Knowledge-based economies and information and communication technologies[1]

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Introduction: what is a knowledge-based economy?

Modern economic growth relies upon productivity improvement. This reliance is most directly observable when we consider how, over the past 100–150 years (depending upon the country), productivity improvements in the agricultural sectors of OECD nations have released large quantities of labour from agriculture while simultaneously increasing agricultural output. The labour no longer necessary in agriculture found employment in the industries in urban areas where productivity advances paralleled or led those in agriculture. In the most recent decades, the service sector has absorbed a growing share of the urban workforce but with far more uneven results in productivity growth. In the countries most advanced in this historical process, the extent and depth of transformation have been profound. Landscapes have been transformed into 'built environments' and much of the knowledge about how to make a living or a life in these new work and physical environments has had to be invented.

A central feature of these profound changes is the investment in knowledge to increase the productive capacity of capital goods, labour, and natural resource inputs. To say that industrialised economies are 'knowledge-based', therefore, is a simple recognition that the content and structure of economic activities, as well as many of the social foundations of industrialised countries, may be distinguished from their historical antecedents by the rate and extent of knowledge generation and use. All societies are knowledge-based in their dependence upon a collection of physical artefacts and cultural institutions whose production and articulation requires knowledge. The distinguishing feature of modern knowledge-based societies is the extent and pace of growth and disruption in the accumulation and transmission of knowledge, much of which is new or is deployed in contexts distant from those of its creation.

The centrality of the knowledge base in 'advanced' economies, those economies that have experienced the greatest discontinuity in knowledge creation and distribution, has manifold implications for economic, technological, and social development. For example, the aggregate rate of growth of leading economies increasingly relies upon the creation of new industries, whose rates of growth exceed those of established sectors, and thereby lift the average rate of growth of the entire economy (Kuznets 1966). Over the last half century the industries that are playing this role include modern pharmaceuticals and medical devices, aeronautics, information and communication technologies, and the array of new materials (e.g.,

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plastics). Interactions among these new industries, and also their interaction with the older automotive, machine tool, electrical equipment, and petrochemical industries, have been synergistic. The centrality of science and technology to these newer industries means that technological change not only has a pervasive impact in raising the productivity of labour and capital; it also accelerates economic growth directly and through synergistic effects. Economists have speculated that the macroeconomic effects of these developments may be significant enough to warrant examining the features of 'increasing returns' as a macroeconomic phenomenon (Romer 1986).

The term 'knowledge-based economy' captures a qualitative distinction in the organisation and conduct of modern economic life. Users of the term propose that the determinants of the success of enterprises, and of national economies as a whole, are ever more reliant upon their effectiveness in generating and utilising knowledge (Lundvall 1992). Although scientific and technological knowledge is of key importance, knowledge about how to organise and manage economic activities, particularly those involving the application of new scientific and technological insights, is also a crucial determinant of economic performance. These organisational and managerial improvements are becoming more important as the scientific and technological content of economic activity increases. It is now commonplace to speak of the analysis and construction of company 'capabilities,' of 'learning' as a vital economic activity, and of heterogeneity in the 'cognitive' abilities of organisations.

In short, knowledge contributes to the economy by supporting productivity improvements, the formation and growth of new industries, and the organisational changes that are needed to effectively utilise new knowledge. Each of these aspects has a parallel interpretation when we speak of the contribution of information and communication technologies (ICTs) to the economy.

- ICTs support productivity improvement although, as in the case of the service industry, the rate and direction of the productivity improvement is often uneven. Measurement of this contribution, like that of service innovation, is complicated, and sometimes defeated, by the proliferation of new capabilities that are difficult to compare with historical ones. Much of the vocabulary and conceptual apparatus used to analyse changes in economic outputs and their effects on the economy were derived in the effort to explain the economic effects of mass production and distribution. The unique characteristics of information as an economic input, the roles of production and distribution 'flexibility', the effects of extending and tightening processes of 'control', each of which is closely linked to ICT use, are poorly accounted for or even ignored in traditional measures of physical productivity.
- ICTs support the formation and growth of new industries, e.g., multimedia, e-commerce, and packaged software. The complementarities among ICTs also reinforce the growth within the industry. For example, the growth of graphics-based computing has both reinforced and been reinforced by the development and growth of printers employing laser and ink jet technology. The nature of these inter-relationships is difficult to trace because public statistics often either misclassify or mis-group industrial outputs. We are in serious danger of losing an operational understanding of the structure of modern economies and, therefore, an ability to assess the impact of economic changes on the health of competition or the distribution of economic power.
- ICTs support organisational change. By spreading and re-distributing information within the organisation, it becomes possible to devise new control structures and patterns of work organisation and to reduce the extent and to change the nature of human information processing and filtering. Despite the significance of these methods and their widespread adoption, little systematic research is available either to assess whether they reflect best practice or to measure their influence. For example, the case studies in Zuboff (1988) are still among the most useful studies of the workplace effects of IT (despite the fact that they are now over a decade old).

