

**Surviving the Short Run:  
Ambiguity, Information Exchange, and Robustness of Organizations.**

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As Bob spells out quite lucidly, when economists think about the internal structure of organizations, they typically concentrate on incentives, the aim being to design the rules of the game in such away that leads to efficient (i.e. optimal, in some sense) and fair (i.e. equitably shared) outcomes. Sociologists—at least those in the so-called “new institutionalist” school (Powell and DiMaggio, 1991)—have also focused on incentives, but from the perspective of the institutions rather than the individuals within them. That is, organizations (whether business firms or public bureaucracies) tend to operate according to accepted norms and conventions, regardless of whether the resulting outcomes are either efficient or fair. According to this view, institutions *are* the rules of the game, organizations have strong incentives to adopt the same rules as comparable organizations, and the interesting question is how certain rules become standard across whole classes of organizations. The standard economic and sociological perspectives therefore differ both in their unit of analysis (individuals vs. organizations) and also in their spirit of analysis (utility maximization vs. historical dependency and inertia), but

originate from the same basic understanding that actions are determined according to the incentive structures within which actors find themselves.

Without denying the importance of incentives, I would like to focus on a different aspect of organizational performance that has received far less attention, both in economics and in sociology: that of *capability*. While the wrong incentives can subvert the best laid plans, there are at least some important circumstances (e.g. catastrophe recovery, technological innovations that render current best practice obsolete) in which everyone involved has a strong incentive to solve a particular problem—the real difficulty is whether or not they are capable (individually or collectively) of doing so. The spirit of this approach is therefore very much in line with Marshak and Radner's team theory (Marshak and Radner 1972), and even more so the recent literature on decentralized information processing (Radner 1993, Bolton and Dewatripont 1994, and Van Zandt 1999). But it differs in one very important respect, to which Bob has alluded in his discussion of Jim March's work (Gibbons 2003): whereas in team theory and decentralized information processing, the available information is always well defined, and the individual objectives are always clear, in real organizations decision makers are frequently unsure both about what they don't know, and even what they are supposed to be doing. Another way to say this is that while the organizations of economic theory have to deal with limited information and uncertainty, real organizations have to cope with what we might call *ambiguity*.

## **Ambiguity in decentralized decision making**

The essential idea of ambiguity is that not only do firms face uncertainty over which particular task is required of them by some external environment—they are uncertain precisely how they should go about completing *any* task, or what the corresponding criteria for success might be. Implicit in almost all theories of the firm, is the assumption that even if the accomplishment of a particular task is a decentralized process, requiring the simultaneous, coordinated efforts of many specialized workers, its design is somehow centralized, imposed in a sense “from above”. What I want to contend is this assumption is a convenient fiction. In reality, when a firm embarks on a major new project, *the people involved don’t actually know how they are going to do it*. In fast moving industries from fashion to automobiles, designs are rarely final before the production itself has commenced, and performance benchmarks evolve along with the project. Furthermore, no one person’s role in the overall scheme is ever precisely specified in advance. Rather, each person starts with a general notion of what is required of them, and refines that notion only by interacting with other problem solvers (who, of course, are doing the same). The true ambiguity of modern business processes, in other words, is not just that the environment necessitates continual redesign of the production process, but that *design itself*, along with innovation and trouble shooting, are also tasks to be performed, not only at the same time as the task of production, but in the same decentralized fashion.

When change occurs slowly and the future is predictable—then ambiguity is suppressed, allowing the design/learning and production phases to be effectively separated. In a sufficiently slow moving, certain world, individuals participating in even the most complex tasks have

sufficient time to pass through their learning phase, and settle into the business of routine production. The effect is that the division of labor among the individuals comprising a firm mirrors the hierarchical partitioning of the task itself—hence the persistent hierarchical image of firms. But in environments that subject firms to a rapid rate of change (required, say, for competitive performance), complex tasks must be continuously repartitioned, and available human capital continuously reallocated. And absent some all-seeing, all-knowing supervisor, this repartitioning problem must be solved by the same individuals who still have to perform the task of production. The result, in a successful firm, is a continual swirl of problem solving activity, and ever-shifting interactions between the problem solvers, each of whom has information relevant to the solution of a particular problem but none of whom knows enough to act in isolation. Nor does any one person know precisely who knows what—hence problem solving is a matter not just of forming the necessary combination of resources (as suggested, say, by theories of flexible specialization (Piore and Sabel, 1984)), but of discovering and linking to those resources in the first place.

