Complexity, Genuine Uncertainty, and the Economics of Organization

by
Richard N. Langlois
and
Michael J. Everett

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Introduction.

Economists pay more attention today than ever before to the problems the economic agent faces because of the complexity of the world and the unknowability of the future. Indeed, some see the economic problem as having to do precisely with these phenomena. But many fail to see an important difference between complexity and uncertainty,[1] and instead choose to collapse the two into one.[2] We argue that the distinction is crucial. Merging complexity and uncertainty blurs important differences in the types of organizations and market structures that arises to meet these two problems of knowledge.

1 For instance, Herbert Simon seems to believe that humans could actually conquer complexity if they were not bounded by their rationality, that is, if they possessed the computational ability to handle the complexity (Langlois 1990). Brian Loasby (1976, 1989) is one of the few economists to recognize a difference; in fact, Loasby (1986) reaches the many of the same organizational conclusions as we do here, albeit by a somewhat different route.

2 Thus we see an economist like Williamson (1985, pp. 56-61) describing uncertainty in terms of bounded rationality and the complexity of the contracting process.

Since the work of Coase (1937), there has developed a body of literature — called transaction-cost economics — that recognizes the importance of imperfect knowledge to the explanation of organizational forms. Transaction-cost economics explains vertical integration by assuming *boundedly rationality*, that is, a limited capacity for dealing with complexity, and *opportunism*, which Williamson (1975) describes as self-interest seeking with guile. The basic story is as follows. Contracts between cooperating inputs or stages of production will be feasible when "holdup" by one of the inputs or stages is not possible. But when the environment is complex, and a cooperating input or stage is crucial to production, the preferred organizational mode is for the stages to be coordinated under the *aegis* of the firm instead of through contracts. Thus, governance costs dictate the extent to which production is organized intrafirm or interfirm. When parties in a contract are boundedly rational, incomplete contracts result if the environment is complex. And when contracts are incomplete, the residual rights — those rights not accounted for in the contract— are given as rights of control over an asset. Residual rights of control over more than one stage of production constitutes vertical integration. Thus, the boundary of the firm — the extent of vertical integration — is linked to the complexity of the environment.[3]

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[3] There is also another strand of thought in the transaction cost literature, which we may call the measurement-cost view, as opposed to the asset-specificity view expounded above. This theory too relies upon complexity to explain the boundary of the firm. When indivisibilities are present in the technology of production, then to assure performance, a residual claimant arises to accept responsibility and hire the cooperating inputs (or team members, as Alchian and Demsetz (1972) call them). Notice that it is a complex production technology that gives rise to the

The problem with this conventional story is that it fails to take into account the distinction between uncertainty and complexity. These are two different problems, which organizations handle in different ways. In this paper we develop the distinction between (genuine) uncertainty and complexity and use it as the basis of an argument about the economic roles of firm and market. That argument, in brief, is as follows.

Large firms may or may not possess the superior capabilities in dealing with complexity, such as solving operations-research problems or managing high-volume throughput. The important role of the vertically integrated organization is not managing (static) complexity but of effecting change. Like the human organism, the strategic corporation reflects increased "cephalization," that is to say, increased computational ability in a central directing unit. By separating strategic decision-making from day-to-day decision-making, the modern corporation is able to look ahead and to plan for change. More importantly, the unified asset-holding of a firm allows it to redeploy assets with lower transaction costs than a network of independently owned assets would incur.

But, as with the human mind, an organization conceived of as a central directing unit has its limitations. Like a body of scientists whose research agenda consists in explaining and furthering theories within a known paradigm, we argue,

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inability to measure individual contributions. If one possessed unbounded rationality, this problem would soon disappear, since computational abilities would be limitless and measurement of the inputs' contributions would be costless.

the large organization works best within a framework of understanding whose broad outlines are well known. To the extent that complexity arises within such a known framework, the large organization may be well equipped to handle it.

