Simulating Game Theoretic Micro Trade Networks as the Dynamics of Entrepreneurial Organization Formations

The Need for Entrepreneurial Network Analysis

- Brian Uzzi (1997):“how markets function and competitive dynamics unfold when organizations compete on the basis of their ability to access and reconfigure an external pool of resources and partners rather than firm-based competencies.”
- Entrepreneur is viewed as a strategic rational being who tries to maximize benefits by forming a new partnership and terminating a current partnership when she is better-off without that particular venture (Carland, Hoy, Boulton, and Carland 1984; Schumpeter 1934; Vesper 1980).

The Need for Entrepreneurial Network Analysis

- Tie-formation processes of such organizations picture the interactive dynamics of an entrepreneurial network market where new ventures and organizations can be formed and old ones terminated.
- A stochastic approach, that models entrepreneurs as optimizing agents against nature, does not serve as the appropriate model for entrepreneurial network due to the interactive nature of the market.
- To mimic such processes, the analytical model needs to capture the existence of tensions between cooperation and competition among informal and community-based entrepreneurial partnerships that commonly exist in historical and contemporary societies (Fang, Xia, Sang, and Zhang 1989; Spooner 2007).

Bridging Two Approaches

1. The results shown by these analytical models are often deemed sterile due to unrealistic assumptions. Hence, their results are often limited to describing the existence of certain isolated equilibria that do not explain the reality, especially in terms of the frequency of occurrence, making them deemed unsuitable to explain real world phenomena.
2. Empirical research literatures in entrepreneurial networks often also struggle to find the theoretical frameworks that explain and summarize their findings (Chen and Chang 2004; Das and Teng 2000; Kogut 1988; Park and Ungson 2001; Pfeffer and Nowak 1976). These empirical literatures are capable of summarizing the statistical properties, but failing to answer the “why” and “how,” which are the questions about processes.

Why Use Simulation?

Davis, Eisenhardt, and Bingham (2007) states that, in organizational contexts, simulation can provide:

1. Superior insight into complex theoretical relationships among constructs, especially when challenging empirical data limitations exist (Zott 2003),
2. An analytically precise means of specifying the assumptions and theoretical logic that lie at the heart of verbal theories (Carroll and Harrison 1998; Kreps 1990), and
3. Reveal the outcomes of the interactions among multiple underlying organizational and strategic processes, especially as they unfold over time (Repenning 2002).

The Model of Organizations in Entrepreneurial Network

- The model has a function at the individual level to depict strategic behaviors of an entrepreneur benefiting from the number of direct partnerships with other entrepreneurs while suffering from penalty from the total number of partnerships each of her partners has (indirect connections).
- For an entrepreneurial partnership, the benefit of the increment of the number of direct partnerships is seen as an agglomeration of commitment for resources, where more partners bring more capital and human resources to the table.

The Model of Organizations in Entrepreneurial Network

- The penalty from indirect connections counts the distractions one partner has from her other entrepreneurial ventures, given that she also assigns her resources to those other ventures. If a partner has partners who have different ventures, she suffers from the division of resources of her partners accordingly. Those characteristics could have properties that change as results of learning processes and adaptability of aggregated individuals, which is at organizational level.

The Model

- Reward direct links while penalizing indirect links under a condition that requires a sharing of limited resources
- Individuals are modeled as nodes.
- A link is a collaboration between 2 individuals.
- Resource is modeled as commitment, the inverse of links.

$$u_i(g) = \sum_{j:\, ij \in g} w_i(n_i, j, n_j) - c(n_i),$$

$$u_i(g) = \sum_{j:\, ij \in g} \left[\frac{1}{n_i} + \frac{1}{n_j} + \frac{1}{n_i n_j} \right]$$

$$= 1 + \left(1 + \frac{1}{n_i}\right) \sum_{j:\, ij \in g} \frac{1}{n_j}, \quad n_i > 0$$

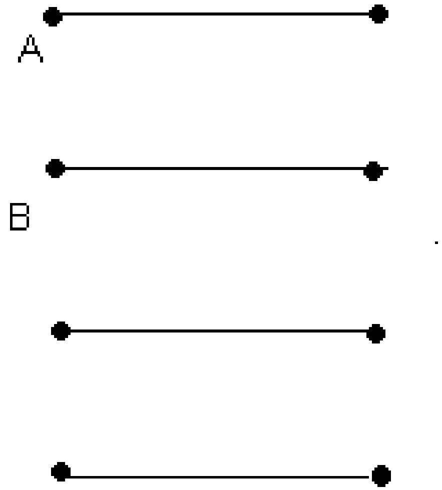
$$u_i(g) = 0. \qquad n_i = 0.$$

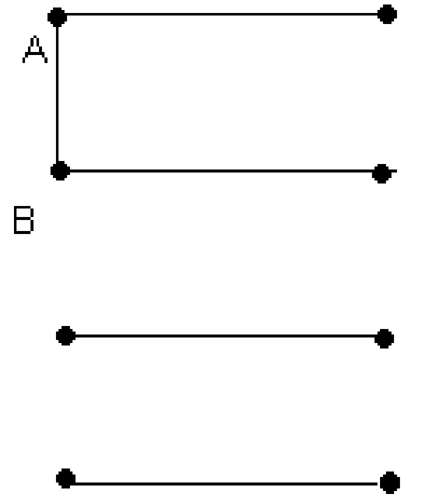
Pairwise Stability

- The following are the conditions for a *pairwise stable* network (Jackson-Wolinsky):

1. *No individual in a Pairwise Stable network is willing to detach from any of her existing links.*
2. *A new link between 2 individuals that are not in the same component can be formed if one individual strictly prefers the new link while the other individual is indifferent.*

Examples: PS





U(A) = U(B) =
1+(1+1/1)(1) = 3
U(net) = 8(3) = 24

U(A) = U(B) =
1+(1+1/2)(1/1+1/2)
= 3.25
U(net) =
2[1+(1+1/2)(1/1+1/2)]+
2[1+(1+1/1)(1/2)]+4(3)
= 22.5

Imperfect Monitoring

- What if an individual (node) is able only to observed within her component? (x-link observation)
- Monitors only other individuals that are directly or indirectly connected.

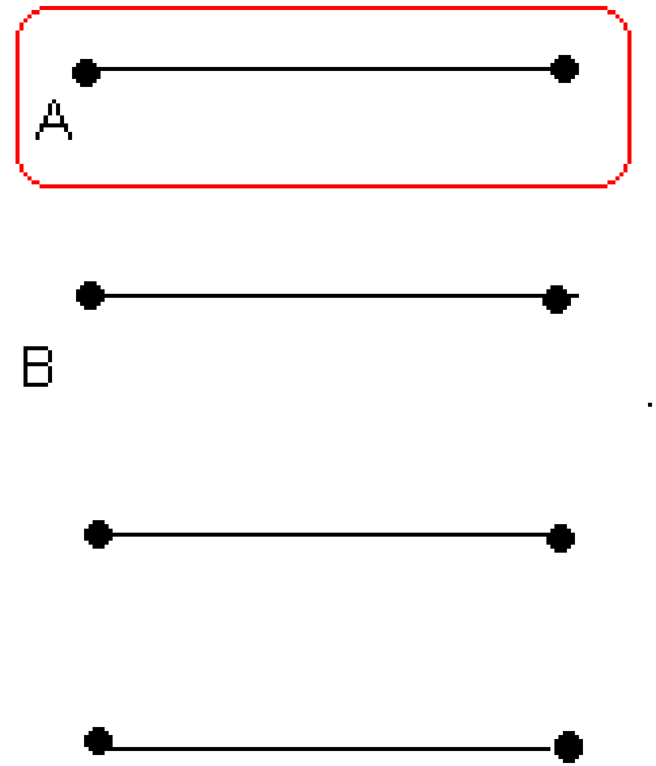
Conjectural Pairwise Stability (CPS)

- The following are the conditions for a *conjectural pairwise stable* network (McBride):

1. no individual in a Pairwise Stable network is willing to detach from any of her existing links.
2. (a new link between 2 individuals that are not in the same component can be formed if one individual strictly prefers the new link while the other individual is indifferent.
3. the belief system will sustain as long as each individual's belief system is not contradictory to her observation.

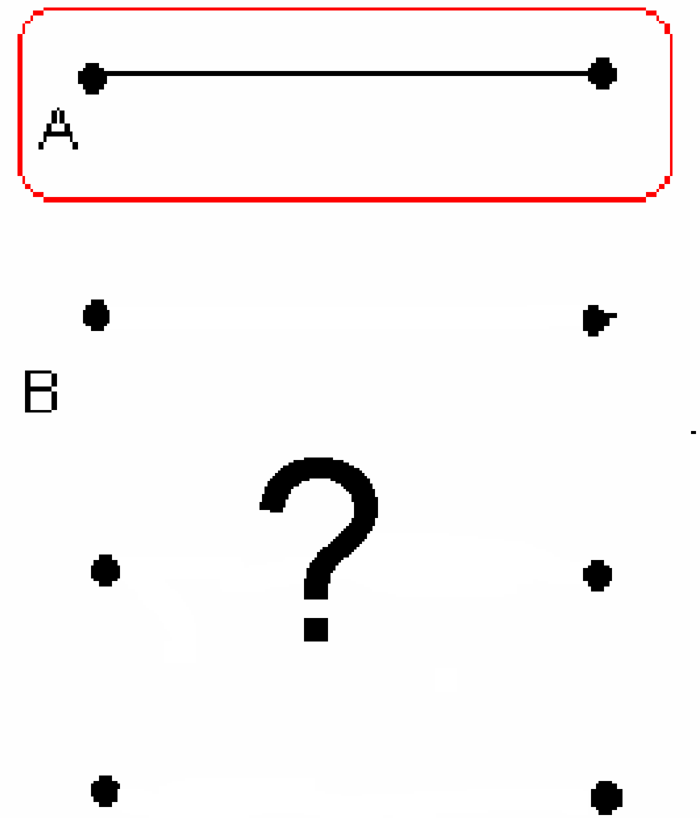
Example: CPS

- Remember that A only monitors within her network.

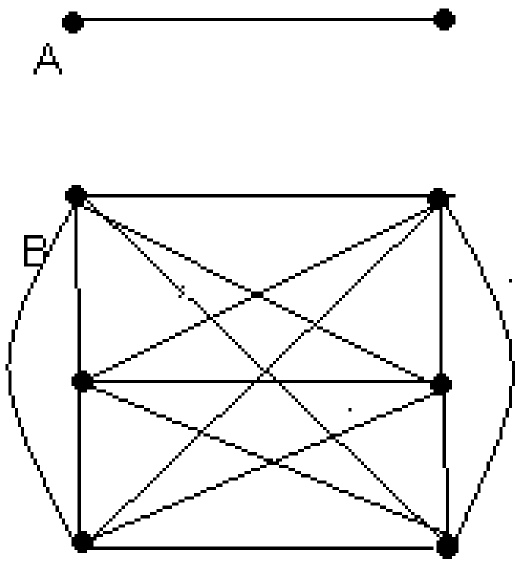


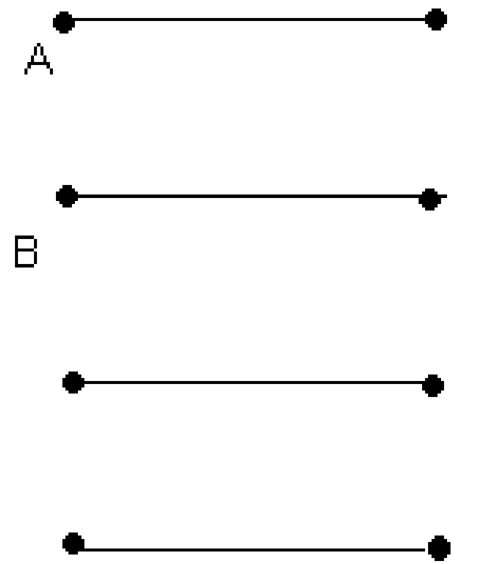
Back to the Example

- Known that $2 < \sqrt{(8-2)}$
- Each i believes that she is not in the largest component (m).
- Each i will not want to connect.
- Each i will not want to disconnect.
- Hence, it is a CPS.

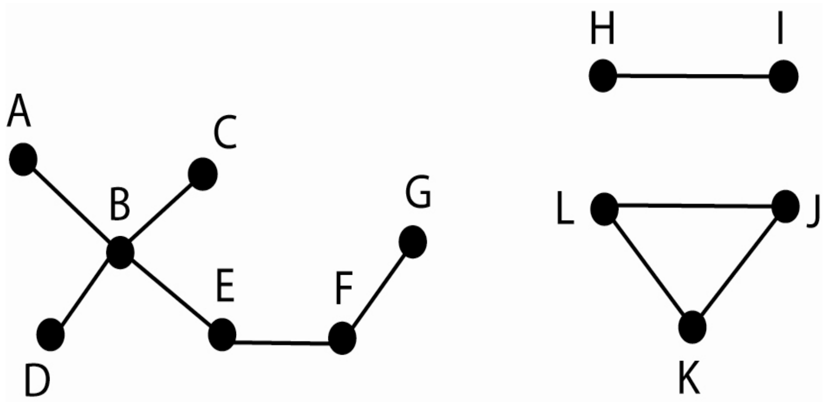


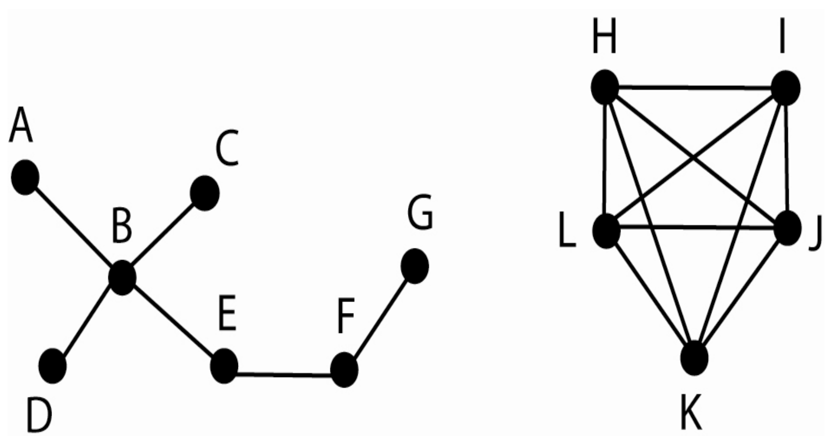
Beliefs & Possible Configurations





Beliefs & Possible Configurations





Different Processes in Network Formation and Equilibrium?

