Agent-Based Modeling of Skilled Migration: Integrating Individual Decision-Making with Economic Structures

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Introduction

- Importance of skilled migration in global labor markets
- Motivation for modeling migration dynamics
- Overview of agent-based modeling (ABM) approach

Research Goals

- Simulate skilled migration using two ABMs
- Integrate macro-level economic structures with micro-level decision-making
- Explore spatial patterns of employment and wage distribution

Theoretical Foundations

- Active Brownian Particles (ABP): modeling economic agglomeration
- Aspirations-Capabilities Framework (ACF): modeling individual migration behavior
- Role of wage gradients and agent's aspirations and capabilities

Migration Studies as a Multidisciplinary Field

Traditional migration theories usually are rooted in one of the following disciplines [2]:

Geography	Economics	Behavioral Science	Social Science

We need to create an interconnected puzzle of theories in migration studies

Traditional Migration Theory

Lee’s Theory of Migration: Push-Pull [3]

- An individual’s decision to migrate is driven both by “push” factors that compel them to leave their place of origin and “pull” factors that attract them to a new destination.
- Neoclassical economists emphasize utility maximization, rational choice and wage differentials.

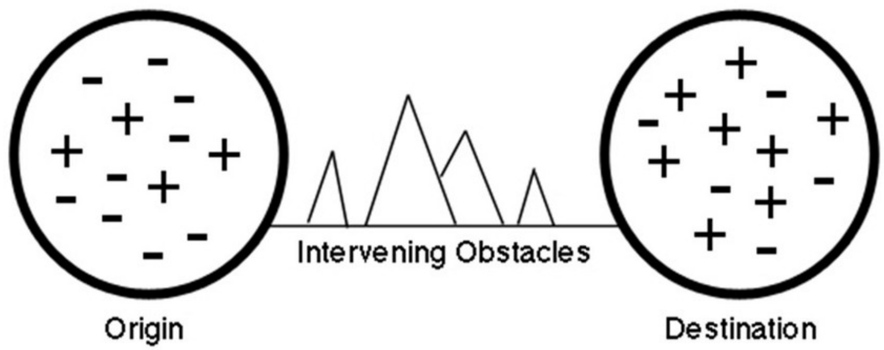


Image courtesy Research Gate Publication of African Renaissance [4]

Limitations of Traditional Migration Theories

- Relocation is costless and unrestricted
- Preferences remain constant over time
- Assumes rational actors maximizing utility
- Push-pull model depicts migrants as passive actors responding to external structural forces, without fully accounting for their agency in the decision-making
- de Haas's Aspirations and Capabilities Framework (ACF) address these limitations and provides a more nuanced approach to representing migrant agency

Aspirations and Capabilities Framework (ACF)

Hein de Haas (2021) theorizes migration is a function of the aspiration to move and the capacity to do so within a set of perceived geographical opportunity structures [4]

Aspirations

- **Instrumental**: Migration is viewed as a means to achieve goals
- **Intrinsic**: Migration is desired for its own sake, motivated by exploration, personal growth, or adventure.

Capabilities

- **Positive liberty ("Freedom To"):** "): An individual is empowered to act and has access to resources for migration
- **Negative liberty ("Freedom From"):** No institutional or political restrictions or barriers preventing them from migration

		Migration Capabilities	
Migration Aspirations		Low	High
	Low		
	High		

Skilled migration

The Macro-Level Influence: Agglomeration Economies

- While individuals possess agency in their decision to migrate, their decisions are shaped by their perceptions of available opportunities
- Agglomeration economic centers are one example of a structural force that attracts skilled migrants.
- Geographically concentrated firms, foster a cooperative ecosystem that boosts productivity, reduces costs, and encourages knowledge sharing.