In other words, there are profound shortcomings in the research base needed to

Advertising poster for an Internet server in the Paris metro, 2001. Free

understand information society developments. The limitations are by no means confined to economics although in what follows the specific problems of economics are highlighted. The following sections outline some key research contributions to the issues that must be absorbed and extended if we are to remedy this situation.

Knowledge is not information

A starting point for improving the economic understanding of knowledge-based economies is a re-examination of the role that knowledge plays in economics with a view to reformation. While the basic agenda for reform is stated in the heading to this section, the significance of this aphorism will not immediately be obvious without an examination of how conventional economic analysis treats information and knowledge. This examination then is extended to reflect issues not ordinarily considered by economists.

The economic analysis of information and knowledge is based upon a theory of communication called the sender–receiver model. This model, dating from the early days of the theory of communication, assumes that knowledge can be 'encoded' by a sender, transmitted and reconstituted by a receiver. While the original purpose of the theory was to analyse the problems of efficiency and error-correction in the message transmission process, economists have generally taken the 'reproduction' of knowledge to be synonymous with the coding, transmission, and receipt of information. Thus, economists, generally, make no distinction at all between information and knowledge. To have information is to have knowledge and one who has knowledge will be able to express it as transmittable information that, once received by another, will reproduce the original knowledge. Scholars of technological change have challenged the view that information and knowledge should be viewed as synonymous by arguing that this view is inadequate for understanding the processes of the spread of innovation generally, and technology transfer in particular.

Why does this state of affairs exist? On the one hand, it serves to focus attention on the incentives for transforming private knowledge into information that may be more readily communicated to others and used by them (Cowan *et al.* 2000). Information, in turn, has important economic properties not shared by other economic commodities, namely: (1) non-excludability (i.e., an individual's possession of information does not prevent another from using it as well); (2) non-rivalry in use (providing a copy of information does not reduce information 'holding'); and (3) low marginal cost of reproduction (once the first copy of information has been produced, subsequent copies are much cheaper to reproduce). These three assumptions are sometimes combined with the more dubious assumption of 'free disposal' (if one has no use for some information, it is costless to ignore it or dispose of it) to suggest that public welfare would be enhanced if everyone had access to all available information. That is, to achieve the highest level of social welfare, information should be a public good in the same sense as free motorways or a state education system. This approach can be used to establish two types of results. The first concern the incentives to produce information. The second type of results address the potential contributions of information-creation processes to the economy, particularly with regard to the existence and contribution of 'increasing returns' to economic growth and welfare.

Economists have recognised that it is necessary to provide some incentive to economic actors if information is to be produced in the first place and become available for exchange (Arrow 1962). Information can be transformed from a public good into an economic commodity to the extent that its reproduction can be limited. The most direct way to limit reproduction is to assign property rights in information. By creating 'legitimate owners' of information, the initial conditions are in place for the operation of a market. Nonetheless, the features of non-rivalrous use and low marginal costs of reproduction make it difficult to enforce property rights. Further difficulties arise from the possibilities that information that is sold will be used in ways that escape the enforcement of property rights, such as imitation, extension, or adaptation. Similarly, a person who possesses information, but who fears its surreptitious expropriation, will be unwilling to provide this information for inspection prior to an agreement to purchase it. This makes it very difficult for

the purchaser to evaluate the quality of the information. These issues all make for some interesting and important economics. There are still many important theoretical and practical research questions to be addressed in these areas that are of enormous importance for knowledge-based societies generally and the information and communication technology industries of these societies.

