An information economics perspective on innovation

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Introduction

This paper has three main objectives: to

(1) introduce the information theoretic or economics of information approach;
(2) show how this relates to innovation, i.e. how it improves our understanding of the innovative process compared to a more conventional economic approach; and
(3) illustrate an example of an information economics model of innovation.

Information economics

Nobel prize winning economist Kenneth Arrow (1984) describes information as an interesting category of goods generally ignored by economists. Information economics treats information explicitly as a resource. Such a perspective takes account of the basic economic characteristics of information and seeks to bring within the economic calculation the value and cost of information. This approach often leads the analyst to quite different conclusions about particular issues than those obtained from more conventional analysis.

An information economics perspective may be more consistent with the reality of a rapidly emerging information age than conventional views. Global society would appear to be in transition from an industrial era to an information era. There are different ways of describing and analysing this phenomenon. From an economic perspective, the economy is becoming more information-intensive. The production, use and communication of information assumes the central importance in the information era that mass production of ordinary goods and services assumed in the industrial era. Studies that have measured the extent and growth of information activities in the economy include Lamberton (1987), Mandeville and Macdonald (1985) and OECD (1981).

As information activities grow in importance, it is likely that the economic characteristics of information will increasingly influence economic activity and the nature of institutions governing it. Thus some understanding of these matters may have considerable efficacy for economics, other social sciences and for policy guidance.

Lamberton (1986) has summarised the more important economic characteristics of information and propositions central to the economics of information into 12 points as follows:

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(1) There is a great deal of difference between personal and group or organisational use of information. The division of information gathering may well be the most fundamental form of the division of labour.

(2) The cost of producing information is independent of the scale on which it is used.

(3) The greater part of the cost of information is often the cost incurred by the recipient.

(4) Learning takes time so that there is a limit to the rate at which decision makers can absorb information.

(5) There are usually significant information differentials in terms of possession of information, access to information and capacity to use information.

(6) The stock of information and the organisations created to handle information have the characteristics of capital.

(7) The output of the information sector is used to a significant extent by industry as opposed to consumers.

(8) The demand for information equipment, e.g. telecommunications equipment and computers, is a derived demand, dependent on the demand for information transmitted and computations performed.

(9) The combination of uncertainty, indivisibility and the capital nature that characterises information and information channels leaves the behaviour of organisations open to random influences and, more importantly, the successful pursuit of efficiency is likely to lead to a loss of responsiveness to change.

(10) The complexity of information activities makes information as a resource difficult to contain within the traditional production function mode of analysis.

(11) The limitations on information as a commodity dictate resort to organisations as an alternative to markets.

(12) Much time has been wasted in definitional debate. It is more fruitful to proceed as Arrow has done and say simply that "information is a descriptive term for an economically interesting category of goods which has not hitherto been accorded much attention by economic theorists".

A recent review of information and communication issues in economics is provided by Babe (1994).

Information and innovation

Within information economics, technology is regarded as information, albeit an important kind of information. Technology is defined as knowledge or information applied to doing things. Technological change or innovation becomes a change in the way of doing things, or doing entirely new things.

Information is inherently intangible, yet our concepts of technology – both in conventional economics and in the popular mind – wrap it very much in the tangible. In other words, we tend to regard technology as if it were an ordinary material good. Nelson (1980) points out that within economics, as well as more generally, technology carries an engineering connotation. That is, technology is characterised by blueprints or recipes like in a cookbook. Technology in this conception is highly codified or tangible and exists in a blueprint book. In this framework technological change or innovation simply involves the introduction of new or improved blueprints. New blueprints come about via a special set of resource-using activities directed to producing them, namely via research and development (R&D).

In the conventional model of the innovative process, R&D conducted within a firm is devoted to the production of new blueprints, or inventions (an idea for something potentially useful) which after more R&D become innovations (commercially successful inventions) which are then adopted by users and thus diffuse out into the economy and society creating economic effects such as increased productivity or whole new industries.

In contrast an information theoretic approach to innovation (Mandeville, forthcoming) moves beyond the narrow confines of tangible, highly codified technology, R&D and the individual firm to encompass a much more holistic view of the innovation process.

Nelson (1980) argues that generally whatever it is that permits a firm to operate a technology in a particular way with particular outcomes is only in a small part describable in a blueprint, teachable by example, or purchasable in the form of a machine. Thus every organisation must learn largely on its own, in a somewhat idiosyncratic and inimitable way. In other words, technology is primarily uncodified information and must be learned.

