Strategic Collaborative Research Networks

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Background in Economics and Management

- Over the past 2 decades, a changing perspective on organizations:
  - From organizations as atomistic, autonomous agents competing in the anonymous marketplace
  - To organizations embedded in a rich network of horizontal and vertical relationships with other organizational actors
- Is the conduct and performance of organizations affected by the network of relationships in which they are embedded?

Why networking?

- Make or buy depending on contracting hazard and transaction costs:
  - Market exchange better when contracts readily written and enforced and transaction costs are low
  - Hierarchies better when opportunism is likely, contracting difficult and transaction costs are high
- Networks: transaction costs not so high that they require hierarchical control, not so low that market exchange is simple/possible
- Networking as a strategy for reaching beyond the boundaries of the organization for complementary INS resources (knowledge and information, labor, capital, goods and services, access to further resources and networks,…)

Strategic alliances and networks

- **Alliance**: Voluntarily initiated cooperative agreement between organizations that involves exchange, sharing or co-development and can include contributions by partners of capital, technology or organization-specific assets

- Strategic network as a set of (bilateral or multi-lateral) alliances

- Organizations engaging in alliances are relationally and structurally embedded

Innovation networks

- **Innovation networks**: networks emerging from organizations' decisions to form strategic alliances aimed at learning and producing new knowledge

- R&D collaborative agreement, research joint ventures, collaborative research networks,…

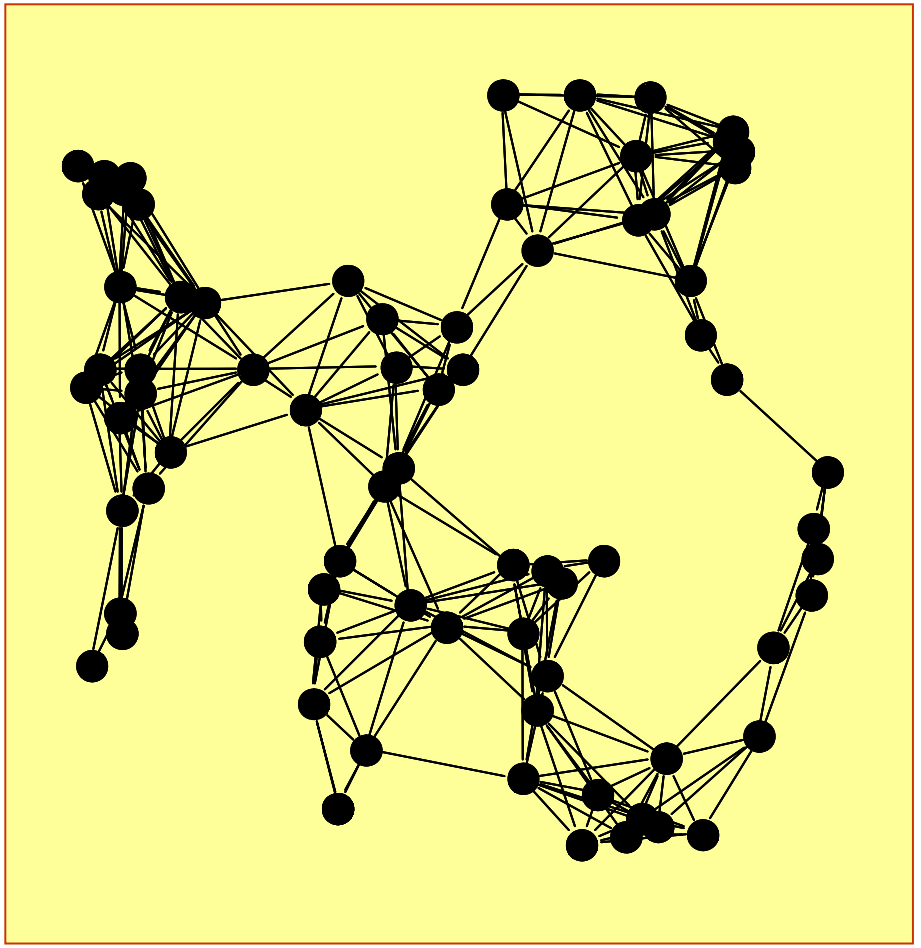
- Purpose: reaching beyond the boundaries of the organization for complementary knowledge resources in order to gain competitive advantage (firms), intellectual eminence (researchers and institutions),…

Innovation in collaborative research networks

- Heterogeneous organizations
- Innovation as the combination of different (existing) knowledge elements
- A demand for both commonality (similarity) and complementarity (differences)
- Empirical properties of the innovation process:
  - Neither too close nor too far: inverted-U relationship between “distance” and success
  - Getting closer: increased post-alliance overlap

Evidence on innovation networks

- Sparse
- Clustered
- Low diameter
- Asymmetric degree distribution
- Small worlds?