Implications of the distinction between information and knowledge (1)

The acknowledgement of a substantial difference between information and knowledge allows us to examine a series of problems particular to the 'conversion' of knowledge into information through some type of representation, increasingly referred to as knowledge 'codification.' If the reverse process, reproducing knowledge from information, were symmetric, i.e., if 'de-codification' was as apparently straightforward as codification, it would be appropriate to ignore the distinctions between information and knowledge. Many of the world's problems would be resolved if only this was true. Unfortunately, the receiver of codified knowledge often needs substantial knowledge to reconstitute this information into useful knowledge (Cohen and Levinthal 1989). Shortcomings in the receiver's existing knowledge and experience, deficiencies in finding adequate representations for knowledge and the inevitability of transcription errors assure that even the simplest efforts to reproduce knowledge fall short of their goal. One has only to reflect upon the futility, on the first attempt, of properly assembling furniture received in pieces with a helpful instructional guide or the frustration experienced by students attempting to master calculus regardless of which of the hundreds of texts they utilise to pursue this goal. Nonetheless, assembling furniture without such instructions or learning calculus without a text is even more difficult. The codification of knowledge works, but imperfectly. Investment in knowledge codification and its improvement is a significant economic activity.

As information creation and distribution become more important economic activities, problems of search and filtering influence the utility of this information and the nature of information services. The delivery of information that will meet the diverse interests of users is a growing problem in which the 'free disposal' assumption is clearly inappropriate. Searching and filtering information requires substantial investment and the construction of specific capabilities.

Complex organisations face mounting problems in 'knowledge management', a term that is becoming widely used to describe several problems. First, the costs of information production provide an incentive for organisations to economise on its production by finding ways to re-use or adapt information that has previously been produced. This is a more sophisticated version of the 'search and filter' problem in which complex and difficult to specify criteria are likely to be required to identify relevant information. One may also regard these issues as intimately connected with the 'networked' quality of knowledge within an organisation. It is not simply who has the relevant information or where it might be stored; it is who would be able to solve a particular problem that becomes a relevant issue for knowledge management. Information and communication technologies could contribute to the solution of these problems, but are unlikely to do so without the construction of social as well as physical networks.

The growing significance of information and knowledge as sources of competitive advantage also resurrects important regulatory issues. One such issue is the relation between the protection of intellectual property and competition policy. Intellectual property protection seeks to prevent 'free riding' by those who might choose to copy the discoveries of others. Since the costs of duplicating or closely imitating others' discoveries may be far lower than the costs of original discovery, society might receive the benefits of competition by allowing such behaviour. If society did so, however, this might markedly reduce the incentive to invest in knowledge discovery. Intellectual property protection provides an incentive for discovery by granting a time-limited exclusive right to the use of specific types of discoveries. In some cases, this exclusive right may confer substantial market power on the owner and allow the

extension of this market power to related technologies, products, and services. In these instances, intellectual property law and competition policy will collide. Averting this collision creates the paradox that efforts to reduce market power are likely to reduce the incentives to innovate. This paradox cannot be avoided simply by 'sitting out' the time-limited nature of the monopoly on a particular type of knowledge, as this delay may allow the owner of the information to create a very strong market position.

The problem of managing knowledge and information raises serious questions about the possibilities of reducing informational asymmetries between producers and consumers. The growth of asymmetries has further implications for competition policy. For example, if information service providers are able to shape the choices available to users, they may be able to influence their purchasing behaviour or their access to information.

Implications of the distinction between information and knowledge (2)

The distinction between information and knowledge also suggests a series of more fundamental issues with respect to the practice of social science research. Equating information with knowledge obscures very fundamental human activities and capacities such as learning and cognition. What makes knowledge 'more' than 'a body of information' is that it involves the abilities to extend, extrapolate, and infer new information. We conclude that an individual or team has knowledge in a particular area if they are able to perform these activities with results that are non-obvious and are useful. It may seem surprising that economics, usually an imperialistic discipline intent on colonising the other social sciences, has ceded so much territory by ignoring issues like learning and cognition that are central to this wider conception of knowledge.

The problem is that to incorporate these issues in economics implies abandoning the 'representative' firm and individual, introducing a range of distinctly non-economic variables into the analysis, and rethinking the fundamental assumption that the individual is the appropriate unit of social analysis. Instead, the economic theory of learning often takes a single economic variable, cumulated production, as the basis for characterising productivity changes due to experience. While this simplification allows economists to create an instrumental variable for an array of 'learning' processes, it is clearly deficient for addressing many organisational and incentive problems. For example, what is the optimal structure of work organisation for capturing and benefiting from productive experience or what incentives will induce an individual to cooperate with others in transferring knowledge to enhance efficiency? While each of these questions can be structured as an economic problem, they create uncomfortable dissonance and have generally remained outside mainstream economics.

