Model Replication:

Adaptation on Rugged Landscapes

Daniel A. Levinthal (1997)

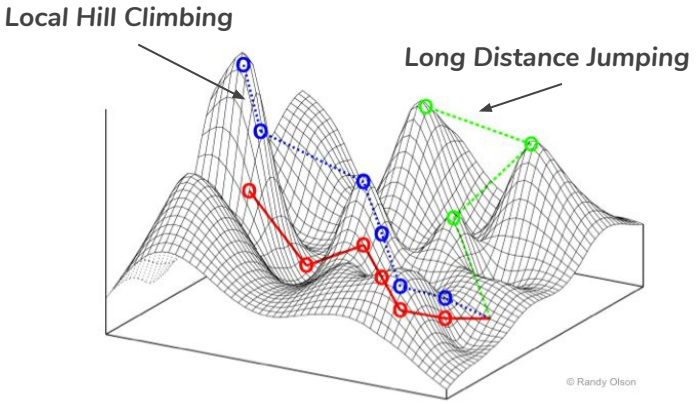
Replicated by

James Paine (Using R)

Jad Saddine (Using Python)

Adaption on Rugged Landscapes

- Tunable ‘fitness landscape’ with peaks and valleys
- Organization features:
  - Binomial (1/0) attributes along N-dimensions
    - Example with N = 4 : 0110
  - Attributes contribute to organizational fitness via K interactions with neighbors
  - Individual fitness contribution determined via uniform [0,1] along permutations of K
  - Total fitness is average of sum of individual components
- Organizations ‘learn’ and modify their attributes via:
  - Local (neighborhood) scanning and long distance (random) jumping
- Organizations can experience selection pressures
  - Fraction of organizations culled each period based on fitness
- Landscape can be noisy or can change



Example:

Org = 0110

K = 2

Part	Contribution
00	0.195
01	0.657
10	0.229
11	0.370

Fitness = (0.657 + 0.195 + 0.229 + 0.195) / 4
= 0.363

Model Replication - Local Adaptation

- Organizations look at local neighbors and change form if a better option is found
- “Neighbors” defined as *all possible* forms that differ by *exactly* one dimension, not just forms in existence
- No selection pressures, and only local searches

Figure 1 Emergence of Order (Local Adaptation)

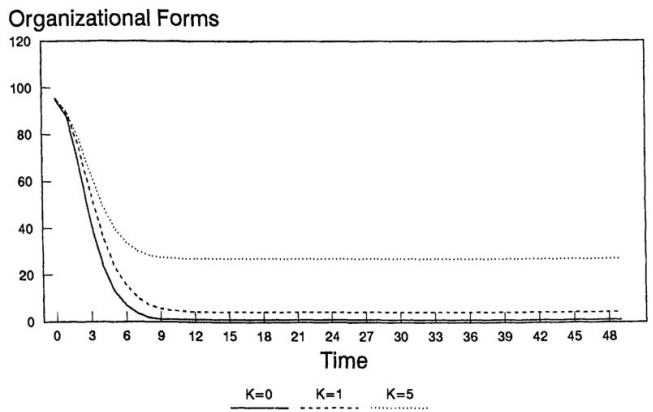
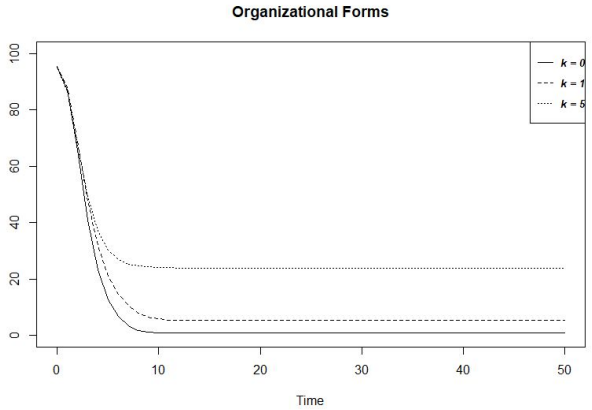
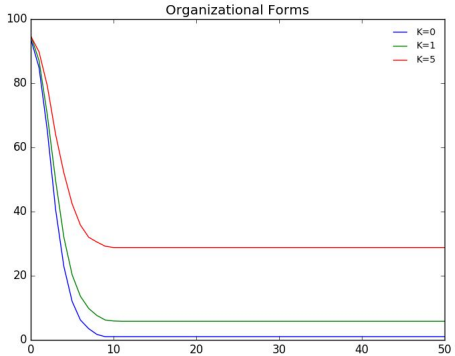