Active Brownian Particles (ACP) as Agglomeration Economies

- Frank Schweitzer (1998) utilized Active Brownian Particles (ABP) to simulate migration and economic agglomeration [6]. Unemployed agents move towards regions with high wage gradient and high density of employed agents. Cooperative effects are incorporated through a Cobb-Douglass production function that influences hiring and firing rates.
- Labor is assumed to be the sole input, with a uniform common β across the region. The production Y is a function of local density of employed agents. The A_u is summarized output by firm e.g. Kapital and assumed to be constant. The A_C term represents the non-linear cooperative effects from interactions among the agents

$$\boldsymbol{Y\,\{l(r,t)\} \;=\; h\,/\,(Ac \;+\; Au\{l(r,t)\}) \;*\; i \;*\; l \;*\; \beta(r,t)}$$

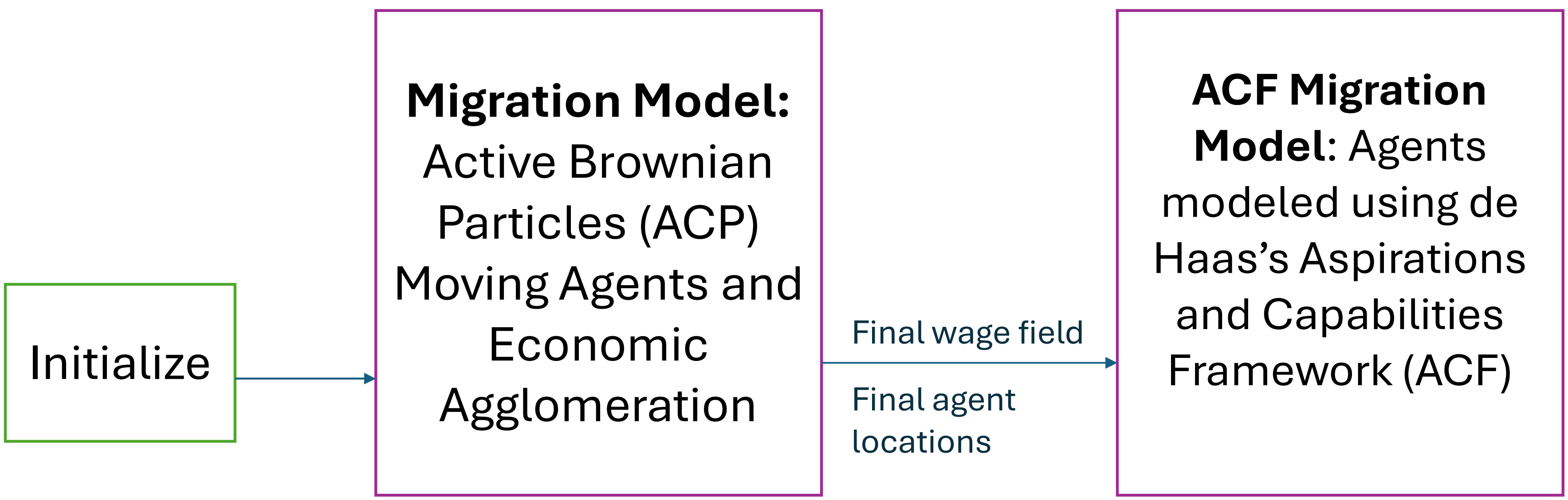
- Wage of agent [6] as a function of local density of employed agents at location r at time t with given input parameters $\bar{A}, a_1, a_2$:

$$\{\boldsymbol{l(r,t)}\} = \frac{\bar{\boldsymbol{A}}}{\mathbf{2}}\left[\mathbf{1} + \boldsymbol{exp}\left(\boldsymbol{a_1 l} + \boldsymbol{a_2 l^2}\right)\right]\boldsymbol{\beta l^{\beta-1}} + \frac{\bar{\boldsymbol{A}}}{\mathbf{2}}\left[\mathbf{1} + \boldsymbol{exp}\left(\boldsymbol{a_1 l} + \boldsymbol{a_2 l^2}\right)(\boldsymbol{a_1} + \mathbf{2}\boldsymbol{a_2 l})\,\boldsymbol{l^{\beta}}\right]$$