With regard to R&D, Macdonald (1983) argues that if technology is the totality of information which allows things to be done, such total information is unlikely to arrive in a crystallized package from the conventional R&D process. All that emerges from R&D is information – rather than full-bodied inventions and innovations – and this must be supplemented by other information before things will be done. Some examples of this other information include:

- information embodied in the hardware of associated technologies, or earlier versions of the technology in question;
- information suggested by users;
- software required to make the hardware work;
- information required to effect complementary organisational change;
- information related to marketing, understanding user needs and market feedbacks; and
- information obtained via a process of learning by doing.

In other words, innovation is a broad informational process of which the encapsulation of information in machinery, or the production of information via R&D are only parts. The innovation process needs to be viewed as a process of information flow as well as information creation.

The conventional view of innovation which regards the production of technological knowledge as something that is created mainly within the isolated firm is extremely narrow (see Lamberton's tenth point). A more realistic view embraces the concept of innovation as a social process involving many participants (Rosenberg, 1976). The production of new technology often depends mainly on the flow of technological information among firms. It is a process whereby bits of information are gathered from a variety of sources, mostly outside the industrial firm, to be assembled in new patterns within the firm. Technology builds on technology in a cumulative manner in the industry as a whole reflecting two economic characteristics of information. Information cannot be exhausted, but its quality can be enhanced by adding new information to the existing stock. Since the cost of production of information is independent of the scale of use (Lamberton's second point), it may pay an industry to share it as widely as possible.

Silicon Valley has been outstanding in high technology industry because the participants in the semiconductor and related industries acknowledge information as a fundamental resource and have adapted various non-market mechanisms (see Lamberton's eleventh point) to cater for its flow (Rogers, 1982).

Such mechanisms include informal personal networks, highly mobile experts, second sourcing, imitation and more recently, with the onset of the information superhighway, strategic alliances and joint ventures between firms.

One of the limitations of the conventional emphasis on hardware and R&D is that it predisposes observers and policy makers to overlook innovation in the service sector. The service sector, which includes most of the new, fast-growing knowledge industries and employs over 70 percent of the labour force, does not do much R&D as conventionally defined. Thus it is not usually considered as a source of new technology. Yet we are seeing an explosion of new products and services – innovations – based on information technology and telecommunications (IT&T) platforms emanating from the service sector. Many service industries are innovating via a process of adoption and adaption (Free *et al.*, 1993), adopting IT&T and adapting it to produce new products and services from Bankcard and EFTPOS to on-line services. Also in many service activities it may be that separate R&D – in other words searching and learning as a separate process – may not work very well. Instead learning and doing may be inseparable – the organisation learns as it goes along.

Does the foregoing discussion imply that we should scrap the conventional model? Not exactly – it still offers some general approximation of reality. Further, for some industries, such as chemicals and pharmaceuticals, it reflects reality very well. A new pharmaceutical product is often invented by a process of R&D within one large firm. After a lot more R&D and testing it is approved, becoming an innovation, which is then sold to the public. Rather than tossing out the conventional model, we need to be aware both of its limitations and of the broader information theoretic perspective.

We can provide a summary contrast of the two approaches to innovation as follows:

(1) *Conventional approach*

- linear flow from invention to innovation to diffusion;
- fairly precise;
- emphasis on R&D, the individual firm and on manufacturing industry;
- emphasis on tangibles such as inventions, machinery and blueprints.

(2) *Informational approach*

- non-linear, e.g. importance of market feedbacks;
- non-precise;
- information from many sources as well as R&D; innovation as a social process; innovation in services;
- emphasis on intangibles and thus on communication flows as well as on information creation.

An information economics model of innovation

Innovation is about the production of information (Arrow, 1962). Innovation is also an exploratory, learning process. The outcome of trying what has never been tried before, of exploring the new and unknown is inherently uncertain. Since the "meaning of information is precisely a reduction in uncertainty" (Arrow, 1979), innovation must be regarded as "most centrally, an informational process" (Rogers, 1982). Such a perspective on innovation – as an informational process – seems far removed from the conventional view that innovation is about the production of new machines and techniques. From an information-theoretic perspective, innovation becomes a collective, social, learning, evolutionary process in contradistinction to a one-off technical process.

Conventional theory about innovation is applicable mainly to a polar extreme case of tangible information. In other words, it treats information as if it were a tangible good. Of course, in some instances information is embodied in the tangible – for example, a patent specification or a machine – but for theory and analysis to proceed solely on this basis is like attempting to investigate all of microeconomic phenomena with only one polar extreme model of the firm and market structure. At least the microeconomist's tool kit has always included the two polar extreme models of perfect competition and monopoly. These served the professional well enough until the vast world in between – imperfect competition – began to warrant serious investigation in the 1930s.

