# Scale and Spatial Complexity: Agent-based models and geographical economics

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# Scale

- Body→ Household→City→Region→Nation
- Interscalar Relationships
- Example: Household racial heterogeneity and neighborhood diversity

# Spatial Complexity

- ‘Spatial’ economic models often treat space as a distance matrix
- But space can also be understood in terms of differentiation among places and gradients between them.
- Agent-based modeling is well-suited to representing space in terms of local differentiation
- Once space is meaningfully introduced into economic models we find that it has significant implications for model results and, by extension, for policy recommendations

# Space in Economic Modeling: Geographical Economics

- Developed initially by Paul Krugman (1991) extended by many others (*Journal of Economic Geography*)
- Identifies economic trajectories of cities with workers and firms moving among cities in search of higher utility (for workers) and profits (for firms)
- Goods are available in different cities at cost plus a transportation fee. This differentiation, combined with increasing returns to scale, drives the model with a ‘home market effect’ that induces consolidation of economic activity

## A critique of geographical economics

- Equilibrium is enforced exogenously by linking the movement of firms and workers to maintain optimal proportions
- Because equilibrium is enforced rather than arrived at, space is reduced to an added cost on certain goods
- Focus is on distance rather than differentiation

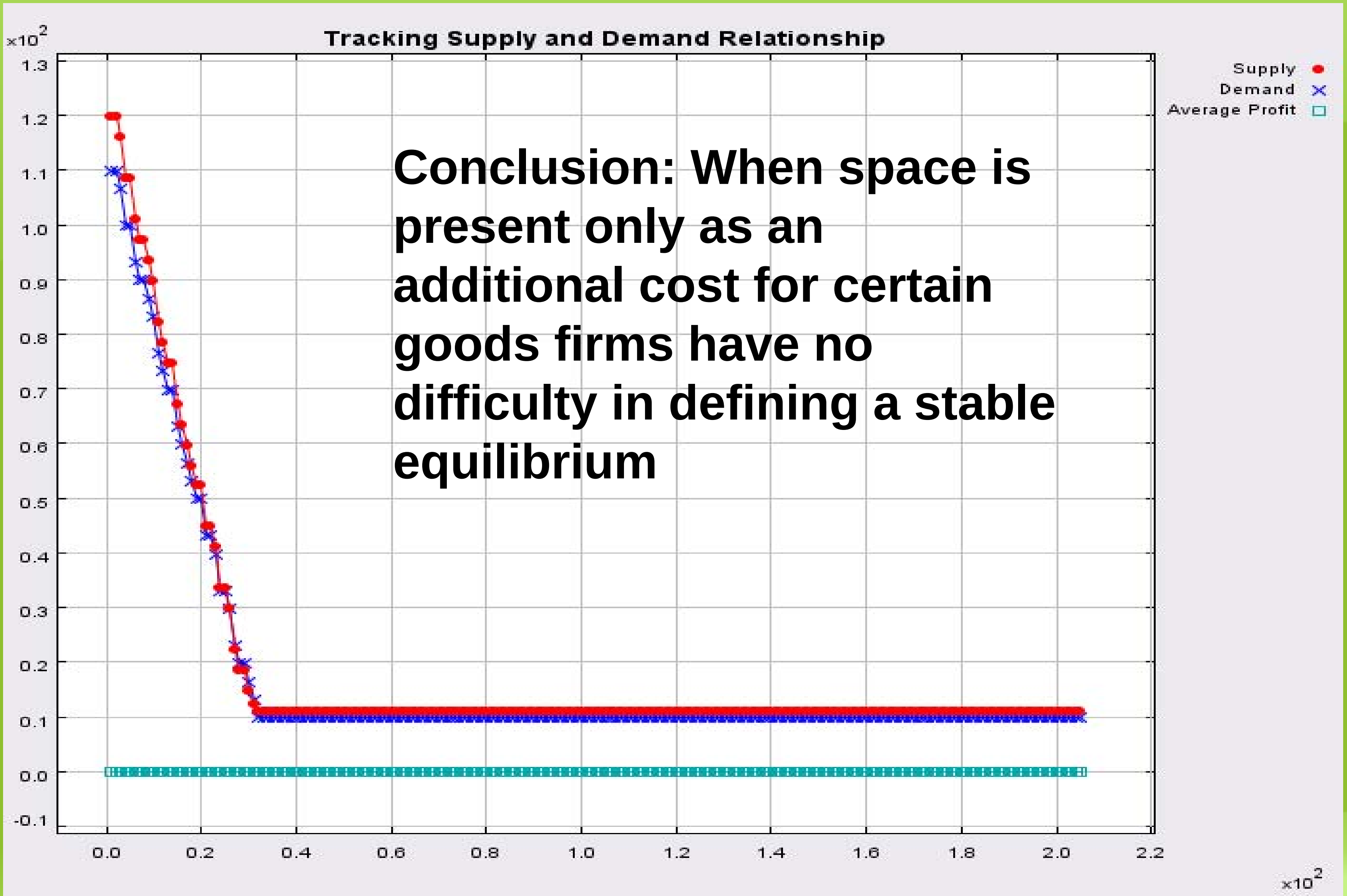
# Agent-based Reinterpretation

- Start from simple propositions (Box A), build towards replication of formal deductive model (Box C)

