MEASURING THE KNOWLEDGE-BASED INFORMATION ECONOMY

Don Lamberton and Max Neutze
Urban Research Program
Australian National University

Report prepared for the Australian Bureau of Statistics
March 1999

Terms of Reference

This paper has been produced under a consultancy contract with the Australian Bureau of Statistics which required "... the preparation of a discussion paper on emerging needs for statistics about the knowledge based economy, the information sector and related concepts..." The paper was required to outline "the statistical indicators which might be appropriate to meet these needs and the concepts of, and the interrelationships between

- the knowledge based economy,
- the information sector,
- the information economy, and
- the information society.

The paper should assess the suitability of the current range of statistical indicators available about information technology and telecommunications in the context of these broad concepts. It will also need to consider the links between these indicators and those which look more widely at science and technology generally. In this context the paper might also cover statistics about research and development, innovation, the diffusion of advanced technologies, patents, payments and receipts for technical know-how and similar data. How globalisation might impact on science, technology and knowledge based outputs, might also be considered. Similarly the measurement of knowledge based indicators may lead to a consideration of issues such as skills, training, education and the utilisation of human resources on science and technology.

In considering the most appropriate indicators, the discussion paper should address relative priority and ensure that the output is measurable."

We have found these terms of reference very demanding and have given little attention to some that we regard as secondary or where we do not have the required information or expertise. These include: the impacts of globalisation; a detailed consideration of science and technology; and the diffusion of advanced technology (we do not believe that scientific and technological information and training need be treated differently from other kinds of information and training). Nor have we given detailed attention to the information society. In addition we have not carried out a detailed investigation of all of the current statistical series produced by the Bureau, choosing instead to concentrate on principles. We have argued in terms of directions in which data collection should progress rather than attempting to define specific collections.

Introduction

This paper first describes in very broad terms the impact of the rapidly growing and changing use of information in the economy and society. In particular it traces the changes that have been required in economics as it seeks to understand these impacts and include them within the discipline. It shows why the concept of an `information sector' is inappropriate when the change towards a knowledge-based economy has pervaded all sectors and attempts to identify the major, interwoven barriers to new thinking: technological determinism, the primacy accorded the market form of organisation and the influence of natural science traditions.

After sketching an approach to measurement and its possibilities, several major issues are addressed: information as capital; a taxonomy of information; measurement technique for the secondary information sector; and international dimensions. The paper closes with comments on current ABS collections and some suggested steps to the future.

Recognition of emerging needs for statistical indicators appropriate to the knowledge-based economy has focussed on the concept of an information sector, which groups together producers and users of information, contrasts them with traditional sector categories such as agriculture and manufacturing, and goes on to consider the interrelationships between sectors. It is our contention that a necessary first step must be in a different direction, addressing the role of information in all economic activity.

This step seems a logical one. Starting in the 1930s Colin Clark and others popularised the distinction between the primary, secondary and tertiary sectors of the economy and argued that shifts from one to the other could be understood as a function of differences in the income elasticity of demand for food, fibres and minerals; manufactured goods; and services. That classification of industries seems less useful now, especially since about 70 per cent of employment is in services and, as recognised in input-output tables, the three sectors are by no means independent. One of the reasons for the growth in the service sector is that functions that were once performed by mining, farming and manufacturing firms are now performed by separate firms in the service sector. Many of those services themselves are information intensive. If they are purchased from an external supplier they are, in the new terminology, in the primary information sector (PRIS) but if they are provided in house they are in the secondary in
formation sector (SRIS). Whether they are provided in-house or purchased from an external supplier depends on the nature and use of the information and the ability of the managers to understand, interpret and use it. The recent management fad for outsourcing shifts the provision of information services to the primary information sector (PRIS) from the secondary information sector (SRIS).

The Information Revolution

The second half of this century brought many spectacular changes in the provision of information services—TV, computers. satellites, fibre, local area networks (LANs), wide area networks (WANs), the Internet and “globalisation"—and a growing agreement that society was experiencing a fundamental transformation. Many of us now see ourselves in the middle of the Information Revolution, with a profusion of labels dependent upon one's perspective: the information economy, the control revolution, the clever country, the global village, the knowledge-based society, the network economy, the weightless world.

The complexity of these changes and the pervasiveness of the decisions, processes and issues they occasion have led to a voluminous literature dealing with both technical and socioeconomic aspects. A very well-placed observer estimated that there were some 20,000 publications in a narrowly defined economics of information by the early 1980s. Rapid growth from that base has been accompanied by an even greater literature of more general economic and social writings, because the role of information is inherently social and has fostered much interdisciplinary study. Information was said to "occupy a slum dwelling in the town of economics" in the early sixties (Stigler 1961) and more than a decade later was described as "an economically interesting category of goods....not hitherto accorded much attention by economic theorists" (Arrow 1973). In this paper we draw freely on this literature with minimal quotation and citation.

The pervasiveness of change that we wish to emphasise calls for radical rethinking of the way an economy functions and this in turn creates a need for different measures of economic activity and performance. It seems useful to illustrate this pervasiveness as a first step.

Growth and productivity

Growth and productivity are prime economic concerns and the notion that "the difference between the economic potential of the Stone Age and this or the next century is a different range of relevant techniques and information" (Robbins 1968) would probably not be too strongly contested. However, to the extent the role of information/knowledge in affecting growth and productivity was acknowledged in measurement efforts, the focus tended to be on one particular kind of information: that generated by research and development (R&D) expenditures. The notion that experimentation is a part of all economic activity has gained currency in recent years. Business gathers intelligence and experiments with, for example, products, marketing, organisational forms, asset management, training, and alliances; consumers experiment with new products and services; and governments experiment with forms of intervention.

Recently, the inability of analysts to show any significant contribution to performance from the enormous expenditures on IT—a curiously imprecise category of technology which logically ought to include paper, pencils and little black books as well as sophisticated computerised data systems—generated the as yet unresolved productivity paradox. The central issues are, first, that IT expenditure takes in only one element of the information input. Human skills, organisational capital and, above all, information itself also are essential elements. The productivity analysis has been conducted in the hope which we believe unwarranted, that the information/knowledge role can be treated just like that of any other good. IT expenditure is not a good proxy for this information package.

And now New Growth Theory seeks to write knowledge into the production function, with inadequate attention to the absence of precise definitions of knowledge and how to measure it and therefore how to estimate appropriate input-output coefficients and the data quagmires to which that leads. It is unlikely that anyone ever thought of technological change as wholly or even nearly wholly exogenous—as manna falling from heaven. New Growth Theory probably errs too much toward the other extreme, trying to make technological change wholly endogenous. What we need is an information perspective that recognises that both processes are involved: that while the production of new knowledge can be a normal, everyday activity, some of the greatest achievements come out of left field.