Standard explanations

- Sparse: costs of link formation
- Skewed link distribution:
  - Heterogeneity in attributes and goals
  - Preferential attachment
- Clustered:
  - Relational and structural embeddedness, social capital, trust and control
  - Agglomeration effects (innovation "in the air", industrial districts, labor, face-to-face interactions, tacit knowledge,…)

But…

- Empirical studies emphasize the causal role of network-oriented structural and strategic motives in partner selection
- Very little (static), if any consideration at all of partner complementarity in alliance formation
- Is partner complementarity/similarity causal?

A simple model of collaborative networks

- Organizations located in a knowledge space, holding distinct endowments…
- …form collaborative links with partners whose knowledge endowments both resemble and complement each other
- What does this simple (dyadic) rule imply in terms of the properties of the larger network of all partnerships?

The decision to enter a collaborative agreement

- Knowledge space: $K=\{0,1\}\times\ldots\times\{0,1\}=\{0,1\}^w$
- Knowledge portfolio of i: $\{v_z(i);z=1,\ldots,w\}$
- v(ij) is the commonality of i and j (facts known to both): $v(ij)=\#\{z: v_z(i)= v_z(j)=1\}$
- s(i,j) is i's complementing of j (facts known only to i): $s(i,j)=\#\{z: v_z(i)> v_z(j)\}$

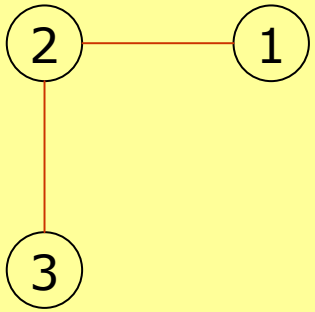
The decision to enter a collaborative agreement

- For successful innovation, i and j must both be similar to and complement each other
- We model this by assuming success requires a commonality of δ and reciprocal complementarity of γ
- The partnership ij innovates successfully if and only if $v(ij)=\delta$ and $s(i,j)=s(j,i)=\gamma$
- Only organizations with $\delta+\gamma$ ideas are alliance ready: others are not considered (don't show in data + would imply empty networks)

The decision to enter a collaborative agreement

- Take organizations 1, 2 and 3, and w=5
- Let δ=2 and γ=1
  - 12 forms
  - 13 does not form
  - 23 forms
- Entire network easily constructed

Position	1 2 3 4 5
Org. 1	1 1 1 0 0
Org. 2	1 0 1 0 1
Org. 3	0 0 1 1 1



Equilibrium of the network game

- The strategic alliance game is a simultaneous link formation game

- Organizations' incentives to form (or not to form) a partnership are symmetric, only dependent on technological fit (robust to the introduction of competition)

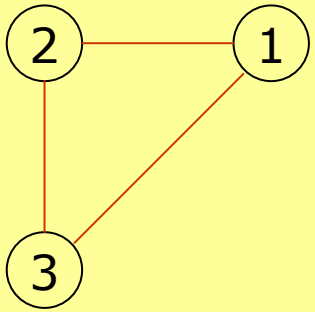
- There is a **unique** (pairwise stable) equilibrium network:

$$g^{*}=\{ij: v(ij)=\delta \text{ and } s(i,j)=s(j,i)=\gamma\}$$

Cliques

- Take again 1, 2 and 3 (changed), and w=5
- Let δ=2 and γ=1
  - 12 forms
  - 13 forms
  - 23 forms

Position	1 2 3 4 5
Org. 1	1 1 1 0 0
Org. 2	1 0 1 0 1
Org. 3	0 1 1 0 1



Knowledge abundance, complementarities and ties I

- All organizations are alliance ready
  - $\#\{z: v_z(i)=1\}= \delta+\gamma$
  - Low $(\delta+\gamma)/w$ corresponds to young industries where little is relevant for successful innovation (close to origin, thus large cliques potentially)
  - Larger $(\delta+\gamma)/w$ maps mature industries, where little is left to discover (further from origin, smaller cliques potentially)

- How do δ, γ and w interact in the process of establishing a collaborative research network?