Figure 1 from Levintal



Reproduction in R



Reproduction in Python

Model Replication - Local Adaptation

- Levinthal occasionally swaps concepts of unique Organizational Forms and unique Fitness values
- Histogram below was for one particular instance of landscape
- Able to to get a wide variety of outputs by rerunning the simulation

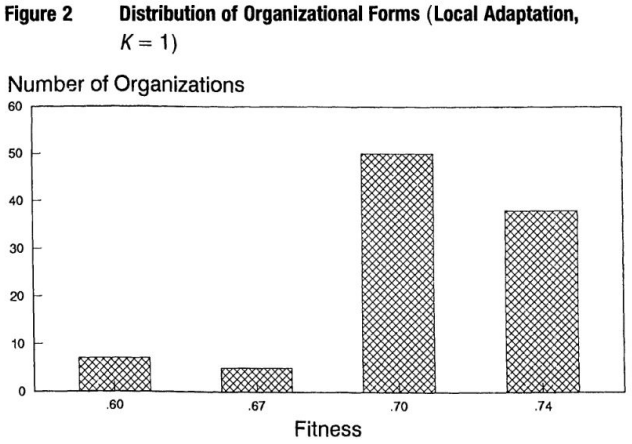
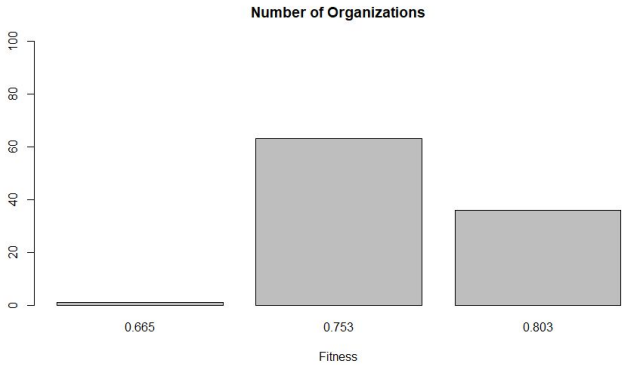


Figure 2 from Levintal



Reproduction

Model Replication - Radiation of Forms

- Start with 100 copies of exactly 1 firm type
- Both long-jump (random searching) and local adaptation is at work
- Initially, long-jump improvements cause explosion of firms. Afterwards, local adaption whittles firm count downwards
- See *Nuances* section for note about replication difficulties here

Figure 3 Radiation of Forms Under Adaptation

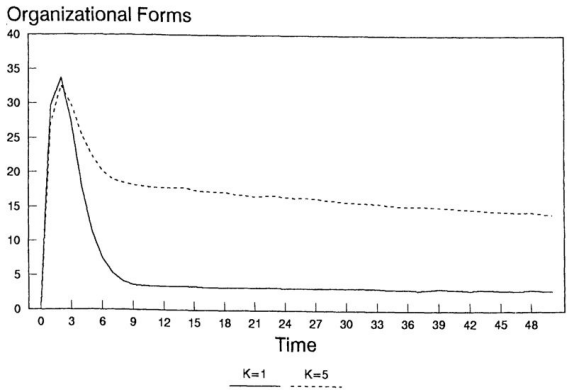
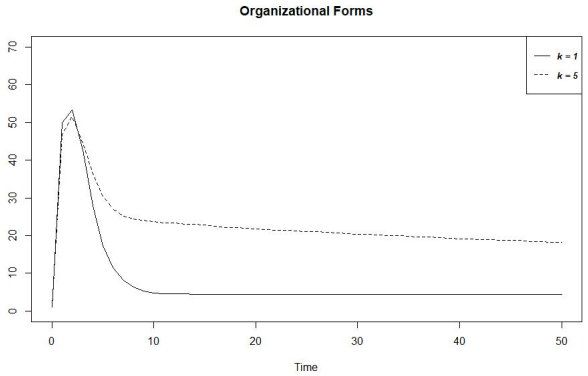
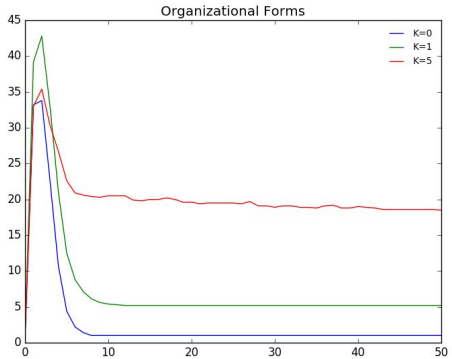