  Version 1.0 (Very Box A)

- No movement permitted (equilibrium relationship between workers and firms maintained).
- Space as distance

# Model Results



# Agent-based models: Further complications (on the way to Box C)

Version 2.0

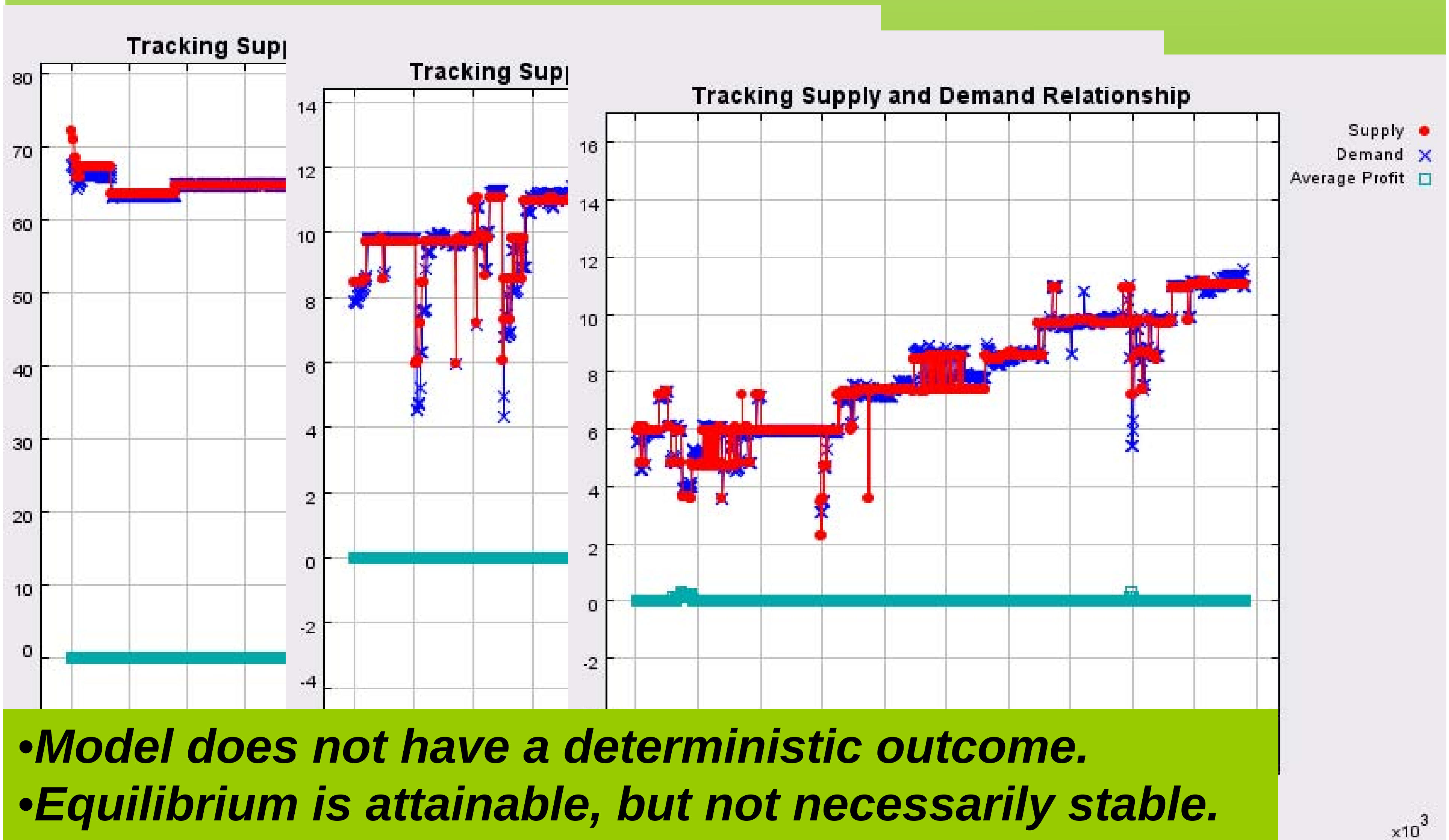
- Introduce the possibility of worker migration