- Two parameters:

1. *The number of individuals in the network, (N).*
2. *The probability of the links in the network in its initial state, under limited observation that allows a change in the individuals' beliefs, P(i).*

Simulation Model

- A random number generator assigns links according to probability *P(i)*={0.0, 1.0} at state S_0.
- Probability *P(i)*=0.0 is when no individuals are connected, whereas *P(i)*=1.0 is when network consists only of one clique at S_0.
- The utility function of each individual follows accordingly.

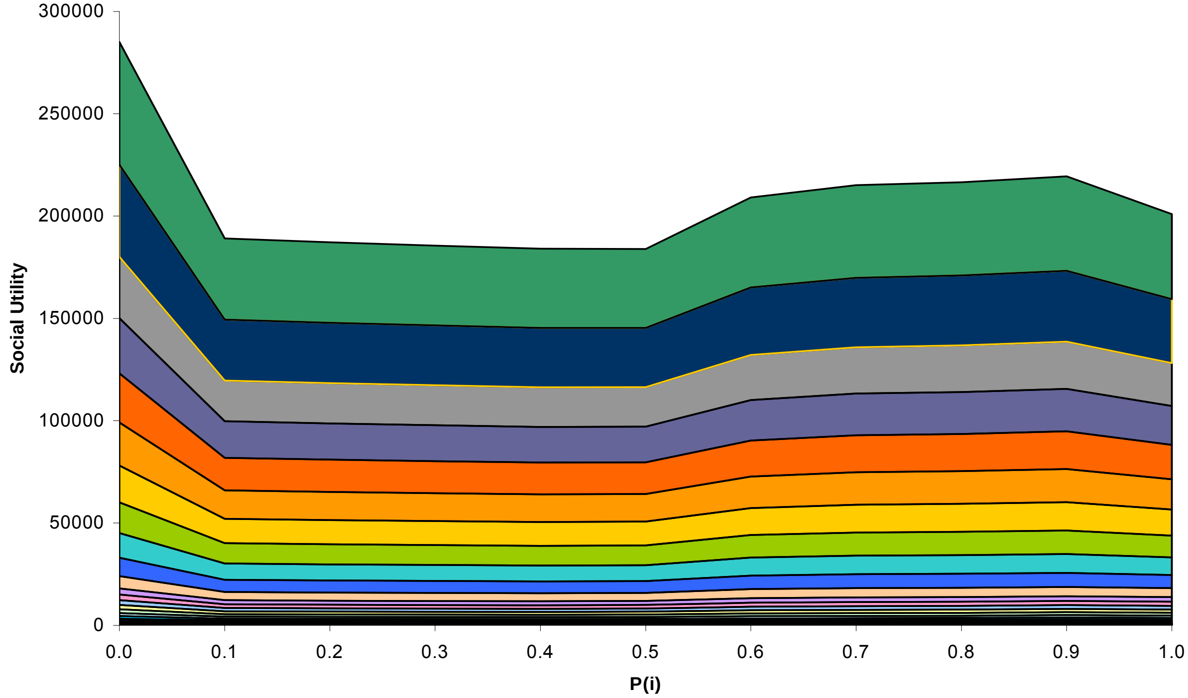
Deviation

- Each individual considers a deviation when to get a better utility when:

1. Disconnection an existing link increases utility.
2. When adding a new link increases utility.
3. Stop considering to add a new link when the sum of one's link is more than N/2.

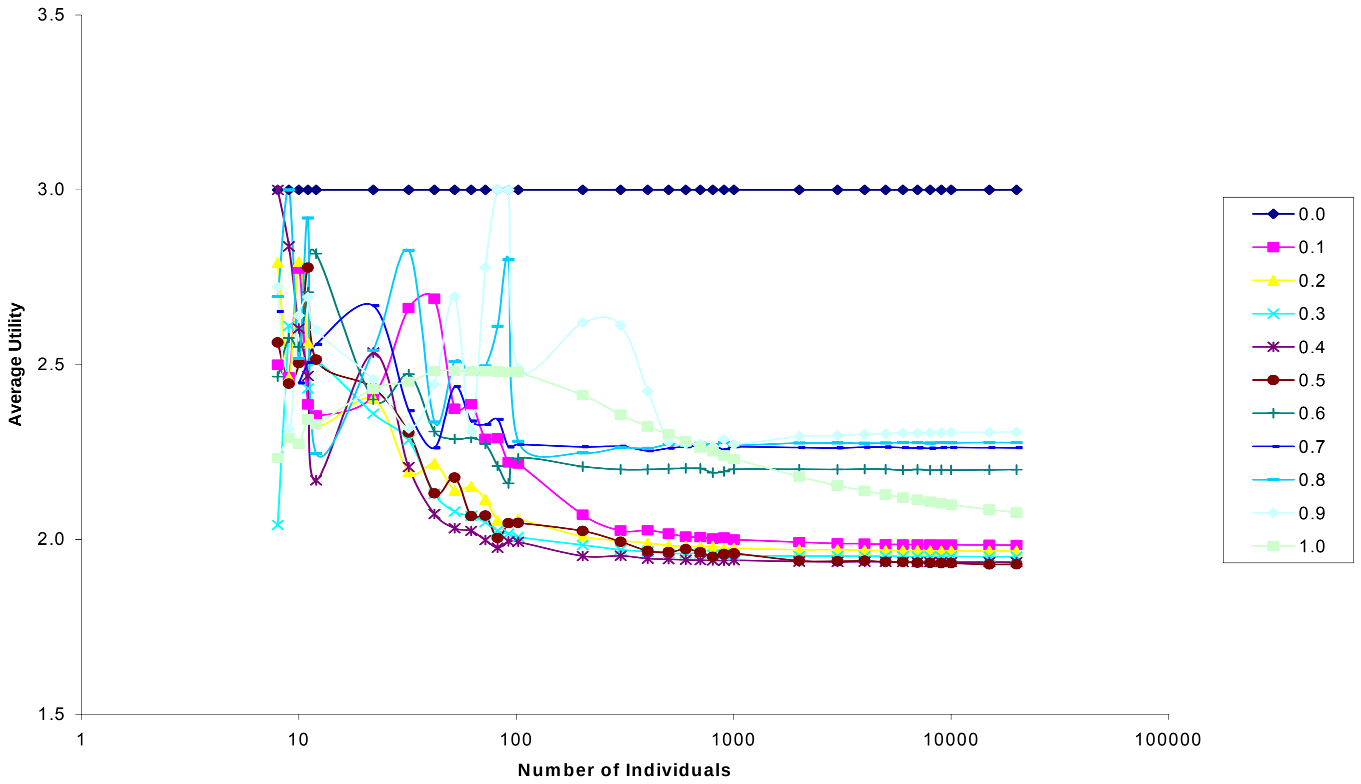
Note that there is no mutual consent required. The process is sequential: an unwanted link initiative can be sequentially disconnected.

Simulation Results



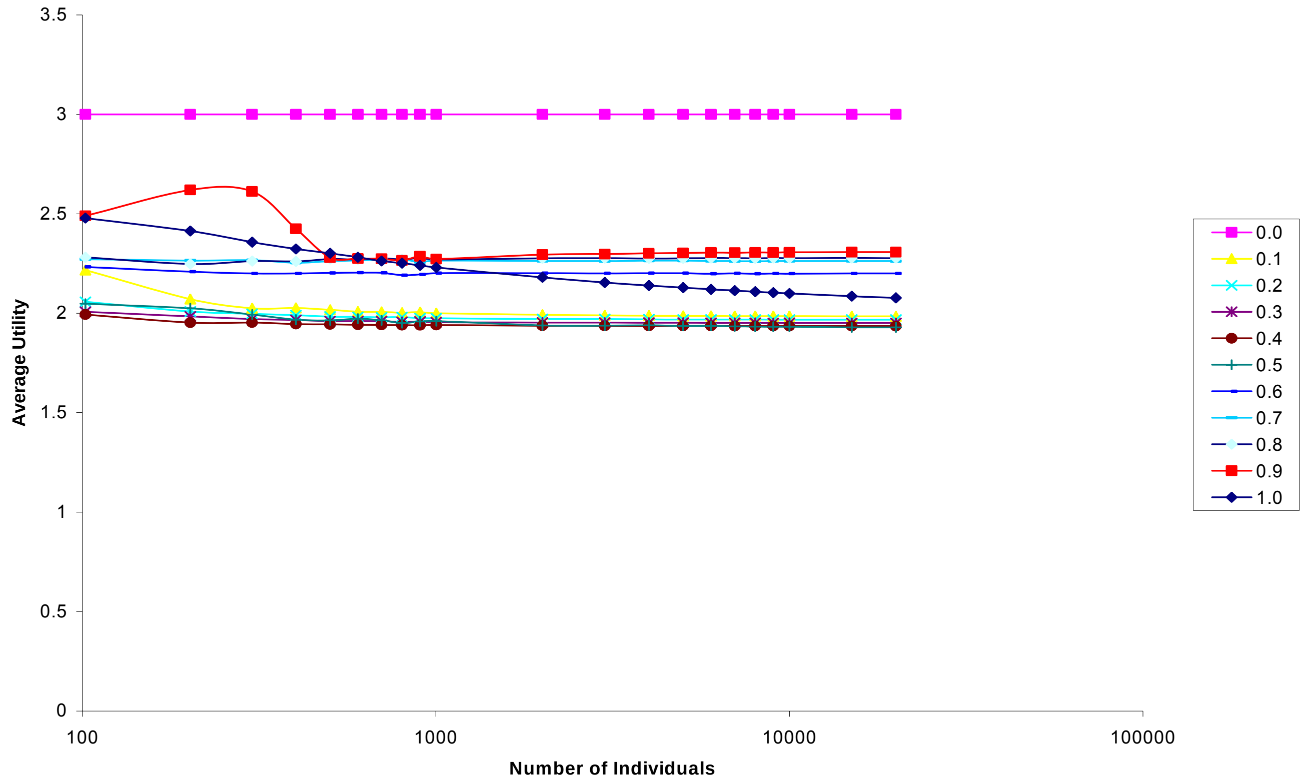
- Highest Social Utility when P(i)=0.
- 0.5<=P(i)<=1 is higher than 0.1<=P(i)<0.5

Simulation Results



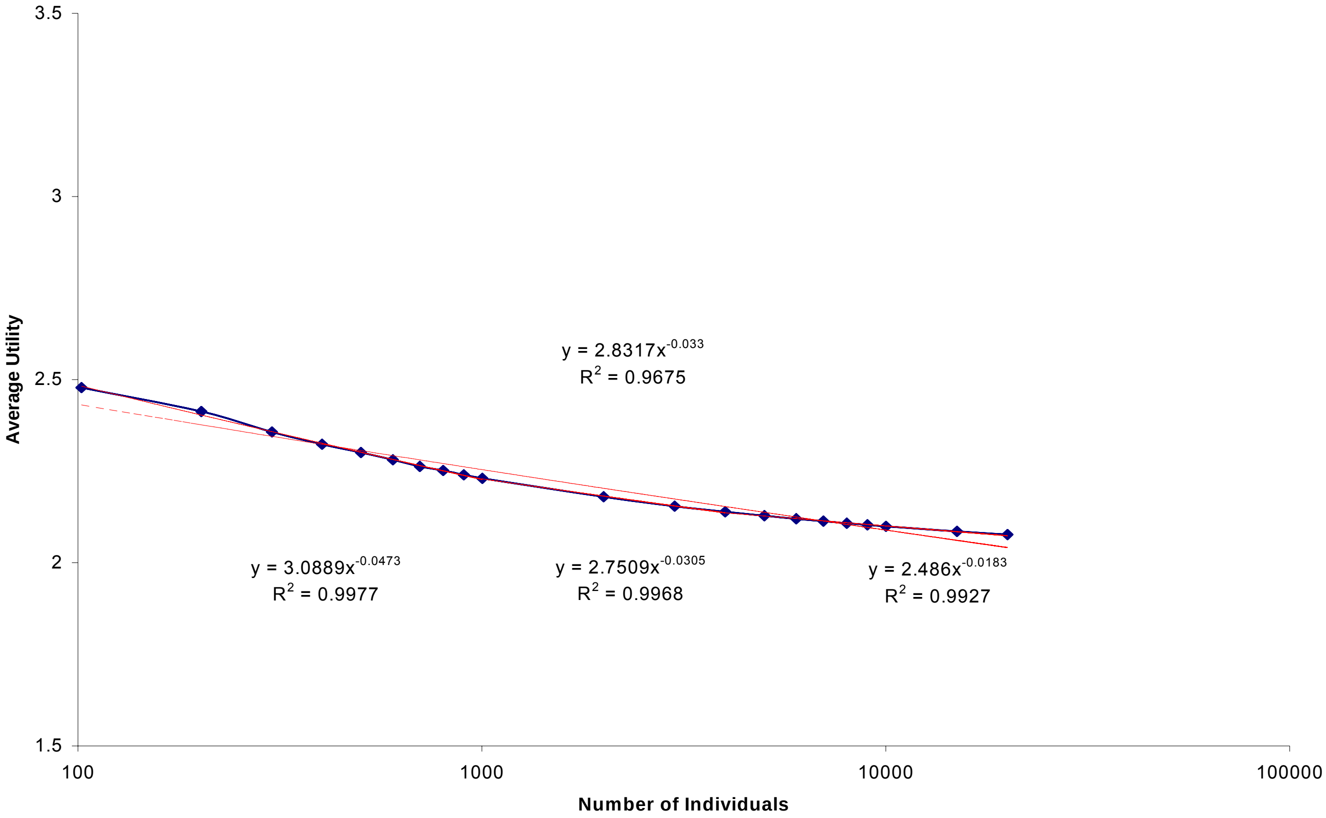
- Average Individual Utility stabilizes when N>500, except when P(i)=1.