Cognition is even more problematic for economists because it raises questions about individual and company differences: how differences in cognition arise and how cognition can be improved. Fortunately, scholars of business and management studies have moved to fill this gap with examinations of the development of managerial and technological competencies (Teece & Pisano 1994). While these studies often suggest that the identification of 'competence' is much more straightforward than it is, either in management practice or research, efforts to map this territory are a considerable improvement over prevailing economic theory and practice. Again, it is initially surprising that economists have ceded this territory since 'positive economics' takes an agnostic position on firm differences, arguing that to the extent that such differences exist they must be comparably efficient or else the less efficient variant will be eliminated through market competition. It is actually a short step from this position to the view, which would be common ground for business and management scholars, that short-term positions of comparable efficiency allow short-term survival while longer-term survival involves different selection processes in which firms may be well-advised to invest.

There is not, as yet, any general guide to the modelling of learning that adequately represents the variety of learning processes within the organisation. Moreover, the measurement of relevant characteristics of the competi-

tiveness of a firm can no longer be confined to measures of cost. Learning to become more flexible in the changeover to new outputs, to reduce the turnaround time in design cycles, or to smooth the coordination with suppliers and distributors may or may not be directly reflected in the firm's costs while they will be reflected in the firm's revenue. These possibilities suggest a renewed focus on how firms' capabilities and competencies are influenced by technological change.

The ideas of competence (cognition) 'destroying' and 'enhancing' technical change have become mainstream within the business and technology management literature. The processes of organisational change engendered by the use of ICTs clearly shift the relative values of different competencies within the organisation. The common assumption in studies of ICT diffusion has been that the increasing use of ICTs implies an ever-greater accumulation of competencies and, therefore, improvements in organisational 'fitness' and competitiveness. This does not follow if we recognise that the adoption of ICTs can be competence-destroying as well as enhancing. Why then should an organisation adopt a technology that is 'competence-destroying'? One answer is that *some* of the characteristics offered by ICTs become a necessary component in the competitive position of the firm. Failing to adopt, therefore, is infeasible; however, adoption does not of itself assure success.

Distinguishing between information and knowledge opens up a productive line of research that can bridge the management and economics literature. The process of adaptation that occurs with the greater use of ICTs provides useful illumination of the roles of cognition and competencies as influences on the relative performance of firms. To fully incorporate these influences, however, requires interdisciplinary dialogue between technologists, business scholars, and economists.

The production and use of knowledge involves networks

If we recognise that modern knowledge-based economies require a more complete economic theory of learning and cognition, it follows that we must also re-examine the issues of collective versus individual repositories of knowledge. Since Adam Smith, economics has emphasised the specialisation features of the "division of labour". The heritage of Fordism and growing rates of turnover in industrial employment in some countries (especially the US) served to reinforce the credibility of analysing the organisation of work in terms of 'interchangeable' workers. In approaching the issue of knowledge production, economists were initially, and to some extent remain, fascinated by the dichotomy of the inventor and the entrepreneur. Schumpeter's *Capitalism, Socialism and Democracy*, is, in many respects, an extended investigation of the dialectic of 'managed knowledge creation' *vs* 'entrepreneurship' (Schumpeter 1943). During the last 20 years, new entrepreneurial institutions have evolved, many of them associated with 'venture capital,' in which entrepreneurial initiative is linked to highly focused innovation 'strategies'. This experience suggests a more complex institutional theory of innovation management. Such a theory requires a re-assessment of the performance of new enterprises. Some of the issues that must be considered include the governance of technical enterprises by specialised financiers, the success of the new enterprise in realising new technological opportunities, and the new incentive structures provided by the willingness of financial markets to value intangible capital.

The heritage of Schumpeter's vision is particularly apparent in the historical development of the field of innovation studies. Much of the early work in this field was explicitly a debate about the role of the individual inventor and the 'innovation' process, taken to involve the collective efforts of many different specialists and to constitute a division of labour. A similar tension exists in the literature of the history of science, where the traditional narrative of 'great men' was contested by examinations of simultaneous discovery, the 'invisible colleges' found in any substantial line of research investigation, and, eventually, the research laboratory itself.

In recent years – perhaps because the process of knowledge development itself has changed – the conflict between the individualist and collective views has been resolved in favour of the view that the knowledge creation process

is essentially collective, particularly in areas of knowledge creation intimately connected with commercial application. A 'division of labour' with a strong hierarchical principle of organisation, however, remains the dominant 'lens' through which these collective processes are seen, particularly in economics. Extending this model to encompass the complex issues of governance that arise in cooperative research and in 'networks' or 'clusters' of innovative activities is an increasingly important activity in the innovation studies field.