Version 3.0

- Introduce the possibility of firm relocation

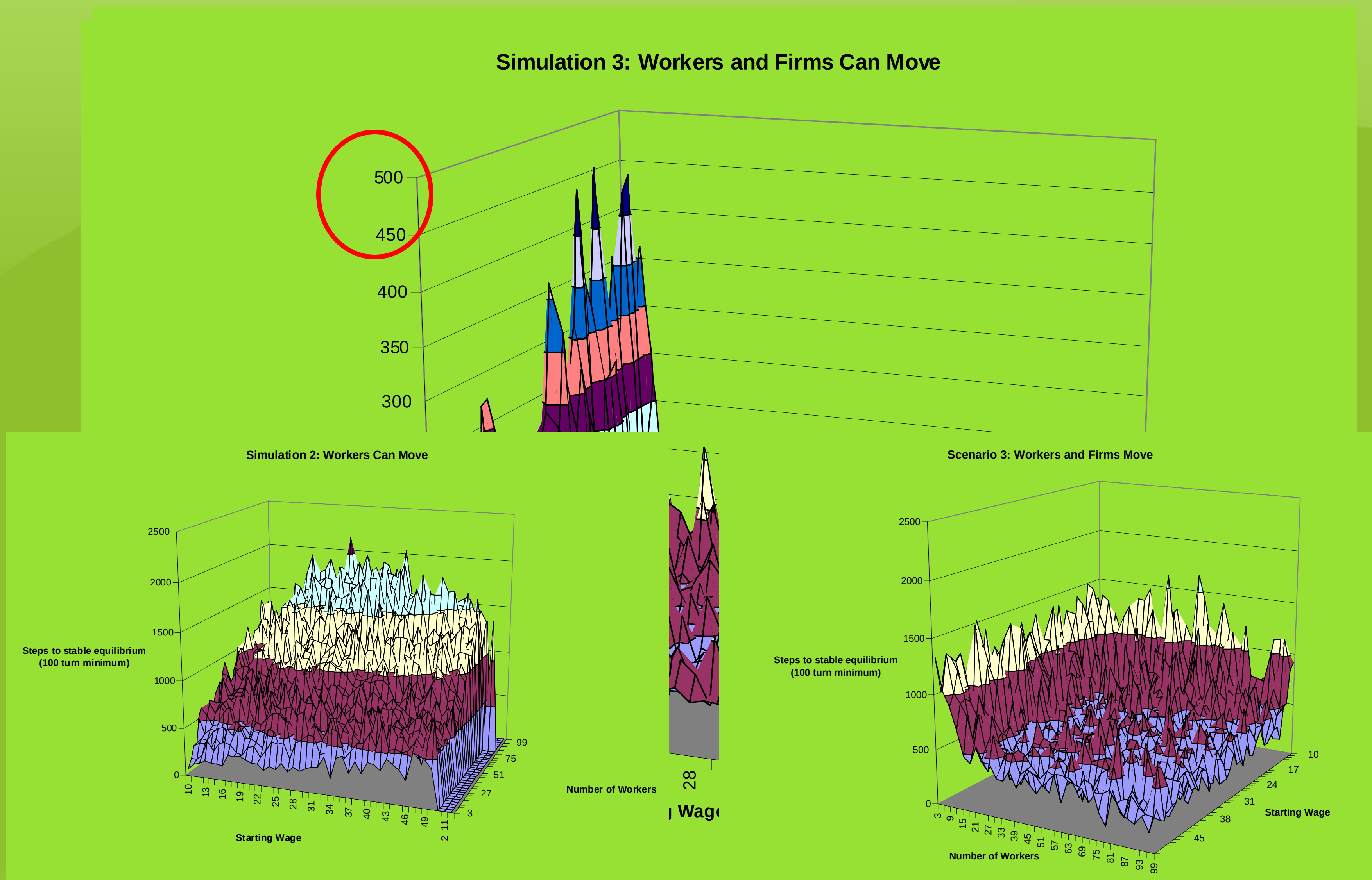
- Space is still represented very simply…
  - no cost for migration, no policies that would advantage or disadvantage one city over another
- …but focus is now on points of disequilibrium that act as drivers for the movement of people and capital

# Model Results




- *Model does not have a deterministic outcome.*
- *Equilibrium is attainable, but not necessarily stable.*
- *Disequilibrium is nearly always a possibility*