Figure 3 from Levintal



Reproduction in R



Reproduction in Python

Model Replication - Selection Pressure

- No learning/adaptation, just selection pressures
- See *Nuances* section for notes on the unclear nature of how selection process occurs
- Two methods employed:
  - James (R scripting) - Cull lowest fitness entities via random draw proportional to genetic load
  - Jad (Python) - Threshold to remove each time step

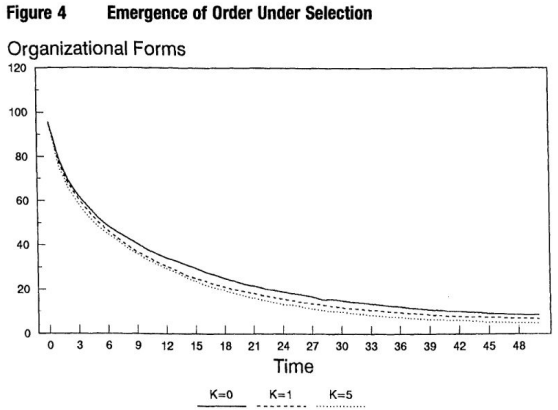
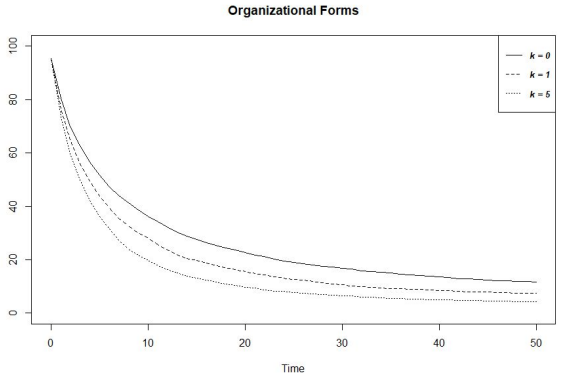
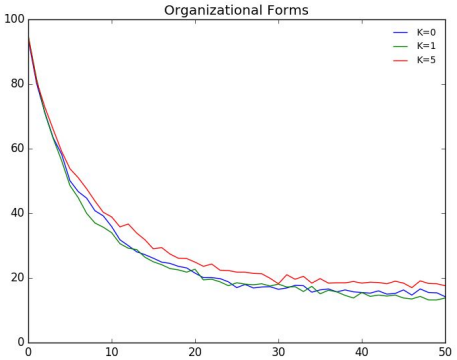


Figure 4 from Levintal



Reproduction in R



Reproduction in Python

Model Replication - Radiation of Forms

- Single dominate form, or group of forms at higher K, emerge over time
- Figure shown by Levinthal is for specific random instance

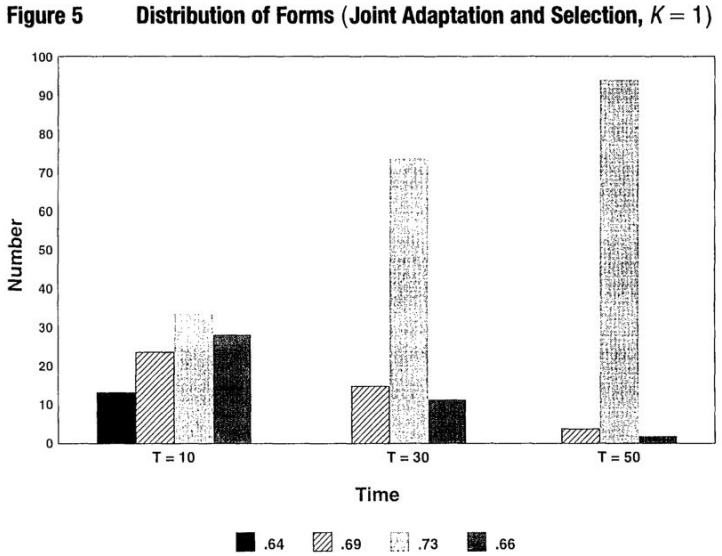
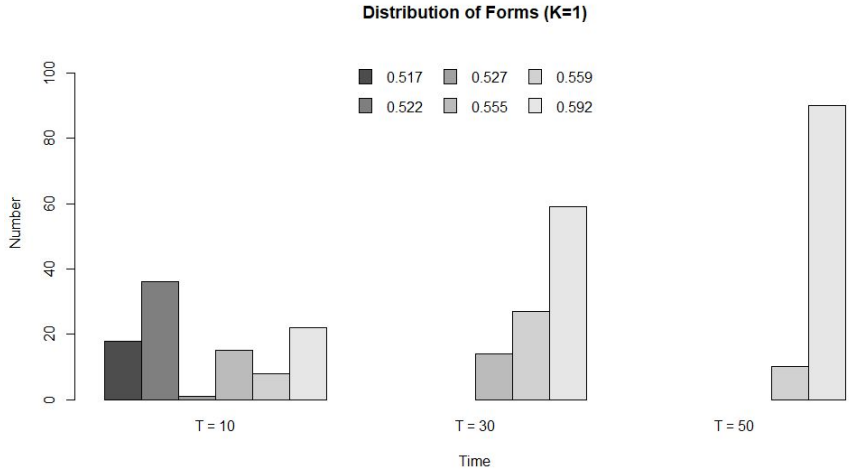