Tale of Two Agent-Based Models

Migration and Aspirations-Capabilities Framework Models

Model Architecture



Migration Model (ABP-Based) Parameters and Rules

- Number of agents
- Economic landscape size
- β
- A
- Hiring rate/Firing rate
- Minimum wage

- Agents are randomly placed on the grid
- Fifty percent of the agents are employed
- Only unemployed agents move
- Agents move toward regions with higher wages and to greater concentrations employed agents.
- Wage field using Moore neighborhood and cell not available, choose nearby random cell

ACF Migration Model Parameters and Rules

- Inherits from Migration Model
- Skill
- Wage expectation
- Decision value
- Aspiration factor
- Capabilities factor
- Decision threshold

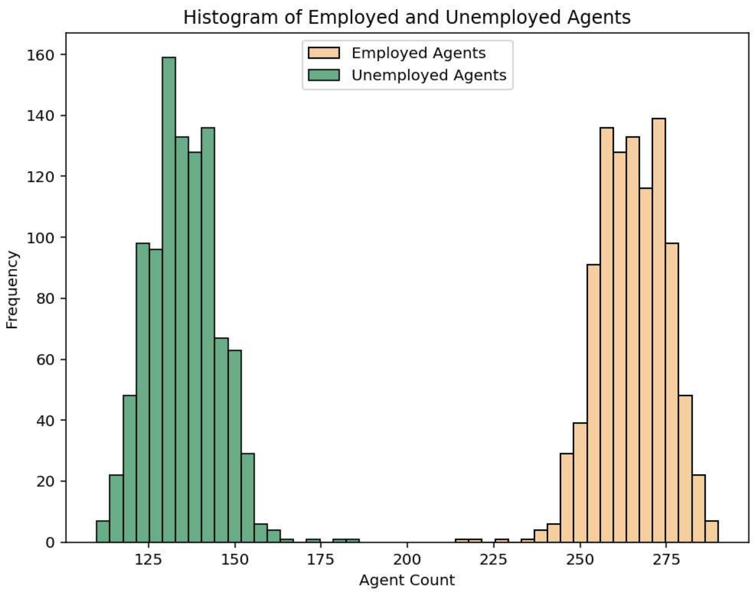
- Inherits from ABP Agents
- Decision value = (aspiration factor * wage differential) + (capability factor * skill)
- Move the decision value exceeds the agent's decision threshold

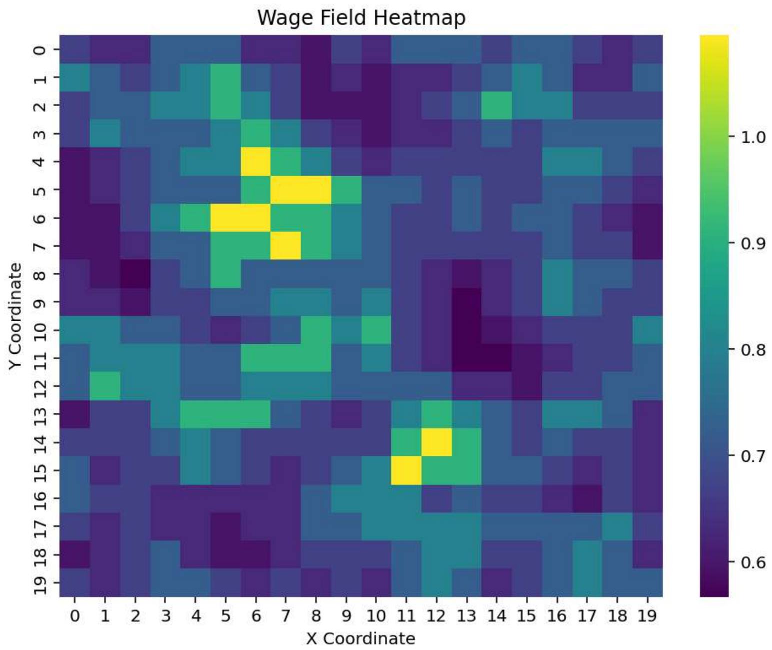
Experiment Design

- Experiment 1: Migration Model only
- Experiment 2: ACF Migration Model only
- Experiment 3: Combined model with sequential execution
- Settings: Grid size = 20 rows and 20 columns, 400 agents, 1,000 time-steps