### **Information exchange and robustness in organizational networks**

From a modeling perspective, ambiguity is a problematic feature both of catastrophe recovery and also continual innovation in the face of rapidly changing environments. Unlike uncertainty, which one can think of as random draws from a known distribution, ambiguity reflects what decision makers do not know. In that sense, it sounds like what economists call “Knightian uncertainty” (after Frank Knight), but it is even more general, capturing the uncertainty that

individuals have about their own roles in a distributed problem solving activity in addition to what they don't know about the world. Deriving as it does from a multiplicity of non-independent sources (uncertainty about your role is different from uncertainty about the environment, but is not independent of it), ambiguity is, by nature, hard to parameterize, and therefore hard to model.

One approach that gets around these difficulties (albeit at the cost of some fidelity to the problem at hand) is to focus not on the causes of ambiguity, but on its *effects*. When solving complex problems in ambiguous environments, individuals compensate for their limited knowledge of the interdependencies between their various tasks, and uncertainty about the future by exchanging information—knowledge, advice, expertise, and resources—with other problem solvers within the same organization. Ambiguity, in other words, necessitates communication between individuals whose tasks are mutually dependent, in the sense that one possesses information or resources relevant to the other. And when the environment is rapidly changing, so too are the problems—hence intense communication becomes an ongoing necessity.

In this view of organizations, the problem of coping with chronic ambiguity is therefore equivalent to the problem of distributed communication. Firms that are bad at facilitating distributed communications are bad at solving problems, and therefore bad at handling uncertainty and change. We can now think about organizations as *networks of information processors*, where the goal of a network is to handle large volumes of information transmission efficiently, but without overloading its individual processors. On the surface, this approach sounds very much like that adopted by Radner and others in the literature on decentralized

information processing. Both approaches model firms as networks of information processors, each of which has limited processing capabilities, hence limited ability to supervise others (i.e. a finite span of control). But individuals in problem solving organizations must not only supervise their subordinates—they must coordinate their activities as well. In this (admittedly simplistic) view of the world, we can think of two kinds of information processing—production-related processing (the kind imagined by Radner et al.), and coordination-related processing—where workers specialize in the former, and managers in the latter.

A *robust* information processing firm is therefore one that distributes not only the production load, but also the burden of information exchange (i.e. coordination) as evenly as possible—thus maximizing the volume of information that can be processed without suffering breakdowns. And hierarchies, although they make highly efficient *distribution* networks, are extremely poor at information exchange. Imagine, for example, an organization in which every activity must be monitored, coordinated, and approved by formal chain of command. In theory, such strictly hierarchical organizations do exist, the army being perhaps the quintessential example. But in practice, as soon any ambiguity enters the picture, the chain of command is immediately saturated by the demands of processing endless requests for information and guidance. In a pure hierarchy, each request must be passed from its source (the person with the question) up the chain of command until it reaches some *lowest common ancestor* node, at which point it can be relayed down to the target (the person who has the relevant information or resources). The successful transmission of the request depends on every node in the chain performing its information processing duty, but not every node is burdened equally. The higher up the chain of command a node sits, the more indirect subordinates (source-target pairs) it has, hence the

greater its information processing burden. In a pure hierarchy operating in an ambiguous environment, the burden of information processing is so unevenly distributed, that unless something is done to accommodate it, the hierarchy will almost certainly fail.

