Modeling Organizational Architecture

ESD 342 Class 20

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Learning objectives

- Appreciate some *additional range* of organizational research *including some simple models*
- Appreciate one organizational modeling approach relative to our growing understanding of the use of network models
- The emphasis is on ways of thinking/modeling- my management experience nonetheless informs my perspectives.
- I do not consider the very important issue of culture dealt with by JM

Lectures 19/20: Outline

- A brief tour of research on organizations
- The organizational design problem
  - Design variables, fundamental metrics and the bottom line
  - Processes
  - Properties
- Organizational Design/Architectural Analysis by selected, simple quantitative models and a "modeling framework".
  - Arrow; Sah and Stiglitz
    - Simple decision-making non-network models
  - Dodds, Watts and Sabel
    - Network model incorporating hierarchy as base
    - Information transfer for problem solving
    - Robustness assessments and identification of superior structure
    - Assessment of the contribution of DWS paper
- Possible future work and Conclusions

Modeling Organizational issues

After the introduction about organizational design in L19, several aspects of modeling that relate to **organizational structure** (or architecture) are now briefly explored:

- **Decision Theory**

- **Communication**

- Note that both of these are properties models and do not discuss or try to look at models for formation or evolution of actual organizational structure or the development of rules, etc.

Modeling Decision Making Processes

- Items to be covered (briefly)
  - An axiom concerning multiple decision makers (team or organizations) with multiple alternatives (Arrow)
  - Multiple decision makers and decision structures/organizations (Sah & Stiglitz)

Arrow's Impossibility Theorem

Individual	Preferences	A vs. B	B vs. C	A vs. C
I	A>B> C, A> C	A	B	A
II	B>C> A, B> A	B	B	C
III	C>A> B, C> B	A	C	C
Group preferences		A>B	B>C	C>A

Groups using ***majority rule*** are not necessarily transitive

Implications to Consensus Decisions, Cooperation and Organizations

- There is a real difficulty with ***intransitivity-almost certain in a large group with a large number of options-***
  - ***Large teams*** with ***multiple choices*** to rank are ***unproductive*** and should be avoided
  - Single person decision after all team input is heard is one possible alternative
  - Avoid group participation in ranking-just binary decisions or picking the best among a group of alternatives
  - Sum ranking votes on single alternatives (with an arbitrary tie-breaking rule and/or elimination of lowest total)
  - Facilitators (and/or decision-makers) can force a series of two way choices and eliminate any losers from further consideration

- ***Some organizational hierarchy*** is ***essential to effectiveness particularly if one wants to rank a long list of attributes***

Decision-making Structures and Organizational Implications

- Sah and Stiglitz work is foundation and expanded by Catalani and Clerico
- Models for different decision-making structures
  - Framework involves "approving (or not) *generalized* Projects"
  - Good (g) or bad (b) projects can be accepted (a) by individuals with probabilities p_1 and p_2

	“good” project or design change	**“bad” project or design change**
Accept	P_1 Ideal = 1.0	P_2 Ideal = 0.0 **Type II errors**
Reject	$1-p_1$ **Type I error**	$1-p_2$

Amount of Type I and II Errors for individual decision-maker

Decision-making Structures and Organizational Implications II

- Sah and Stiglitz work is foundation and expanded by Catalani and Clerico
- Models for different decision-making structures
  - Framework involves “approving (or not) Projects”
  - Good (g) or bad (b) projects can be accepted (a) by individuals with probabilities p_1 and p_2
  - for “polyarchy”-simultaneous judgment and any **one** person acceptance
    $P_a^g = p_1(2-p_1)$ and $P_a^b = p_2(2-p_2)$
  - for “hierarchy”-series of decisions with only approved considered at next level, $P_a^g = p_1^2$ and $P_a^b = p_2^2$