Knowledge abundance, complementarities and ties II

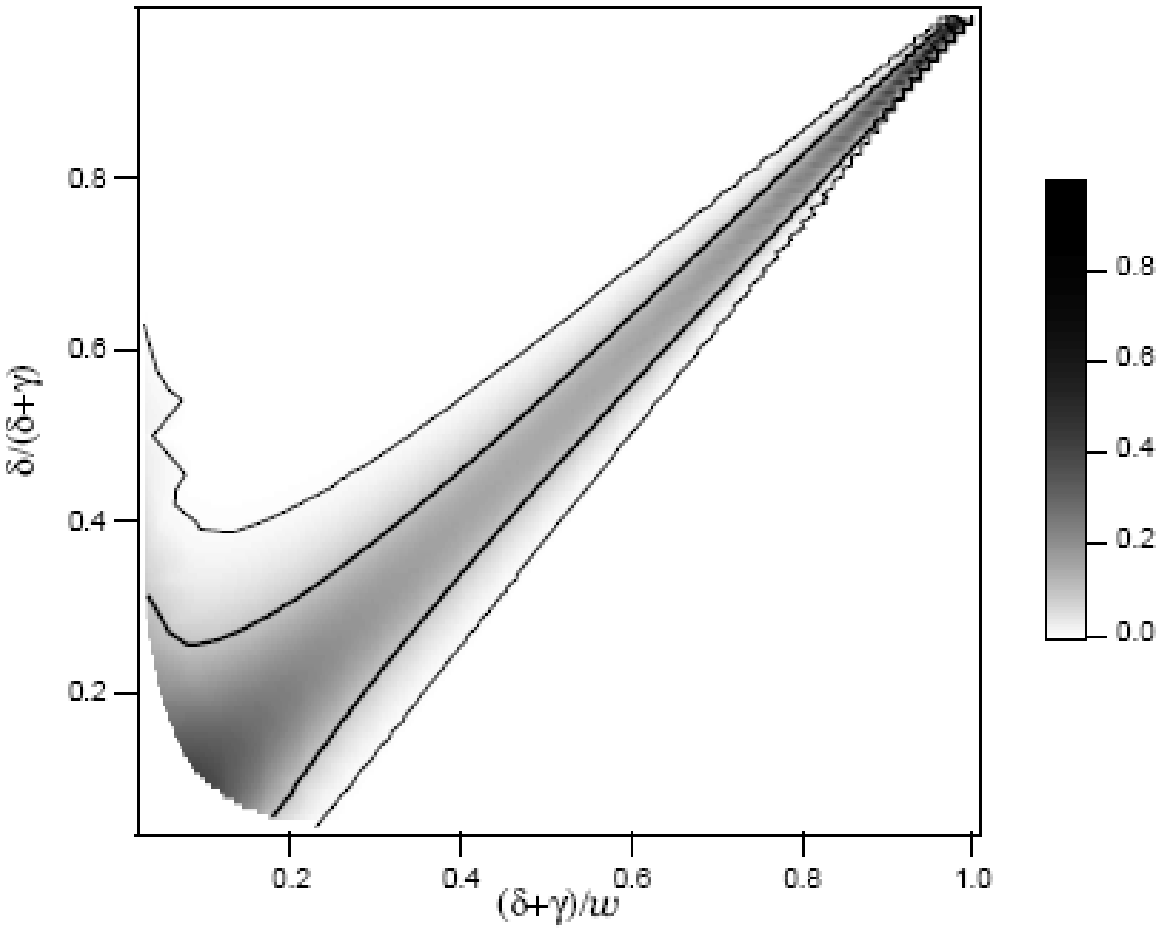
- ij requires that i knows exactly δ of j's δ+γ pieces of knowledge
- This is most likely when i knows any particular fact with probability δ/(δ+γ), thus an expected w×δ/(δ+γ) facts
- But i's knowledge is exactly δ+γ
- ij is thus most likely when (δ+γ)/w=δ/(δ+γ)