ICTs are increasingly important tools in the scientific and technological knowledge creation process. Their direct significance as 'laboratory instruments' is, of course, the most immediate of these roles. It is less well appreciated that, accompanying the spread of ICT in scientific and technological research, has been the spread of computer-mediated communication as a central element in research discourse. The early growth of the Internet as a tool of the research community and the origins of the world wide web in a scientific institution are clues to the significance of computer-mediated communication in facilitating the knowledge creation process.

As the communication of scientific ideas, findings, and speculations through computer-mediated communication channels becomes denser, the boundaries delimiting laboratories, researchers, and the state of scientific and technological knowledge become less distinct. Arguably these developments are not new; the process of research communication has co-evolved with scientific and technological investigation. The ever-more rapid increase in the speed and volume of these communications and their capability to intimately link far-flung researchers does, however, represent a profound change over what prevailed 40 or even 30 years ago.

Accompanying these developments is the growth of identifiable (i.e., communicated) scientific research performed in the private sector, a development that some have suggested may undercut the traditional justifications for the public funding of scientific research. Moreover, equally confusing for economic theories that would suggest the importance of appropriability and, therefore, maintenance of confidentiality in the technical research process, researchers from private sector companies are engaged in an increasingly visible set of exchanges of information with other private sector researchers. One interpretation of these developments is that the processes of communication and collective construction of knowledge are co-evolving (Gibbons *et al.* 1994). Determining the terms of exchange and the strategic policies governing such exchanges are issues that are becoming increasingly salient for research managers and leaders of technology-based firms.

These issues are magnified by the increasing globalisation of knowledge generation and distribution. No country is likely to retain leadership in a wide range of disciplines by relying exclusively only upon its own researchers to generate the knowledge necessary for maintaining a viable competitive position. These developments suggest a much higher degree of effort to understand interaction between economic and other influences on the distribution of information and the creation of "knowledge networks", the social structures in which information is transformed into knowledge (David and Foray 1996).

The industrial economics of knowledge-based societies

As knowledge creation and distribution become increasingly organised through networks and network communication processes, the organisation of economic activity more generally is following along a similar path. The boundaries of the firm are shaped by the availability of coordinating technologies and the capacities to extend the 'span of control' in governing productive processes. Although, in recent years, 'outsourcing' has come to be seen as conveying a higher degree of risk than previously was appreciated, the competitive procurement of intermediate products and services remains an attractive strategy for many firms.

Idealisations of the 'networked firm' sometimes ignore the very real costs of coordinating and disciplining myriad suppliers and contractors whose interests are never wholly consistent with those of the contractor. Nonetheless, for those products and services that can be well specified and that do not, themselves, provide the competitive differentiation supporting a

company's viability, a pattern of "outsourcing" is likely to persist leading to industrial structures that can best be characterised as networks.

Economists have developed several methods to examine these developments, none of which is entirely satisfactory. The orthodox approach is to view these developments as the extension of competitive markets and, thus, a progressive vertical division of labour by which one might also expect horizontal de-concentration to follow when substantial economies of scale or scope are not present. Orthodox economics, however, has a rather dismal record in explaining industrial structure.

In analysis or *a priori* prediction, transaction cost approaches fare little better than orthodox approaches. It is one thing to say that the extent of an enterprise is shaped by the transaction costs of establishing alternative structures; it is quite another to observe what these costs actually are. By employing the transaction cost approach, one might confidently predict the direction of change to be expected from a change in the rules governing transactions, but have little idea of the magnitude of the changes to be expected or how these changes may be amplified by virtuous or vicious cycles.

The evolutionary economics viewpoint, particularly as it is employed in industrial dynamics, does provide a predictive framework based upon the aggregation of the growth processes of individual enterprises and an assessment of their capacities to adjust to shocks in their established routines. Evolutionary economics, however, is far weaker than either orthodox or transaction cost approaches in assessing the division of labour among enterprises. It therefore has little to say about the potential for change in the pattern of vertical and horizontal integration where this pattern is not predominately shaped by the entry of new firms or the demise of incumbents.

What seems to be needed is a hybrid theory that combines elements of market process, the analysis of transactions, and the dynamics of entry and exit of individual enterprises. Such a theory is unlikely to be developed deductively. Instead, it requires an empirical foundation. The examination of the formation of new business models and the complex structure of incumbent and new entrant firms engaged in various electronic markets is a particularly promising observational "laboratory" for developing such theories (Hawkins *et al.* 1999).