Decision-making Structures 2

- Hierarchy of n people rarely accepts anything bad (but often rejects good changes- type II increases)
  - “and gate” analogy and redundancy
- Polyarchy of n people rarely rejects anything good (but often accepts bad changes- type I increases)
  - “or gate” analogy

Generalization to "Committees"

- Can vary number of people on committee, n and number who must approve for acceptance, v. Optimum decision structure depends on :
  - Quality of deciders (p_1, p_2 for each person)
  - Quality of suggested changes (proportion good and good and bad impacts for suggested changes)
  - Decision Resource Constraints-how many evaluations, how much time to evaluate, how much effort to get information- and the value of good decisions in specific cases

Application of concepts

- Where might you apply polyarchy? Of committees?
- Where might you apply hierarchy? Of committees?
- Application depends upon relative costs of Type I and Type II errors in the domain of interest. If Type I errors have costs (I) >> costs (II) for Type II errors, polyarchy is appropriate

Application of concepts II

- Where might you apply polyarchy? Of committees
  - Choosing low-cost pilot programs with large opportunity, doctoral thesis acceptance of qualified candidate; hiring temporary agencies
  - It is more or less the way the United States runs it national research agenda (many federal agencies (DARPA, NSF, DOE etc... and some states .. each agency has a different selection process, different goals and different biases). Hierarchical firms are often uncomfortable with such a process
- Where might you apply hierarchy? Of committees?
  - High downside risk with some forgiveness for missing out on some positive results
  - Appropriate examples include product programs, manufacturing expansion, and most acquisitions but these are often reduced to non-independent single committee decisions
  - Essentially applied in tenure cases in universities, hiring in many firms and in some inappropriate places in industry and government.

Possible Implications to Organizational Structure for Decision-Making

- With Speed and Quality as the major constraints, committees of ***simultaneous reviewers*** have significant advantages.
- Use Hierarchy of Committees for High Risk (big downside only) Decisions-hiring, promoting to key jobs, new products
- Use polyarchy for small risk improvement ideas to be "piloted".
- If speed, correctness and efficiency are all important (as they usually are in a competitive situation)
  - ***expertise*** of decision-makers is ***critical***
  - ***alignment around definition of "goodness"***
- For organizations*,*
  - Expertise and alignment give meaning to the well-known advice: ***"make decisions at the right level"***
  - The extremely ***high value*** of expertise promotes ***learning,*** knowledge capture (and hiring) to a critical property of organizations undergoing moderate rates of change

Modeling Decision Making Processes

- Items covered (briefly)
  - An axiom concerning multiple decision makers (team or organizations) with multiple alternatives (Arrow)
  - Multiple decision makers and decision structures/organizations (Sah & Stiglitz)
- Items not covered
  - Garbage-can models (and other messes)
  - Repetitive Game Theory (ala Axelrod but being done by economists in business schools- a leading example is R. Gibbons at MIT), social and informal contracts etc.
  - Agent-based models (e.g. Carley)
- Modeling communication (necessary for decision making but not sufficient)- following slides

Dodds, Watts and Sabel Organizational Modeling for Communication Robustness

- The questions being addressed are:
  - Topologies (architectures) of total organization
  - Choice of topology for robust problem solving
- ***In order to develop a diverse set of organizational structures*** relative to communication, DWS develop an ***organizational structure generator***
  - Starts with **hierarchy with L levels** and branching ratio b (the formal organization)
  - m additional links are added ("informal organization" -***actually*** the method they use to develop diverse organizational structures- ***generalized hierarchies***)

Dodds, Watts and Sabel Organizational Model for Communication Robustness

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  - Randomly **adds m weighted links**
  - Probability of two nodes being linked, P(i,j) depends on depth of lowest common ancestor and also their own depths