Information Asymmetry

A second illustration of the pervasiveness is so-called informational asymmetry: some people or organisations have information others lack and this can have major equity implications and can, in the information economy, contribute to patterns of income distribution. Such asymmetry, of course, bears on regulatory matters such as universal service obligations of providers of information and providers of services such as telecommunications which give access to information, and the very role of government if one sees political survival as requiring broad transfers of income and wealth. In this way asymmetry considerations go to the heart of utility theory and economic justice.

One of the most basic efforts to treat the concept of justice—the Rawlsian approach—defines the optimal distribution of income/wealth as that which would be agreed upon by people who did not know what their own position would be within the distribution, the so-called ‘veil of ignorance’. But that effort founders when we try to clarify the meaning of the veil of ignorance, used to define the just distribution. It has to be assumed that some knowledge is possessed by all citizens, but they do not know how they might fare as history unfolds. The human dilemma of uncertainty intrudes. There always will be room for disagreement about empirical fact. It is difficult, even impossible, to separate empirical fact from political opinion, e.g., in the case of free trade doctrine. And no one can have all

knowledge, so there will always be a need for those who know different but complementary things to cooperate.

Informational asymmetry may seem at first to be a simple matter: the best offer A knows to be available for a given purchase is $x whereas B knows where the same purchase can be made for $x - 10%. Reality proves much more complex and raises issues of understanding, capability of understanding, learning and purchasing power to buy information and advice. The capacity to make use of information may depend upon a very complex set of complementarities, as illustrated in the current rapid diffusion of Internet access and the reported reasons for dropout from the Net.

These reasons demonstrate the important links between the availability of technological equipment and other resources. A US study found that dropouts were younger, poorer and less well educated than continuing users. While teenage users were especially likely to drop out, females were not more likely to drop out than males. Initial commitment and motive and sunk costs emerged as important factors affecting perseverance (Katz and Aspden 1998).

If we abandon the notion of the business firm that figures in economics textbooks, i.e., a point in space at which resource inputs are magically transformed into goods and services consumers are willing to buy, we have to come to grips with a firm as part of a network, as an organisation that has been created very largely to handle information. Similarly, establishments are parts of the sub-network that makes up a firm. Firms and other organisations, be they private, governmental or even a professional group such as the economics discipline, have to manage real and intangible assets, monitor their environment, store and retrieve information, communicate, coordinate and make decisions. A new textbook on Australian economics uses the local petrol station as its illustration of the firm but the very great differences between a local petrol station and the latest worldwide alliances in airlines or telecommunications have to be recognised and incorporated in our understanding of the economy.

Information Technology

It is helpful to consider briefly the role of IT, defined as is the current fashion by the fact that it handles information electronically. In terms of our pervasiveness theme, we emphasise the role of coordination, a role that is only partly guided by price signals and has to rely to a great extent on administration. IT has extended the range of coordination enormously and is believed to have reduced the costs of coordination at the same time as it has increased its reliability. Computers compute but they are also coordination instruments, holding and processing information to keep human and machine activities in step.

We might distinguish three stages in an application of IT. Of course, earlier stages of such an innovation are themselves information processes. Once these have taken place and there is a belief, generated by technological fervour or cost effectiveness analysis, that this particular application reduces the costs of coordination, we can consider the ensuing events. A first stage could well be the substitution of IT for human coordination and the associated data processing, as has happened in banking and insurance. The human role in keeping tabs on what is happening is diminished and this eventually occurs even for the functions previously performed by middle management.

As we would expect if cost is believed to have fallen, more coordination will be used. This second effect has been apparent, for example, in travel, finance and maintenance systems. There are gains from pooling of information, which many multinational firms have always reaped.

A third kind of consequence is to reorganise and become more coordination-intensive so as to take even greater advantage of the perceived gains. This reorganisation may be internal to the existing firm or, very probably, may extend to relationships with other firms. Here again, industries like airlines and telecommunications are prime examples where the potential for change focuses on the organisations themselves and the possibilities for redesign.

Of course, these stages and processes are not necessarily sequential: information may be imperfect; the perceptions of costs and benefits may be hazy; some knowledge of staff made redundant may be lost; and there will be political issues stemming from competitive relationships within and between managements. Information from internal and external sources does not mix easily and management fashions can change with remarkable speed. The overall outcome, which can seldom be separated out from other sequences of events, is clearly an empirical matter and not to be prejudged in terms of some doctrinal position. Tidy arithmetic will not be possible for either a small business or a major international alliance.

Perhaps the most fundamental thought underlying the development of an information economy was that it involved a change in the kind of work to be done. If economic development is an evolution towards a more and more complex pattern of coordinated activities, it involves an increasing division of labour. To the extent that this turns on economies of scale and scope, it does not hold promise of a computerised world in which 'small is beautiful'. Furthermore, these modernised economies would seem to devote considerable resources to maintaining political and monetary stability. There has been a growth of international organisation; and the open economy so generally advocated may prove to be in need of state underwriting of risks. Both involve costs. We may now be at a stage where we are reducing the volume of traditional work but are only beginning the task of maintaining national and international stability.

In respect of the nature of work, the expectations were for a change from physical labour to intellectual effort, with possible locational changes ÿ the global village seemed to have idyllic settings. To date the evidence seems to favour the forces for propinquity and cities and their congestion seem set to remain. It would also be unwise to omit sweatshops from cyberspace scenarios.

Intellectual property

Property rights and a legal system have been an integral part of infrastructure. As would be expected in an information economy, intellectual property rights loom larger e.g., patents, copyright, design, trade secrets, and plant variety rights. This reflection of the progress of the information economy illustrates a typical response pattern. As might have been expected, in part because patent law is one of the oldest instruments of state economic intervention, the response has been to accommodate new types of property rights within the existing framework - new wine into old bottles. Proof of the adequacy of these measures is still awaited. However, the complexity of protection of the intellectual property in software, for example, appears to represent a great challenge. And there are complex interrelationships between intellectual property and the entire standards setting process. Standards may be set by government intervention but may also emerge from firms that have dominant positions in particular ma
rkets.

The greater importance of intellectual property in the information economy has been reflected in both national legislative efforts and also in flourishing activity at the international

level. International competition and trade duelling can be seen in the agenda of GATT, TRIPS (Trade Related Aspects of Intellectual Property Rights) and WTO. Regulation is closely related to property rights.

Regulation and globalisation

The theory that regulators are captured by those they are supposed to regulate (partly because the latter have more information) seems to have been replaced by endogenous regulatory theory—a new label that seems to legitimise capture by making it a natural outcome of the membership structures. Whatever the label, informational asymmetry plays an important role and cannot be ignored in the major regulatory developments at the WTO, more especially in competition law and investment agreements. It is also important in judging the ability of small regulatory authorities to effectively regulate large corporatised or privatised public utility suppliers.