Figure 5 from Levintal



Reproduction in R

Model Replication - Survival Under Change

- Tracks survival of incumbents after a change in the landscape
  - Note: concept of ‘One-Dimension’ versus ‘Five-Dimension’ change does not match original description
- Can get *the same behavior* without changing the landscape!
  - The single change just exacerbates the trends seen when there is no reshuffle

Figure 6 **Survival in Changing Environments (Change in Fitness Contribution of One Dimension**

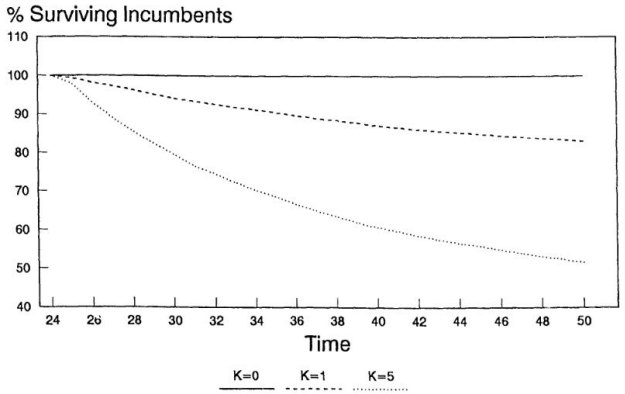
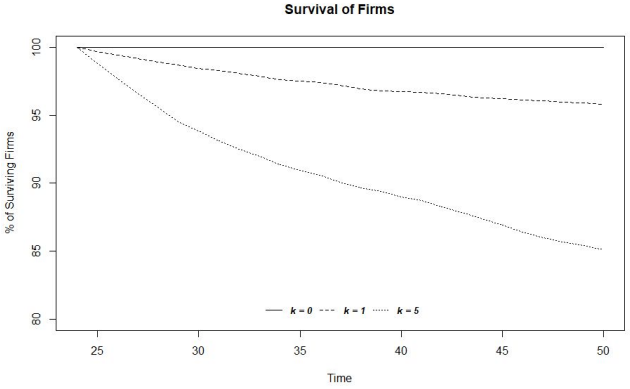
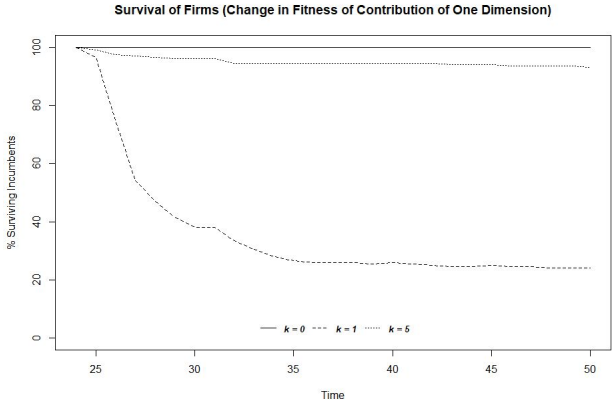


Figure 6 from Levintal



No Reshuffle
(Reproduction in R)



Reshuffle, 1 Replication, 1 ‘Dimension’
(Reproduction in R)