Density and degree distribution

- Take organizations 1 and 2, w=6, δ=2 and γ=1
- Array the ideas of 1 in the first positions
- Probability of ij: $q={}_{\delta+\gamma}C_{\delta} \times {}_{w-\delta-\gamma}C_{\gamma} / {}_{w}C_{\delta+\gamma}$
- Degree distribution binomial

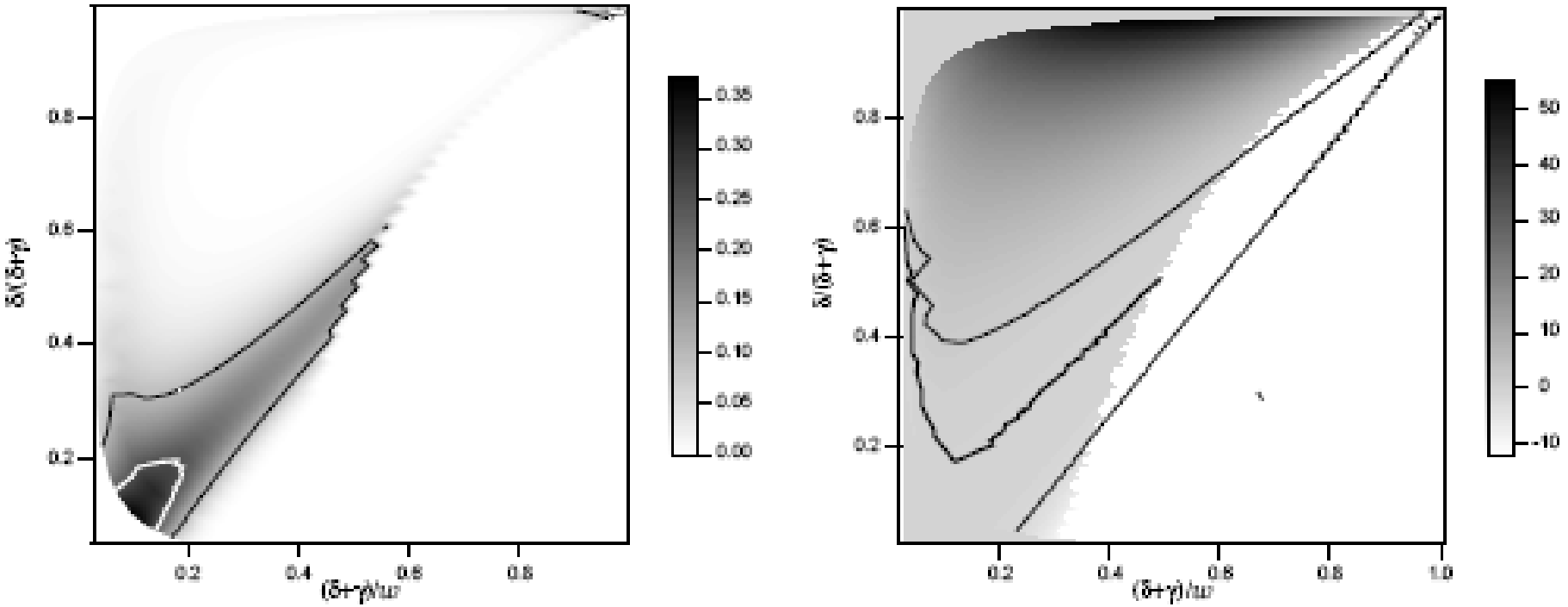
Position	1	2	3	4	5	6
Org. 1	1	1	1	0	0	0
Org. 2	-------			-------		
	δ 1s			γ 1s		

