sometimes fail to do so because the ensuing supply of laborers to the region soon outstrips the demand, resulting in many unemployed migrants in the region despite their expectations of available jobs when they originally made the calculation to migrate. Essentially, in this instance, the competition for employment was greater than the agents expected.

In the future, our model can be improved by introducing the consideration of additional aspects in the agent's decision-making process, such as political and demographic factors, which can reinforce the model's applicability to the real world. Further specification of the parameter's values to reflect specific regions at specific periods in time can generate valuable data for policy-makers. Additional attributes to increase agents' heterogeneity would be welcome, such as various encumbrance factors including agent marital status, dependents, current financial wellbeing and language ability. Such variables would allow for increased differentiation in agents' utility calculations resulting in more diverse migration choices. Nevertheless, increased heterogeneity also increases complexity, thus the modeler should be meticulous and conservative in her analysis of the model's output.

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