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Industrial Dynamics: Why Connections Matter

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Modelling time

In *Value and Capital*, Hicks (1948, p. 115) defined '[e]conomic dynamics [as] those parts [of theory] where every quantity must be dated'. Subsequent theoretical development has shown that this is not a sufficient criterion. In the Arrow-Debreu system not only must every quantity be dated, it must also be indexed by location and state of the world; yet in a model that conforms to these specifications there is no room for dynamics, but a single equilibrium which extends over all dates, locations and contingencies. There is no arrow of time: later dates influence earlier allocations in precisely the same way as earlier dates influence later allocations; there is no sense in which one thing can lead into another. Indeed, within such a model there is no scope for decisions by economic agents: an equilibrium allocation is deduced directly from the basic data, which includes a complete set of preferences but requires no algorithms of choice. The individual is of measure zero (Hahn [1973] 1984, p. 64), not only because a single person's preferences and endowments have no perceptible effect but because no individual is allowed to take any initiative. Everything that could possibly happen must be incorporated in the specification of one or more states of the world, either as an exogenous event or as a possible consequence of human action; the occurrence of any novelty, either endogenous or exogenous, violates this requirement and demonstrates that the apparent equilibrium had been derived from false premises.

It is as well that all differences between dates are incorporated in a single equilibrium, because no resources are available to cope with change, having already been optimally allocated within that equilibrium. There are not even any resources available to cope with equilibration. Walras eventually realised that his suggested process of disequilibrium production, in which producers converged on equilibrium output by trial and error, was not compatible with the prior derivation of equilibrium; error implies waste, and there is no margin for waste in specifying the equilibrium allocation. Nor is there any margin for the costs of ensuring a perfect match between projected decisions. Therefore the process of achieving the deduced equilibrium, whether it be the original allocation or a revised allocation which is appropriate to a new configuration of data (though such revisions are strictly incompatible with the conceptual framework), cannot happen within a functioning Arrow-Debreu economy. As good general equilibrium theorists do not hesitate to point out, the markets – strictly a single market – in which this equilibrium allocation is represented by a complete set of contracts open once only, and close before the economy starts operating. It is not surprising that this looks less like a model of a market system than a model of a command economy.

The requirement that all transactions are arranged outside the economy in order to ensure that within the model there are no transaction costs has significant implications. As Coase (1988, p. 15) pointed out, if there are no transaction costs there can be no problems with externalities; impacts on third parties, whether beneficial or harmful, should simply be added to the list of goods and to the preference systems of those affected by these impacts. Thus there can be no unexploited gains from trade – indeed there are no third

parties – and therefore no scope for beneficial policy interventions to remedy system failures. If it is nevertheless thought appropriate for particular theoretical purposes to incorporate costs of transacting, then it is illegitimate to compute equilibria separately from the analysis of the transacting process. Moreover, not only does this process generate costs; these costs depend on the ways in which transactions are organised and the sequence in which agents search for the best attainable set. It is also a natural consequence of transaction costs that some transactions, especially those for dates at which there are many possible states of the world, are likely to be postponed, and it may seem attractive to commit some resources to the development of systems for making and implementing later decisions. This, of course, is the basis of Coase's explanation for the firm; it is also the basis for an explanation of markets as institutional arrangements for facilitating a series of transactions (Ménard 1995, p. 170), and for the creation of various kinds of reserves, as Menger ([1871] 1976) observed, in the form both of goods and of capabilities, direct and indirect. However, none of these phenomena can be accommodated within the Arrow-Debreu system.

If we wish to incorporate the process and costs of change within our models we need to modify our use of dates: they are now required not to ensure that the set of variables is complete but in order to identify the sequence in which things happen and in which knowledge and possibilities become available. But, as has been demonstrated in many multi-stage models, this may not make much difference to the analytical strategy, as long as it is assumed that agents correctly, if incompletely, anticipate future knowledge and future possibilities and make correct deductions from their anticipations. However, when Hicks moved from his early definition of economic dynamics to his later view of economics as necessarily 'on the edge of history' he was accepting history as a process in which people do not know what is going to happen, even as a set of possibilities, and in which therefore it is not possible to deduce optimal choices or optimal allocations because some of the necessary data cannot exist.