Dodds, Watts and Sabel Network Organizational Model for Communication Robustness

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  - Starts with **hierarchy with L levels** and branching ratio b
  - Randomly **adds m weighted** links
  - Probability of two nodes being linked, P(i,j) depends on depth of lowest common ancestor and also their own depths
  - Organizational distance $$x_{ij} = (d_i^2 + d_j^2 - 2)^{\frac{1}{2}}$$
  - Overall $$P(i,j) \propto e^{\frac{-D_{ij}}{\lambda}} e^{\frac{-x_{ij}}{\zeta}}$$
  - Where $\lambda \; and \; \zeta$ are adjustable parameters allowing different organization structures to be generated by their network model. Varying **these parameters** leads to

Organization Categories from the DWS Model

- **RID** (Random Interdivisional) high ζ and low λ

Links are allocated **exclusively** between node that have as their lowest common superior the "top node". Links between random levels as homophily is unimportant

- **CP** (Core Periphery) low ζ and low λ

Links are added **primarily** between subordinates of the top node alone

- **LT** (Local Team) low ζ and high λ

Links are added **exclusively** between pairs of nodes that share the same immediate superior

- **MS** (Multiscale) intermediate ζ and λ

Connectivity at all levels but the density of connections is **greater the higher** one goes in the hierarchy

- R (Random) the extra m links are added to the hierarchy randomly (not shown)

Processes Used in the Organization Model Study in DWS

- The study basically models ***information exchange*** with a stated purpose to study distributed **"Problem Solving**" (decision-making?). Model assumptions:
  - Information passing based on local + "pseudo-global" knowledge (higher nodes know less and less about more)
  - The task environment is characterized by a rate of information exchange, μ and variable amounts of ***problem decomposability*** weighted by the social distance, x_{ij} and the "decomposability" parameter ξ with

    the weight, S, related to distance ξ and ξ as

$$s = e^{-\frac{x_{ij}}{\xi}}$$

As ξ becomes large, problems that are **not dependent** on organizational distance become important in the organization. This is a useful modeling device

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Properties of the Organizational Models studied by DWS

- Robustness
  - Congestion robustness: the capacity to protect individual nodes from congestion (overload).
  - Connectivity robustness:
  - Ultrarobustness:

Properties of the Organizational Models studied by DWS

- Robustness
  - Congestion robustness: the capacity to protect individual nodes from congestion (overload). **This is accomplished by the structure giving the minimum of the maximum congestion centrality**
  - Connectivity robustness:
  - Ultrarobustness:
- Results

Properties of the Organizational Models studied by DWS

- Robustness
  - Congestion robustness: the capacity to protect individual nodes from congestion (overload).
    - Better structure results in **Minimal congestion centrality and this is shown for MS (only CP is competitive but *not as reliable*)**

Properties of the Organizational Models studied by DWS

- Robustness
  - Congestion robustness: the capacity to protect individual nodes from congestion (overload).
    - Better structure results in Minimal congestion centrality and this is shown for MS (only CP is competitive but *not as reliable*)
    - **All structures are OK with decomposable tasks** (excepting the pure hierarchy?) **but MS and CP are best when larger scale interactions are significant.**

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  - Congestion robustness: the capacity to protect individual nodes from congestion (overload).
    - Minimal congestion centrality is better structure and this is shown for MS (only CP is competitive but not as reliable)
    - All structures are OK with decomposable tasks but MS and CP are best when larger scale interactions are key.
    - **Maximum uncongested size is for MS (CP again second)**

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    - Minimal congestion centrality is better structure and this is shown for MS
    - All structures are OK with decomposable tasks but MS and CP are best when larger scale interactions are key.
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  - Connectivity robustness: The capacity to remain connected even when individual failures do occur.