Results: Experiment 1

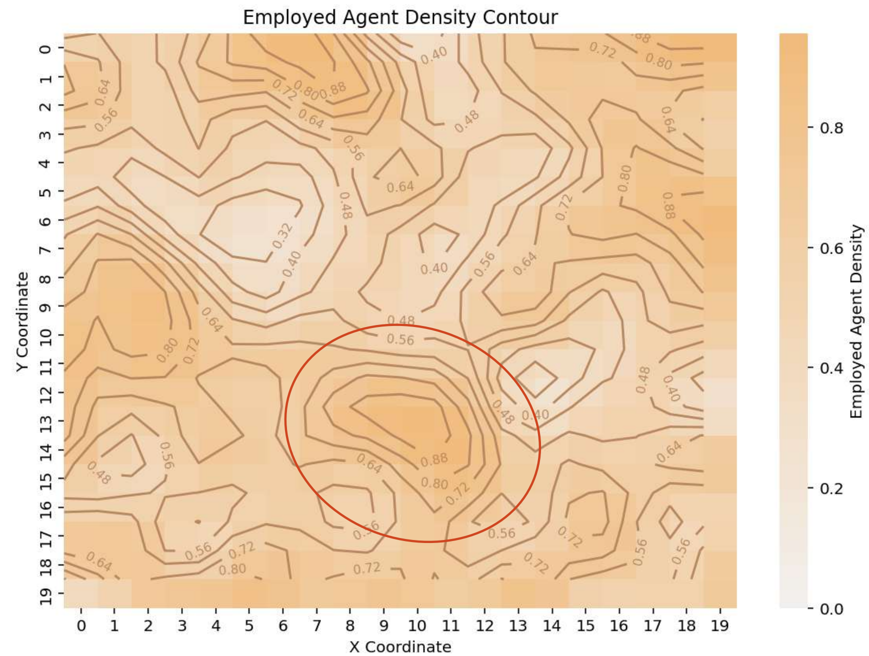
- Histogram suggests net increase of employment among agents
- Wage heatmap feature two dominant hubs, represented by yellow cells, surrounded by less densely clustered regions shown in shades of green





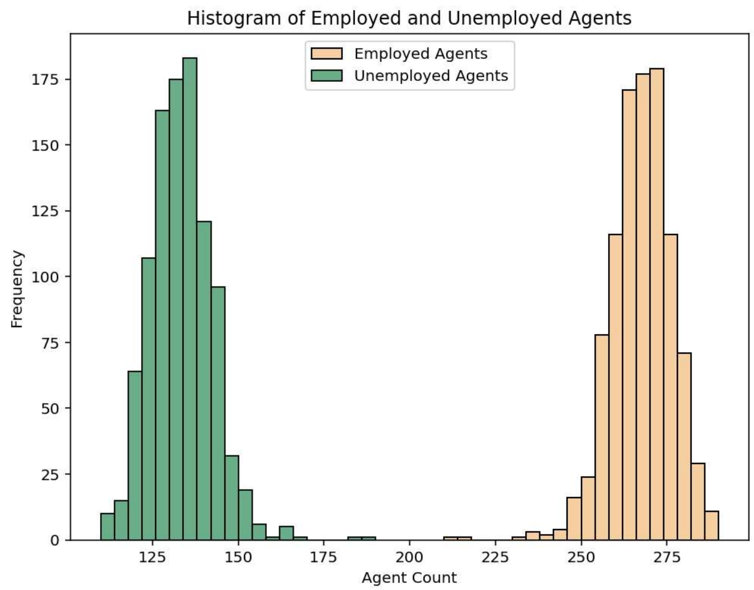
Results: Experiment 1 (continued)