An obvious approach is to bypass overtaxed nodes by creating some kind of shortcut, thus redirecting the congestion through the extra network ties. Building and maintain new ties, however, leaves individuals less time for production—hence both congestion and ties are costly. What is the most efficient way to do balance these two kinds of costs? According to some recent work (Dodds, Watts, and Sabel 2003), the answer depends on the kind of environment in which an organization is trying to survive. When the kind of problem solving necessitated by the environment requires only individuals who are close to each other in the formal hierarchy to exchange information, a structure that resembles a hybrid of Marshak and Radner's team theory and Radner's information processing hierarchies emerges: individuals who share the same immediate superior interact intensely, but individuals who are "organizationally distant" operate independently. At the other extreme, when the nature of the problem is so ill-defined or else so poorly matched to the organization's formal structure as to render it effectively irrelevant, information processing is concentrated almost exclusively in the upper echelons of the organization (the "core") while the lower levels (the "periphery") remain more or less pure hierarchies.

Finally, for environments that fall somewhere in-between these two extremes, the best performing class of organizational networks appears to be something called a "multiscale" network, in which most horizontal communication occurs in the core, but now one sees (a) a

significant amount of it occurring in the periphery as well, and (b) a significant amount of vertical communication between the core and the periphery. Multiscale networks have a number of features that make them attractive objects for further analysis. 1) Over a wide range of environmental conditions, multiscale networks minimize the likelihood of congestion related failure. 2) Even in the event that failures occur anyway, multiscale networks remain extremely resilient to disconnection. 3) No other class of organizational networks that we have studied exhibits both *congestion-* and *connectivity-robustness*: core-periphery networks handle congestion well but are easily disconnected; and team-based networks are bad in both senses, except in very special cases (i.e. the case mentioned above), when they perform very well. 4) multiscale networks achieve their robustness efficiently in the sense that most of the attendant benefits are generated by a relatively small number of additional links. 5) The superior robustness of multiscale networks also conveys better scaling properties than other classes of networks in that for a given level of environmental volatility, multiscale networks can grow to larger sizes before suffering failure. 6) The properties of multiscale networks are themselves robust in the sense that they are insensitive to small (or even quite large) changes in the network parameters. Networks resembling multiscale networks may therefore be expected to arise in real world business firms and bureaucracies. While empirical evidence supporting or refuting this last prediction is currently hard to come by, and therefore it deserves to be taken with a grain of salt, some recently documented accounts of firms surviving serious and unanticipated failures appear to lend qualitative support to the argument.



## **Surviving the short run—Information exchange in catastrophe recovery.**

In 1997, the Toyota group suffered what seemed like a catastrophic failure in their production system, when a key factory—the sole source of a particular kind of valve essential to the braking systems of all Toyota vehicles—burned to the ground overnight. On account of their much vaunted just-in-time inventory system, the company maintained only three days of stock, while a new factory would take six months to build. In the meantime Toyota's production of over 15,000 cars a day would grind to an absolute halt. This was the kind of disaster with the potential to wreck not just the company itself, but the entire Japanese automotive industry. Clearly then, both Toyota, along with the more than 200 other companies that are members of the extended Toyota group, had ample incentives to find a solution. The real question was: how? How does one rapidly regenerate large quantities of a complex component, in several different varieties, without any specialized tools, gauges, and manufacturing lines (almost all of which were lost); with barely any relevant experience (the company that made them was highly specialized); with very little direction either from Toyota or Aisin Seiki (the factory owner); and without compromising any of their other production tasks? Actually it's not clear that one could do it at all, nor was it clear at the time to any of the senior managers of the Toyota group. After all, if this were the kind of disaster that their risk management executives had considered, they would never have left themselves vulnerable to it in the first place.