Simulation Results



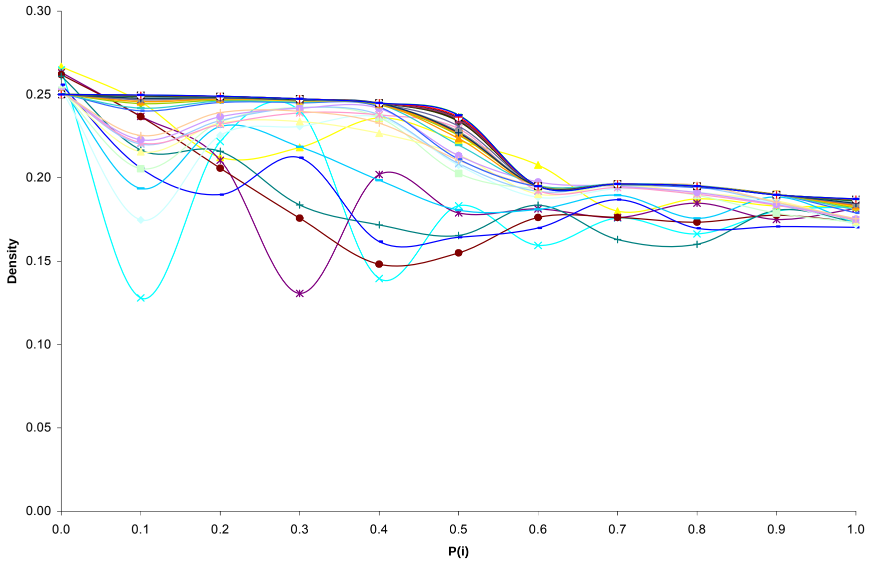
- Average Individual Utility stabilizes when N>500, except when P(i)=1.

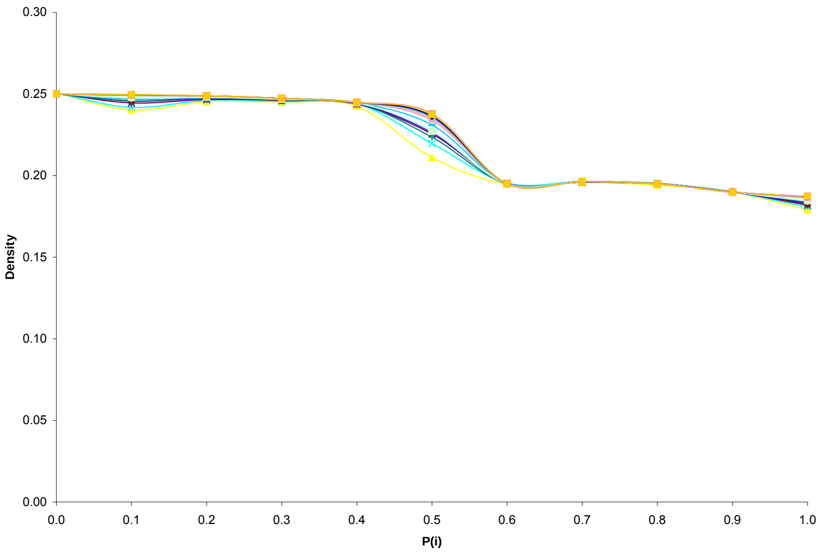
Simulation Results

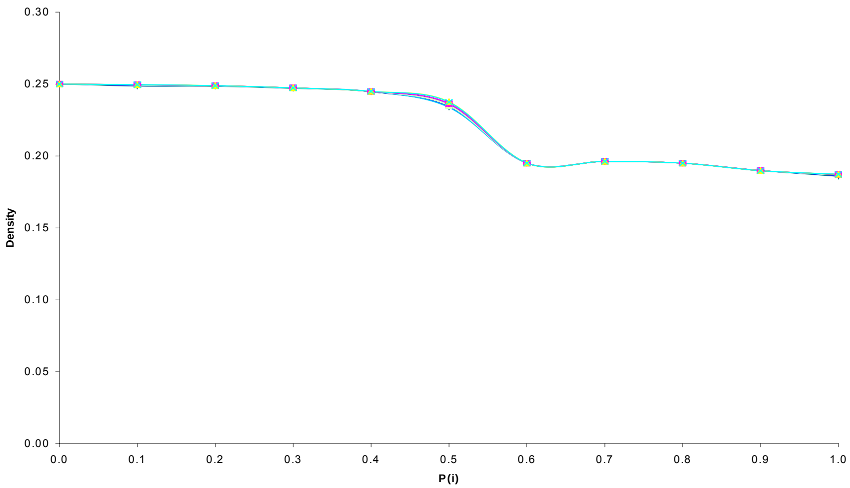


- The decrease of *Ya* for *P(i)*=1.0 fits a power-law at N>100.
- The 3-section power-law fitting has elbows at *N*=1000 and *N*=4000.

Simulation Results

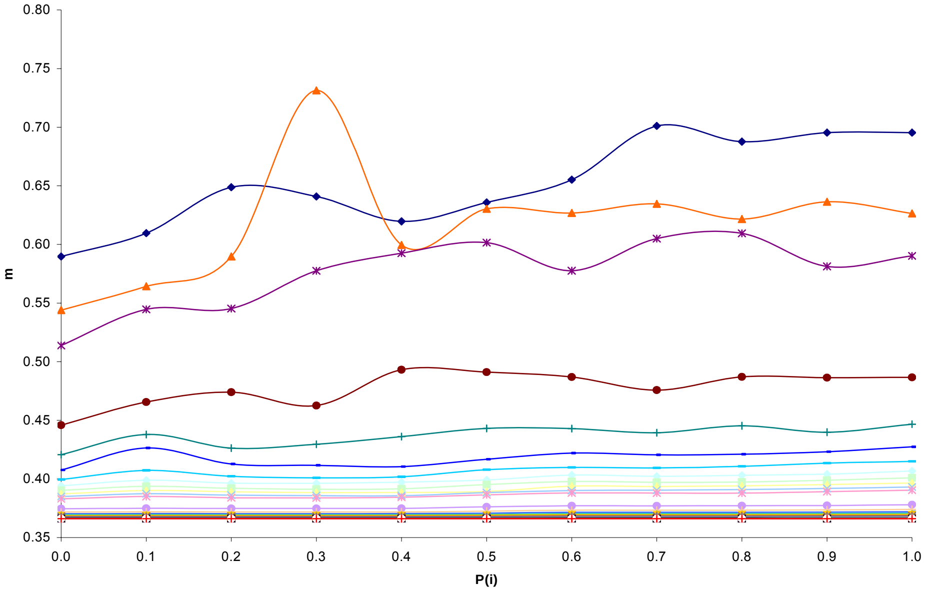


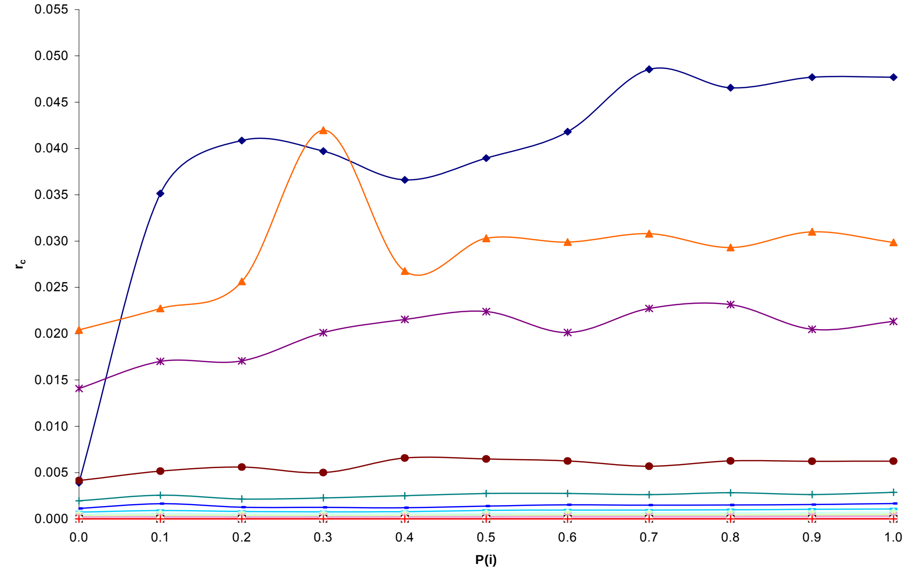




- Density across *P(i)* converge to lesser deviations at N>200, especially when N>2000.

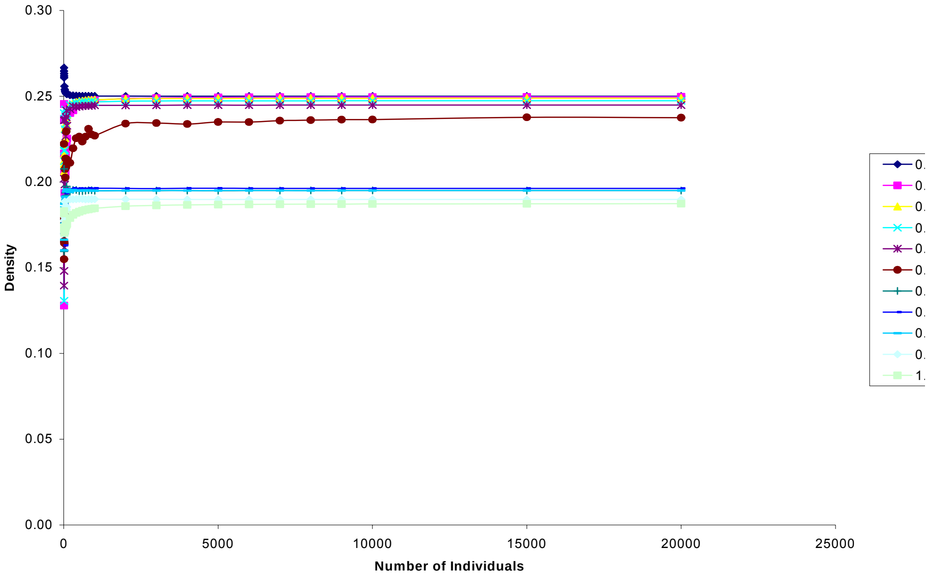
Simulation Results

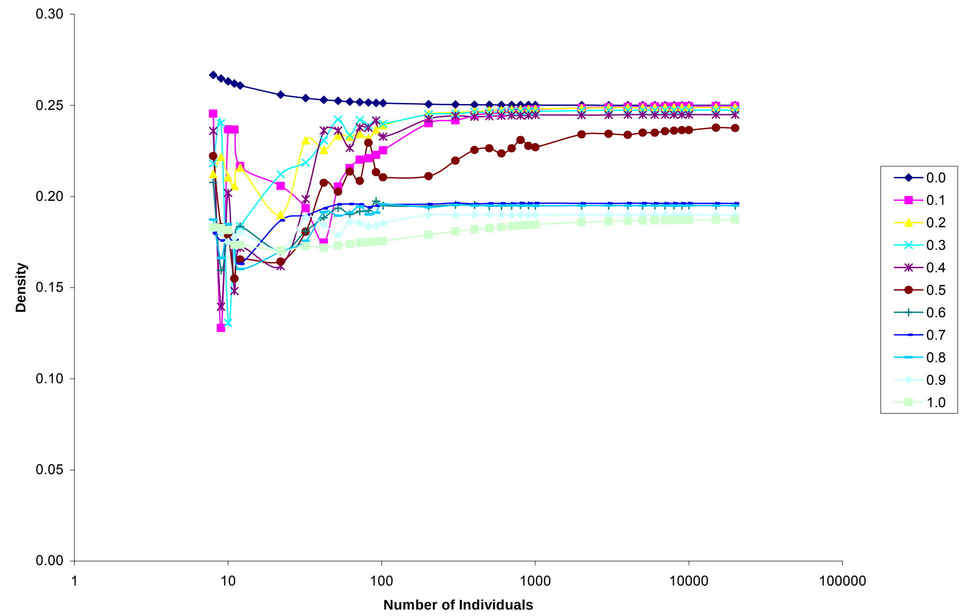




- *Tipping-point* of information diffusion (r) [Newman]: $r > \frac{\Sigma L_{ij}/N}{\Sigma L_{ij}^2/N - \Sigma L_{ij}/N},$
- Attraction Factor (m): $2m(m+1) = \frac{(L_{ij}/N)(L_{ij}/N+1)(L_{ij}/N+2)}{(L_{ij}/N)^3}.$
- Both are volatile when N<200, but go to m=0.37 and r<0.0001 when N>=200.

Simulation Results





- The density is asymptotic to 0.25, P(i)<0.5, N>200
- The density is asymptotic to 0.20, P(i)>0.5, N>200
- Equilibrium for CPS, P(i)=0, is asymptotic to 0.25 only at N>30

Simulation Results

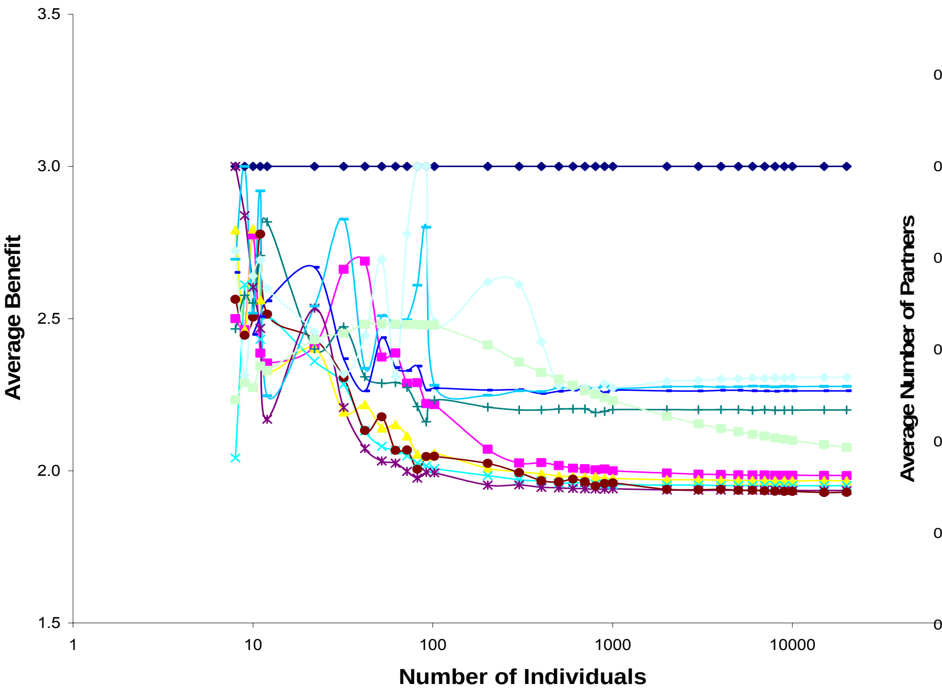
- Co-Author Model can be stable under CPS, while it can’t be under PS. It could be stable when N>6.
- Simulation results confirm analytical results: P(i)=0 yields to the highest utility because each individual believes that others belong to a larger component; initiating a new link will result in a worse off utility.
- Network is more predictable as N increases as shown by stabilized average utility and density.
- The small number of m, *m*={0.37, 0.70} throughout *N*={8, 20000} and *P(i)*={0.0, 1.0} confirm that the Co-Author Model as a decentralized homogeneous model.