By contrast, genuine uncertainty may be best dealt with by a large number of small organizations who can try out different paths. This genuine uncertainty calls for system-wide trial-and-error learning. To put it another way, genuine uncertainty is best dealt with by entrepreneurs capable of imaginative leaps when the structure of the problem is unknown. Variation among entrepreneurs will be greatest in an environment in which many courses are explored and alternatives tried. The larger the number of potential entrepreneurs, the greater the likelihood of creating niches.[4] Large organizations with their culture, i.e., their paradigm, already established are far less responsive to exploring new and unknown avenues.[5]

Complexity and uncertainty.

The guru of complexity and bounded rationality, Herbert Simon (1961), describes economic actors as being "intendedly rational but only limitedly so." Individuals who act in a complicated world do not possess the computational skills necessary to

4 We may liken this to the inventions produced among different cultures throughout history. All the cultures together we may take as the number of organisms. Eliminate one or more of these cultures, for instance the Chinese of the middle ages, and we find that many useful inventions would have arrived much later (or not at all). The more cultures, the greater the rate at which inventions will arise.

process all the information provided by the environment, both external and internal; such individuals, therefore, must "*satisfice* because they have not the wits to maximize" (Simon 1957, emphasis original). Given sufficient computational powers or a stalwart expert system, however, Simon's actors are able to decide rationally in a very complex world. Simon "often writes as if there really does exist a well-defined optimization problem out there, and the solution to that problem is the benchmark of rationality; the only difficulty is computational complexity" (Langlois 1986b, p. 227).[6]

People cope with complexity by devising heuristics and simple procedures that achieve satisfactory (or satisficing), though not optimal, guides to action and decision making. Procedural rationality, another concept of Simon's (1976, 1978a, 1978b), arises because humans do use procedures to simplify action and decision-making in complex environments when their computational capabilities are limited. Procedural rationality is, as Hargreaves Heap (1989 p. 118) says, a "second-best optimising" that is "subject to the constraint of limited computational capacity."[7]

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5 Again we may liken this to culture. But instead of having many different cultures we have only one large culture. Niche seeking will be diminished since all individuals operate in then same environment.

6 Loasby (1989, p. 143) also recognizes this fact about Simon, who, he says, "does sometimes give the impression that we do live in a fully defined system, if only we had the wits to understand it."

7 For a discussion of the heuristics used in judgments made in the face of complex environments, see for instance, Tversky and Kahneman (1982). They show that these heuristics are not necessarily the best for the making the decision, but admit that they are "highly economical and usually effective." These suboptimal rules result because of human's limited computational abilities, that is, they do not fully understand the nature of the biases to which they are prone.

Like institutions, these procedures are mechanisms to reduce the entropy of the environment.[8] And like institutions, these procedures are constructed to work within a certain culture or framework. We will say more about these procedures in the next section.

Limits to cognition may not mean merely complexity within a known framework but also lack of knowledge about the framework itself (Loasby 1976; Littlechild 1986). Genuine uncertainty has been variously defined, but the common theme runs throughout. Loasby (1976, p. 9) asserts that "when someone says he is uncertain, what he usually means is not just that he doesn't know the chances of various outcomes, but that he doesn't know what outcomes are possible. He may well be far from sure even of the structure of the problem he faces." Loasby calls this partial ignorance. Chapter 3 distinguished between parametric and structural uncertainty. Parametric uncertainty is uncertainty of the conventional statistical sort — uncertainty about which of several known states of the world will prevail. By contrast, structural uncertainty exists when the outcomes themselves are unknown.

Other writers, notably Shackle (1969, 1979), Lachmann (1976, 1977), and Littlechild (1986) claim that the alternatives of choice have to be invented or created in one's mind through the use of imagination. As Littlechild (1986) describes it, "the agent's task is not to estimate or discover, but to create. He must

[8] On the latter, see Chapter 4 above.

therefore exercise imagination." Littlechild calls this the radical subjectivist approach. Again, uncertainty results from the fact that the structure of the problem the agent faces is itself fuzzy and the alternatives unknown.