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  - Congestion robustness: the capacity to protect individual nodes from congestion (overload).
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    - All structures are OK with decomposable tasks but MS and CP are best when larger scale interactions are key.
    - Maximum uncongested size is for MS
  - Connectivity robustness: The capacity to remain connected even when individual failures do occur.
    - **Random best for targeted attack but MS as good until 4 of the 6 hierarchy levels are removed (LT and CP are significantly worse)**

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  - **Ultrarobustness**: A simultaneous capacity to exhibit superior Congestion and Connectivity robustness

Properties of the Organizational Models studied by DWS

- Robustness
  - Congestion robustness: the capacity to protect individual nodes from congestion (overload).
    - Minimal congestion centrality is better structure and this is shown for **MS**
    - All structures are OK with decomposable tasks but **MS** and CP are best when larger scale interactions are key.
    - Maximum uncongested size is for **MS**
  - Connectivity robustness: The capacity to remain connected even when individual failures do occur.
    - Random best for targeted attack but **MS** as good
  - **Ultrarobustness**: A simultaneous capacity to exhibit superior Congestion and Connectivity robustness—clearly **MS** fits this definition by their measures and simulation

Ultra robustness

- Dodds, Watts and Sabel argue that one of their 5 structures is Ultrarobust.
  - The “Multiscale” Structure has superior (or at least near best) robustness and reliability to a variety of failure modes
    - Congestion
    - Node Failure
    - Link disconnection
- Reactions ?

- If one compares the difficulty of forming different kinds of links leading to MS, LT, CP etc. (costs or tradeoffs with other processes or properties), would MS still be always superior?

Ultra robustness II

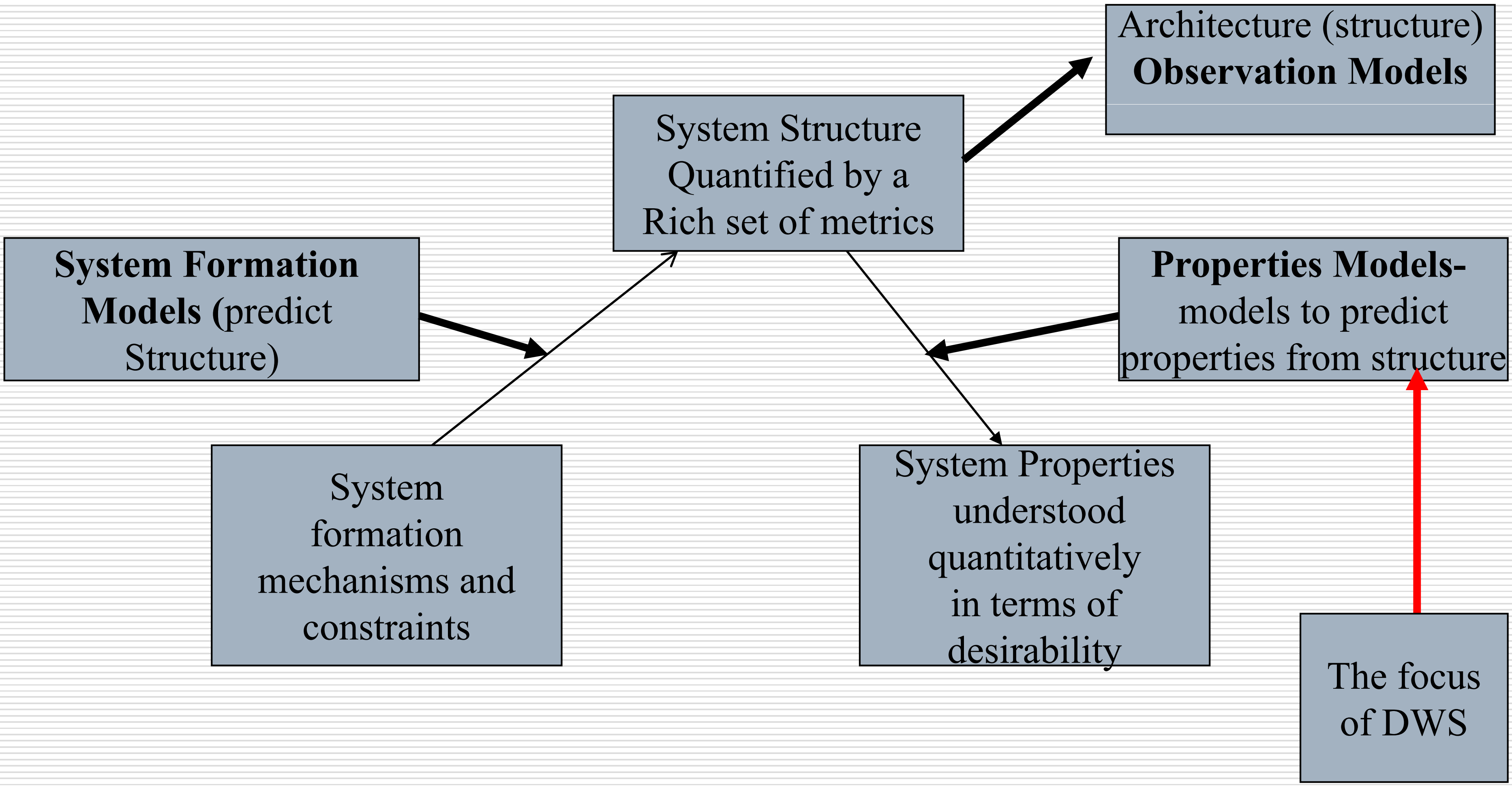
- Dodds, Watts and Sabel argue that one of their 5 structure is Ultrarobust.
  - The “Multiscale” Structure has superior (or at least near best) robustness and reliability to a variety of failure modes
    - Congestion
    - Node Failure
    - Link disconnection
- Reactions and link cost tradeoff.