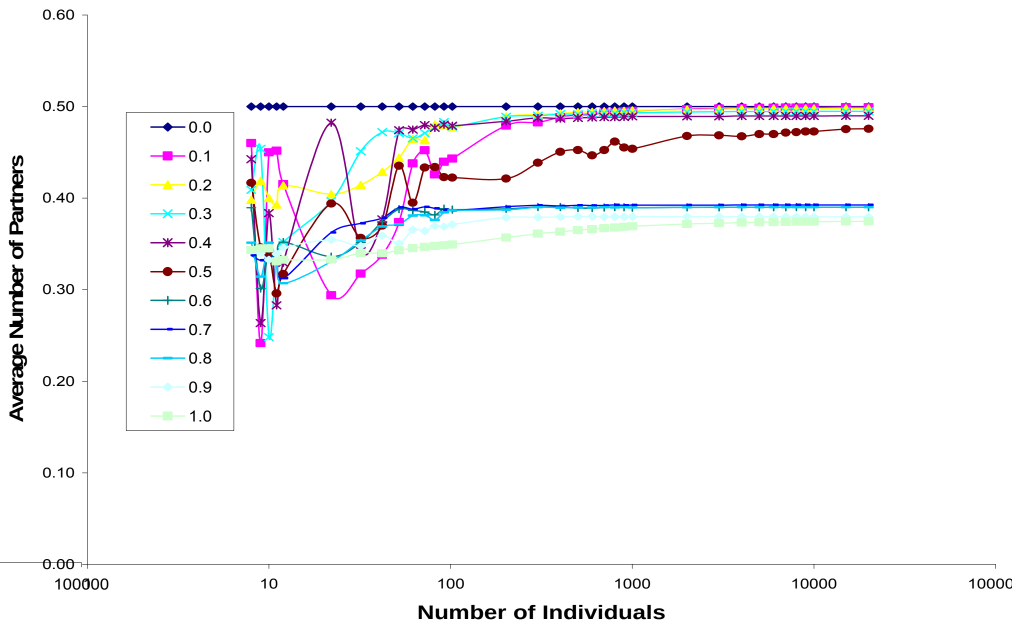
Simulation Results

- Small tipping point (r<0.05) shows that it does not take too much of each individual's initiative to diffuse information in the Co-Author Model. This finding is consistent with Newman's (in press) finding that the tipping-point will be smaller as the number of the individuals in the network increases.
- Recall that the observation of each individual is limited to her own component. Hence, it is very plausible that the unanimous profile of beliefs is attributed to the diffusion of information from the dynamic interactions of individuals in the sequential network formation processes. Therefore, the results show that observational limitation is not necessarily preventing information discussions as long as there are dynamic interactions of the individuals in the network.
- The density that mimics CPS's density (0.25) suggests that individuals belong in small components.

The Theory

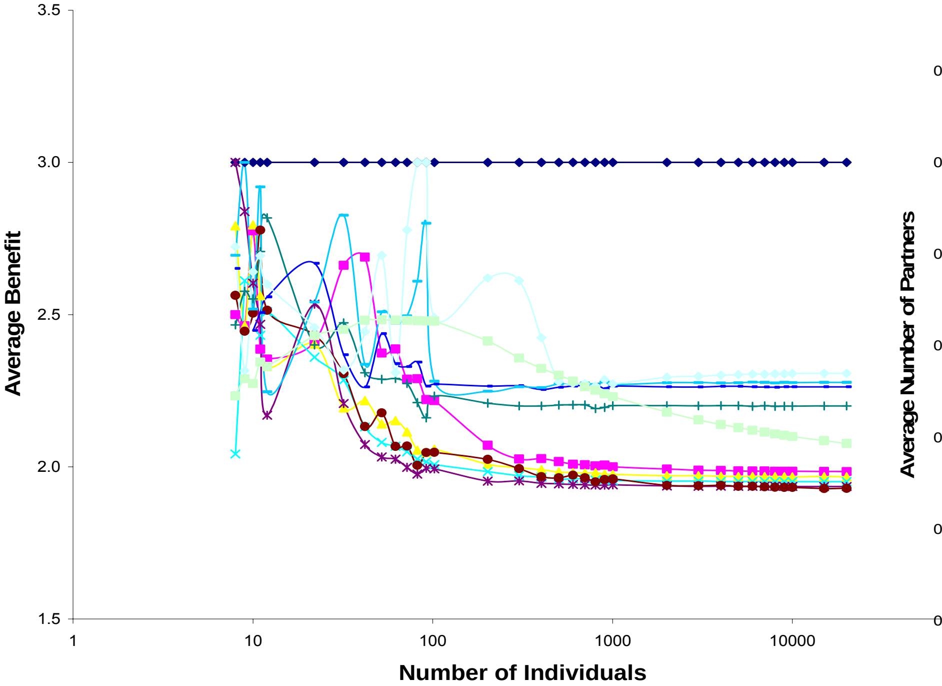
- <u>Result 1</u>. *For entrepreneur network g with N<200, there is irregularity in average utility and density.*

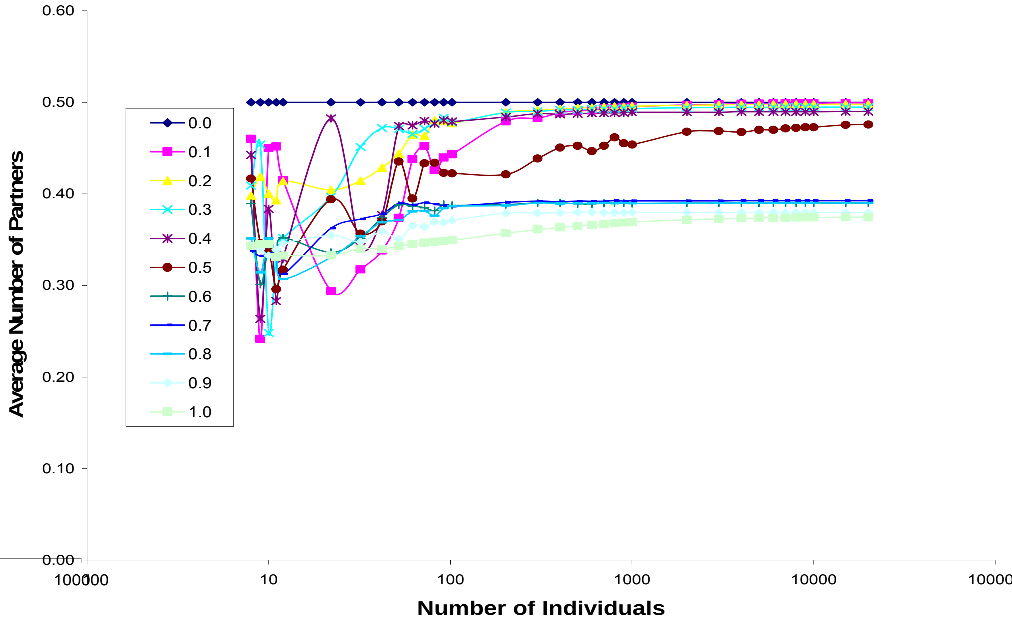




The Theory

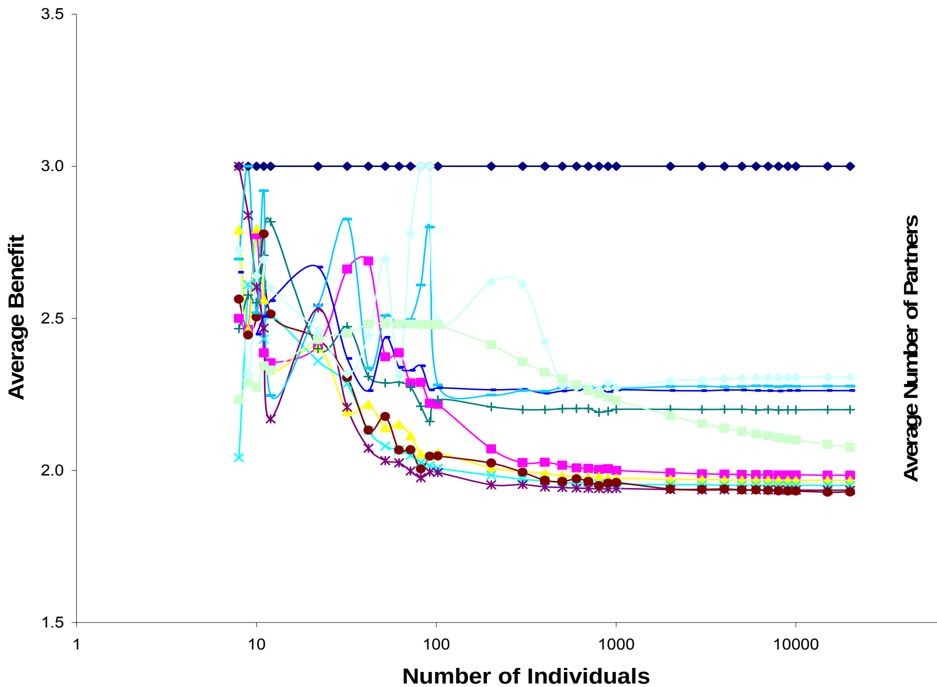
- Reflects trial-and-error processes of new entrepreneurs trying to establish new partnerships and balancing the tension between cooperation and competition

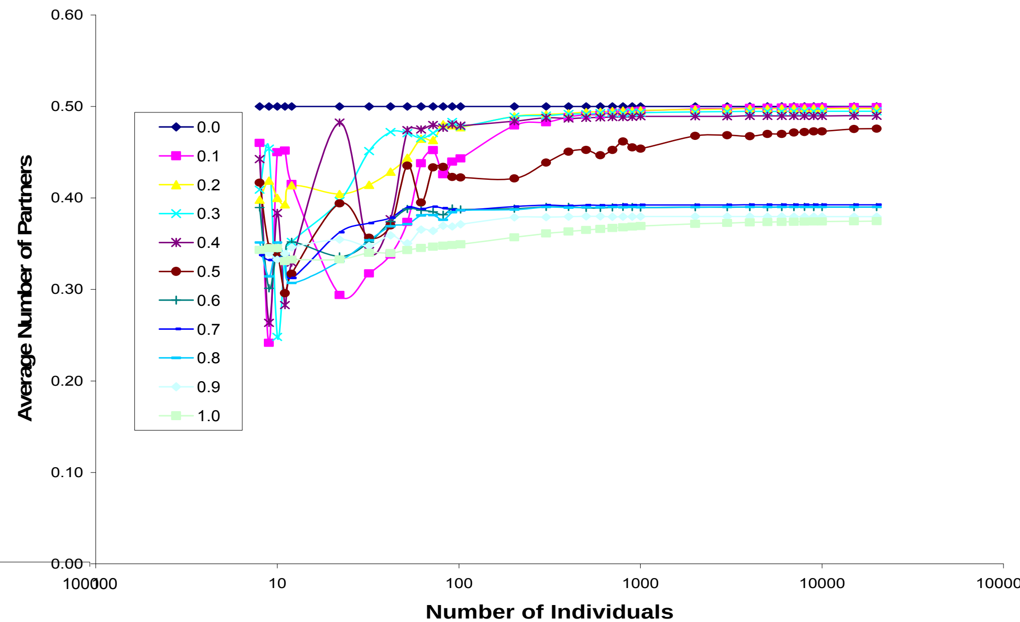




The Theory

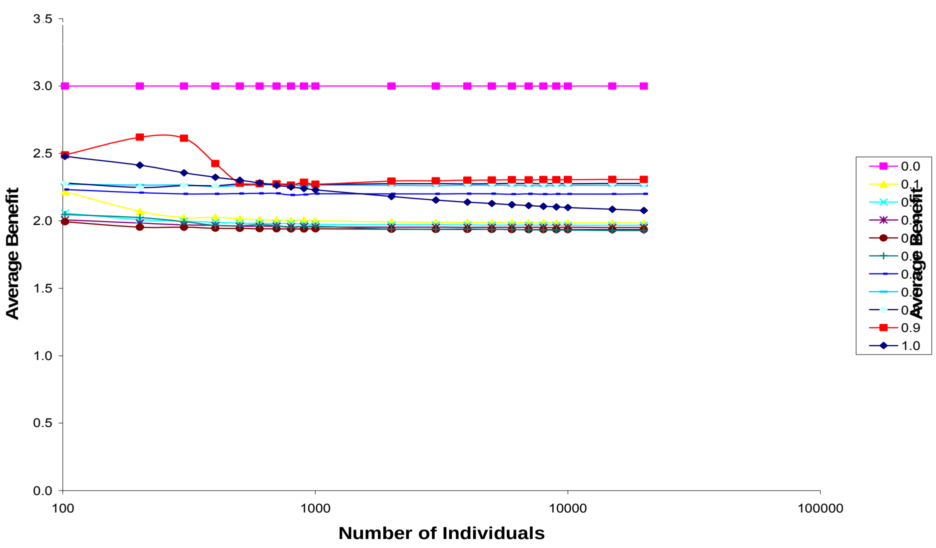
- This result matches empirical findings by Das and Teng (2000), Khanna, Gulati, and Nohria (1998), and Park and Ungson (2001).