An information economics model of innovation involves the development of a simple model that looks at two hypothetical polar extremes. Although the characteristics of technological information may vary continuously along a number of dimensions, it will be convenient for the analysis here to think of it varying along the following continuum: The extremes of the continuum are characterized by opposite emphasis on the degree of codifiability or tangibility of technological information.

Thus Mandeville (forthcoming) has developed an information economics model of innovation along the lines of a continuum with highly intangible, uncodified technology at one end and highly tangible, codified technology at the other (Figure 1).

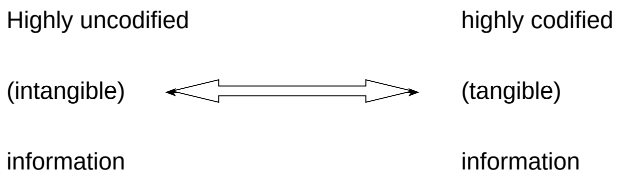

Figure 1.
Codifiability continuum of technological information

Technology is information applied to doing things. Some of that information is codified into machines, blueprints, technical and trade journals and patent specifications, but much of it is uncodified know-how. Codification represents embodied learning. The more learning that has taken place about a technology, usually the more codification that has occurred. Codified technological information is information that has been formalized (Bell, 1979). It has been arranged or organized into a pattern and embodied in something – that is, made tangible. As such, it can potentially be communicated non-personally without a human intermediary. Codified technological information can refer to techniques or known ways of doing things whose use yields predictable inputs and outputs (Nelson, 1980). Techniques may be represented by blueprints or recipes that provide sufficient guidance to enable one to be able to use the technique (Nelson, 1980).

There are degrees of codification of technological information. A patent specification represents a degree of technology codification, a working machine produced in a laboratory represents a further degree, that machine mass-produced in a factory is a further degree, while an improved model represents still a further degree.

Highly uncodified information is pure, intangible information. It includes both undeveloped ideas, as well as the know-how required to make a technology work. It is best communicated via personal communication between people. In the process of doing things, including the generation of new technology, codified and uncodified information are complementary.

The degree of inherent complexity of a technology as well as its degree of newness determine how codified it is. Applying the newness criteria, generally speaking, the older or more mature a technology, the more that it has been codified. Know-how is still important, but the bulk of technological information has been codified. In a highly mature industry, it is likely that the innovative process does not require much information movement. By contrast a new industry based on a new technology is in a fluid situation where the bulk of technological information has yet to be codified. The innovative process in a new activity is likely to require a good deal of movement of information between participants in order for information to build on information and learning to accumulate. Thus the concept of codification is likely to be most important in context where a good deal of technological information is required to be moved.

Considering the two extremes of the continuum in Figure 1, most of the real world probably lies somewhere in between. However, it is likely that the bulk of economic phenomena associated with innovation occurs toward the left of the continuum – toward the intangible and uncodified. Yet conventional analysis focuses almost exclusively to the right – toward the tangible and codified. Thus in contrast to the conventional view, an information-theoretic perspective would assign a relatively minor role to highly codified, tangible technology in the workings of the innovative process.

Information has conventionally been regarded as a public good or collective good of the purest kind since it can exhibit both non-exclusion and non-rivalry in consumption. The simple informational codifiability continuum model in Figure 1 suggests a new interpretation on the public goods versus private goods distinction. Conventionally they are considered opposites with the market mechanism being the appropriate allocative framework for private goods and government or some other non-market mechanism being appropriate for public goods.

The more codifiable a technology is, the more it begins to resemble a public good in the sense that once created, additional users can use it or copy it at little or no cost. But paradoxically, the more codifiable a technology, the easier it is for the market mechanism to facilitate its exchange, the easier it is to commodify it or make it into a private good. In other words, both public goods and private commodity goods relate to the highly codifiable end of the technology spectrum.

Highly uncodified technology is not a commodity; it is so intangible that transactions costs will be too high to facilitate convenient exchange via the market mechanism. But uncodified technology is also not a public good in the sense that additional users can obtain it at little or no cost. Indeed, the more uncodified the technology, the more important user costs (Lamberton's third point) become. A basic problem for conventional economics coming to grips with technological change is that highly uncodified intangible technology slips through the conventional concepts such as public and private goods.

Conclusion

This paper has attempted to demonstrate that an information economics perspective, both generally and in the context of a simple model, improves our understanding and provides new insights into innovation, compared to a more conventional economic approach.

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