Model Replication - Robustness

- To illustrate robustness, Levinthal shows the degree of variability in the number of peaks versus K
- Footnote references use of TurboPascal and memory limitations
- Pre-calculating fitness landscapes in R allows for calculating up to K=N-1
- R shows more somewhat more variability in peak number

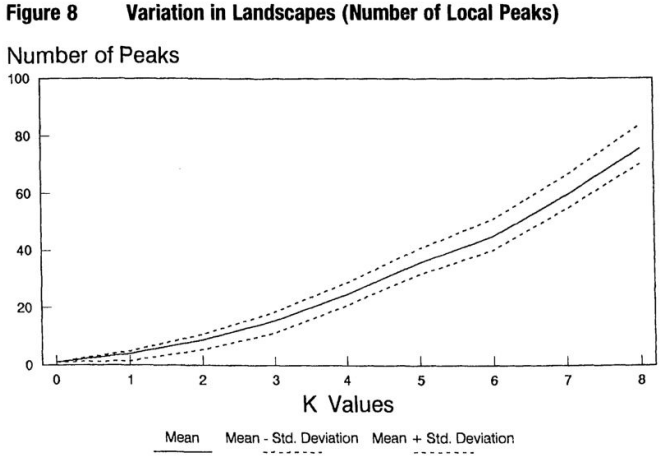
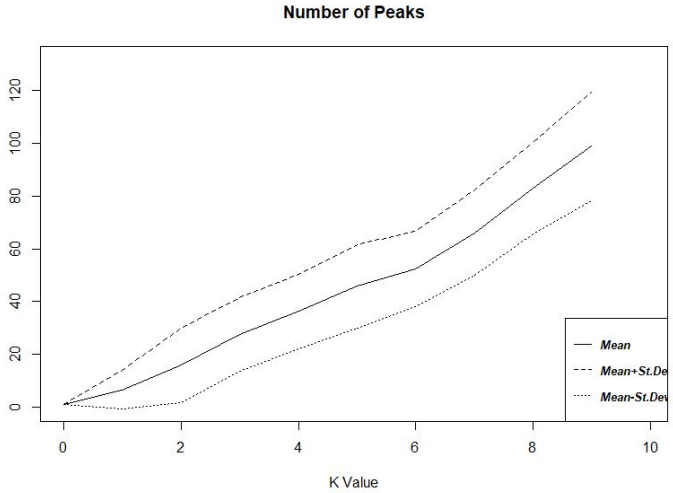


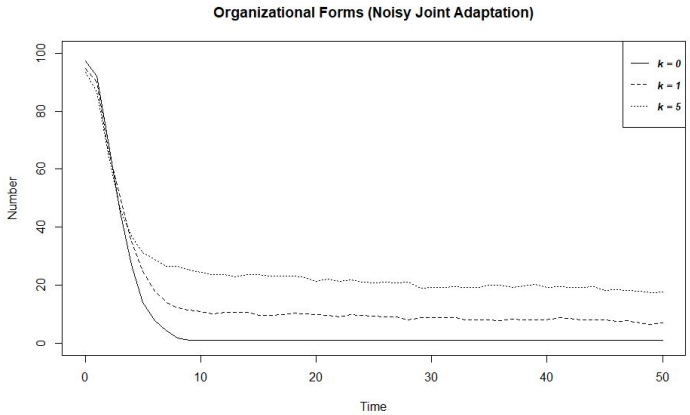
Figure 8 from Levintal

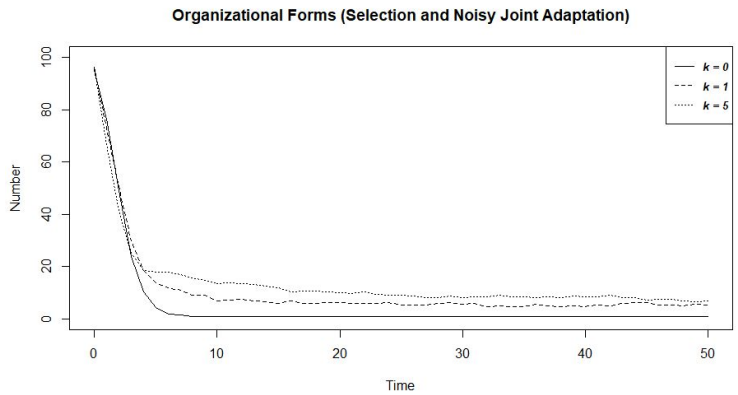


Reproduction in R (up to K = N-1)