The most spectacular of these developments figure under the globalisation heading, which for the most part are designed to further the interests of business rather than consumers. A major element of the wave of agreement arising from the information revolution is to be found in thinking about the manner in which global society is being created. While it falls short of the global village in miniature, a Transnational Communities Program established recently under the UK ESRC at the University of Oxford is a good illustration of research interest. It is based on the belief that the rapid growth of transnational networks, which connect people regardless of distance or international borders, is creating entirely new flows of information, culture and capital.

The Oxford Program will explore the human side of globalisation rather than its economic aspects, e.g., looking at the way expatriate managers and their families adapt to living and working in the UK. Both the economic and human perspectives are affected by business, media and telecommunications. IT—telephone, fax, e-mail and the Internet—helps create networks and those networks exert social, cultural, political and economic influence.

These illustrations have been intended to make clear that understanding how the information economy works calls for much more than a narrow definition and measurement of an information sector of the economy, information as a good or service or technological dimensions. For an open economy, capital has to include machines and buildings, stocks of information/knowledge, a wide range of capabilities (both individual and organisational), and even language as capital. This has implications for treating expenditure on research, development, education and training as investment rather than consumption. The legal and political framework is a kind of capital, although we may prefer to talk about institutions and infrastructure. However, the distinction between capital and institutions itself is challenged by the information perspective, which requires us to see information conditions shaping those institutions.

In sharp contrast to models of the economy that assume perfect competition where all information is universally available at no cost, all economic activity spends heavily on getting information. Information is costly but information-handling is an essential element of production, marketing, innovation and development processes. The information perspective permeates the roles of both business management and government, in the latter case both as participant in economic activity and as custodian of the public interest. The latter role may cross the boundary between the information economy and the information society,

The Information Perspective in Economics

The neglect of information by the economics discipline is well-documented. The most elegant theorising found it convenient to ignore the problem by assuming 'perfect knowledge' and thereby having an excuse for not studying what was long ago recognised as a major `industry' (Knight 1921). The implication to be drawn from such theory—that this industry did not exist—did not seem to worry theorists, at least not until it was quantified for the US economy, at 29 per cent of GDP (Machlup 1962). Then began the migration from the slum dwelling, but mainstream economics would tend to go on working with assumptions that decisions were made on the basis of such rich and accurate information, that the costs of information were negligible, and all decision-makers had full competence in interpreting and using it. Mounting evidence that information handling in all its forms—production, storage, dissemination, use—was a major claim on resources, was, at first, inconvenient, but later it provided an effective challe
nge to the intellectual conservatism that Adam Smith had called "prejudices of education".

Some aspects of information could be more easily accommodated than others; informational asymmetry, for example, could—with the help of game theory—yield a considerable literature, a literature so large that for many informational asymmetry became the whole of information economics. There was, however, a growing awareness of a much wider range of embarrassments for mainstream economics. Consider, as examples, the following short selection of comments from economics literature since the 1950s:

- "The prices of all goods could be deduced if we knew with sufficient detail for each person in the market the answers to the questions 'What does he like?' and 'What does he possess?' It did not occur to most of those who built the beautiful neoclassical structure of static value theory to put upon the same footing a third kind of question: " What does he know?" or "What does he believe?" (Shackle 1957);

- "The pursuit of profit has become the pursuit of knowledge" (Boettinger 1967);

- "Knowledge is not a pile of homogeneous material, but a complex structure of heterogeneous thoughts, each available at zero marginal cost but usable only together with resources available only at positive and often very high cost" (Machlup 1982);

- "There is need for modelling of the economy, or of its parts, in which information is continuously being collected and processed and in which decisions, based on that information, are continuously being made" (Stiglitz 1985);

- "It may well be that only the observing and modelling of real organisations - something economists have been reluctant to do - can lead to models of technology and cost which fit usefully into a unified theory of organisational design" (Marschak 1986);

- Information is "the problem case in which the internal tensions of the [economics] discipline come to the surface" (Boyle 1992);

- "The old metrics designed to quantify duplicative production and accumulation will not quantify new ideas nor will they measure and sort the inputs and outputs of an economic system geared to change... [W]e need a new paradigm: new models, new variables. This will mean new measures" (Carter 1996).

Fundamental flaws in mainstream reasoning have been revealed. In particular, the fragility of much theorising has been demonstrated; big differences in outcomes follow from small changes in the assumptions made about information. Attention has focussed on alternative

ways of organising an economy and this in turn has demanded a return to square one. Textbooks customarily began with several questions: What is to be produced? How is it to be produced? For whom is it to be produced?

The transformation brought about in the Information Revolution requires consideration of other questions: What do decision-makers know and believe? How are decisions made and by whom? How much information should be acquired before decisions are made? How can the separate decisions throughout the economy be coordinated?

The focus then shifts to organisation; a shift that may possibly hold promise of mending the rift between economics departments and schools of management, although both are likely to need a good deal of interdisciplinary help if they are to cope with the complexities of information and organisation. IT-oriented management and business economists have both shied away from matters of organisation. From an IT perspective, the best technology should be adopted and organisational adaptation will take place. The economist takes the technology as given and ignores the need for and cost of informational and organisational arrangements.

Barriers to New Thinking

There appear to be two major, interrelated barriers to new thinking about the information economy: technological determinism and the primacy, even the tyranny, of the market. We might add a third barrier: the fact that we work in the 'glare of natural science'. Norbert Wiener castigated his social science colleagues for their wish to emulate the physical sciences: they had gone from thinking it necessary to believing it possible. This issue has a direct bearing on the development of and dominant attitudes within both mainstream economics and computer and information science, but it will not be discussed further here. We shall see that all three tend to belong in Smith "prejudices of education" or what today might be called organisational obsolescence or lock-in.

Technological determinism

Publicity for a recent information economics book for use in management schools highlights the intractable nature of these barriers: "Technology changes. Economic laws do not" (Shapiro and Varian 1999). Several comments need to be offered here. First, technology is useful knowledge. This includes the knowledge embedded in the machines on the factory floor and the design of the building in which they are housed. But it should include also the knowledge about how to organise and coordinate the activities involved, research capability and managerial capability. As we indicated earlier, computerisation could permit coordination and lead to changes in organisational design. In discussing the information economy, it is vitally important not to restrict the scope of the definition of technology, for example, the common restriction of information technology to technology that uses electronics.

These biases, especially that relating to technology, have played a major part in the efforts to conceptualise and measure the information economy. To clear the way for a fresh start, we must retrace the path from the pioneering work of Machlup (1962), Porat (1977), the OECD (1981, 1986) and the influential work of Miles and his colleagues (e.g., Miles et al . 1980). The simple truth is that the Miles report, Mapping and Measuring the Information Economy , gave virtually no attention to the information economy, preferring to focus on IT. This approach also characterised the 1997 UK Green Paper but it was given the more appropriate title, Mapping and Measuring the Information Technology, Electronics and Communications Sectors in the United Kingdom.