Density and degree distribution



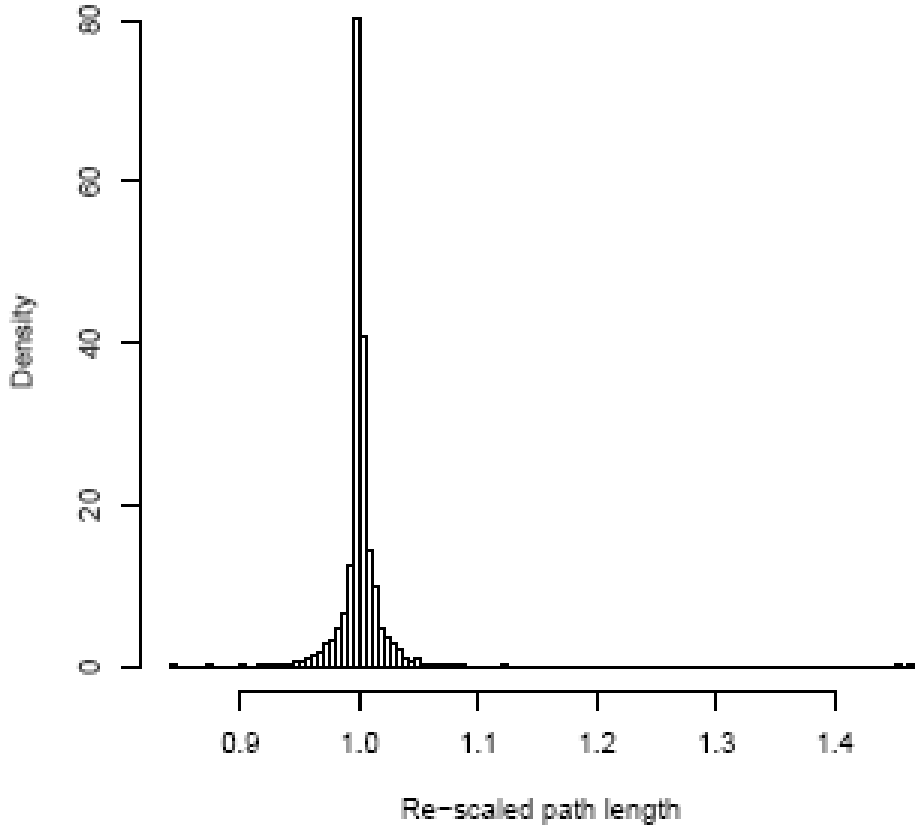
Expected transitivity

- Expected proportion of closed triangles can be computed explicitly as $\Pr\{jk|ij,ik\} = \Pr\{jk,ij,ik\}/q^2$