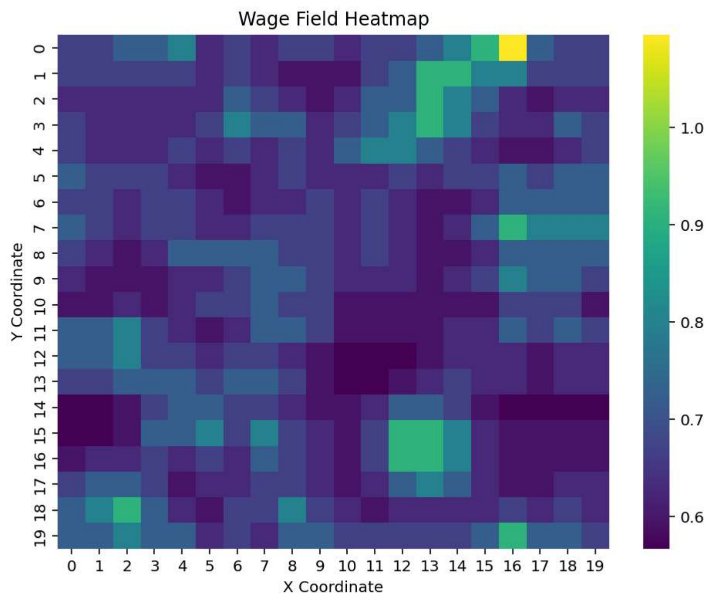
- No strong patterns of clustering in 3D scatterplot – only local regions of employed agents
- The 2D contour map of employed agents clearly shows multiple hotspots based on spatial distribution of employed agents



Results: Experiment 2

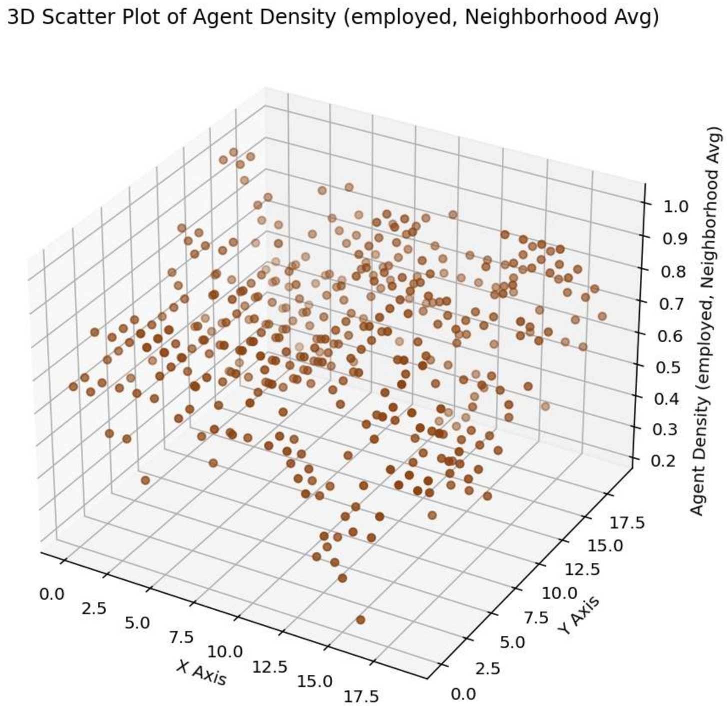
- Similar to experiment 1: shift towards employment for ACF agents
- Smaller-scale agglomeration economies (shades of green) appearing in the wage heatmap