The problem of meeting structural uncertainty is most often associated with the entrepreneur. As Chapter 10 argues, the crucial function of the entrepreneur in Frank Knight's theory is making judgments when the structure of the problem is unknown. Knight (1921, p. 271) is clear on this matter: "(a)ny degree of effective exercise of judgment, or making decisions, is in a free society coupled with a corresponding degree of uncertainty bearing, of taking the responsibility for those decisions."

By contrast, Schumpeter (1934) emphasized the role of entrepreneurs in "carrying out of new combinations." The entrepreneur's only function is that of innovating, of introducing the novel to the economy and destroying the old routines of the circular flow. But the entrepreneur loses his special character "as soon as he has built up his business, when he settles down to running it as other people run their businesses." Carrying out new combinations, almost needless to say, requires one to make a judgment in the presence of structural uncertainty. That is to say, it demands that the entrepreneur create a new paradigm in productive activities. Schumpeter appreciated the fact that the entrepreneur's activities created a discontinuity in the circular flow — a disruption of the old framework, and a creation of a new one.

The theory of vertical integration.

Having outlined the differences between complexity and uncertainty and discussed some of the ways organizations cope with them, let us now try to construct a theory of vertical integration based upon the problems an organization confronts. The story will, of course, revolve around transaction costs — but transaction costs of a kind somewhat different from those discussed above. Costs arising from either asset specificity or some cost of measurement among cooperating inputs in the productive process are costs of an essentially static character. That is to say, they do not explain responses "in the context of the passage of time" (Langlois 1992, p. 105). Vertical integration (or disintegration) cannot be fully explained by these static transaction costs alone; we must also consider the role of learning in organizations over time. As Dahlman (1979) has rightly argued, all transaction costs are reducible to information costs, or more appropriately costs of information and knowledge.

Let us accept the view that knowledge is costly to gain, communicate, put into action, or transfer. Let us also describe the knowledge of an organization as its capabilities. If we recognize the fact that there are limits to human cognition in the face of complexity and uncertainty, then we can also form a picture of an organization's boundaries (Langlois 1992). Since each organization is limited in its capabilities, each is also bound to a limited number of activities it can undertake effectively. The transaction costs of "persuading, negotiating, coordinating, and teaching outside suppliers" (Langlois 1992, p. 113) we call dynamic transaction costs. Where knowledge is tacit and cannot be easily articulated, capabilities are not easily transferable; therefore, the use of the capabilities may be costly without common ownership of the relevant stages of production.

Capabilities may, however, be either internal or external to the firm. Activities in which the firm may effectively employ its capabilities will be undertaken internally; the services of those activities in which the firm cannot advantageously employ its capabilities will be acquired through the market by contractual means. In general, the firm will take on activities that are similar in terms of the knowledge they require but are not necessarily complementary (in the ordinary neoclassical sense) to the activities they already undertake (Richardson (1972)).

As an illustration of the capabilities view of the firm, consider the American automobile industry (Langlois and Robertson (1989)). Before the advent of the moving assembly line and related techniques of mass production, auto makers drew upon the capabilities obtainable in the market from skilled machinists and tool makers. The auto makers were, in effect, assemblers of parts. By developing the moving assembly line in auto production, however, Henry Ford was forced to produce the parts in-house because the costs of communicating and transferring his innovation to outside suppliers was ultimately higher. But as time passed, the market gradually acquired the capabilities of Ford's innovation and succeeding generations of auto producers were able to draw upon these capabilities, thereby requiring less vertical integration.

Now we may connect the notion of the firm as a bundle of capabilities to the idea of complexity. We've already mentioned that the large firm may have an advantage over an individual small firm in dealing with complexity. But we have not yet said anything about the activities that the large firm will have an advantage in. Let us begin by criticizing a popular — but in our view erroneous — interpretation of the benefits of vertical integration for dealing with complexity. Alfred Chandler (1990) argues that the large vertically integrated corporation supplanted the small owner-managed firm because the former was able to take advantage of economies of scale and scope arising from high volume throughput. This meant investing in capital equipment necessary for high-volume production; investing in a regional or international network of marketing and distribution; and employing salaried professional managers to coordinate resource flows by administrative direction. In this interpretation, one of the corporation's advantages lies in its ability to economize on production by high-volume throughput. By implication, the large vertically integrated firm is better able to deal with complexity than a network of small less-integrated ones.