Model Replication - Noisy Search

- Noisy perception of fitness values prior to realization
  - R implementation:
    - Noise is proportional to the distance between searching organization and candidate form
  - Python implementation
    - Noise inversely proportional to the number of organizations that already have a similar form

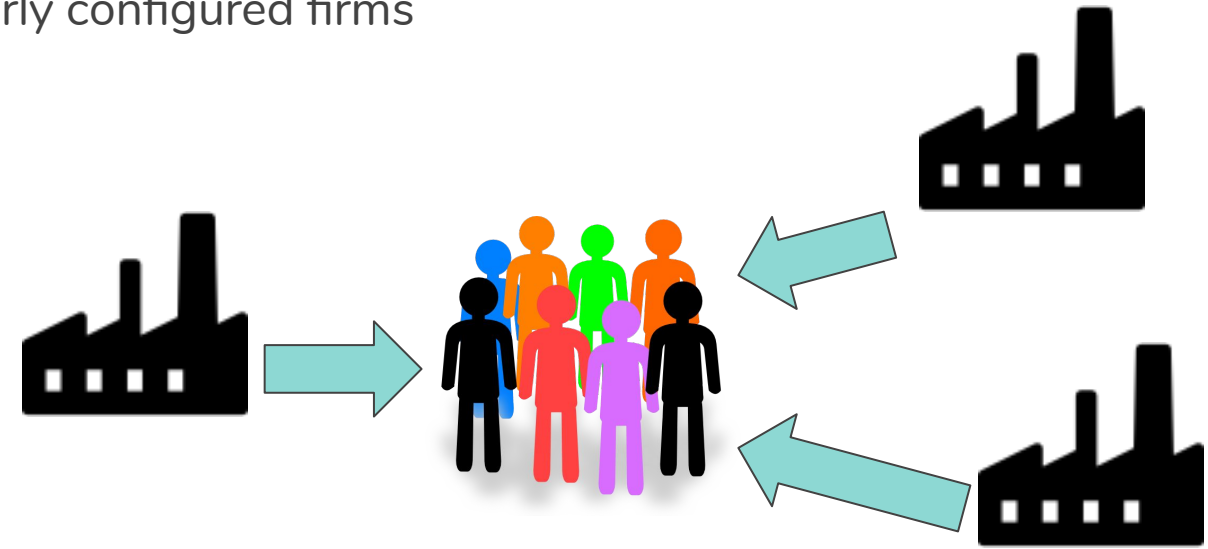


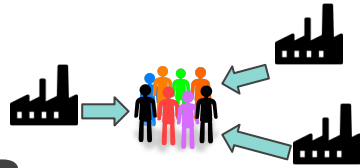


Reproduction in R

Model Extension - Resource Sharing

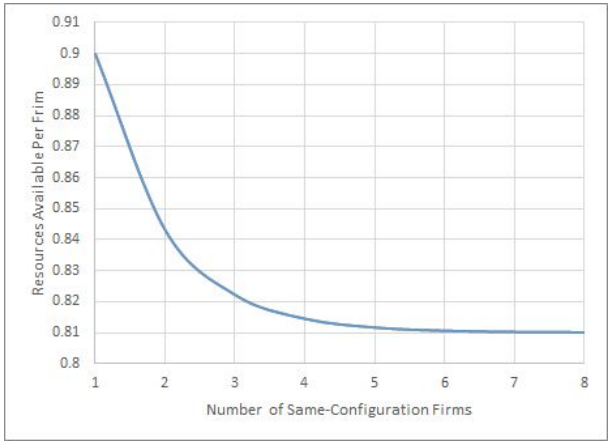
- Reconceptualize ‘Fitness Landscape’ as ‘Resource Availability Landscape’
- Firms of a specific configuration *must share* the resources available among all similarly configured firms