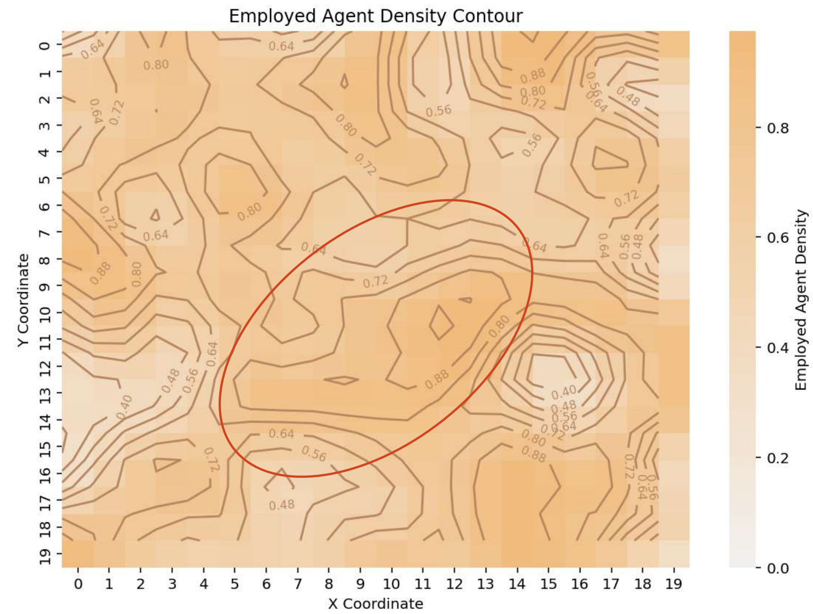




Results: Experiment 2 (continued)

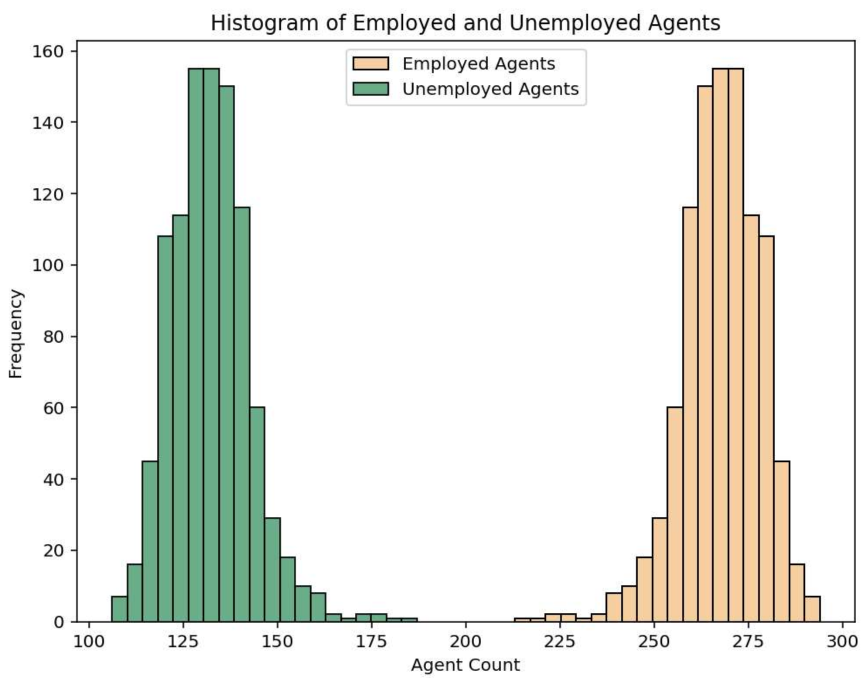
- No strong patterns of clustering in 3D scatterplot – only local regions of employed agents
- The 2D contour map of employed agents clearly shows multiple hotspots based on spatial distribution of employed agents