An alternative interpretation of the rise of the large vertically integrated firms stresses not their ability to deal with complexity <u>per se</u> but rather their relative ability to change the existing configuration of capabilities in the economy.

Silver (1984) and Langlois (1988; see also Chapter 3 above) have argued that vertical integration has survival value in situations when systemic innovation could lead to the creation of new value; in such situations, the interconnected nature of the innovation necessarily makes it costly for a decentralized network to effect the change. Systemic innovation demands a change among several stages of production, making coordination among the stages essential. In a decentralized network of asset ownership, there are costs of informing, persuading, teaching, and negotiating — costs that may be prohibitive if the knowledge involved in the innovation is partly tacit. In contrast, innovation can also be autonomous (Teece 1986) if it occurs in only one stage of production and does not require much coordination with other parts of the productive chain. Ford's innovation in the moving assembly line, for instance, was systemic not autonomous.

Thus, in this interpretation, the advantage of vertically integrated corporations is bound up with change. One of the ways to solve the problems of bounded rationality is for organizations to create a central directing unit capable of effecting change of a systemic character. This is the "cephalization" we mentioned earlier, an idea dating to Frank Knight. (See Chapter 10). This is the real significance of the M-form structure introduced in large corporations beginning in the late nineteenth century: the ability to separate day-to-day decision making from strategic decision-making, allowing the corporation in effect to look ahead and plan (Williamson 1985).

But why do such firms have survival value once change is effected? In a sense, adoption of the M-form is actually a kind of decentralization. It is almost an attempt to mimic the market, except for the strategic-planning ability and legal control over the parts of the corporation retained by headquarters. This allows the corporation to change in response to new opportunities. What about coordination of complex resource flows? It is not in fact clear that corporations are better than markets in coordinating static resource flows, even high-volume ones. The value of the corporation lies in its ability to adapt to change, especially change that requires coordination among several stages of production. However, it is historically true that the corporation brought rationalization in Max Weber's sense, that is, brought to bear systematic thinking about resource allocation. It is significant that the greatest success of administrative coordination was in areas that could be understood as static operations research problems: railroad scheduling, throughput in Standard Oil's refining and distribution, etc.

Central direction of resource flows is not always superior to market allocational schemes, for stability allows the agents of production to learn. Capabilities once the sole property of a few firms become diffused to the market. Transaction costs, static and dynamic, will in the long run of real time — as opposed to the Marshallian conception of time in operational terms — evanesce as predictability of action emerges (Langlois 1988, 1992). Overcoming complexity, then, is matter of learning and creating predictable patterns of behavior. Internal organization thus loses its advantages as soon as change ceases, since an absence of change allows agents to predict and learn complex relations among all aspects of production and distribution.

The separation of strategic control from the day-to-day operations of the corporation represents a truly innovative organizational reaction to a decreasing complexity in one aspect of production and distribution: operations capabilities can be learned and transferred. At the same time, it is also a reaction to the more-or-less constant complexity in other areas, such as implementing innovations, redirecting capabilities in a systemic way, and conducting strategic policies for the organization as whole. Thus we see that the M-form corporation has an extremely important adaptive ability. Are we thus suggesting that the corporation is always better able to deal with uncertainty than the market? Not necessarily. The corporation is body of routines and capabilities (Nelson and Winter 1982; Teece 1980, 1982, 1986). This means that there are limits to what the firm can do — limits to its adaptability.

Because of bounded rationality, firms devise procedures for a number of problems, including inventory control, production scheduling, planning multistage production systems, quality control, integration of operations into the strategy of the organization, etc. At the strategic level, organizations formulate a set of procedures for defining goals and policies for the organization as a whole. All these procedures reflect the fact that humans and organizations must satisfice in complex situations because of their bounded rationality. We may view the set of procedures employed by an organization as comprising its culture (Robertson 199)). In turn, we may view corporate cultures as paradigms (Loasby 1976, 1986).