- **How do we assess the DWS work?**

Assessment of Network model by DWS

- The model is not about the mechanism of formation of organizations but only about the structure-property relationship. It does not add to our knowledge of formation constraints or models of this kind

Schematic of Engineering System Model Types within a Framework



Network Model types of interest

- **Models/algorithms used to "observe" systems**
  - Calculation of structural metrics
  - Communities, motifs, coarse-graining, hierarchy
- **Models for predicting/explaining Structure**
  - Models for formation/growth processes of systems
  - Most network models such as random, small-world etc. implicitly fall in this category
  - Cumulative advantage, preferential attachment, bipartite community formation, heuristic optimization relative to **constraints**, hierarchy (or heuristics) + random
- **Models for predicting/explaining properties of systems**
  - Predicting properties from structure – architecture
    - Flexibility, robustness, performance of functions
  - Operational processes or functions
    - Communication, problem solving, decision-making, learning
    - Search and navigation
    - Failures and cascades, epidemics

Lectures 4, 6,7, 11 and 14

Sociology

Lectures 10, 13, 17, 18

Sociology, Engineering CS & OR

Lectures 8, 15, 16, and 19

OR

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Assessment of Network model by DWS II

- The model is not about the mechanism of formation of organizations but only about the structure-property relationship. It does not add to our knowledge of formation constraints or models of this kind
- The random weighted additions to a hierarchy was a creative device to simulate different kinds of organizations (5 broad types but continuous variation among the types is possible with tuning of ζ and λ
- They also introduce a way to simulate the interdependence of tasks (local decomposability)
- Although they only modeled communication, this is relatively important in a number of other properties and thus can argued to be fundamental
- The paper **does not** introduce totally new fundamental insights about organizational design. What is its potential practical significance?

Practice Assessment of DWS Paper

- The paper is really only about trying to derive a "structure-property" relationship and does not cover realistic structure formation. They do not consider the organizational structure generator as a model of structure formation nor should anyone else.
- The paper combines ideas from sociology and OR (as well as statistical physics) which is an approach Watts pursued and I applaud
- There are two issues to consider when assessing whether this model may have practical relevance:
  - Do real organizations have to deal with (a non-significant number of) problems whose solution requires participation by actors at large organizational distances (problems which are not locally decomposable) ?
  - How would one realistically arrive at the hybrid structures that DWS identify as best in dealing with such problems?
- I will consider these issues largely from my practical experience

Organizational Problem Decomposition

- In large functionally oriented firms, typical major organizations might include (for large firms 7 or so levels) sub-hierarchies for the following functions.