Miles et al. noted that the information economy had been identified with the economic role of information; information had always been important but information categories were not familiar ones in official statistics. The OECD contribution had been to take up the approach pioneered by Machlup and modified and publicised very effectively by Porat. Basically, this was done by identifying the production of information goods and services as an information sector. This effort too was influenced by the recognised pervasiveness of the new information technologies and by the need of the OECD Committee for Information, Computer and Communications Policy (ICCP) to monitor developments in those technologies and to measure the associated changes in employment. The state of the art of national and international statistical classification schemes for occupations and industrial activities did not allow both impacts to be captured for all economic variables.

An indirect approach (said to be analogous to an inverted matrix) was devised, built upon a typology of information occupations within the workforce whose primary function was the collection, processing and distribution of data and information. In practice, the function included the production, storage and utilisation of information. The ICCP emphasised that the term information economy was not intended to describe "a distinct socio-economic phenomenon" (1986, 8). This OECD typology is set out in Table 1.

From a goods and services perspective, a primary information sector (PRIS) was defined to include all information goods and services sold on established markets. An information good or service was one that intrinsically conveyed information or was directly useful in its production, processing or distribution. A broad distinction was made between:

- services that involved information handling, e.g., legal and accounting services, education, broadcasting, data processing, and

- goods for information activities which further subdivided into consumption and intermediate goods, e.g., office supplies, radio & TV, watches, calculators, and investment goods, e.g., office machinery, communications equipment, electronic components.

The OECD primary information sector goods and services classification is set out in Table 2.

Just as the occupation categories included workers primarily engaged in a particular activity, so goods and services were included in accordance with the major activity of the basic statistical unit: establishment or enterprise as the case may be. The contribution of these goods and services to GDP at factor cost was assessed using a value added method of measurement. In this way the economic impact of information activities at intermediate as well as final stages of demand were included. This was possible because the data were available for value added at a far more far more disaggregated level than for final demand. While the principal products or services were those making the major contribution to value added, if data were inadequate, gross output or even employment was used instead of value added.

A secondary information sector (SRIS) was defined to record the value added by information activities that are not marketed. They are produced and used in establishments that are primarily producing non-information goods and services, i.e., those not already included in the PRIS. They may be an adjunct to manufacturing processes, for example, legal services provided by legal firms to
the general public and to business firms through established markets are included in the PRIS. In-house legal services used by a manufacturing or retailing company would be included in the SRIS.

The importance of the SRIS arises from the basic characteristics of information and information channels. Information can be bought and sold as a commodity but only to a limited extent. This follows from some of its basic characteristics:

- information being indivisible in its use. No one is willing to buy the same information twice;
- information is not fully appropriable and can readily be copied;
- information is not used up; and
- a seller of information still has it.

Organisational forms are then shaped by these underlying conditions. It would seem likely that an economy with overall increased information intensity will therefore have a larger SRIS. Outsourcing, as mentioned earlier, amounts to a shift in the opposite direction, from the SRIS to the PRIS.

An alternative approach was preferred by Miles et al (1990). They argued that the notion of an information economy had gained prominence, not because of the overall growth of the information sector but "because of the emergence of new IT, and the widespread recognition of the revolutionary role of the technologies involved... The information economy, then, hinges upon the application of new IT" (10). They conceded that this would be seen as "crass technological determinism" but rejected the charge: "It is by no means our claim that new technology is causing the emergence of an information economy" (11). They went on to state that "the information economy is best conceptualised as involving a particular stage in the development of industrial society. "Information economy" is a shorthand description for this complex of changes associated with—not caused by in a simple deterministic sense—IT and its diffusion through the formal economy and society at large" (11).

What then is IT? From the many definitions available, Miles et al. favoured emphasis on the convergence of computing and communications. Boundary problems arose: stand-alone microcomputers would be excluded but the abacus and smoke signals included!

The solution, so we were told, lay in the realisation that some process was leading to the convergence; that process was at the heart of the new IT; and that to the extent that computers and telecommunications have been transformed by that process, they are at the core of IT. Because that process was facilitating transformations in the whole economy—the information economy—the interesting issue was the extent to which products and services were IT-intensive.

As a final step, the factor promoting convergence—with increased power of computers and telecommunications and reduced costs, but on a narrowly defined basis—was identified, i.e., what "is popularly referred to as 'the microelectronics revolution' ". Crucially, it is the radical, rapid, and continuing development of microelectronics power that has provided the basis for the development of new IT: for the proliferation of new products and processes throughout the economy" (15).

Because the UK Green Paper (1997) has acquired authoritative status in relation to the information economy, we draw attention to the extent to which the underlying reasoning follows on from Miles et al. ITEC (Information Technology, Electronics and Communication) is now the sector to be mapped and measured and "Informatisation" is now "the progressive application of information and communication **technologies** to the input,

storage, processing, distribution and presentation of information" (s. 3.1, our emphasis).

In a potted history of mapping and measuring the information economy, earlier work is labelled as pre-ITEC and dismissed (s. 2.1). There is scant appreciation of the profound role of information as explored in, e.g., Machlup's work cited above (Machlup and Mansfield, 1983). Consider just one illustration: liquidity as a substitute for knowledge. Here is a simple notion that in due course requires us to think about uncertainty and the organisational arrangements for handling the relationship between money and knowledge—a relationship that, even in the ITEC context, might illuminate patterns of change in consumer and business behaviour and elicit policies. But the Green Paper and the ITEC approach generally are incapable of considering it.

History most certainly has a contribution to make as it poses major questions such as: Is it reasonable to assume that the information economy began with microelectronics? What of the quite remarkable changes that led earlier to the growth of clerical occupations to such an extent they became the dominant occupational group? What of a future in which it is conceivable that electronics might merge with or be supplanted by biotechnology?

Faced with our present classificatory dilemma, it is helpful to ask what lies behind this three-pronged promotion of ITEC primacy. First and foremost, there are governments and those responsible for policy rhetoric. As Mathias warned:

> "Some present day governments (of both parties) in Britain, as elsewhere, like some economic historians and contemporary tourists, have been too impressed by dramatic instances of the latest technology when making judgements about the sources of productivity. In a similar way, some industries ... become invested with a totem or fetish quality, whereby they symbolise in the public mind the fate of the entire economy and become a test of national viability, success against foreign competitors, patriotism and even a sort of collective national virility" (1983, 18-19).

A cursory study of economic history shows how these iconic industries rise and fall, for example, steel, textiles. motor vehicles and aerospace.

Governments which proclaim universal reliance upon the market test and censure efforts to pick industry winners are nevertheless willing, even enthusiastic, about picking technologies. They are aided in such initiatives, first, by the firms and industries producing the new products and services who have an interest in shaping policy stances, and, second, through public acceptance of those new products and services. This is part of the promotion of shared models of the future, which rely upon self-fulfilling prophecy and rhetoric.