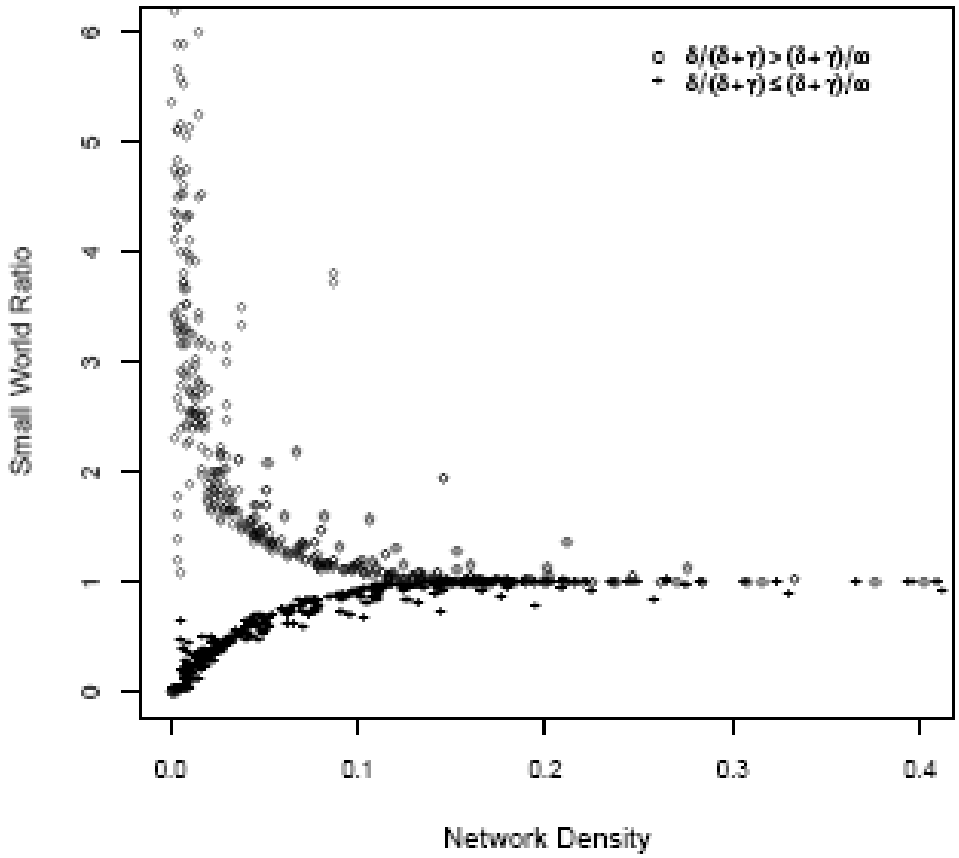
Average pairwise distance

- No explicit formula but asymptotic result: $\lfloor \delta/\gamma \rfloor + 2$, and numeric simulation



Small worlds?

- SW ratio: rescaled transitivity/rescaled distance



Commonality, complementarity and small worlds

- Heterogeneous organizations with different ideas seek partners to assemble these ideas in the right portfolio: random graph features with short distances

- Strategic organizations take into account the cost and benefits from each potential alliance, and the need for a precise balance between commonality and complementarity: local correlation in the alliance decisions and excess transitivity

Commonality, complementarity and small worlds

- Small worlds are most present when similarities are much more important than complementarities, i.e. when what we share matters more than where we differ…

- Robust to the introduction of competition in the form of "winner-takes-all" contest

Collaborative research networks and coalitions

- Strategic network as a set of multi-lateral alliances
- Problem of the funding agency is to bring together the right expertise
- Problem of the agents is to pool enough knowledge while avoiding free-riding
- Asymmetric information

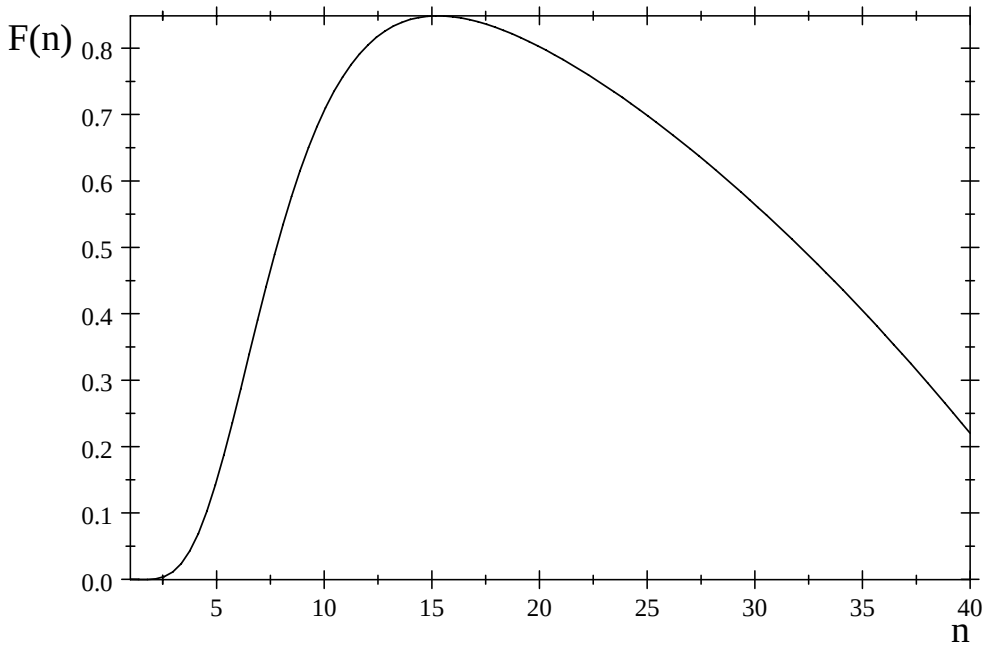
Simple representation

- The objective is to pool a set of w ideas
- Knowledge portfolio of i: $\{v_z(i);z=1,\ldots,w\}$, with $Pr\{v_z(i)=1\}=p$, independently $\forall z,i$
- Knowledge of the group of k agents in position z:
  - 0 if $v_z(i)=0$ $\forall z=1,\ldots,w$
  - 1 otherwise