The idea of organizations adopting paradigms as frameworks in which to work and design their research, policy, and operations programs is borrowed from the work of Kuhn (1970). Kuhn conceived of scientists as choosing a certain paradigm in which to conduct their research, solve puzzles, and gather relevant supporting facts. Kuhn calls working within a particular paradigm "normal science." Normal science is for Kuhn (1970, p. 28) "determination of significant fact, matching of facts with theory, and articulation of theory." Furthermore, "the aim of normal science is not major substantive novelties," but "the solution to all sorts of complex instrumental, conceptual, and mathematical puzzles," (Kuhn 1970, p. 29 and p. 30). Loasby (1976, p. 195) elaborates on Kuhn as follows:

Paradigms permit a concentration on short-run questions; what Kuhn calls normal science is short-run science. In academic work as in business, long-run questions, even if no more intellectually taxing, are much less comfortable, because they tend to open up an unpalatable — and sometimes potentially infinite range of options. They may require the managing director to consider what business he should be in, or the academic the proper scope of his subject. An acceptable paradigm affords protection from such disturbing speculations.

In fact, Loasby (1986), extends Kuhn's analysis much farther: he connects it to the psychological theory of Kelly (1963), who sees people as scientists employing a framework that guides them in what is acceptable as rational behavior. Like the scientists in Kuhn's work, people in Kelly's world operate under a paradigm adopted as their psychological stance on life and in which they pursue what can be termed, in analogy with normal science, normal behavior. Kelly regards people as "trying to make sense of the world and to do so by imposing some kind of interpretative framework upon it" (Loasby 1986 p. 45). Moreover, bounded rationality is the reason they must tax themselves with a such a framework (Loasby 1986, p. 45). The complexity of the world forces us to comprehend it only by creating frameworks and theories about how we suppose it to function. In effect, we abstract from the complex whole and interpret it in piecemeal fashion, just as scientists do when constructing theories and models. But organizations themselves confront the problems of complexity. Loasby (1986, p. 50) argues that "organizational efficiency requires specialization of skills and routines, and this specialization entails the learning of particular cues and responses — a particular framework for interpreting events." Since organizational coherence requires adoption of such things as procedures, heuristics, interpretive frameworks, or inclusively an organizational culture, the capabilities of the organization are forged within this culture of normal science. Solving the problems of bounded rationality within an organization, then, is part of normal science.

We are concerned, though, not only with normal science but with what Kuhn calls revolutionary science. Revolutionary science is the response to crisis within a paradigm (anomalies that persistently remain unexplained). These anomalies between theory and observation provoke scientists to reevaluate their research agenda within a paradigm or try to create new paradigms to guide them. Scientists sometimes have to look beyond normal science to see anomalies not as puzzles needing further explication but as requiring changes in the paradigm itself. Copernicus acted upon the belief that the Ptolemaic theory was incorrect and did not represent a true understanding of nature. Copernicus reacted by abandoning this paradigm and creating a new one. A change of paradigm is, for Kuhn, a revolution. But superseding a paradigm demands that there be a better, more capable paradigm: a paradigm is discarded only when another takes its place. Thus the Ptolemaic system was abandoned only when Copernicus' theory offered a more satisfying explanation.

Again we may project Kuhn's theory of the growth of scientific knowledge into one of organizations and competition. Schumpeterian competition, with its emphasis on discontinuous change — a disturbance of the accepted framework and a creation of a new one— is highly parallel to revolutionary science. Schumpeterian competition often happens outside the boundaries of existing firms. This is to say that existing firms do not have the capabilities to effect change of the nature of revolutionary type. These firms lack the capabilities for dealing with radical uncertainty because their paradigm, that is, their culture dictates what normal science is. Radical uncertainty, we already suggested, is best encountered by a large number of firms trying out different paths.