The primacy of the market

The second element is what we have called the primacy accorded to the market mechanism. A strong case can be made (Simon 1991) for viewing the economy, not as a market economy, but as an organisational economy, with market relations amongst organisations. Those promoting IT seem unwilling to recognise that the market is "the largest and most effective information system in existence" (Machlup 1979). It does not seem unreasonable to say that when bureaucracy, both private and public, is added to the market, the resulting aggregate is the information economy. The primary and secondary information sector concepts emerged from attempts, working with very limited statistical data, to show how such an economy functioned through the combined roles of the market and administrative decision. Analysis of the linkages within and between industry sectors and between information and non-information sectors involved much more than the "

information component" that Miles et al . conceded had been a features of all s ocieties.

An Approach to Measurement

Against this background, we shall now restate the objectives of defining and measuring the information economy and proceed to outline an approach that we hope escapes the fascination of hardware and the influence of vested interests and is built upon the fundamental features of the knowledge-based information economy: uncertainty, organisation and learning. The objective is to understand the working of such an economy and to enable purposeful and wise decisions and policy interventions that foster both beneficial growth and economic justice.

The changes we are exploring have implications for the distribution of income. Ideas about income shares are not to be divorced from the ongoing activities in the economy; they have historical dimensions. It made sense in the Industrial Revolution to draw a sharp distinction between capital and labour power, and the categories of wages, profit and rent were thought to correspond to meaningful politico-economic groups. Changed skills, the growth of scientific knowledge and new technology have blurred the capital/labour distinction. Changed conditions in agriculture and the development of corporate business eroded the socio-political content. We now have to contemplate a further stage in this evolutionary process in which information and organisation dominate the demand on resources.

One useful approach may be to concentrate on the ways in which economic activities use knowledge and information (Machlup said knowledge was information of indefinite tenure) and the kind of knowledge and information they use. Some possible classifications include:

1. Knowledge and information as investment:

- in the knowledge and skills of people through education, training and on-the-job experience;
- in the organisation of production through software and business organisation;
- embodied in buildings, plant and equipment; and
- in intellectual property produced through research and creative activity and taking the form of, for example, printed matter, musical scores and film and video recordings.

2. Knowledge and information as ephemeral goods used in consumption and production:

- market information used by producers and consumers about prices and quantities traded and about expected demand;
- information which is purely a consumption good including most news, artistic performance and much of the information provided through the media;
- information supplied by those with the necessary knowledge and access in the process of supplying services including legal, accounting, medical etc services.

Possible classifications of the ways in which information is used overlap to some extent with the above classifications:

1. Producers of information which is then processed into a form in which it is useful to, and supplied to, other people. These include researchers, creative artists and collectors of information.

2. Producers of services who use their knowledge and skills to select and process information required to provide a service in which that information is embodied. This includes most professions such as medicine, law, accounting, management and some aspects of education.

3. Disseminators of information including the media, telecommunications, artistic performance, printing and publishing and other aspects of education.

Measurement Possibilities

1. The measurement of information intensity

Consistent with our reservations about the usefulness of defining an information sector of the economy, the ideal approach would be to measure the information intensity of different activities, including not only producers of goods and services but also consumers, government and non-profit activities. If this were possible there would be no need to make the essentially arbitrary decisions about what activities are in and what activities are not in the information sector. One of the dangers of defining an information sector which remains constant over time is that the most important changes may occur at the boundaries as individual classes of activities become more or less dependent on knowledge and information.

The difficulties with this approach, obviously, are in finding adequate measures of information intensity. A few spring easily to mind:

- proportion of expenditure on education and training;
- proportion of employees who have qualifications at different levels;
- proportion of expenditure on marketing , including information about markets for inputs;
- proportion of expenditure on research and development and protection of intellectual property;
- proportion of expenditure on purchase of information;
- proportion of expenditure on communication; and
- proportion of expenditure on equipment used to transmit, store and process information.

The complexities involved can be illustrated in one case: R&D. The expenditure under this heading covers a number of elements: the production of knowledge, and maintaining research enterprises, with some parts attributable to education and training and communication, and probably, to routine testing, product marketing and public relations.

Even this list of potential measures of information intensity is necessarily incomplete and the various indicators are subject to weighting, though they are self-weighting to the extent they are expressed in dollar terms. Developing a satisfactory measure of information intensity will take some considerable time. Most other approaches fall somewhere between this and the identification of an information sector that remains constant over a period of time.

2. Classifications of goods and services

The value of the marketed output of goods and services that comprise information or for which knowledge and information comprise a high proportion of the total costs can, in principle, be aggregated. There is a good deal of overlap between such a classification and an industry classification since many industries are classified by what they produce and the best source of data on the value of production is the value of output of firms in particular sectors. These features are illustrated in Table 2 which reproduces the OECD list of the primary information sector. Of course, it omits the secondary information sector: the value

of goods and services that are produced within firms that are not primarily engaged in producing information goods and services, and are used within the same firms rather than being sold.

The main advantage of this approach is that, like the occupational classification, it can in principle capture the value of sales of information goods and services from establishments and firms that are not primarily engaged in the production of them. The disadvantage is that it counts only those information goods and services that are sold and therefore misses in-house equivalent activities. The methods of measuring the SRIS and their difficulties will be discussed later.

3. Occupational classification

Occupational classifications are available in a good deal of detail, especially from the Census (See Table 1 for the OECD Information Occupations). Their main advantage is that an occupational classification is likely to reveal the extent to which the use of tacit knowledge, or of information that workers have the skills to process and apply, is an important component of the jobs of individual workers. Within the limits of the existing occupational classification system, such workers can be identified even within industries that are not mainly in the information sector. Even if current occupational classifications do not fully reveal such information, it should be possible to adapt them so that they do.

The main disadvantage is that, in the first instance, they provide only the numbers of employees in the information sector. If the rather heroic assumption is made that earnings of employees reflect their marginal productivity, it might be possible to estimate the proportion of the total output of labour which arises from tacit knowledge and the processing and application of information by employees. But it does not reflect at all the product of information and knowledge embodied in physical or organisational capital of the kinds described above.

A second disadvantage is that estimates of the numbers and gross incomes of workers engaged in any fixed list of information intensive occupations will not capture changes over time in the extent to which an individual occupation uses information or is dependent on high levels of tacit knowledge or ability to interpret information.

4. Industry classification

This is the common starting point for those wanting to get some idea of the significance of the information sector defined in the traditional way to include all firms/establishments primarily engaged in an activity usually defined in terms of using a common input or technology or producing a common output. Statistics of this kind are available for a large number of industrial subdivisions.

Its main advantage is that, since it is based on information collected from relatively small productive units such as establishments, it can provide data about the value added in any aggregation of those units. It is the only source of value added statistics which have the great advantage that they include the value of output from capital as well as from labour, and measures of the amount of capital and labour used.