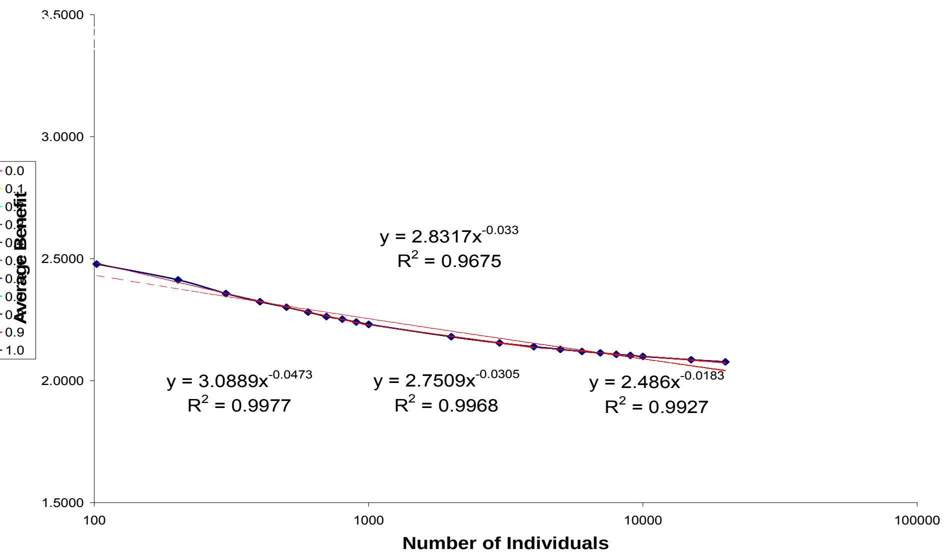




The Theory

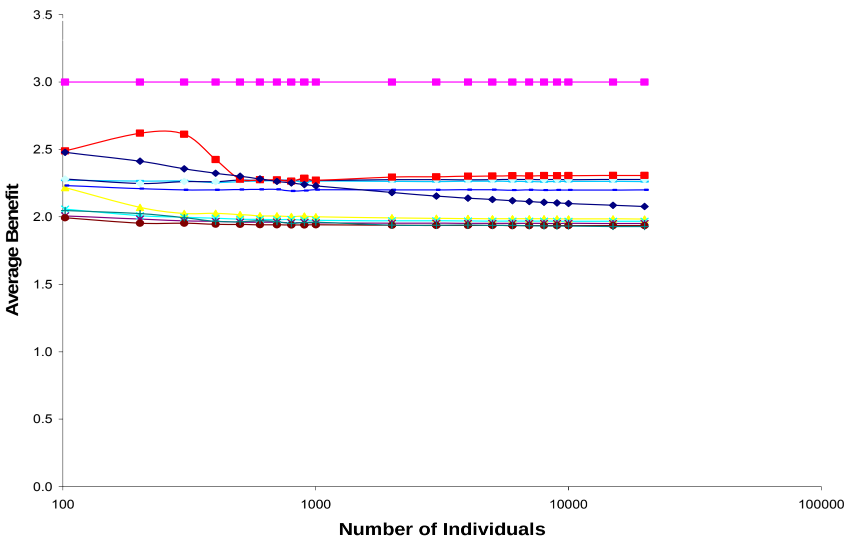
- *<u>Result 2</u>. For entrepreneur network g with N>200, entrepreneurs with more partners in the beginning end up with larger benefits than entrepreneurs with lesser partners at the end.*

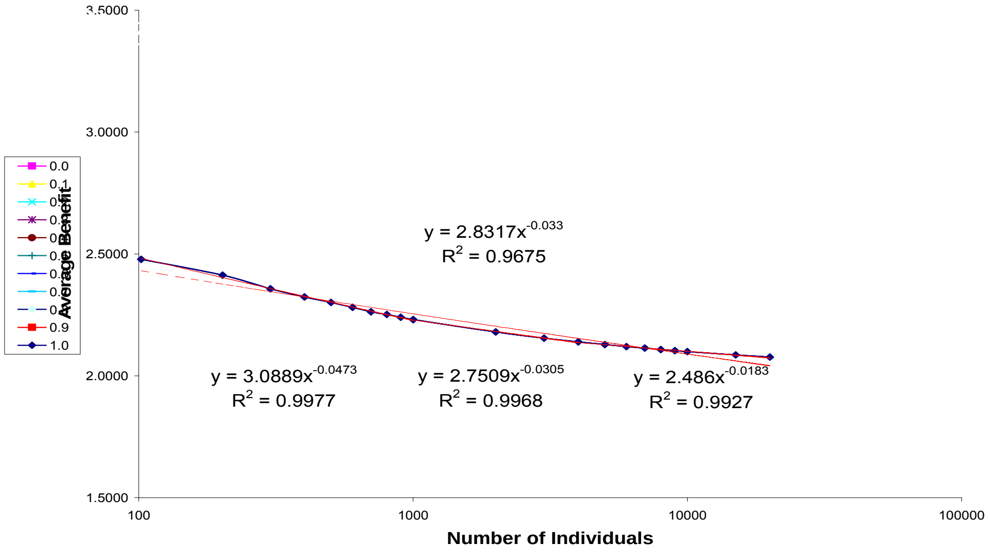




The Theory

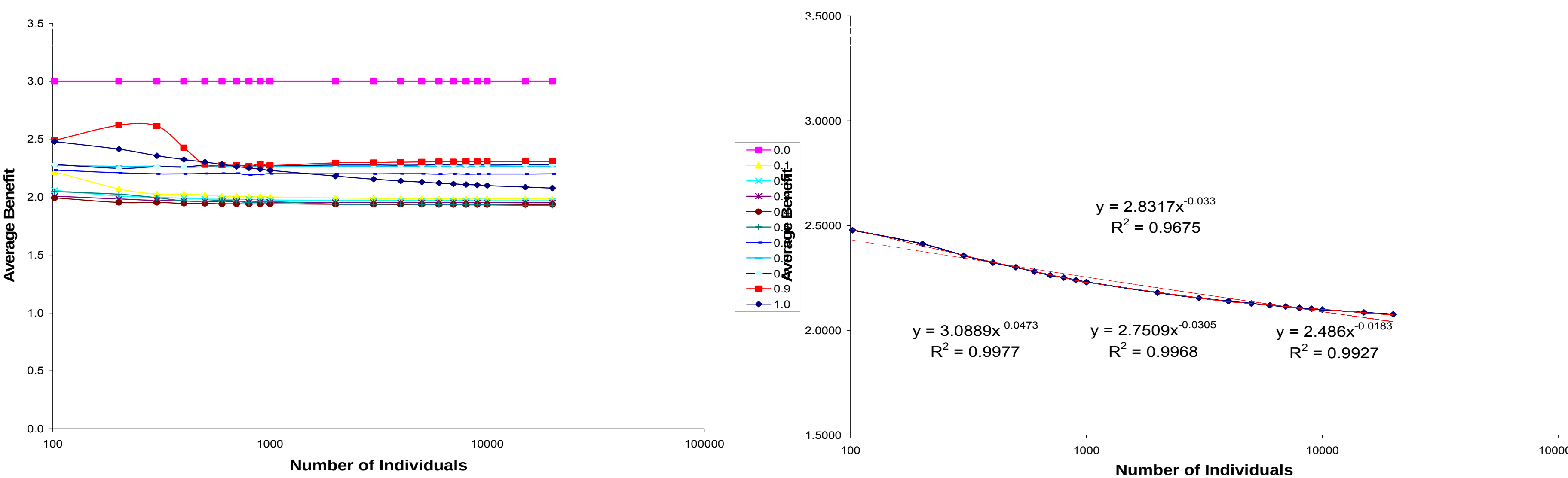
- There are fewer trial-and-error processes and the entrepreneurial network stabilizes as the number of people in the network increases to be more than 200.





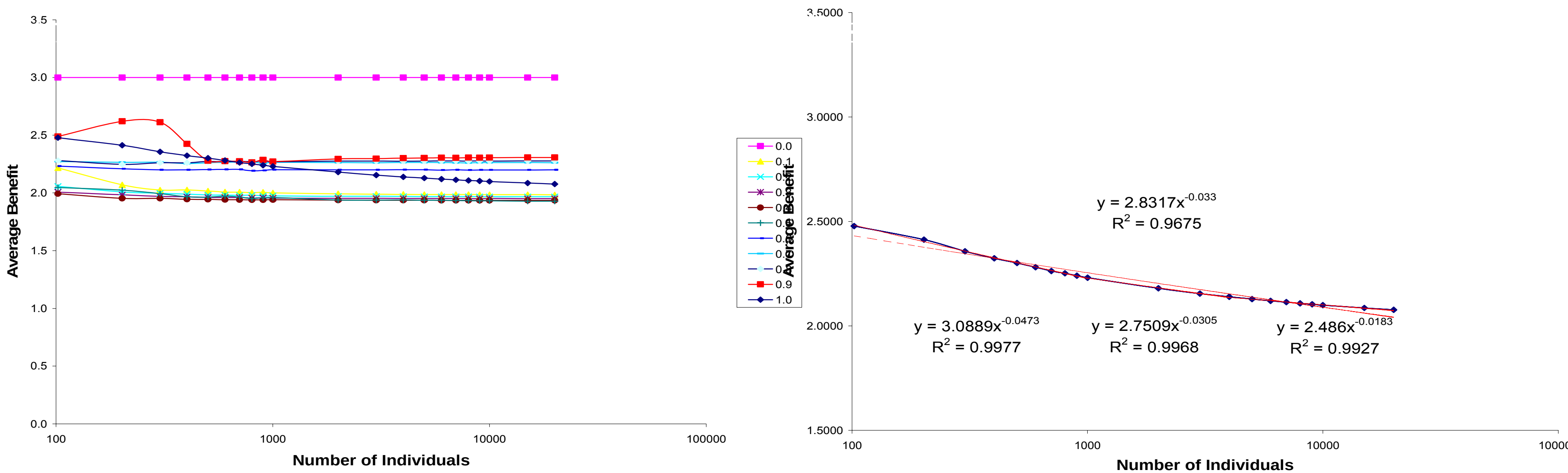
The Theory

- The benefits are higher for those who have initially been members of established organizations, alias the “old boys”. This shows that for a more established market, established organizations start to provide more benefits to their existing members and show efficiency with shared resources and information.



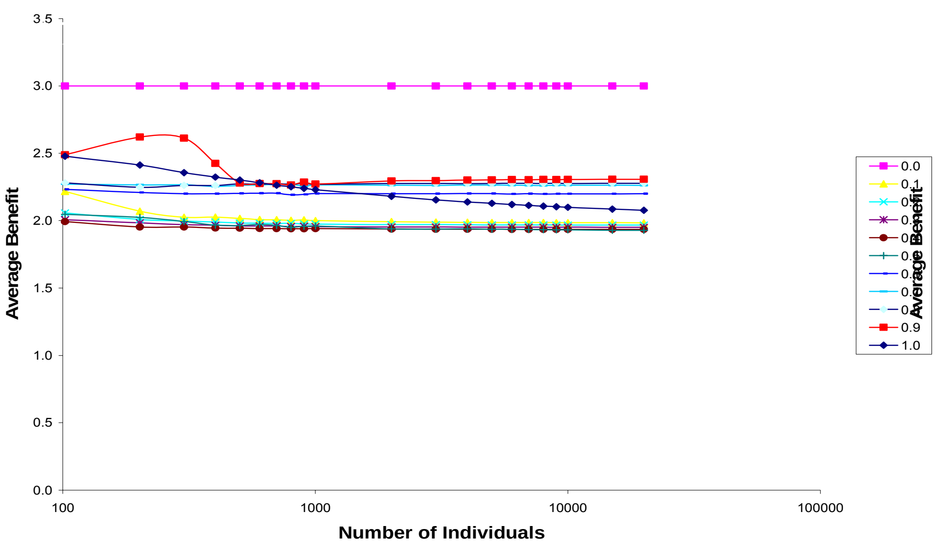
The Theory

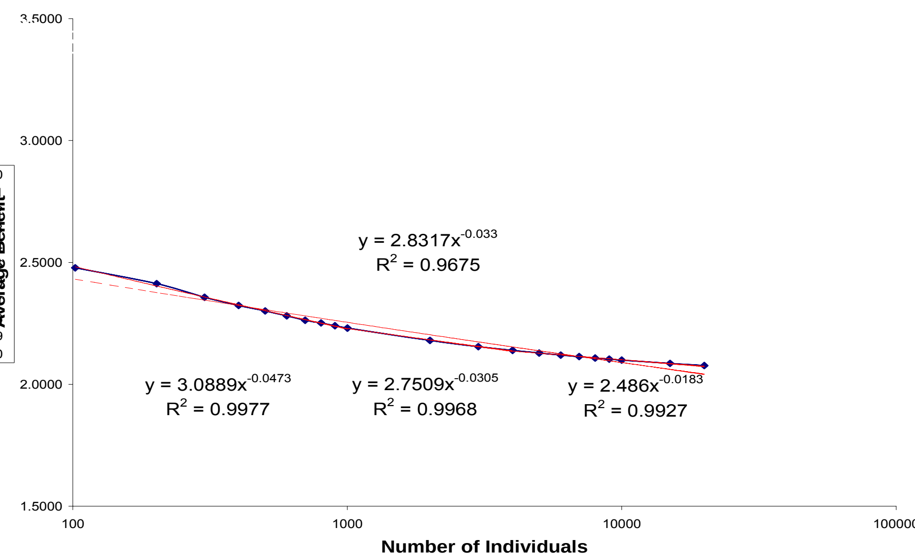
- This is consistent with Cowan, Jonard, and Zimmermann’s (2006) conclusion in their empirical studies that “firms with more partners tend to accumulate more knowledge over the history of economy.”



The Theory

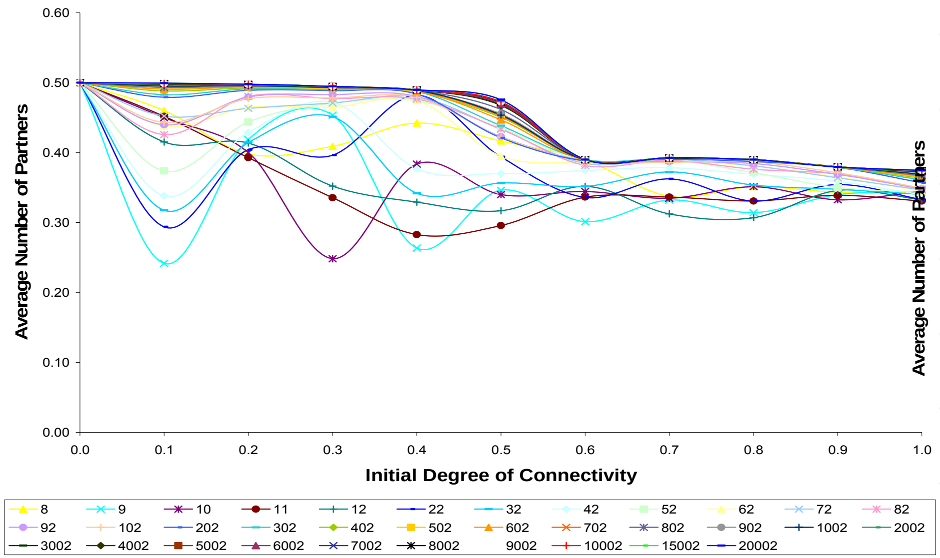
- Rowley, Behrens, and Krackhardt (2000) also found using an empirical analysis that an embedded business network can result in incremental innovations, while Burton, Sørensen, and Beckman (2002) found that entrepreneurs accrue resources through their previous associations in their studies.