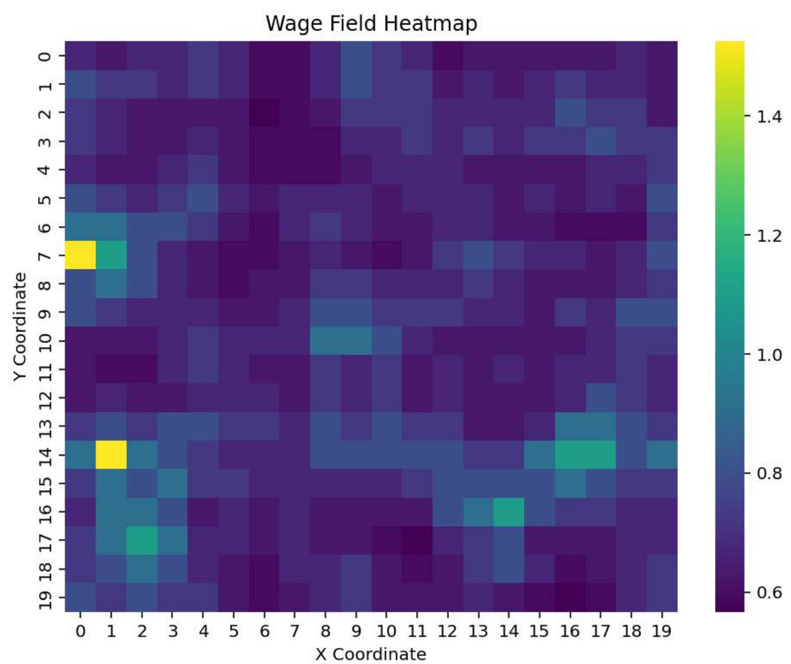




Results: Experiment 3

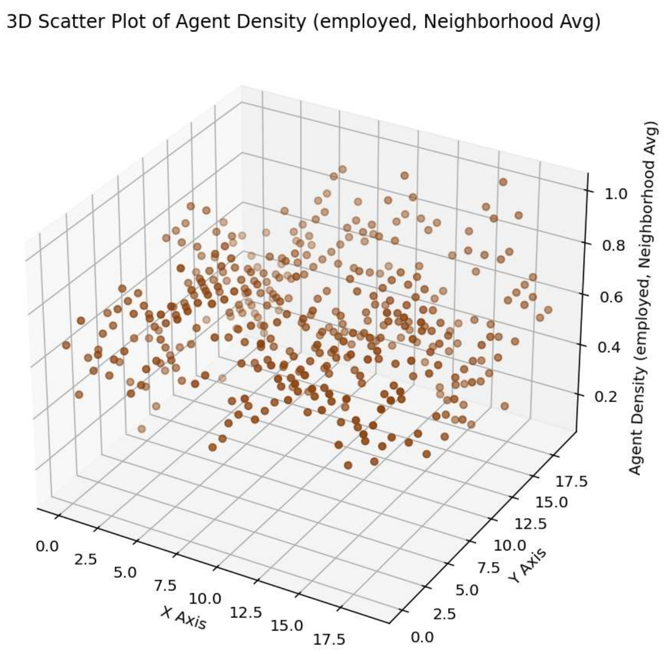
- Strong shift to employed agents – possibly indicating an unintended strong bias of employment
- Smaller-scale agglomeration economies (shades of green) appearing in the wage heatmap and two dominant hubs