One important disadvantage is that the smallest unit from which data can be collected may be engaged in a variety of activities, some of which are information intensive and others mainly goods handling or the provision of services which embody little information. This is a problem even when data are collected by establishments which are classified according to their main activity. It is even more of a problem if data relate to larger units. Accurate

information about the different activities that occur within an establishment or a firm may not be available from the accounting records of the firm and could be estimated only with difficulty.

Another important disadvantage is that the industry classifications currently in use are not designed to reflect the information intensity of individual firms or establishments. It is quite possible that different establishments using the same inputs or processes or producing the same output may vary greatly in information intensity.

Using an industry classification may not reveal the tendency for many parts of the economy to become more information intensive over time. For example, farmers are increasingly dependent on information about markets and about climatic expectations and conditions in different parts of the world in making decisions about what to produce, when to harvest and when and where to sell. Similarly, investment and production decisions in the mineral industry are dependent on market expectation, investment on the long term future and production on the more immediate future.

Several major issues arise from this suggested approach: information as capital; a taxonomy of information ; measurement technique for the SRIS; and international dimensions of the knowledge-based economy.

Information as Capital

We might recall Joan Robinson's remark: "K is capital, K is investment. Then what is K? Why, capital of course. It must mean something, so let us get on with the analysis.." But getting on with the analysis poses the old question in a different form: Is expenditure on information investment? Is information capital? Faced with incomplete, specific information for an investment decision, there is a problem of the optimum level of expenditure to acquire more information. If the information acquired remains of value into the future and the economic benefits accrue at a later date than the acquisition of the information, the expenditures on information are investment and should be treated as K.

Like other forms of capital, information is structured; its parts complement each other, imposing sequences or lags, and it interacts with other "assets". For example, a reputation for consistent behaviour can reduce information costs.

The issue of inclusion of information in the measure of capital is part of a broader set of capital measurement problems. A recent U.S. study (Kirova and Lipsey 1998) has sought to catalogue omitted elements:

Education: Only capital spending on schools and equipment is now regarded as investment. What about other education expenditure - 6.6 % GDP in 1990-94?

R&D: This is government consumption in the US accounts but is usually highlighted in knowledge production studies. Add another 2.7 % of GDP.

Consumer durables: Allowing households to invest in computers. Together with cars, this would add another 6 %.

Military spending: Again this is government consumption although 1.3 % is on military hardware.

Why stop at these elements? There are other candidates:

Software: The total of computer and communications hardware expenditure is large compared with expenditure on factories, buildings and other durables. But if hardware qualifies, why not software, which is necessary and durable.

Information: There is much information from experimental activity other than R&D.

Education: Similarly there is much expenditure of education/training in private firms and within government authorities other than schools and universities not captured in the education statistics.

Organisational capital: Administrative systems (including language and communication capabilities) have to be built up over time and maintained.

Institution building: It would seem to make sense to view this as necessary capital if one looks to the recent experience of Eastern European economies where they have had to be rebuilt.

The implications of this extended coverage of information as capital are wide-ranging. Obviously, the data collection net would have to be cast much more widely. Numerous applied studies, e.g., the productivity paradox, would have to be reworked. Very little productivity analysis has attempted to measure the impact of information ÿ the work of the International Development Research Centre in Canada being a notable exception. One senses a mixture of Information Age ingeniousness and ingenuousness in a paper quantifying the productivity of space telescopes as the output of research papers (using the telescope data) per square metre of telescope mirror! These implications in turn link with managerial capabilities and there we find prisoners of technology hype and management fads.

It would be foolish to ignore the difficulty of implementing full coverage of information/knowledge capital expenditure. Consider first the breadth of experimental behaviour. Both collection and economic research focus on R&D because R&D statistics are available and despite R&D being defined in terms of the scientist's rather than the economist's conceptual framework. While the boundaries of R&D have shifted a little, much experimental behaviour and associated expenditures are excluded.

A second and even more baffling case arises with tacit knowledge. We are indebted to scientist Michael Polanyi for shaping the tacit knowledge concept: "We know more than we can tell". Such knowledge cannot be readily articulated and is not easily communicated but it is nevertheless an element of capital, whether we assign it to the human capital or organisational capital category.

The tacit element has been recognised as important in, for example, the transmission of skills and innovation processes. From both managerial and policy viewpoints, it is desirable to understand its role in developing chains of events; from the initiation of the creation of tacit knowledge to, in some cases, its conversion into codified knowledge which then becomes amenable to handling by IT, and to the maintenance of the stock of tacit knowledge. It would seem that in practice at the level of the individual business, the role of tacit knowledge has much to do with the problems of outsourcing. And at the aggregate level the difficulty of preserving tacit knowledge and bringing it to bear on successive innovation initiatives would seem a major policy matter; a matter which, unresolved, leaves innovators to labour and learn again, Sisyphus-like, at considerable cost.

While much of these information/knowledge capital expenditures are difficult to quantify, the central role of an information/organisation/learning nexus is apparent. As Carter (1996) warned: "The division of labour between model building theorists and suppliers of off-the-rack data, principally from government sources, is ending. New approaches, perhaps grounded in other disciplines, must be developed to quantify knowledge variables like firm learning, know-how, adaptation" (67).

A Taxonomy of Information

Several definitions of an information society have been distinguished analytically: technological, economic, occupational, spatial and cultural. These suggest ways of devising a taxonomy of information. So too do various dichotomies that have come into general use: tacit vs codified knowledge; scientific vs technological knowledge; informal vs formal information flows; private vs social information; information consumed vs information as capital. There is a clear need to identify characteristics that are economically significant. Demand forecasting research for new communications services has noted this approach but has in practice not succeeded in getting beyond the characteristics of the technologies involved. Dimensions that would seem relevant might include the frequency of observation, the static or dynamic nature of the information, the degree of accuracy required, the promptness with which the information must be available, the complementary information needed and the universality of its distributi
on.

Measurement Technique for the SRIS

Statistics for the SRIS are a mixture of hard figures and estimates. If employees are assumed to receive the same proportion of sectoral value added independently of the sector in which they work, then the SRIS can be estimated from labour force and GDP data. It is important (i) to exclude from PRIS labour those whose activity is non-informational; and (ii) to measure both employee compensation and operating surpluses of self-employed and unpaid family workers. Figures on supplementary payments are often sparse.

While the SRIS is very important to implementation of the information perspective, traditional coverage from official statistics is far from complete. This represents a major, perhaps the greatest, challenge facing efforts to create official statistics that will give a reasonably accurate image of the information economy.

International Dimensions

Just as the domestic economy displays growing information intensity, so too does the ' global' economy. The 'tides among nations' are very much a matter of communication and information flows. Attention has tended to focus on several categories, e.g., finance and entertainment ÿ but some foresee political activity as a major new focus for IT and the use of information for this purpose both domestically and internationally.