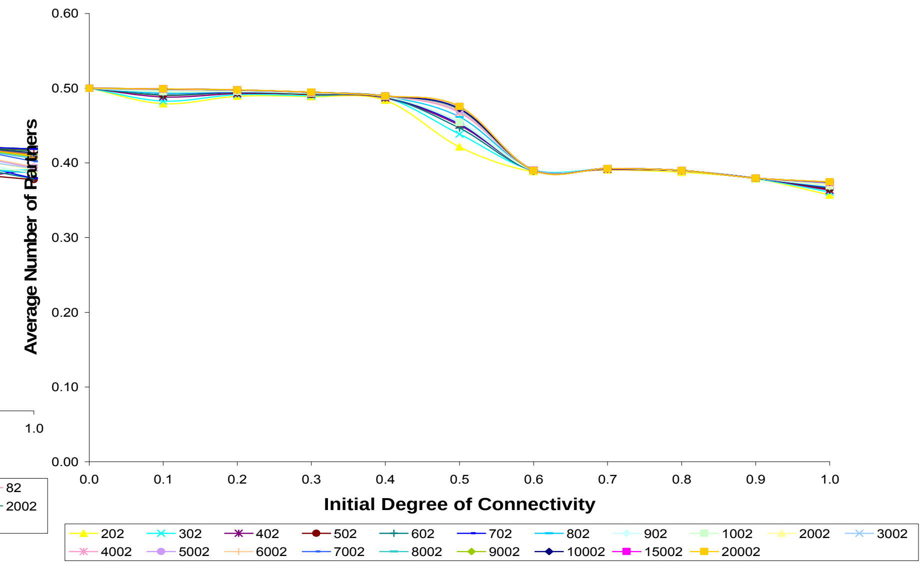




The Theory

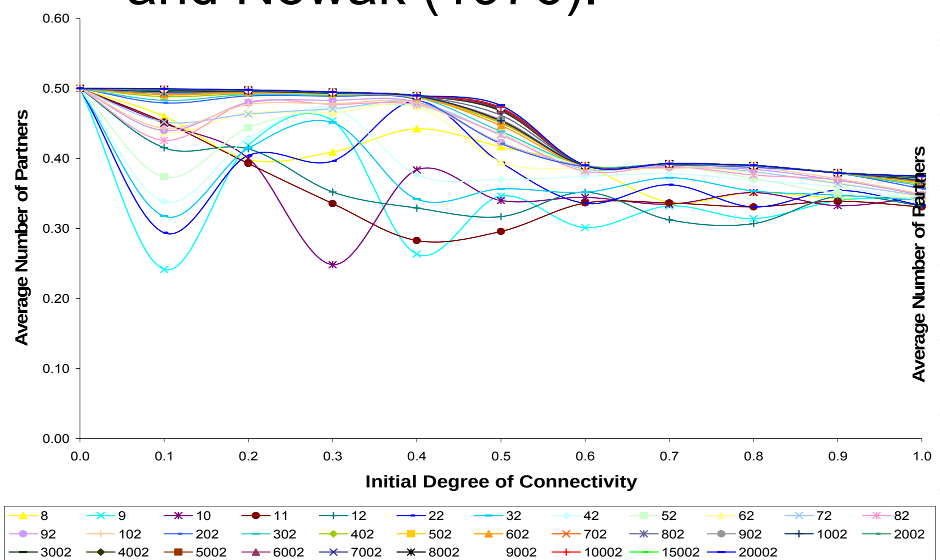
- *Result 3.* *For entrepreneur network g with N>200, entrepreneurs with more partners in the beginning end up with lesser partners at the end and vice versa. Further, figure 10 shows that a large entrepreneurial group attracts more partners.*

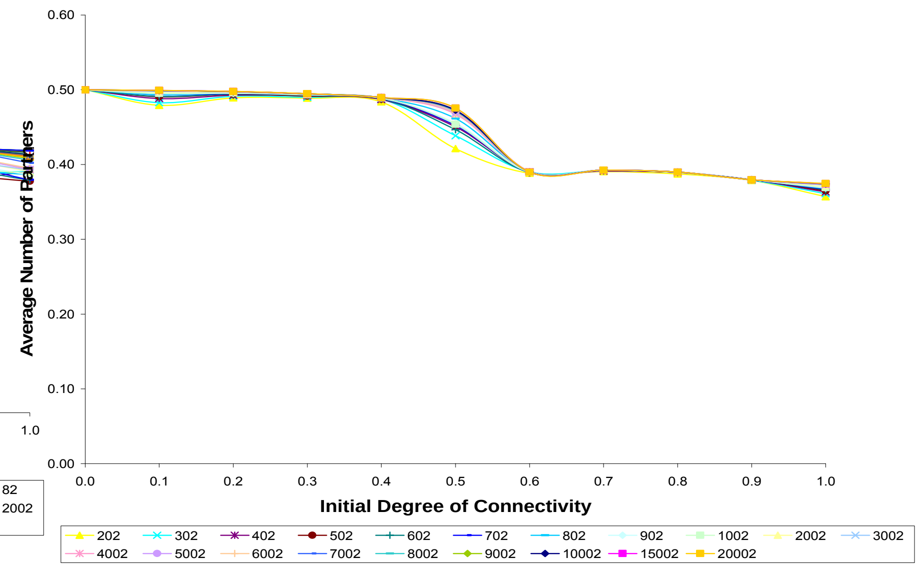




The Theory

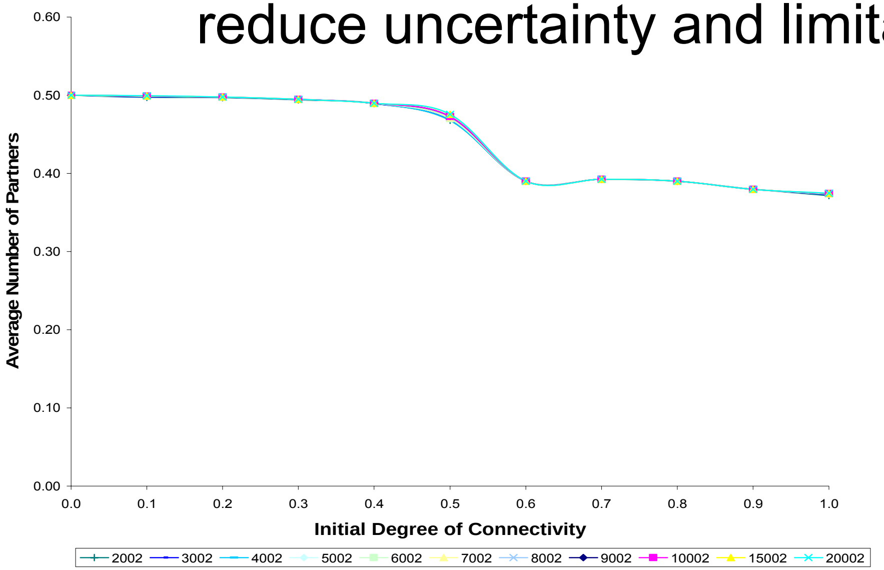
- Although an entrepreneur is being penalized for having connections with those who have more partners by the utility function, the simulation shows a contradictory result that entrepreneurs with more partners actually attract more partners, implying that a large entrepreneurial group simply is an attraction for people to attempt to join. Matches Kogut (1988) and Pfeffer and Nowak (1976).

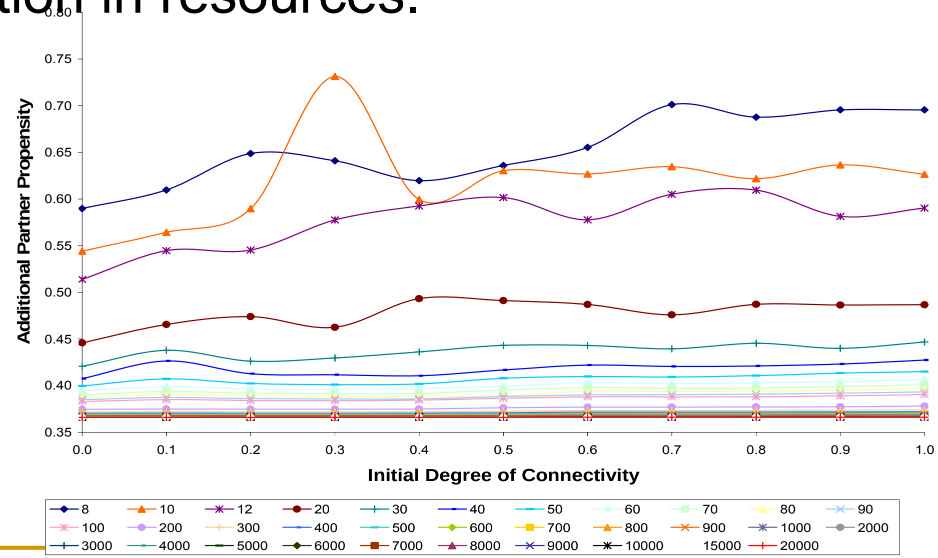




The Theory

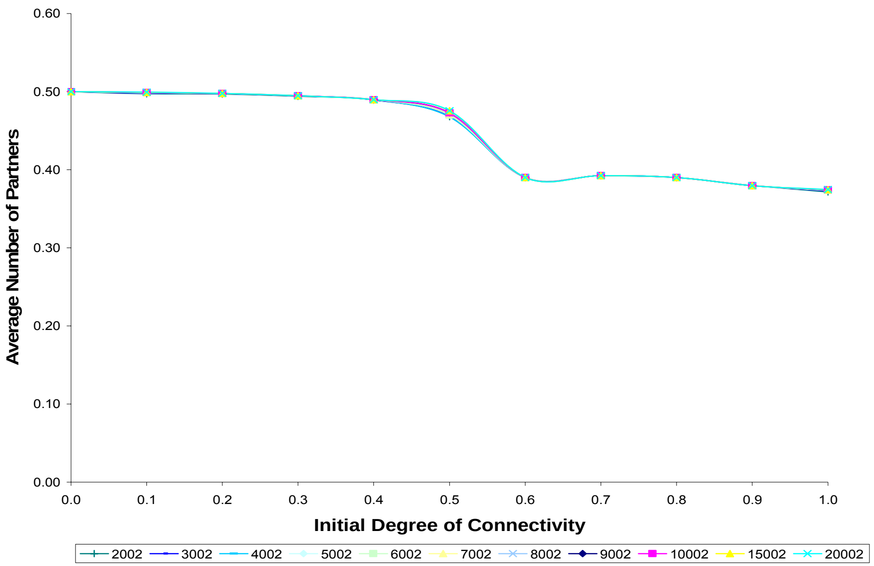
- The existence of large established entrepreneurial organizations are often countered by formations of new organizations by the “young Turks” who are not initially associated to them. There is a sense of survival of the fittest for competition in this situation; smaller newcomers cannot compete with stronger pooled resources of larger established entities. Hence, it is a logical solution to form an alliance that serves as a resource pool to reduce uncertainty and limitation in resources.

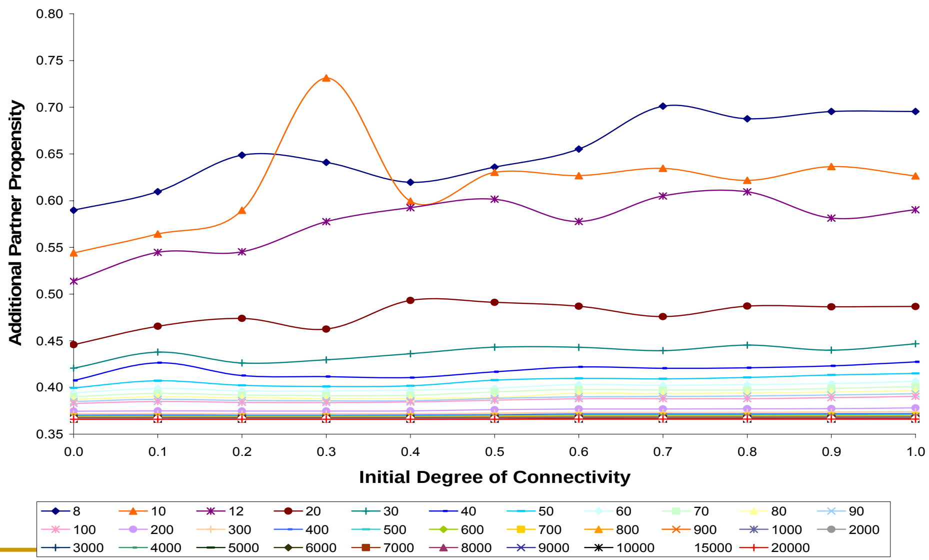




The Theory

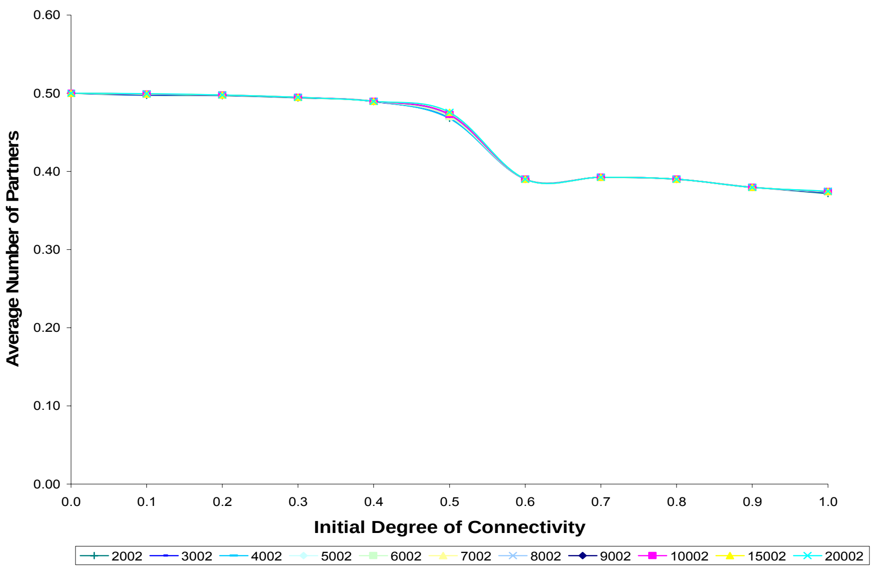
- This situation can be explained by the fact that a partner in a large organization, although being penalized for the indirect connections held by her partners, is also benefited by the fact that she also has a lot of partners.