Problem of the funding agency

- Create a consortium with largest chances of succeeding, given the individual cost c>0 of funding a relation and complete ignorance about agents
- Maximize w.r. to n

  $F(n)=(1-(1-p)^n)^w - c\times n(n-1)/2$
- c=0.001,p=0.3 and w=10: $n^*\sim 15$



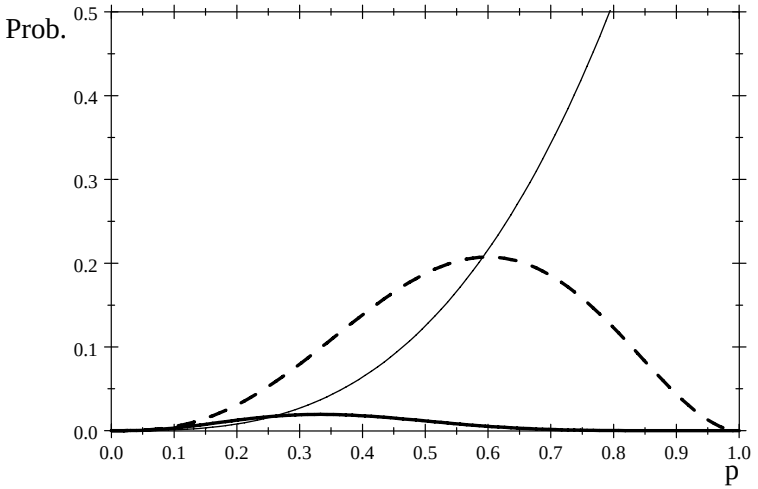
Strategic problem of the agents

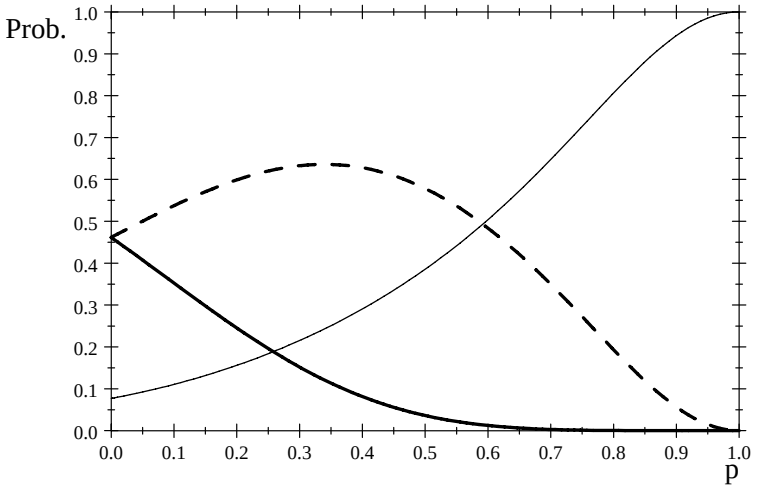
- Form an optimal-sized group given (some) knowledge of others
- No consortium larger than w can form
- A successful group of size k≤w forms if it pools enough knowledge and no sub-group does so

Org. 1	1 1 1 0 0	
Org. 2	1 0 1 0 1	No
Org. 3	0 0 1 0 1	
Org. 1	1 1 1 0 0	
Org. 2	1 0 1 0 1	No
Org. 4	0 1 1 1 0	
Org. 1	1 1 1 0 0	
Org. 2	1 0 1 0 1	Yes
Org. 5	0 0 1 1 0	

Example

- Denote $p_k(w)$ as Pr{a w-successful group of size k forms}
- Multinomial distributions involved
- $p_1(w)=p^w$
- $p_k(k)=k!\times p(1-p)^{k-1}$
- Ex: w=3, $p_1(3)$ thin, $p_2(3)$ dash, $p_3(3)$=thick





Interests of agency and agents differ...

- Agency interested in making sure enough knowledge is gathered
- Only a subset of the funded connections will be activated strategically
- The funded consortia are NOT cliques but a collection of smaller, interlocked cliques
- Strategic behavior on the organizations' side induces a "waste" for the agency

To be done…

- Multi-clique participation of agents and clique overlap
- Lower bound on transitivity (assuming lowest possible overlap)
- Contrast strategic clique distribution and the clique distribution induced by funding strategy
- Aligning interests?