In the meantime, however, we should note that "No international agency publishes data series on the local production of knowledge and inward flows of knowledge" (Romer 1994, 20). It seem worthwhile to add that Romer had become critical of his own earlier work in which he relied on physical capital measures, and wished he had stuck to his guns about the importance of evidence relating to knowledge and information.

Current Collections by ABS

The Bureau currently collects data about the information economy in several different ways, only a few of which are designed primarily to shed light on the extent of production and use of information. As described above, some approaches to estimating the size of the information economy require very general statistics about the occupation of the workforce, value added in different industries or the value of production of information goods and services. This section starts with very specific collections and moves on to more general collections.

1. Industry-wide statistics are collected in four main areas:

- research and development expenditures in business, government, higher education and private non-profit organisations. These data estimate the expenditure on new knowledge produced through research and development in different sectors of the economy;

- expenditure on innovation defined as "...new products and processes and significant technological improvements in products and processes." The data collected include the sources of the innovations which gives some information about diffusions of innovations;

- data on the number of patents have been collected every second year in the research and development surveys, but only numbers of patents without information on expenditure on the protection of intellectual property through patents. There does not appear to be any collection that deals with the purchase of information through licences, though data on international trade in services includes royalties.

- human resources in science and technology (8149.0) which records individuals with qualifications in these fields employed in different industries; and

- the use of information technology in households and government and in business by sector. Some data on expenditure are included in all of these collection and in addition the collections relating to business and government include number of staff years involved in operation and support and a classification of expenditure into capital, operation and support. In the case of government, in-house and outsourced services are distinguished.

2. Industries providing information technology and telecommunication services have been surveyed.

- Information Technology (8126.0) includes data on the structure and performance of the industries producing information technology goods and services international and trade in them.

- Telecommunications Services (8146.0) provides similar data on the provision of such services, though in some areas there are limits to the data that can be provided because of the dominance of a single supplier.

3. Particular service industries which are entirely or very predominantly in the business of handling information have been surveyed, or in some cases information is compiled from administrative sources. The data collected in general permits value added to be estimated for each industry. These include:

education and training
hospitals
interest groups
cultural industries
libraries and museums
travel agencies
real estate agents
amusement and theme parks
technical services
selected business services
legal and accounting services
film and video production and distribution
radio and television services
private medical practice
consultant engineering services
performing arts
sound recording studios

Although the above industries vary in information intensity any attempt to define an information sector based on industry classifications would include large parts of each of them. Other service industries such as retailing, for which data are collected, and wholesaling, which is a recognisable function but much more difficult to recognise as an industry, also included large information components. Data are available for industries in the financial services sector which is almost solely involved in handling information. Also some manufacturing industries, in addition to those producing computers and other information IT goods, produce large amounts of information goods, for example machinery used in accounting and in recording and transmitting sound and pictures. The publications on manufacturing commodity statistics provide data on the production of goods that can be used to classify some as information goods.

4. Many quite general statistical collection could be used to estimate various dimensions of the information economy. These include:

- The Census which can be used to classify all employed persons according to whether or not they are in an occupation which is primarily involved in handling information, or an industry that produces primarily information goods and services. Less detailed data on occupations are available from the monthly labour force surveys and from service industry surveys.

- The Household Expenditure Survey, within the limits of its classification of goods and services, can be used to estimate the value of final consumption by households of information goods and services.

- Input-Output Tables provide a comprehensive picture of the Australian economy, though only for a broad classification of industries. It does, however, provide information on Australian production, imports and exports for over 1000 commodities classified to the industry from which each originates.

It is clear that the data collected at present can be used to make estimates of the extent of the knowledge-based information economy once a classification of goods and services, occupations or industries according to whether or not they fall within the “information” category is made. What is missing is data about information intensity, of the kind included in the recently published Human Resources in Science and Technology (8149.0), that can

be used to make those classifications. Such data are especially important in gauging the extent to which goods and services, occupations or industries become more or less information intensive over time.

Other difficult issues that need to be faced are:

- how to assess the importance of tacit knowledge as distinct from codified information,
- how to measure both flows and stocks of information, and
- how to measure the secondary information sector.

Steps to the Future

Much of the response of statistical agencies to pressures for change seeks security by contemplating only change that can be accommodated within the existing statistical system. We think this can lead only to further distortion of the image of the economy and of ideas about how the economy functions. The changes taking place are pervasive and enduring and call for radical revision of modelling and measurement. There is an opposing view: that firms and other organisations will give up their struggles with computer equipment, software and information and turn to outsourcing as is done with electricity and water (The Economist 1999, 63). We do not deny great scope for outsourcing, e.g., data mining and, provided the necessary security measures and social sanctions can be invented, even information services involving the handling of confidential information. We do, however, emphasise the human role in communication, organisation and learning. In response to those who foresee a solution to the human dilemma
of dealing with uncertainty in ever more automation, we refer to two recent remarks:

> "What will retain value, is what computers cannot produce: that most intangible and elusive of economic goods ÿ the creative output of the human mind" (Jonscher 1999, 285).
>
> "What information consumes is rather obvious: it consumes the attention if its recipients. Hence a wealth of information creates a poverty of attention and a need to allocate that efficiently among the over-abundance of information sources that might consume it" (Simon, quoted in Hardin 1999, 13).

In these circumstances, it is not possible to give an assurance that what we suggest needs to be measured is measurable. Just as many organisations now find themselves obliged to experiment, so statistical agencies must seek out the new paradigm, new models, new variables and new measures. It hardly needs to be said, but all information is costly.

The starting point is the information perspective. Here the UK Green paper's ITEC technology-oriented framework (Table 3) captures an essential part of the evolving system but this must be joined with a wide-ranging coverage of informational activity, irrespective of whether it takes place wholly within organisations or is traded in markets.

This experimental approach needs to draw upon the new thinking that is shaping the information perspective, rather than be preoccupied with fine tuning categories within the existing systems. Efforts to achieve international consistency should not inhibit experiments. Limited trials in collecting new statistics and cooperation between statistical agencies and between agencies and business could be beneficial. We commend Carter's view: "As the knowledge-based economy evolves, businessmen will rely upon traditional measures at their peril ÿ and at ours. Economists claim that "no one listens to them", but

reports on GDP growth and other measures of input and output certainly reverberate in the capital markets. Now that "the rising tide" no longer "floats all ships", policy makers will need to focus on the details about winners, losers, and the costs of change" (67).

Some possible ways in which collection of better information about the knowledge-based information economy could be advanced are the following.

1. Non-technological innovations Information from the surveys on research and development and innovation could be complemented by surveys of innovations in areas such as forms of organisation, management and marketing. This would recognise that technological information and knowledge are not the only important kinds. Expenditure on organisational, management and marketing innovations would include purchase of expertise from consultants, by hiring new people with appropriate experience or by staff training.