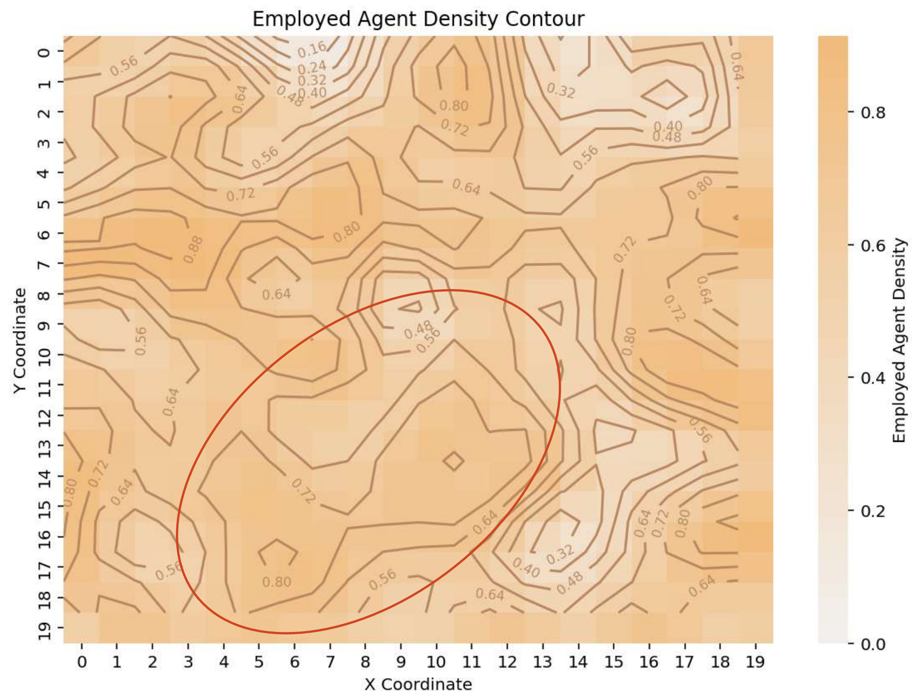




Results: Experiment 3 (continued)

- No strong patterns of clustering in 3D scatterplot – only local regions of employed agents
- The 2D contour map of employed agents clearly shows multiple hotspots and reveals multiple, more pronounced hot spots of employed agents





Cross-Experiment Discussion

- Consistent employment bias across models
- Differences in spatial clustering
- Influence of model sequencing
- Need for parameter tuning

Limitations and Future Work

- Current model does not include skill-based migration effects
- Plans to incorporate skill, policy constraints, and network effects
- Potential applications in labor market forecasting and urban planning

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ABP Agents Step()

In each step, the ABP Agents:

1. Only unemployed agents move
2. Update wage field:
   a. Calculates local labor density (luv) by identifying Moore neighborhood, counting the number of employed agents and dividing by the number of total cells

   $$luv = \frac{total\ employed\ in\ neighborhood}{neighborhood\ size}$$

   b. Calculates wage of neighboring cells
   c. Unemployed agents move to cell with high wages. If it is already occupied, they try moving to a random unoccupied neighboring cell.
   d. Potentially update their employment status

ACF Migration Model

Inherit Model Parameters from Migration Model

Number of agents: Influences spatial density

Economic Landscape: Each grid cell's wage is initialized to zero.

β: Used as a parameter for a Cobb-Douglas production function

A: Constant parameter of base productivity where cooperative effects are negligible when calculating local wage field [6]

Hiring rate and Firing rate: Firm's hiring and firing rate and given initially as a constant but change according marginal revenue of firm

Minimum wage

Decision value

ACF Agents

- Inherits attributes from ABP Agents
- Agents' initial locations can inherit from the ABP's final agents' locations or randomly assigned
- **Skill**: a value randomly assigned between 1-5 representing agent's skill level from low to high
- **Wage expectation:** agent's expected wage from randomly assigned number ranging from 15-25
- **Decision threshold:** a value used in their decision-making to migrate randomly assigned between 0.1 – 0.5
- **Aspiration factor:** a parameter that is set by default to 0.2 showing wage expected influence on actual wages
- **Capabilities factor:** a parameter that is set by default to 0.3 showing skill influence on decision threshold
- **Decision threshold**: A parameter that is initialized with the model that determines if ACF agent moves the decision value that the agent exceeds this threshold

ACF Agents Step()

In each step, the ACF Agents:

1. Move (Inherited from ABP Agents, only move is unemployed)
2. Change their employment status (inherited from ABP Agents)
3. Update their wage expectations based on the following:
   a. Based on de Haas's aspirations-capabilities framework, ACF agents evaluate whether to stay or potentially move based on the decision value calculated as follows:

      decision value = (aspiration factor * wage differential) + (capability factor * skill)

   b. Wage differential is the difference between wages at their current location and in neighboring locations.
   c. Agents are imbued with their skill, aspiration factor, and capability factor that does not change throughout the simulation.
   d. If the decision value exceeds the agent's decision threshold, then they move.