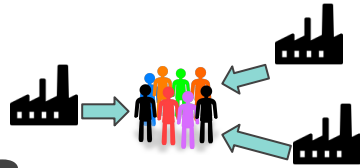


Model Extension - Resource Sharing

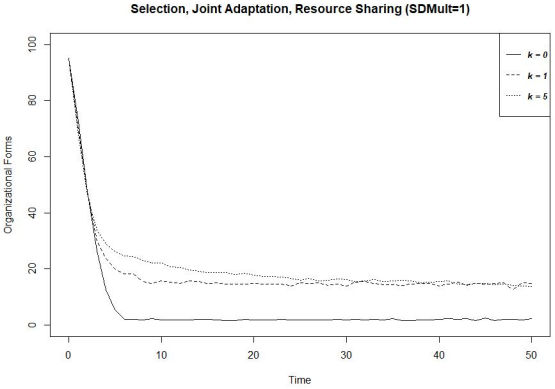
- Sharing:
  - Initial resources are the maximum realizable if there is only 1 firm of that type
  - Additional firms of the same type reduce the realized resources nonlinearly to a minimum (modeled as distances of multiples of the overall fitness standard deviation)
  - Modeled as non-linear reduction function
    - Idea is that resource might be purchases of a good or service
    - More firms means more consumption in total
    - But more firms also means less value extraction per firm
    - E.g. drop from going from 1 to 2 firms much larger than going from 14 to 15 firms
- Assumptions:
  - Modeled with and without noisy perception of resource values
  - Assume that firms can see how many other firms are already there, and will discount resources accordingly
  - Firms still subject to selection pressure each time period
- Question: How does this affect dynamics?
  - First mover advantages
  - Peaks become less attractive with more entrants

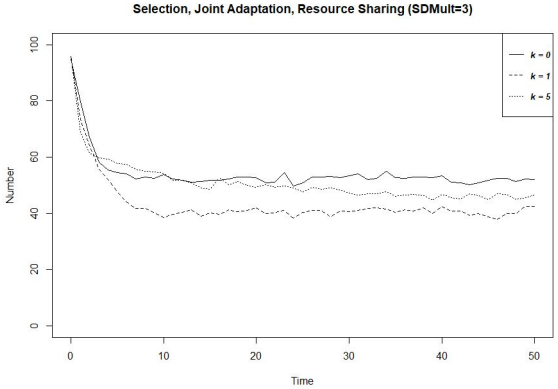


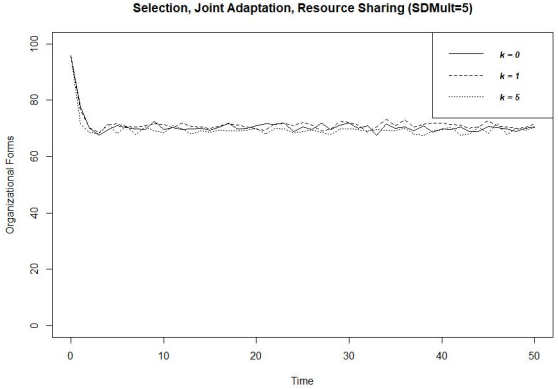
Example of Reducing Resources for High-Resource Configuration