It was Frank Knight (1921) who first emphasised the crucial distinction between risky situations, in which there is an agreed procedure, logical or empirical, for distributing probabilities over a closed set of outcomes, and situations of uncertainty, in which there is no such procedure – and often, as Shackle was to insist, no way to ensure that all possible outcomes had been recognised. Knight pointed out that risk, as he defined it, was a calculable cost and that, since the correct method of calculating each risk was public knowledge, risk-bearing was a productive service not sharply distinguishable from any other and therefore not a distinctive source of income. 'Profit' is then a misleading name for a not-very-particular kind of earned income and risk-bearing belongs in the production function, posing no threat to the homogeneity that is required for perfect competition. However, when faced with uncertainty, appraisals and choices depend on the perceptions and skills of each individual, or group of individuals, and only after the event (and not always then) is it possible to reach agreement on the appropriateness of the procedure to the particular circumstances. Thus there is no reliable way of specifying uncertainty-bearing as an input in a production function or of preserving the homogeneity of perfect competition. Profit is the reward, not for risk-bearing but for successful entrepreneurship which has coped with uncertainty by means which could not be public

knowledge: entrepreneurs might calculate, but the correct basis for their calculations could not be deduced from the basic data.

However, although the result of any attempt to cope with uncertainty must itself be uncertain, Knight did not believe that success was purely a matter of chance; nor was it simply the consequence of alertness to opportunities which, once perceived, are clearly genuine – which is the basic case of Kirzner's (1973) theory of entrepreneurship. It was a reflection of human capabilities, and a distinctive and valuable resource. In his first published article, George Richardson (1953) drew on Knight's analysis of the significance for economic efficiency of the deployment of distinctive entrepreneurial capabilities (which are not among the inputs to standard models) and, as can now be seen, was only a thought away from the argument of his famous article of 1972. Equilibrium theory has gone beyond Arrow-Debreu, but it necessarily reduces uncertainty to risk in order to achieve proofs of equilibrium; industrial dynamics does not. In the following section I will attempt to indicate the foundations of this contrast.

Connections

In an outstanding new book, Jason Potts (2000) has opened a meta-theoretical perspective on the relationship between equilibrium theorising, as generally practised, and dynamic analysis. The Arrow-Debreu system exists in integral space, where every element is directly connected to every other element, just as the Newtonian model of the solar system exists in a unified gravitational field. In the Newtonian system bigger masses have bigger effects, and in the Arrow-Debreu system stronger preferences have bigger effects, but whatever the magnitude of the effect in either system it impacts directly on every other element in the system. There are no gravitational shields or specialised intermediaries to constrain interactions; 'markets', which provide connections that are indirect, have no existence except as a metaphor for direct and costless transfers of property rights, and all 'choices' are transparent. Although the Arrow-Debreu model, which is very carefully located in integral space, is no longer generally regarded as the central model of economics, nevertheless the widely-adopted principle that outcomes may be directly deduced from the data relies on the same integral conception. George Richardson (1959, p. 24) long ago pointed out that in the world of practice there is no direct link between data and outcomes, but only an indirect link by way of beliefs and intentions; whether consciously or not, economists have recognised Richardson's observation as a threat to the concept of a fully-connected economic system and the theoretical technique that relies on it, and have either ignored the issue or produced some notably unrigorous stories to support their practice. The rhetorical purpose of invoking rational expectations is to justify this procedure by rendering illegitimate any inquiry into the way in which data are interpreted.

Since a fully-connected equilibrium is a completed project, it is closed to further enquiry (though one may compare the equilibria that correspond to different data). However, by assuming that 'in the beginning there was a fully-connected system' it is possible to generate apparently well-defined analytical problems by postulating that some carefully-chosen connection is missing from a set that is otherwise complete; it is then possible to

derive a local equilibrium incorporating agents' reactions to this solitary deficiency, relying on the results of the fully-connected model to absorb that local equilibrium, and ignoring or finessing the once-powerful argument that only a general equilibrium analysis ensures validity. This reliance is often implicit, and sometimes appears to be unconscious.