Nevertheless, they succeeded, but not in the way one might have expected. As documented by Toshihiro Nishiguchi and Alexandre Beaudet (Nishiguchi and Beaudet, 1999), rather than relying on the guidance and coordination of an inspired leader, the response was a bewildering

display of truly decentralized problem solving: more than 200 companies reorganized themselves and each other to develop at least six entirely different production processes, each using different tools, different engineering approaches, and different organizational arrangements. Virtually every aspect of the recovery effort had to be designed and executed on the fly, with engineers and managers sharing their successes and failures alike across departmental boundaries, and even between firms that in normal times would be direct competitors. Within three days, production of the critical valves was in full swing, and within a week, production levels had regained their pre-disaster levels. Had either Toyota or Aisin attempted to centralize the recovery effort, it seems clear that it could not have succeeded—even as it was, Aisin was completely overwhelmed. The key to the recovery was that both design and production could proceed simultaneously and in a highly coordinated manner across many firms, without any one manager or even any single firm having to do the coordinating. Yet the kind of distributed coordination this activity required had not been consciously designed, nor could it have been developed in the drastically short time frame required. The surprise was that the capability appeared to have been there all along, lying dormant in the network of informal relations that had been built up between the firms via years of cooperation and information sharing over routine problem solving tasks. No-one could have predicted precisely how this network would come in handy for this particular problem, but they didn't need to—by giving individual workers fast access to information and resources as they discovered their need for them, the network did its job anyway.

Much the same kind of recovery happened in lower Manhattan in the days after September 11 2001 (Kelly and Stark, 2002; Beunza and Stark, 2003). With much of the World Trade Center in rubble and several other nearby buildings closed indefinitely, nearly 100,000 workers had no

place to go on September 12. In addition to the unprecedented human tragedy of lost friends and colleagues, dozens of firms had to cope with the sudden disappearance of their offices along with much of their hardware, data, and in some cases, critical members of their leadership teams. Yet somehow they survived. Even more dramatically, almost all of them were back in business within a week: an achievement that even their own risk management executives viewed with amazement. Once again, the secret to their success was not so much that any individual had anticipated the need to build up emergency problem solving capacities or was able to design and implement these capacities in response to the particular disaster that struck. Rather, the collective ability of firms and individuals alike to react quickly and flexibly was a result of unintentional capabilities, based on informal and often accidental networks that they had developed over years of socializing together and collaborating on unrelated and routine—even trivial—problems. When talking about their recovery efforts, manager after manager referred, often with puzzlement and no small sense of wonder, to the importance of informal relationships and the personal knowledge and understanding that these relationships had engendered.

Perhaps the most striking example of informal knowledge resolving what would appear to be a purely technical problem occurred in a particular company that lost all its personnel associated with maintaining the data storage systems. The data itself had been preserved in remote backup servers, but could not be retrieved because not one person who knew the passwords had survived. How they survived this potentially devastating (and completely unforeseeable) combination of circumstances was astonishing, not because it required any technical wizardry or imposing leadership, but because it did not. Rather than calling in a team of cryptography experts, the remaining employees gathered together, and in what must have been an unbearably

wrenching session, recalled everything they knew about their colleagues: the names of their children; where they went on holidays; what foods they liked; even their personal idiosyncrasies. And they managed to guess the passwords. The knowledge of seemingly trivial factoids about a coworker, gleaned from company picnics, or around the water cooler, is not the sort of data one can feed into a risk management algorithm, or even collate into a database—in fact, it is so banal that no-one would have thought to record it, even if they could. Yet it turned out to be the single most critical component in that firm's stunning return to trading only three days after the towers fell.

How the serendipitous networks described in the accounts of the Toyota-Aisin crisis and the recovery effort in Lower Manhattan came into existence, and whether or not they look like, or function like, the multiscale networks described above, are issues that remain unresolved. Nevertheless these accounts do suggest that in the short run: (a) capabilities may be more relevant than incentives; (b) organizational robustness may be at least as important as efficiency; (c) environmental ambiguity necessitates distributed coordination; (d) distributed coordination may be more critical to robustness than distributed processing; and (e) informal networks, both horizontal and vertical, appear critical to distributed coordination. At the very least I would advocate that these issues are worthy of more attention from economists than they have received; and that being the case, I would further suggest that a modeling approach is required in which information exchange and organizational robustness are modeled explicitly.

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