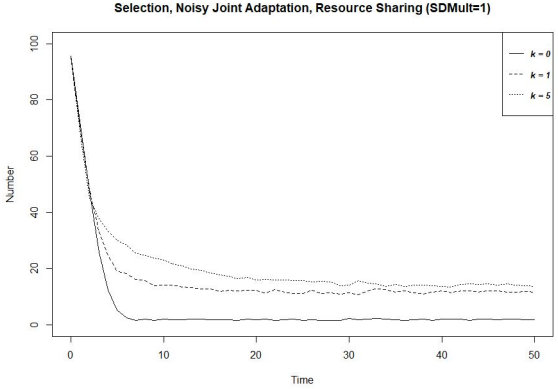


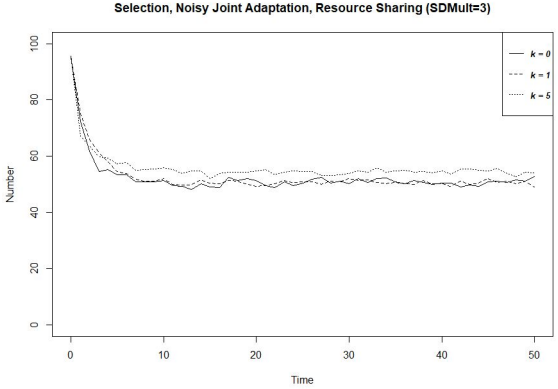
Model Extension - Resource Sharing

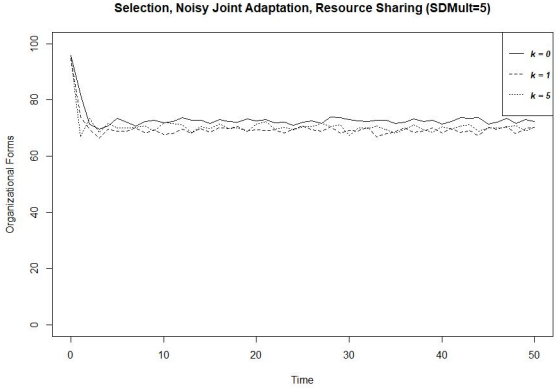






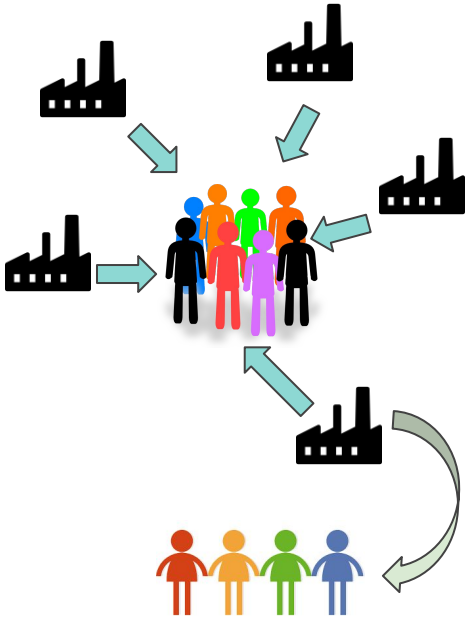






Model Extension - Resource Sharing

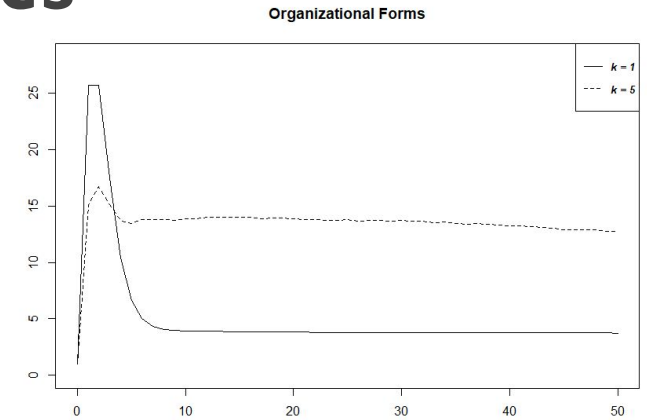
- When sharing:
  - Noise matters less at higher K-values and higher costs of sharing
  - K-values become less important as the cost of sharing increases
  - Final organizational form count continue to oscillate around a mean value (especially at higher cost of sharing and K values)
- Observations:
  - Value of high local peaks begins to diminish as organizations flood the area
  - Long distance searches become more likely to find under-filled configurations areas
  - Local searches spread organization around peaks in similar, but still different, configurations
- Applications
  - Product type/diffusion
  - Physical resource consumption (might have to switch to more linear cost function)
  - Dynamics of Niche exploitation / firm movement



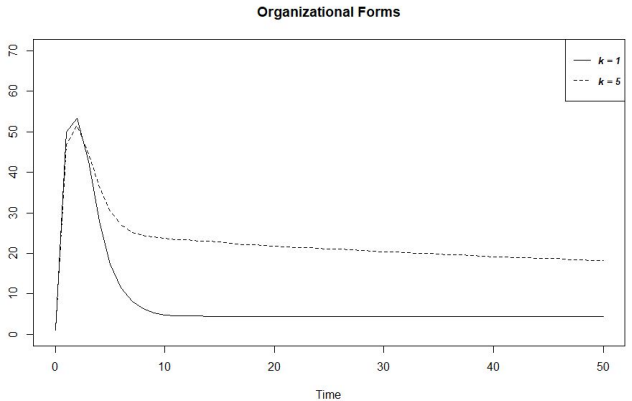
Model Replication Nuances

- Selection Process is not totally clear
  - How exactly are organizations culled each period?
    - James: Random number proportional to Genetic Load
    - Jad: Threshold
- Exact full algorithm, as written, has departure from presented results
  - From page 939: “organizations that survive engage in both local and distant (i.e., long-jump) search efforts.”
    - Behavior not replicated in R
    - To replicate in R, organizations engage in distant search and then, if and only if distant search failed, engage in local search

As described: Both Searches



As executed: Single/Sequential Search



Thank You!

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R code available at:
https://github.mit.edu/jpaine/Model-Replications