The identification of a strictly-limited deficiency in an otherwise fully-connected system is the standard method of generating soluble problems in economic theory. There are two variants of this method: in what might loosely be called the 'Harvard' version the deficiency results in some welfare-reducing failure which creates a space for government intervention, while the 'Chicago' version demonstrates that the result is a new equilibrium in which economic agents reduce the damage to negligible proportions. 'Harvard-style' analysis is illustrated by 'New Keynesians' who produce a caricature of Keynes's results which accepts the internal validity of new classical reasoning but makes a case for government action. An appropriate example of 'Chicago-style' reasoning in the context of this paper is Oliver Hart's (1996) explanation of the firm as an optimal allocation of property rights, which may be briefly examined.

Here the problem-generating deficiency is a narrowly-specified constraint on the feasible contracting space, which is sufficient to frustrate the contractual alignment of incentives but has no other implications. The consequences, and the narrow scope, of this deficiency are so clearly defined that farsighted contracting is possible about the right to make decisions, which Hart identifies with ownership; thus the missing connection can be restored by an appropriate allocation of property rights. Since, by virtue of the background general equilibrium model, such an allocation is Pareto superior, there must be a set of contracts which make it universally acceptable; there are, of course, no obstacles to efficient contracts for property rights. The result is an analysis that combines theoretical novelty with the apparent validation of a general equilibrium theory in which allocations are derived directly from the data, without postulating any interaction between agents. By virtue of its construction, there are no dynamics in this model; the appropriate allocation restores the connection between data and outcomes, allowing all dates and contingencies to be provided for. The standard analysis of production remains untouched. Thus the 'firm' which the model purports to explain is just an extension of the 'market'; neither has any organisational or institutional existence as a particular set of connections.

Oliver Williamson's approach looks more promising. Although he differs from Coase in insisting that the fear of opportunistic behaviour is a necessary condition for the existence of a firm, he follows Coase, and differs from Hart, in modelling the firm as a system of resource allocation by direction. This immediately suggests the possibility of a theory of organisational development, which may lead to changes over time both in the way that the firm is organised and managed and in the scope of its activities. Unlike Hart's model, in which the departure from a fully-connected system is a strictly limited theoretical move for strictly tactical purposes, the Coase-Williamson conception implicitly defines the firm as a network of privileged connections, leading naturally to Herbert Simon's vision of an economy in which firms, not markets, are the primary forces. Williamson, however, appears never to have appreciated the fundamental significance of this

conception, for he has denied the validity of Simon's vision (Williamson 1996, p. 145) and has never shown much interest in what firms actually do – which is to develop and use connections, of many kinds as we shall see. It is therefore no accident that he has never analysed the development of firms over time, despite Nooteboom's (1992, p. 285) observation that his theory seems to demand a time-dimension.

The limitation of Hicks's early definition, which was not obvious when he constructed it, is that it does not distinguish between an economics in which time is just one dimension of a good, and an economics which is embedded in time. This is a distinction that Hicks himself subsequently made and effectively employed, not least in demonstrating that Keynes' *General Theory* contains elements of both conceptions, which has caused much trouble to those trying to interpret it. Marshall's *Principles* is similarly ambiguous, with similar consequences. What we may now observe is that a fully-connected analytical system can treat time only as a dimension; an economics in time must, as a minimum, postulate incomplete connections with future dates and their associated states of the world, and allow these connections to change over time, in part as a result of the behaviour of the system itself.

All systems consist of both elements and connections between them (Potts 2000); a system may be an element in a higher level system, and an element may itself be a system. Thus a comprehensive analysis may need to encompass several levels. In the Arrow-Debreu system, connections can be ignored because they are always perfectly and costlessly efficient, and so attention can be concentrated exclusively on the implications of the data, and the ways in which these implications vary with differences in the data. Alternatively, though with some loss of rigour, this system may be used as a reference model for investigating the effects of particular deficiencies, as we have seen; the term 'market failure' is a clear, if rarely recognised, indication that this is what is going on. The idea that connections are problematic in general, *and should be treated as problematic*, is not seriously entertained.