# Space and Equilibrium



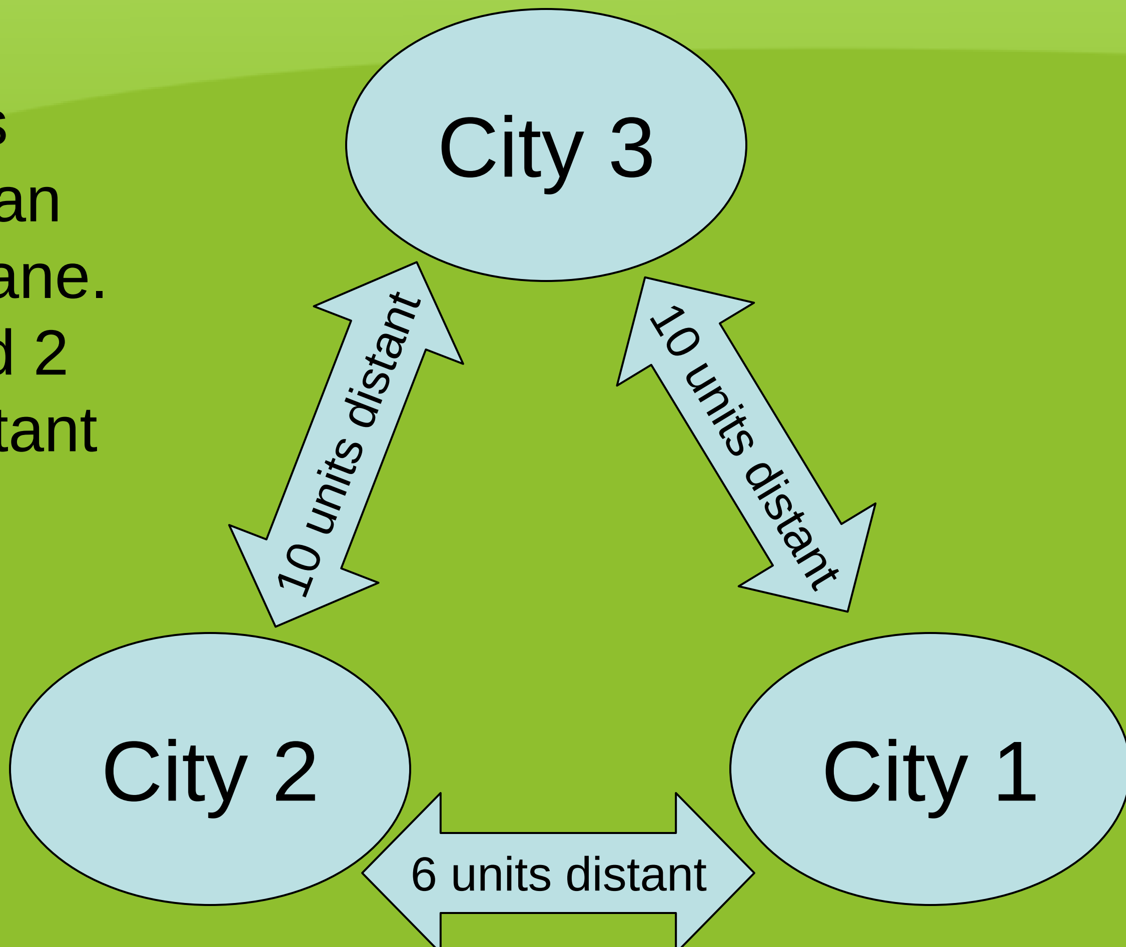
# Implications

- Spatial Complexity:
  - Increasingly complex spatial representations produce increasingly complex economic systems
- Scale:
  - As we begin to consider the impact of space, we become increasingly aware of the need for more complex spatial representations at different scales
- Policy:
  - Complex and multiscalar spatial representation can radically alter predictive model outcomes

# Questions?

# Model starting conditions

Three cities located on an isotropic plane. Cities 1 and 2 are equidistant from City 3



# The basic model of geographical economics

$$Y_r = \lambda_r W_r \gamma L + \phi_r (1-\gamma) L$$

$$W_r = \rho \beta^{-\rho} \left( \frac{\delta}{(\varepsilon - 1)\alpha} \right)^{1/\varepsilon} \left( \sum_{s=1}^{R} Y_s T_{rs}^{1-\varepsilon} I_s^{\varepsilon-1} \right)^{1/\varepsilon}$$

$$I_r = \left( \frac{\beta}{\rho} \right) \left( \frac{\gamma L}{\alpha \varepsilon} \right)^{1/(1-\varepsilon)} \left( \sum_{s=1}^{R} \lambda_s T_{rs}^{1-\varepsilon} W_s^{1-\varepsilon} \right)^{1/(1-\varepsilon}$$