Radical uncertainty involves creating the revolutionary, innovating entirely new production processes or products. In short, it often involves a sharp break from the past. When will variation be highest? Since large organizations are designed primarily to deal with the problems of bounded rationality and operate in a particular culture, seeking radical changes in its research and policy agenda requires the firm to redefine its culture, a task not so easily effected.

Tushman and Anderson (1986) distinguish between competence-enhancing and competence destroying technological changes. Competence-destroying technological change is revolutionary change — change that represents a sharp discontinuity in a product or process and renders existing capabilities obsolete. An example of this in the product class is the substitution of compact discs for records (or an entirely new product such as cement (1872)); in the process class it includes the replacement of the open-hearth process of steel making by the basic oxygen furnace (Tushman and Anderson 1986, p. 443). Competence-enhancing technological change employs and heightens existing capabilities. An example in the product class includes the improvement of the typewriter by changing the power source from mechanical to electrical; in the process class, it includes the Edison kiln in cement manufacturing.

Tushman and Anderson (1986, p. 442) assert that "competence-destroying discontinuities are so fundamentally different from previously dominant technologies that the skills and knowledge base required to operate the core technology shift. Such major changes in skills, distinctive competence, and production processes are associated with major changes in the distribution of power and control within firms and industries." They further hypothesize that "the locus of innovation will differ for competence-destroying and competence-enhancing technological changes. Competence-destroying discontinuities will be initiated by new entrants, while competence-enhancing discontinuities will be initiated by existing firms" (Tushman and Anderson 1986, p. 444). The reason for attributing competence-destroying change to new firms is that "new entrants take advantage of fundamentally different skills and expertise and gain sales at the expense of formerly dominant firms burdened with the legacy (i.e., skills, abilities, and expertise) of prior technologies and ways of operating" (Tushman and Anderson (1986, p. 446)).

Sometimes competence-enhancing technological change involves the organization in one area using economies of scope to invade new areas. For example, GM used its existing capabilities in motorized vehicles to innovate the diesel locomotive and Seiko used its capabilities in electronics to develop quartz watches. Neither one of these firms traditionally competed in these areas until the innovation. GM and Seiko drew upon their capabilities in their traditional lines of business and applied them to new areas. In effect, they had a surplus of capabilities or know-how in how to do certain things (Penrose 1959) — economies of scope in capabilities for certain activities. These innovations required activities of a similar bent.

We must not forget that markets are also organizations capable of generating capabilities. For instance, in entering the microcomputer market IBM did not try to organize all, or for that matter most, of the activities of producing personal computers. Instead it chose to obtain the capabilities through the market, in effect becoming only an assembler and marketer of personal computers (Langlois 1992a). With its corporate culture and rigid hierarchical structure, procedures, and controls, IBM found creating the necessary capabilities too costly when compared with what was available on the market. IBM decided to spin off a semi-autonomous unit to produce the personal computer, exempting it from internal procedures and isolating it from the dominant corporate culture.

It is also significant that IBM came along only once the paradigm or dominant design was established, suggesting that its corporate culture was incapable of producing such a new product — a competence destroying innovation. Such paradigmatic shifts are harder to effect in large corporations with firmly established frameworks of association. If, as Tushman and Anderson assert, the destroying of competences (confronting radical uncertainty) is the result of individual genius, genius that is inspired because it does not operate in an environment with an already chosen paradigm, then the greatest number of entrepreneurs pursuing variable courses will produce the greatest number of changes of this nature. Langlois (1992, p. 120) asserts that "the variation that drives an evolutionary system depends on people being on different wavelengths — it depends, in effect, on outbreeding." Biologists already recognize the importance of breeding size as a prime mover in the variation among populations.[9] Darwin, too, stressed the variation among organisms that made possible evolution by natural selection.[10] And Marshall recognized the benefits of variation: "The tendency to variation," wrote Marshall (1961, p. 355), "is the chief cause of progress."

[9] See, for instance, Lewontin (1974).

[10] Darwin did not see variation alone as sufficient for evolution by natural selection. Along with the principle of variation we should also include the principles of heredity and differential fitness (Lewontin 1984).

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