The obvious objection to treating connections as problematic is that whereas there is necessarily only one way in which a system can be fully connected, there are very many ways in which it may be partly connected; how then are we to know what connections to include in our model? My response to that is to ask a set of similar questions. How are we to know what connections to emphasise in the design of any particular organisation – for every organisation chart defines a partly connected system? How are we to know what connections should be made with other organisations? What connections are most effective in gaining customers? Who are the potential competitors? What are the factors we should take into account when designing a regulatory system for a privatised industry – and is the answer different for each industry? As economists, in what aspects of what other disciplines should we take an interest? What are the significant connections that are missing from our models of purportedly fully-connected systems? We may also ask when connections are best avoided, for example by assigning activities to distinct organisations or problems to distinct theoretical systems. A non-economist would assume, reasonably but wrongly, that the principles governing the separation of activities would be a central theme in explaining the organisation of industry; and the desirability of differentiating

theoretical systems is a key question for the analysis of change, as is illustrated by the insistence of both Schumpeter and Penrose on disconnecting the theory of growth from allocative theory.

Fundamentally, every organisation, every theory, every set of expectations, every plan, and every policy privileges a very small subset of possible relationships; its applicability is therefore always problematic, and can be established only over time – and never for all time. Like the economic agents who are our nominal subjects of study, we have to work in time; why not therefore try to develop theories which are embedded in time, and take seriously the selective development of connections over time as a result of fallible human action? In the remainder of this paper I will discuss three themes which seem to me central to such dynamic analysis: knowledge, institutions, and organisation. I shall argue that these themes are closely related.

Knowledge

Economists nowadays quite often write about information; it is a convenient way of implementing the strategy already discussed of removing a particular connection from the basic fully-connected model and thus generating a potentially-publishable paper. Information may be coarsely rather than finely partitioned, so that agents are unable to discriminate between states in which different actions are optimal; particular items of information may be missing – notably information about future actions by others; or information may be unevenly distributed. But the content of information is not itself treated as problematic; often indeed it is explicitly information about the probabilities of a closed set of possible states of the world. Underlying knowledge is complete, even if information is not. Thus even when information is dispersed and incomplete, the information sets of all agents within a model are drawn from a single and complete set. This avoidance of Knightian uncertainty is crucial for the analytical strategies that are used.

The denial of Knightian uncertainty motivates the standard treatment of complexity. The assumption of an underlying single and complete information set ensures that all simplifications are derived from a single correct source, which provides a common basis for all transactions among agents (or rather for the analysis of these transactions). It is then natural to misinterpret Simon by treating bounded rationality as equivalent to a cost of information, and satisficing as an optimal response, and to avoid asking how boundedly rational agents can know enough about the correct model to be certain that their simplifications, though not the whole truth, are nothing but the truth. The answer to that unasked question may be found in what I propose to call Hayek's Impossibility Theorem: 'any apparatus of classification must possess a structure of a higher degree of complexity than is possessed by the objects that it classifies; and . . therefore, the capacity of any explaining agent must be limited to objects with a structure possessing a degree of complexity lower than its own' (Hayek 1952, p. 185).

The question may also be applied to those who analyse complexity in this way: how do they know that their models of complex systems are adequate representations of the

systems to which they are applied? To this question also, Hayek supplies the answer. Just as our analysis of systems should not take as its reference point a fully-connected system, which directs us to questions about specific failures and their remedies, but start from the problem of creating and maintaining connections that are appropriate for particular purposes, so the problem of complexity is not one of simplifying a complete model but of constructing some representation by selecting and linking elements. Both are exercises in Knightian uncertainty, for which there are no correct procedures, but the possibility of rewards for skill.

This is how we develop knowledge, by varying our construction systems as we 'construe the replication of events' (Kelly 1963, p. 72). Knowledge is structure, in the form of categories into which phenomena or concepts may be grouped, or in the form of relationships between such categories; and structure implies a non-integral space. It is an imperfectly connected system of imperfect connections in which, as Knight (1921, p. 206), observed, we focus on similarities and ignore differences that we hope will not be relevant to our current enquiry. Any of these connections may change over time, as Paul Nightingale (2000) shows in a recent analysis of pharmaceutical research strategies. The world system of knowledge is far from complete, and the knowledge possessed by – or even accessible to – any individual is a very small proportion of that world system. Nobody knows how a Boeing 737 works; and nobody knows how the Boeing Company works.