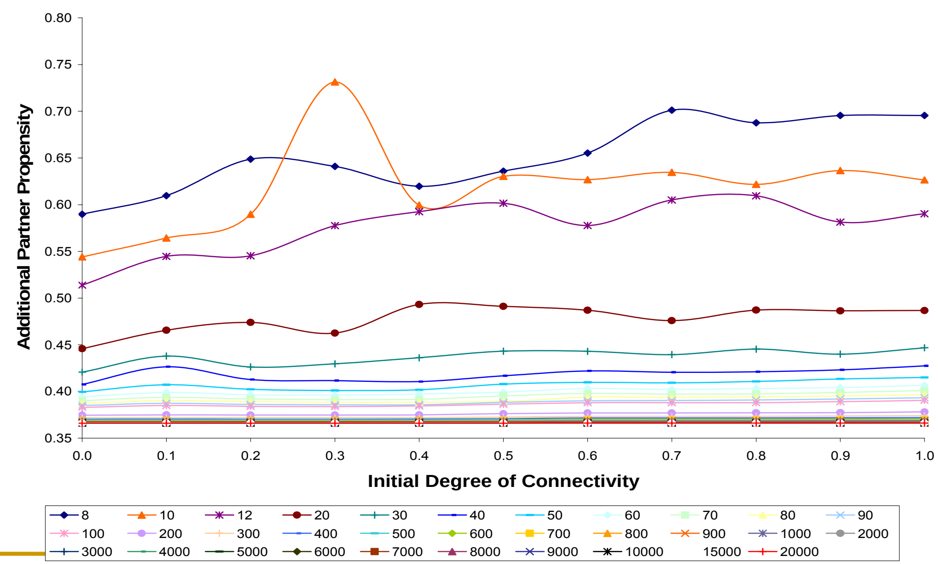




The Theory

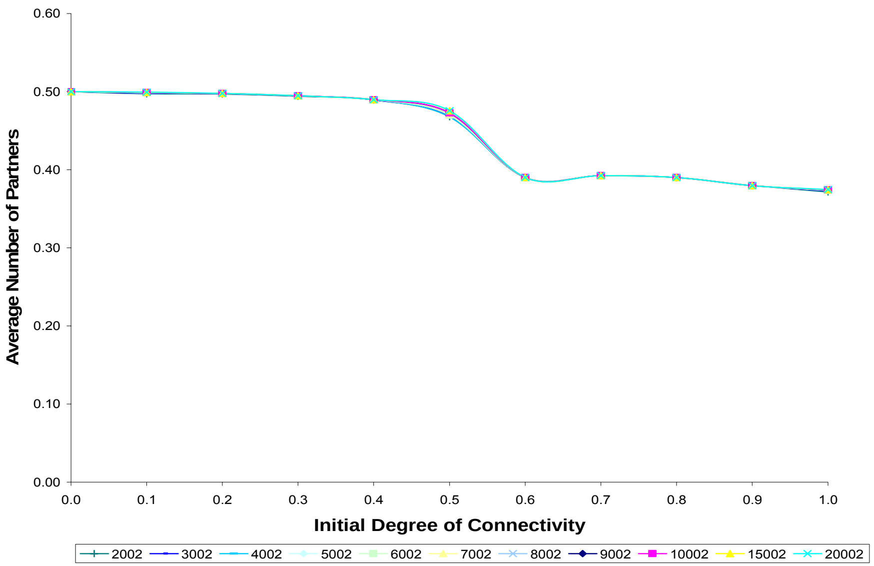
- So, in essence, the partnerships in that organization become truly cohesive, with mutual bonding and becoming a clique, or in a sense, a conglomeration that is often referred as an “old boys’” club. Since a commitment of time, money, and other resources are required for direct partners, a clique symbolizes its fair distribution among the members of an organization.

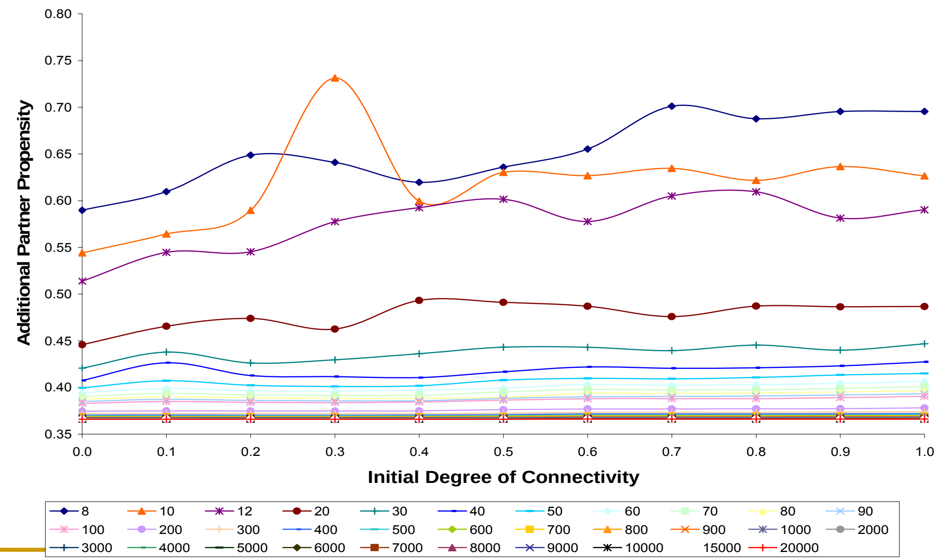




The Theory

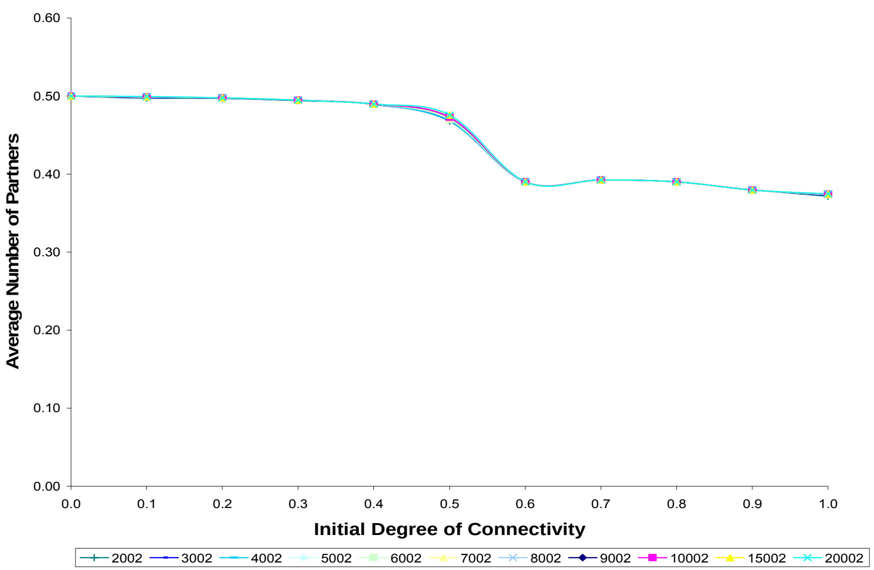
- Beckman, Haunschild, and Phillips (2004) explain this phenomenon in their empirical findings that business entities tend to reinforce the multiplexity of their networks, to the point of interlocking, when facing market uncertainties. Uncertainties in this context are explained by the increment of number of entrepreneurs in the market that can potentially form new competing ventures that harm the existing alliances.

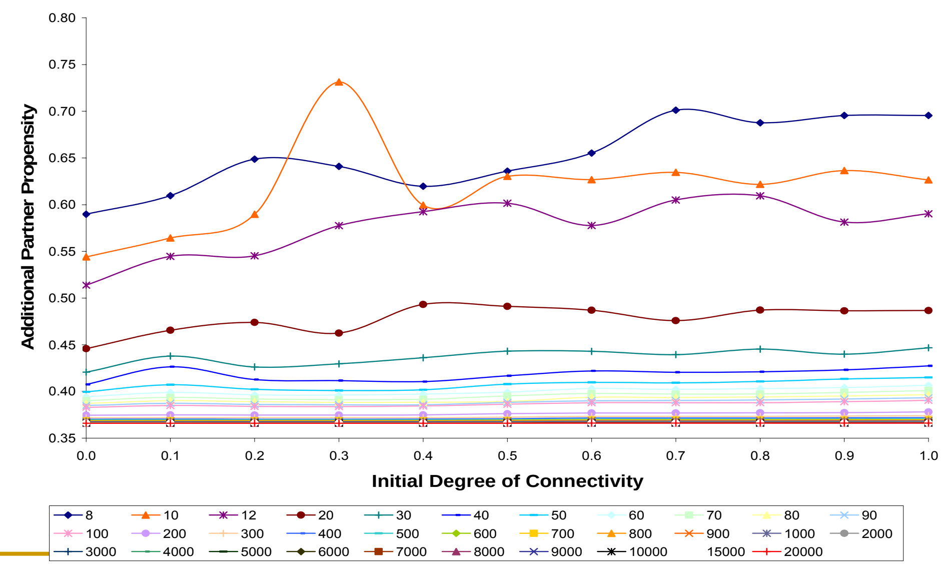




The Theory

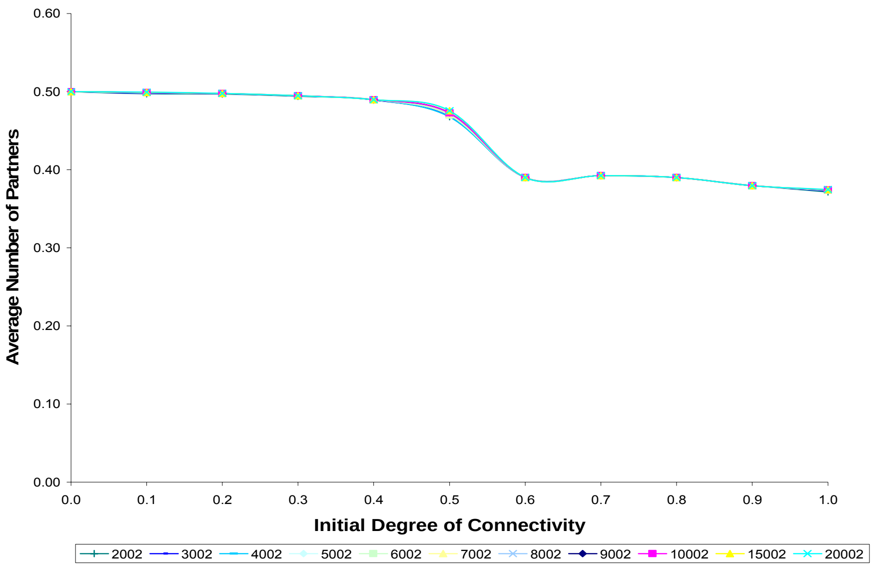
- So, the cohesiveness in form of a clique is a natural reaction of resistance of the old boys against the newcoming young Turks in terms of a fair distribution of responsibilities and resource pooling when facing an external threat.

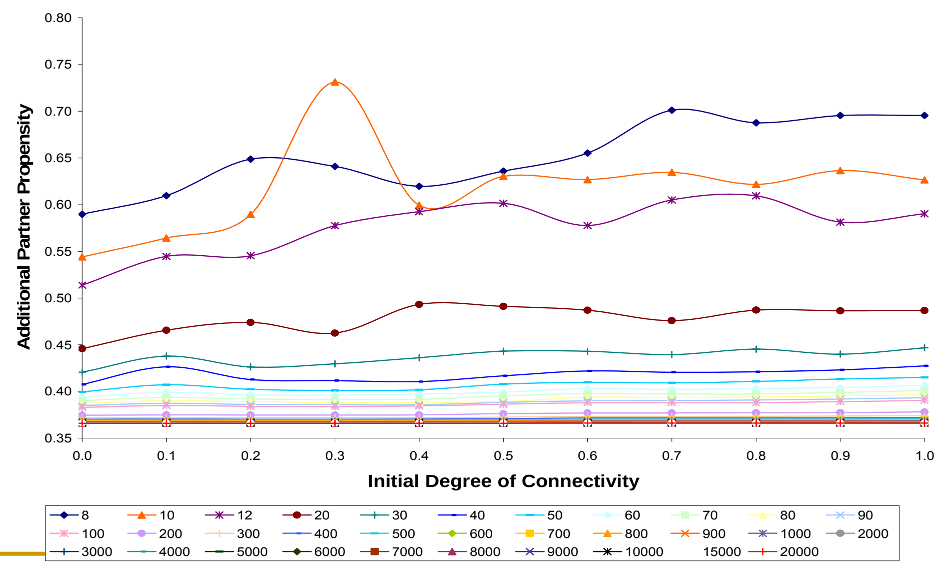




The Theory

- Moreover, it also explains why, in empirical findings, common-background organizations, which often serve as professional associations as well as social institutions, are cohesive and prevail when facing a more plural situation (Phillips 2005; Roberts 2007).





The Theory

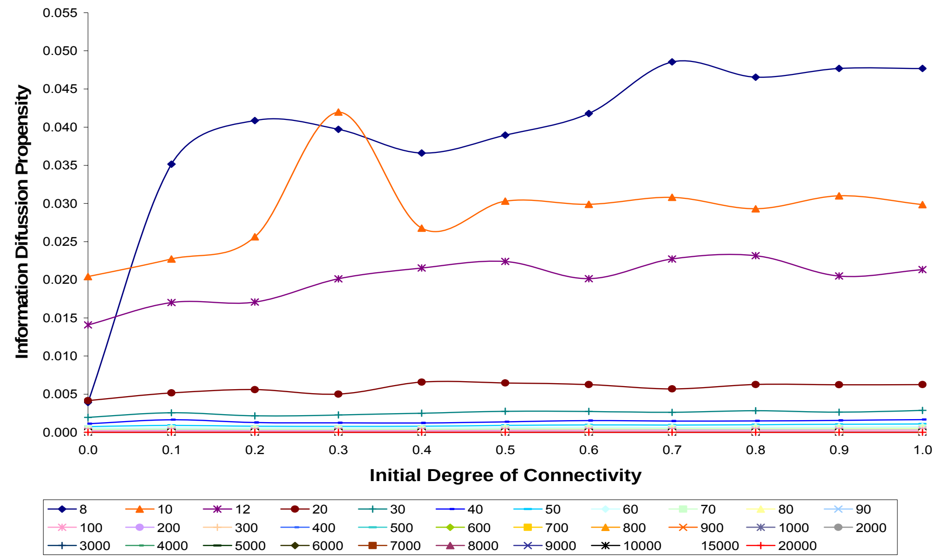
- Result 4. *A synthesis of figure 3, 6, and 7 show that there is resistance from the large groups' members to accept new partners in spite of the propensity of large entrepreneurial groups to attract new partners, causing the rejects to form new competing entrepreneurial groups that become larger than the pre-existing groups*.
- Despite the propensity of a large entrepreneurial group to attract new members as explained in proposition 2, the members of the established organization tend to stay and refuse to accept new members while becoming to be very cohesive once an organization is established and institutionalized. As a result, the rejects form competing alliances of “young Turks” that tend to end up larger than the initially established “old boys” market leader and eventually take over the market.