Manu-facturing	Sales & Marketing	Product Develop	Finance	HR	etc

- What problems might exist that require input across large organizational distances ?
- What are some possible solutions?

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Organizational Problem Decomposition II

- In large functionally oriented firms, typical major organizations would include (for large firms 7 or so level) sub- hierarchies for the following functions.

Manu-facturing	Sales & Marketing	Product Develop	Finance	HR	etc

- One solution is to organize by sectors, markets, location etc. to become essentially smaller. In small firms, the functional organizations (and thus organizational distance through the hierarchy) would be smaller.
- However, if large firms can be decomposed to a set of non-interacting small firms then they will generally be more successful breaking themselves up. Pure conglomerates do not work. However, one can still strive to organize to minimize the "large-organizational-distance" problems and this is what is often implicitly if not explicitly considered in most attempts at reorganization.

Possible Organizational Solutions to non-decomposable problems I

- Have highest levels totally absorb knowledge below them in hierarchy
- Become a small firm or a group of small firms
- Result: Loss of efficiencies of scale and reason for existence of large firms
- Re-organize so the nasty problems come into more closely related organizational entities.
- Result: some success but also *organizational cyclic instability*
- Flatten the organization and rely on “Local Teams”
- Result: manager-coordination overload, how does one person with 15 direct reports know that all 210 relations among his or her reports are being maintained? Multiple levels at this branching ratio are particularly vulnerable.

Possible Organizational Solutions to non-decomposable problems II

- Some widely used approaches in large firms
- *Co-location* (for example of personnel or finance people with unit management) as a means to strengthen communication while maintaining organizational reporting through functional hierarchy.
- *Cohort* strengthening at large organizational distance ("old" IBM, Japan, others)
- Training for and *rewarding cross-organizational knowledge* and contacts (Japan)
- Matrix Management, co-location and rewards structure balancing can work but takes significant coordination efforts
- Importantly, the DWS paper shows that whatever approaches are taken, they should be a little stronger as one goes up the hierarchy and a little stronger with shorter organizational distances (**MS is best).** Many of the widely used approaches are actually stronger at lower levels.

Possible Future Research and Applications of Organizational Network Models

1. Observation of Collaborative Problem Solving in Large Organizations
   - Is task decomposability observable and different in different organizations?
   - What communication paths are actually followed in problem solving of non-locally-decomposable problems in selected J/G and US firms?

2. Observation of Social Networks within organizational hierarchies
   - Identification of important characteristics that determine such networks (age, hiring group, educational institution, neighborhood, functional specialty, co-workers, etc.)
   - Possible role/utility in organizational architecture and effectiveness
   - Management rules and practices that affect these social networks including rewards and incentives

Possible Future Research and Applications of Organizational Network Models b.

- 3. Modeling of the cost of lateral links
  - based upon effort to forge, impact on "Unity of Command" and accountability
  - Trade-offs with communication and problem-solving at different levels of task decomposability
- 4. Simulation of knowledge capture and learning processes
  - Accountability for local and global learning
  - Observations in a variety of global and local organizations
- 5. Formal vs. informal lateral links
  - How well do "idealized" matrix organizations compare (robustness simulation) to the ideal organizational types depicted by DWS?
  - How well do specific matrix organizations compare (actual observations as the basis for simulation comparison) to the ideal organizations depicted by DWS?

Possible Future Research and Applications of Organizational Network Models c.