Rather than bounded rationality, which (as already noted) is usually interpreted as a particular limitation in processing knowledge, it is better to begin with bounded cognition. This has the advantage of corresponding with current ideas about the development of human cognitive abilities. In the early stages of evolution, standard behaviours were genetically programmed; later creatures were genetically endowed with some capacity to vary behaviour; and in the pre-conscious stage of evolution towards *homo sapiens*, individuals formed classification systems and linkages between categories of sensory perceptions and actions which proved sufficient for the survival of the species. These structures of knowledge were necessarily backward-looking; in Jim March's phrase, they followed 'the logic of appropriateness'; but what appeared to be appropriate could differ between individuals because of differences in the sequence of their experiences. Despite our intellectual pretensions, this is still the basic method of knowledge formation in modern humans; that is why 'we know more than we can tell', and in particular why we can perform many actions that we are unable to specify in detail. However, the emergence of consciousness introduced the important novel possibility of creating ideas about the future by making conjectures about new categories and relationships as yet unrecognised, leading to the possibility of taking novel actions with the intention of producing novel effects. The scope for variation between individuals was correspondingly increased, and with it the rate at which knowledge could grow. This new possibility, we should remember, is a modification of the old capabilities, which are not displaced, and relies much more on linkages than logic. Indeed, as psychologists have shown, our powers of logical reasoning are still primitive in relation to the ability to make novel connections.

The need to construct knowledge, and the role of imagination in doing so, was emphasised by Adam Smith ([1795] 1980) in his psychological theory of the emergence and growth of science as a combination of classification systems and causal links, which he illustrated by the *History of Astronomy*. The stimulus to imagination was provided by the failure of existing patterns of knowledge to account for newly-observed phenomena – an intrinsic motivation, beginning with unwelcome surprise and concluding with delight in creating a new pattern that worked, that appears to have had substantial survival value and to be still effective, but which is not prominent in economic theory. Since new 'connecting principles' (Smith's prescient phrase) led to new expectations, new activities and new observations, what began as an aid to ordinary living gradually incubated a new category of knowledge called 'scientific'. As the psychological and practical value of this knowledge became more apparent some people came to devote particular attention to it; and as its growth accelerated it began to divide into distinctive branches, each with its own set of connections which gave rise to its own anomalies and consequent stimulus to imagination.

Having explained how the dynamics of scientific development led to specialisation which accelerated the process, Smith later transferred this analysis from science to the economy, and made the power of the division of labour to increase productivity the basis of his dynamic economic theory (Smith 1976b). Smith was well aware that increased specialisation had its opportunity costs in the neglect of potentially important connections; this led him to include education as an important function for government, and to give a special role to 'philosophers or men of speculation' who imagined novel connections between divergent specialisms – or, in Schumpeter's (1934) language, conceived of 'new combinations'.

Institutions

Individuals develop structures of knowledge, including knowledge of how and when to perform particular actions, and how to frame sets of premises as a basis for deductive reasoning. They learn how to make sense and how to make decisions, both of which require more than logic, as Chester Barnard (1938, p. 305) emphasised. However, unless they live a purely solitary existence they do not have to do this on their own. The activities of others create a range of vicarious experiments which they may use to test their own conjectures or to incite their imagination to produce new conjectures; or they may simply adopt apparently successful patterns of behaviour or satisfying ways of organising knowledge. (This is how we all start as infants.) It is an obvious economy, and sometimes an aesthetic pleasure, to free-ride on other people's wisdom; that is how Smith explained the diffusion of new cosmological theories which appeared to resolve worrying problems, and also the adoption of rules of behaviour which appeared to conform with moral sentiments (Smith 1976a). Ways of thinking and ways of acting that are common within a community need not originate as solutions to co-ordination games; they may arise from individual efforts to solve individual problems.