The Theory

- Result 4. *A synthesis of figure 3, 6, and 7 show that there is resistance from the large groups' members to accept new partners in spite of the propensity of large entrepreneurial groups to attract new partners, causing the rejects to form new competing entrepreneurial groups that become larger than the pre-existing groups*.
- This is confirmed by empirical findings of Powell, White, Koput, and Owen-Smith (2005) in Biotech industries, where startup firms pool their resources, resulting in capability to attract new capital and to take over the market leadership. Nonetheless, it is important to emphasize that the cohesiveness of these organizations in the network is strongly influenced by their members' views of the outside world. In some sense, the glue of the bonding can be interpreted as a result of "us versus them" sentiments.

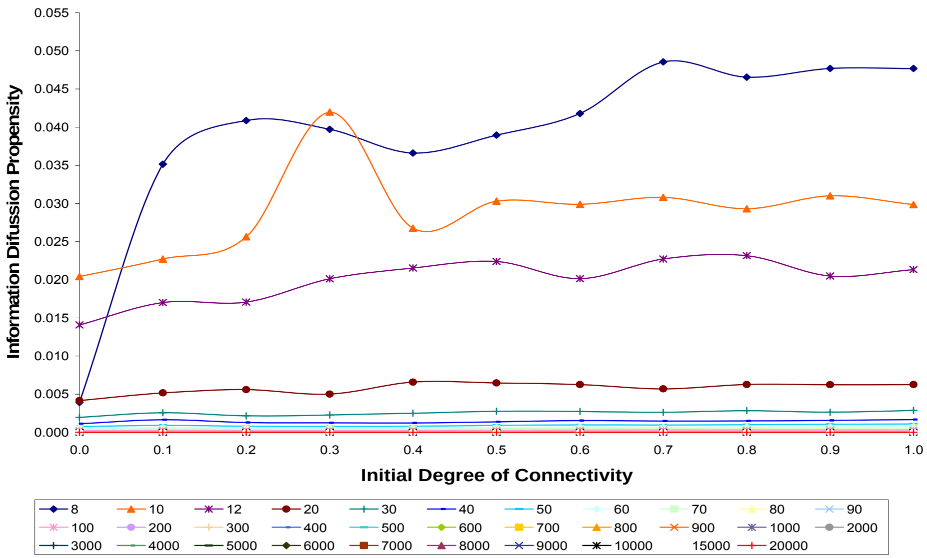
The Theory

- *<u>Result 5.</u> There is a propensity toward information diffusion in this network. Observational limitation does not prevent information diffusions because there are dynamic interactions among individuals in the network.*



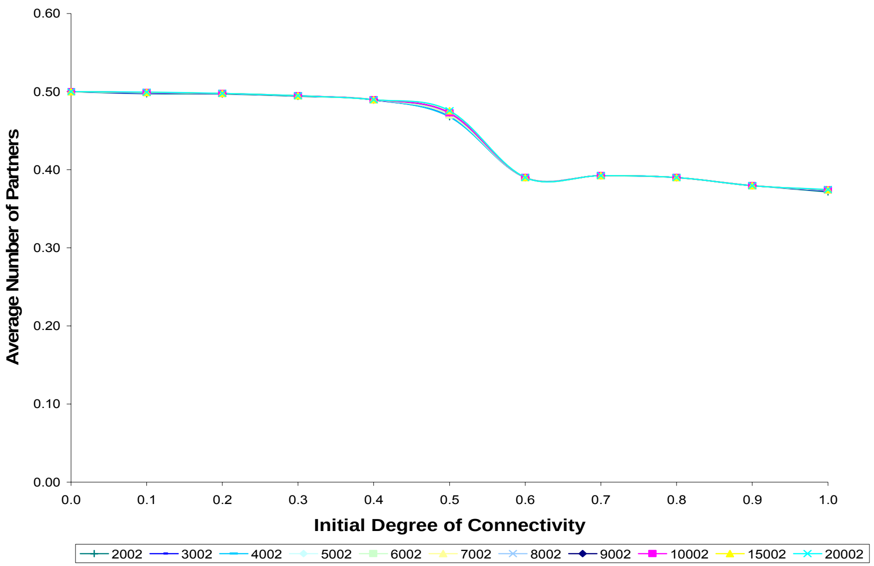
The Theory

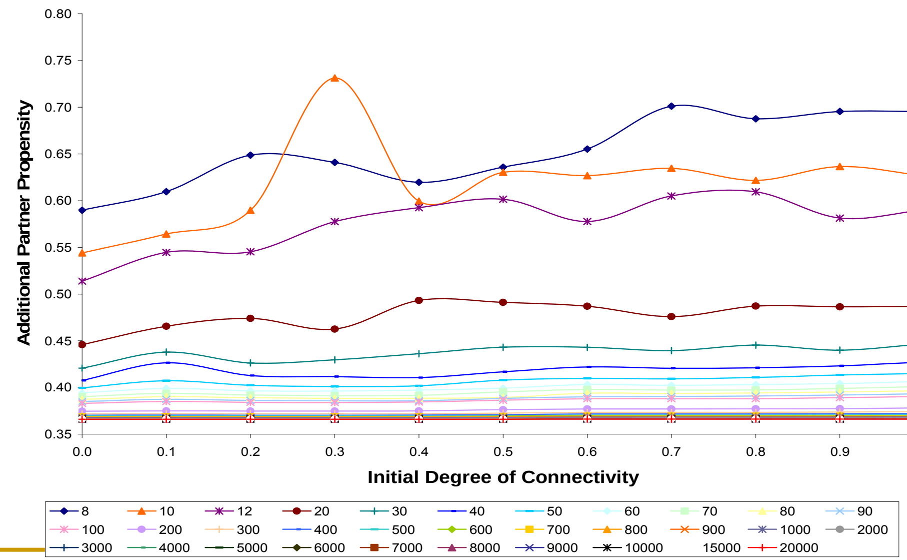
- This reflects a secondary network that is more peer-to-peer in passing information. People do not tell everything to everyone, especially secretive information. However, those whom the secret teller trusts enough to tell might also have different confidants who are not associated with the first teller of secrets.



The Theory

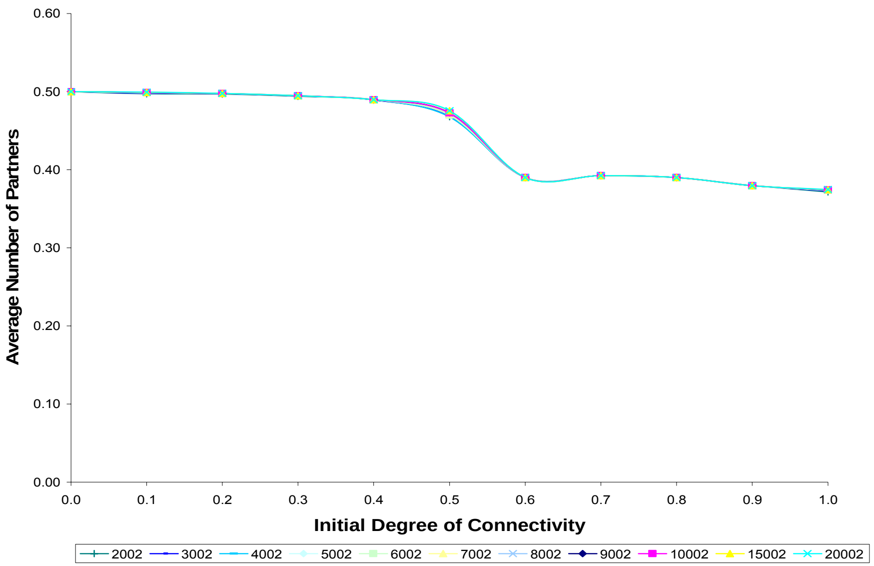
- Beckman, Haunschild, and Phillips (2004) explain this phenomenon in their empirical findings that business entities tend to reinforce the multiplexity of their networks, to the point of interlocking, when facing market uncertainties. Uncertainties in this context are explained by the increment of number of entrepreneurs in the market that can potentially form new competing ventures that harm the existing alliances.

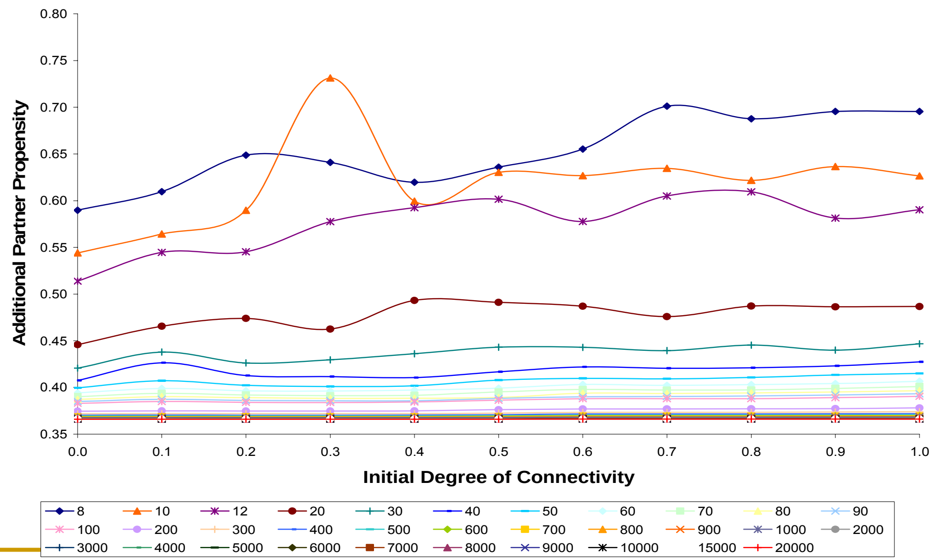




The Theory

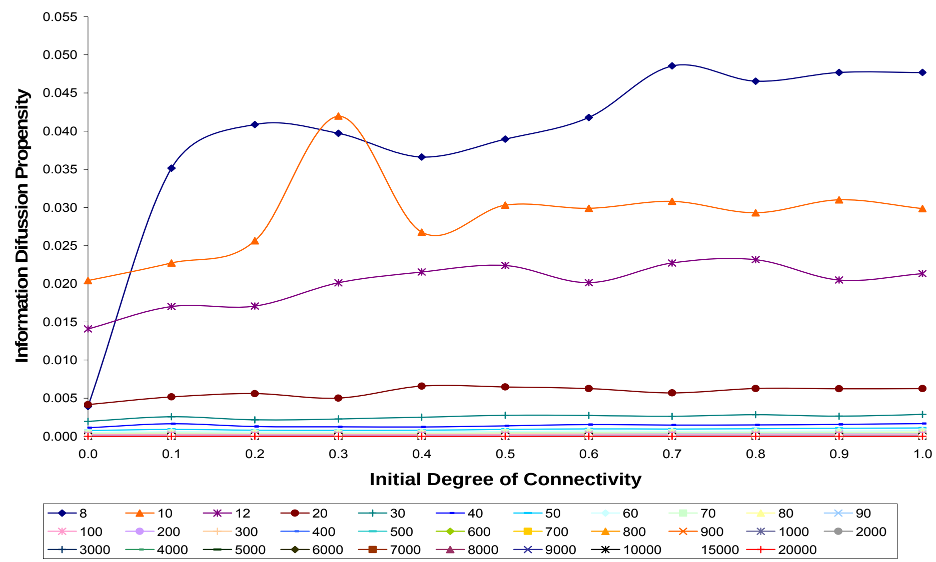
- So, the cohesiveness in form of a clique is a natural reaction of resistance of the old boys against the newcoming young Turks in terms of a fair distribution of responsibilities and resource pooling when facing an external threat.





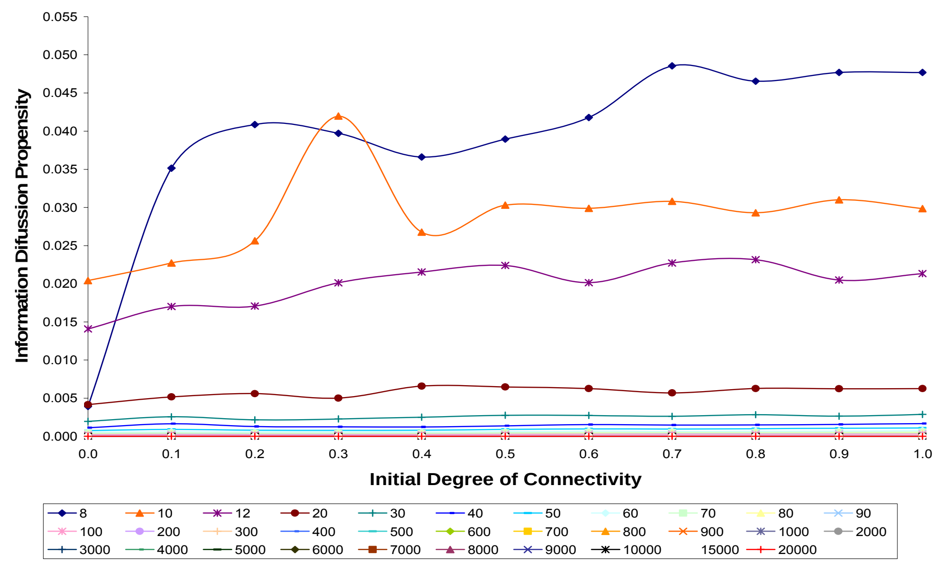
The Theory

- This explains the passing of rumors through the information grapevine, even in a competitive market.



The Theory

- Agrees with Cross, Nohria, and Parker's (2002) "to build better networks, focus on who knows what" and "People should be connected when a strategic payoff is likely."
- Those 2 are corrections to the myths of to build better networks, we have to communicate more" and "Everyone should be connected to everybody else."



Conclusions

- Answering Uzzi's question as to how the market's functions and organizations' competitive dynamics operate on the base of structural configurations of partners and pools of resources and my own question as to how the learning process and adaptability of strategy in the Co-Author network.
- Organizational behaviors in the network context as an endogenous function of its members' motives and describes the properties of its equilibrium.
- The simulation results and explanations exemplify how a simple analytical model, that is dependent only on the function of the motives of self-benefiting individuals, can produce contradictory properties in aggregated organizational behaviors when facing complex interactions in network context and also match empirical findings.