- 6. Observe link formation costs in various existing firms
- 7. Extend the model to simulate decision-making with different decision-making structures (Sah and Stiglitz)
- 8. Extend the model (or build a new one) to simulate **flexibility**
  - Changes in problem-solving intensity
  - Changes in task decomposability
  - Changes in knowledge needed to survive
  - Changes in leadership style needed
- 9. Extend the model to allow the communications to be between intelligent agents (use of ABM)
  - Give agents known **social cognition** patterns from cognitive psychology such as “Machiavellian intelligence”, cooperative intelligence, etc.

Overview Assessment of DWS Paper III

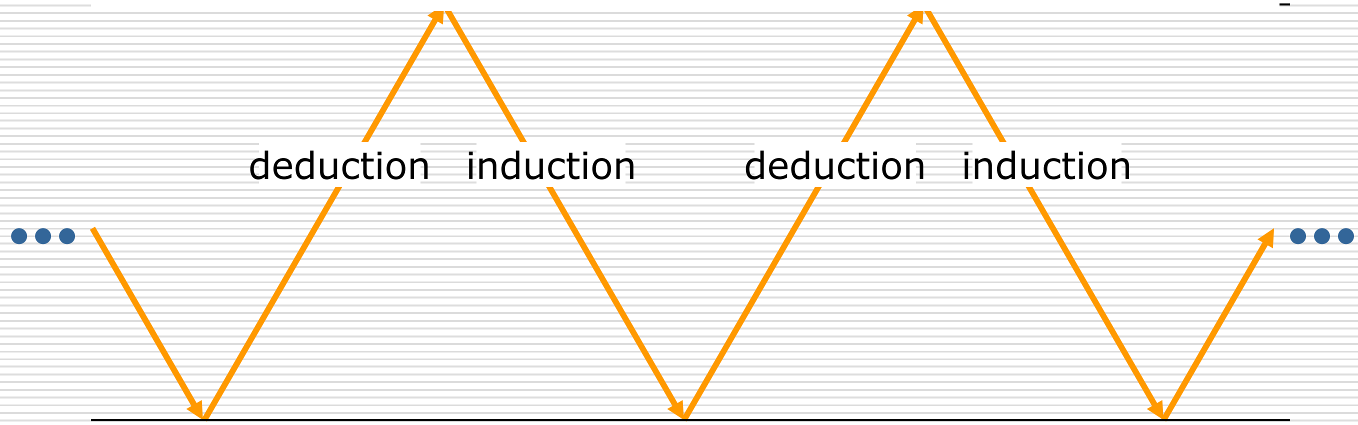
- The paper is really only about trying to derive a "structure-property" relationship and does not cover realistic structure formation. They do not consider the organizational structure generator as a model of structure formation nor should anyone else.
- The paper combines ideas from sociology and OR (as well as statistical physics) which is an approach Watts pursues and I applaud
- The paper gives some practically useful direction to organizational changes.
- The structure generator and the problem decomposability approaches suggest a number of potentially fruitful future research directions (where actual observations of organizations are also pursued).

Comparative Progress in Understanding and performance: CLM objective/subjective observations

- 1940-2000 improvement
  - Energy transformation systems (x 10-20)
  - Information processing systems (x 10^{12} to 10^{15})
  - Cosmology (x 30-100)
  - Paleontology (x 50)
  - Organizational theory and practice (x ***1.1 to 2***)
  - Small-scale electro-mechanical systems (x10-100)
  - Economic systems (x ***1.1 to 2***)
  - Complex large-scale socio-technological systems (?)
- If these improvement ratios are close to factual, why?
- One hypothesis is the lack of cumulative learning possibly due to **difficulty of observation** (privacy etc. concerns) and thus limited cyclic learning

The Iterative Learning Process

Objectively obtained quantitative data (facts, phenomena)



hypothesis (model, theory that can be disproved)

As this process matures,
what new can the models accomplish?

The major accomplishment will be the rapid facilitation of a transition to engineering (vs. craft approaches) for the design of complex social/ technological systems

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