If the sharing of patterns and routines has such origins, that helps to explain how members of a group who have been acting in parallel may converge on a particular set of

procedures for managing interactions. (Smith was well aware of the importance of this sequence in making civil society possible.) What we call 'institutions' when they are interactive routines are not inherently different from the routines and assumptions on which people necessarily rely in order to economise on cognition for their own private purposes; they are an external supplement to the structure of internal cognition (Choi 1993). Access to this external cognitive capital depends on the appropriate absorptive capacity, which we may think of as receptors which can connect imported elements to internal structures. The development of this capacity is a major function of education; and studies of organisational learning have shown the importance of social interaction within and between productive organisations in facilitating such learning. In both private and interactive contexts, predominant reliance on routines is necessary in order to create space for thought; and in both contexts, variation between individuals widens the range of material about which to think. Codification is an institution which partially formalises tacit knowledge and thus provides the basis for the creation of further tacit knowledge.

An obvious but neglected application of the importance of institutions in encouraging the growth of knowledge is the emergence of markets. A market reduces the costs of making certain kinds of transactions by establishing powerful connections. Mark Casson deserves the credit for noting that the costs of continuing transactions may be reduced by appropriate investment, and identifying the entrepreneurial role of those who make such investments – though as recent events have amply demonstrated many entrepreneurs may be unfortunate or misguided. When a particular class of transactions has been substantially reduced to routine, those using that market, as buyers or sellers, no longer have to think about how to transact and are therefore free to think about what to transact, how to produce the goods or services to be transacted and how to make good use of them (Loasby 2000). Thus the institutionalised connections provided by a market allow the formation of new connections, both in trading relationships and in the form of knowledge about both production and consumption. The emerging interest in the role of the consumer builds on an understanding of market institutions.

Institutions provide the connections which support dynamics; they also have their own dynamics, primarily of adjustments at the margin, but also of regime changes, which typically draw on patterns of connections from some other sphere of activity and may be treated as adjustments at the margin of a higher-level system: the idea that structure influences behaviour, for example, appears in different forms across many fields of human knowledge. Knowledge changes institutions, as institutions shape knowledge. This process drives the history of economic thought, as well as the development of productive knowledge and both managerial and entrepreneurial skills.

Organisations

According to Roger Myerson (1999, p. 1068), 'today economists can define their field more broadly as the analysis of incentives in all social institutions'. Economic organisation, which at one time focussed on the relationship between market structure and economic performance, is now interpreted as the organisation of incentive structures. This is certainly a broadening in one dimension, but imposes serious constraints in others.

Incentives matter; but co-ordination, both within and between firms (and for individuals too – see Kelly 1963) is first of all a cognitive problem. Marshall (1920, p. 138) linked organisation specifically to knowledge, and half-explicitly linked different forms of organisation to different kinds of knowledge. Even Williamson, who considers the merits of different organisational arrangements, treats governance systems as protective devices against pernicious incentives and does not, like Penrose (1959, 1995), consider them as bases for the generation and application of knowledge. Williamson's (1985, p. 48) declaration that 'were it not for opportunism, all behaviour could be rule governed' ignores Knightian uncertainty and its counterpart, Shackleian imagination; opportunities, rather than opportunism, drive the growth of a Penrosian firm.

These opportunities result from new knowledge which is shaped by institutions that are fostered by organisational arrangements; the Penrosian process in its administrative framework combines cognitive, institutional and organisational dynamics. The organisation of a new activity requires new connections to be made, in formal responsibility, in patterns of interaction and in individual cognition. If the activity is successful most of these connections cease to require conscious attention; a new set of institutions releases cognitive skills and organisational capabilities for other purposes. This is 'the receding managerial limit'. At the same time, the absorbed patterns of behaviour, at all levels, change the firm's resources, which may be deployed in directions which are conjectured by the use of these cognitive skills. That such connections between resources and profitable uses are not simply deduced from the data, as in standard theories which are located in integral space, but need to be made is a clear and fundamental difference between Penrose's theory and the standard 'theory of the firm', a difference emphasised by Penrose's distinction between resources and productive services. (Writers on strategy who adopt the 'resource-based view' often underrate the significance of this distinction.) We may also think of a firm's resources as equivalent to Lachmann's conception of capital: they are elements which may be substituted between uses but which in any particular use are valuable because of their specific complementarity (or connections) to certain other elements. If this complementarity produces what was once called synergy or what we now call superadditivity, the additional productivity may be attributed not to the elements but to the connections between them. Chemical bonds may provide an appropriate analogy.