2. Indicators of information intensity In the near future it seems likely that much of the data on the information economy is likely to take the form of indicators rather than full quantitative measures. From this point of view the Bureau could experiment in collecting information on the measures of the intensity of use of information and knowledge listed above. Some indirect measures could be included also. For example, given that tacit knowledge is by definition embodied in skilled people, it might be hypothesised that firms and industries that are more dependent on such knowledge would have a lower rate of turnover of some kinds of personnel. On the other hand, one source of innovation is to buy in the tacit knowledge of new staff, which might suggest greater turnover.

3. Investment in information and knowledge Although aggregate data and indicators of information intensity are valuable in themselves, they would be more valuable if investment in knowledge and information which can be used over a significant period of time, such as general technical and managerial knowledge, was to be reported separately from that which is of short term use only, such as market information. There is evidence from other countries that investment of this kind is large relative to investment in fixed capital and as a proportion of the total expenditure on information. Some data on investments of this kind would have major implications for economic modelling.

4. Time use at work A more innovative, but also more costly approach to measurement of information intensity would be to carry out surveys of how people use their time at work. This would require a lot of work in development of a questionnaire that distinguished activities that were primarily involved in use of knowledge and receiving, selecting, processing and transmitting information. It would also require a new approach for the Bureau in collecting information at place of work from the workers rather than from managers. The rewards could include the development of a new and more useful classification of occupations; or perhaps it should be called a classification of activities.

5. Taxonomy of use of knowledge and information Another possible use of a survey of use of time at work would be the development of a new classification of the ways in which knowledge is applied and information is handled. To date there are a few case studies of these topics in areas such as tourism and medicine, usually in theses of graduate students. These could be of use in setting a framework for the development of economy-wide taxonomies of these activities. It would help us to disaggregate the use of information and knowledge in ways that could be useful for industry classifications and which would feed into studies of the impact of the

increasing use of knowledge of information on employment, and better productivity measures.

6. Spatial dimensions of information flows Information flows between regions and internationally are needed to supplement existing data on production, employment, sales and payments. The data on international payments for royalties should be supplemented with data on payments for other flows of information relating to patents, licences and more ephemeral flows such as purchase of news, market information, books, films and other recorded information.

These suggestions are illustrative only. While they suggest specifics kinds of collections, those collections need to be made within a comprehensive framework. The strength of the national accounting system is in its consistency and the interconnectedness of its parts. The increasing significance of knowledge and information in the economy creates major problems for that system: even what we mean by a commodity or economic efficiency requires the incorporation of information into definitions and models. In taking steps to revise and extend statistical collections, these virtues of national accounting and the progress that has been made in recording the pattern of and changes in money-valued activities need to be preserved. Now we need progress with a parallel, equally consistent and comprehensive set of accounts and models that incorporate information and knowledge.

Table 1 Inventory of Information Occupations (OECD 1986, 35-37)

Table 2 Inventory of the Primary Information Sector Components (OECD 1986, 38-41)

Table 3 UK Green Paper ITEC Classification (Section 3.5)

REFERENCES

Arrow, K.J. (1973), 'Information and economic behaviour', in Arrow, K.J. 1984, Collected Papers of Kenneth J. Arrow, Vol.4, Oxford, Blackwell.

Boettinger, H.M. (1967), 'Big gap in economic theory', Harvard Business Review , 45, 51-58.

Boyle, J. (1992), 'A theory of law and information: Copyright, spleens, blackmail and insider trading', California Law Review, 80, 1413-1540.

Carter, A.P. (1996), 'Measuring the performance of a knowledge-based economy, in OECD Documents, Employment and Growth in the Knowledge-based Economy, Paris, OECD, 61-68.

Economist, The (1999),'For rent', January 9, 63.

Hardin, S. (1999), 'Human work in a computer age', Bulletin of the American Society for Information Science . 25, 13-15.

Jonscher, C. (1999),'The economics of cyberspace', in A. Leer (ed.), Masters of the Wired World , London, Financial Times/Pitman.

Katz, J.E. and Aspden, P. (1998), 'Internet dropouts in the USA. The invisible group', Telecommunications Policy , 22, 327-339.

Kirova. M. and R. Lipsey (1998), Measuring Real Investment: Trends in the United States and International Comparisons , National Bureau of Economic Research, Working Paper 6404.

Knight, F.H. (1921), Risk, Uncertainty and Profit , New York, Houghton Mifflin.

Machlup, F. (1962), The Production and Distribution of Knowledge in the United States , Princeton NJ, Princeton University Press.

Machlup, F. (1979), 'An economist's reflections on an Institute for the Advanced Study of Information Science', Journal of the American Society for Information Science , 30, 111-113.

Machlup, F. (1982), 'Optimum utilisation of knowledge', Society, Knowledge, Information and Decisions , 20, 8-10.

Machlup, F. and U. Mansfield (eds), The Study of Information: Interdisciplinary Messages ,New York, Wiley.

Marschak, T. (1986), 'Organisation design', in K.J. Arrow and M.D. Intriligator (eds), Handbook of Mathematical Economics , Vol.111, Amsterdam, North-Holland.

Mathias, P. (1983), 'The machine: icon of economic growth', in S. Macdonald, D.M. Lamberton and T.D. Mandeville (eds), The Trouble with Technology, London, Frances Pinter.

Miles, I. et al. (1990), Mapping and Measuring the Information Economy, London, British Library Board.

OECD (1981), Information Activities, Electronics and Telecommunications Technologies: Impact on Employment, Growth and Trade, Paris, OECD.

OECD (1986), Trends in the Information Economy , Paris, OECD.

Porat, M. (1977), The Information Economy , Washington DC, US Department of Commerce.

Robbins, Lord (1968), The Theory of Economic Development in the History of Economic Thought , London, Macmillan.

Romer, P.M. (1994),'The origins of endogenous growth', Journal of Economic Perspectives , 8, 1, 3-22.

Shackle, G.L.S. (1957), 'The nature of the bargaining process', in J.T. Dunlop (ed.), The Theory of Wage Determination , Cambridge, Cambridge University Press.

Shapiro, C. and H.R. Varian, Information Rules: A Strategic Guide to the Network Economy , Boston MA, Harvard Business School Press.

Simon, H.A. (1991), 'Organisations and markets', Journal of Economic Perspectives , 5,2, 25-44.

Stigler, G.J. (1961), 'The economics of information', reprinted in D.M. Lamberton (ed.), The Economics of Information and Knowledge , Harmondsworth UK, Penguin Books.

Stiglitz, J.E. (1985), 'Information and economic analysis: A perspective', Economic Journal , Supplement to Vol.95, 21-41.

UK Green Paper (1997), Mapping and Measuring the ITEC Sector in the United Kingdom, London.