These Penrosian single-firm dynamics should be supplemented at least by the two other Marshallian categories of forms of organisation that aid knowledge: the firms within a single trade provide vicarious experiments and vicarious hypotheses to supplement and interact with the particular knowledge of each, and the network of complementary trades is structured on Richardsonian principles of dissimilar ways of organising knowledge to gain the advantages of the division of labour while avoiding unhelpful connections (Richardson 1972), and linked by incremental adaptations and by speculative visions. The organisation of production is also the organisation of knowledge, and both kinds of organisation change over time as the result of what happens in time. The dynamics of industrial organisation have never been better presented than by Allyn Young (1928) in a paper which rejected the applicability of equilibrium modelling to an understanding of this process of generating value as a consequence of rearranging connections by

reconfiguring the internal and external boundaries of the firm. Increasing returns are returns not to the elements but to the connections between them. Such an imputation is impossible in a theoretical system which assumes a fully-connected economy, but it is a natural implication of Marshall's (1920, p. 318) definition of increasing returns as mediated by organisational change.

That the concept of general equilibrium is not applicable to these dynamics is also my view, but local and temporary equilibria may serve very well to indicate the knowledge and relationships – connections of various kinds – on which people may reasonably rely in order to construct useful novel connections. Innovation is carried by continuity, and continuity may be expressed by an appropriate concept of equilibrium, applied to particular structures of knowledge, institutions, or organisation, which should be regarded as different system levels, though not necessarily, or indeed usually, ordered in a simple hierarchy.

Dynamic variety

Industrial dynamics relies on differences, not only between but also within industries; indeed it is the effects of these differences on behaviour, continually modifying and occasionally disrupting the environment in which firms are operating, requiring new interpretations and sometimes prompting new perceptions, that provide the dynamics. These processes combine the generation of variety and the elimination of variants which do not match the criteria by which they are judged; and these criteria are themselves a proper and neglected field for analysis, for there are different criteria in different selection environments. It is therefore not surprising that some writers on industrial dynamics are attracted to evolutionary concepts; but that is not a requirement. On the contrary, there is danger in simply replacing the field theory of physics with neo-Darwinian biology, which excludes human purpose and sharply differentiates the context of variety generation from the context of selection, whereas in human brains and human organisations the contexts are often combined. It is safer to draw inspiration from Adam Smith's evolutionary model, which includes complex motivation, imaginative conjecture (often driven by aesthetic considerations), selection and diffusion, increasing differentiation and means of integration. Neo-Darwinians seek to confront us with a stark choice between design and natural selection among blind mutations; standard economic theory opts decisively for design, occasionally supplemented by appeals to selection processes to ensure that the design is optimal. Both are corner solutions in the space of theoretical strategies; industrial dynamics avoids corner solutions by choosing a sequence of ex-ante decisions and ex-post realisations that may lead to fresh decisions.

As we have noted, contemporary models of economic organisation often depend on the concept of asymmetric information, which certainly corresponds to an aspect of reality. But I suggest that the more important asymmetry is of interpretation and of perception, which leads some individuals and some organisations to take actions that others have dismissed, or never even thought of. Frank Knight's theory of entrepreneurship and the firm was based on interpersonal differences in the capacity for judgement – what we might call making connections that prove to be appropriate – and of differences for each

individual between fields of activity (Knight 1921, p. 241). Shackle's (1979, p. 26) beautiful phrase 'the imagined, deemed possible' invites us to consider the stimulus and sources of imagination and why some products of the imagination are deemed possible by particular individuals while others are not.

Imagination and the assignment of possibility require the making of new connections, and often the discarding of old connections, a process that is easier to understand in retrospect than it is in prospect. Because new knowledge, new institutions and new organisations must all develop from connected systems (at some level) that already exist, change is always path-dependent; but this dependency may vary greatly in both degree and kind, often leaving much scope for imagination, especially if we extend Shackle's phrase to include the imagined, deemed capable of being made possible. Since the number of connected networks that are conceivable is unimaginably greater than the number that can be handled by any human brain – or indeed by any organisation that depends on manageable interactions between human brains – it is not surprising that there will be a great variety of opinions about what will work, and what will be profitable. There will be a high rate of failure; economic dynamics requires both ex-ante and ex-post selection.

This variety, and its potential, justify concluding this sketch of industrial dynamics by invoking George Richardson's (1975, p. 359) principle: 'Surely it is of the essence of competition that the participants hold uncertain and divergent beliefs about their chances of success'. This is competition between different ways of thinking; and the co-ordination problem within an economy is that of achieving the necessary compatability between different ways of thinking while preserving the differences. There are difficult incentive issues here, but they are not the incentive issues that dominate Myerson's conception of economics, for they are linked to co-ordination problems at many levels, at each of which some connections are to be encouraged and others avoided. Knight (1921, p. 268) observed that '[w]ith uncertainty absent . . it is doubtful whether intelligence itself would exist'. Why should we be satisfied with the analysis of rational choice when we have the opportunity to study intelligent action?

Note. The first draft of this paper was presented at a meeting of the Network of Industrial Economists at the University of Reading on 19 December 2000; this is an amended version of a presentation at the DRUID Winter Conference. I am grateful for comments received on both occasions.

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The Research Programme

The DRUID-research programme is organised in 3 different research themes:

- The firm as a learning organisation
- Competence building and inter-firm dynamics
- The learning economy and the competitiveness of systems of innovation

In each of the three areas there is one strategic theoretical and one central empirical and policy oriented orientation.

Theme A: The firm as a learning organisation

The theoretical perspective confronts and combines the resource-based view (Penrose, 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi, Teece and Winter, 1992). The aim of this theoretical work is to develop an analytical understanding of the firm as a learning organisation.

The empirical and policy issues relate to the nexus technology, productivity, organisational change and human resources. More insight in the dynamic interplay between these factors at the level of the firm is crucial to understand international differences in performance at the macro level in terms of economic growth and employment.

Theme B: Competence building and inter-firm dynamics

The theoretical perspective relates to the dynamics of the inter-firm division of labour and the formation of network relationships between firms. An attempt will be made to develop evolutionary models with Schumpeterian innovations as the motor driving a Marshallian evolution of the division of labour.

The empirical and policy issues relate the formation of knowledge-intensive regional and sectoral networks of firms to competitiveness and structural change. Data on the structure of production will be combined with indicators of knowledge and learning. IO-matrixes which include flows of knowledge and new technologies will be developed and supplemented by data from case-studies and questionnaires.

Theme C: The learning economy and the competitiveness of systems of innovation.

The third theme aims at a stronger conceptual and theoretical base for new concepts such as 'systems of innovation' and 'the learning economy' and to link these concepts to the ecological dimension. The focus is on the interaction between institutional and technical change in a specified geographical space. An attempt will be made to synthesise theories of economic development emphasising the role of science based-sectors with those emphasising learning-by-producing and the growing knowledge-intensity of all economic activities.

The main empirical and policy issues are related to changes in the local dimensions of innovation and learning. What remains of the relative autonomy of national systems of innovation? Is there a tendency towards convergence or divergence in the specialisation in trade, production, innovation and in the knowledge base itself when we compare regions and nations?

The Ph.D.-programme

There are at present more than 10 Ph.D.-students working in close connection to the DRUID research programme. DRUID organises regularly specific Ph.D-activities such as workshops, seminars and courses, often in a co-operation with other Danish or international institutes. Also important is the role of DRUID as an environment which stimulates the Ph.D.-students to become creative and effective. This involves several elements:

- access to the international network in the form of visiting fellows and visits at the sister institutions
- participation in research projects
- access to supervision of theses
- access to databases

Each year DRUID welcomes a limited number of foreign Ph.D.-students who wants to work on subjects and project close to the core of the DRUID-research programme.

External projects

DRUID-members are involved in projects with external support. One major project which covers several of the elements of the research programme is DISKO; a comparative analysis of the Danish Innovation System; and there are several projects involving international co-operation within EU's 4th Framework Programme. DRUID is open to host other projects as far as they fall within its research profile. Special attention is given to the communication of research results from such projects to a wide set of social actors and policy makers.

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