Theories of industrial structure provide the bridge between macroeconomics and microeconomics. The preceding discussion has been devoted mostly to the emergence of structural features of the knowledge-based economy in terms of aggregate growth, productivity, and industrial composition of output. In the remaining sections the microeconomic issues surrounding ICTs are examined.

Traditional microeconomic issues in service pricing: the case of Internet access and services

Applying existing economic theory to the new product and service industries related to ICTs is not straightforward. The prevalence of fixed costs arising from intangible investments in knowledge, tangible investments in high-capacity physical communication networks, and first-copy costs of information already suggests difficulties in relation to the resource allocation and pricing decisions the companies must make. These problems are magnified by the complexities arising from the uncertain depreciation schedules accompanying these investments and by 'uncertainties' in demand. Demand uncertainties arise from the complex process of accumulation of user skills and complementary equipment as well as the externalities created by common adoption of particular products or services. Economically rational pricing policies are quickly abandoned in this environment in favour of heuristic rules such as "ability to pay", "price points", and "value for money".

The industrial economics of the manufacturing industries are simply not a very good guide for many ICT product and service markets. The principal reason for this is that the proportionality between inputs and outputs often fails to apply. The result is that concepts such as marginal costs, "markups", or value added are much more difficult to apply in these markets than those of industrial mass production.

These problems have long been appreciated in the economics of public utilities where key

features of ICT markets, such as high fixed costs and non-proportionality between cost and use, are present. In recent years, renewed efforts have been made to extend economic analysis to deal with some of the issues peculiar to ICT markets.

One of the most active areas of academic research is the area of "Internet pricing" (Varian and MacKie-Mason 1995). Much of the work in this field stems from the straightforward observation that existing Internet prices are often independent of usage leading to a situation where the price to the user is essentially zero. Under these conditions it is to be expected that problems will arise if what is being supplied has any value at all. The principal manifestation of these problems has been congestion effects. Even with rapid expansion in the physical networks supporting Internet use and low *average* costs for transmissions over this network, product and service suppliers as well as users are finding ways to use this 'free' resource ever more intensively. The ensuing congestion has resulted in general delays denoted by the term "World Wide Wait" and specific technical problems for real-time data arising from the unpredictability of signal transit times (system latency). The general delays from congestion are a cost to all users and uses of the Internet. System latency problems selectively discourage use of 'real time' data transmission such as voice telephony or videophone services.

For telecommunication network operators, the existence of congestion effects prevents cannibalisation of their differentiated tariff schedules. Without such problems, the cost of long-distance telephony or video connections (for suitably equipped users) would become distance independent. This suggests a problem for telecommunication network operators.

On the one hand, telecommunication network operators have an incentive to harmonise their pricing schedules for Internet and long-distance telecommunication. On the other hand, to do so by raising Internet access prices would result in tariffs that would be completely unacceptable to many users who are capable of bypassing network operators' facilities. Price harmonisation could, of course, work in the other direction with tariffs for long-distance telephony falling precipitously. This is not likely to happen for several reasons. The preservation of a substantial differential, however, will create competitive pressure to the extent that Internet infrastructures are improved and some degree of usage rationing through positive prices leads to a reduction in congestion and latency effects. This suggests an interesting paradox for telecommunication network operator strategy. By delaying the implementation of Internet pricing, they delay the competitive pressure of Internet telephony, but raise the incentives of alternative network operators to offer bypass services, with or without usage dependent pricing. This is an area fraught with uncertainty since it involves not only the diffusion of appropriate equipment to implement Internet telephony and other "real-time" services, but also the growth of viable "virtual" switching and signalling capacity to link users.

Efforts to implement Internet pricing are likely to be staged and incremental. This procedure allows telecommunication network operators to gauge the demand elasticity of services and prevents major shocks to the system that would obscure the view of how capacity is evolving. Moreover, this process may avoid some of the potentially enormous costs of implementing billing and collection systems extending to individual users. The recent application of a usage-dependent pricing model for transatlantic traffic is a starting point for examining the intended and unintended effects of actual Internet pricing and is likely to be a fertile research area in coming years.

Finally, we must recognise that the dynamic advantages of maintaining low data communication prices may be substantial as they offer incentives for innovation and more intensive (and perhaps more productive) use of local area networks and personal computers. The capital stock represented by these local investments is substantial while their "capacity utilisation" is generally very low. Setting data communication prices that constrict the development or widespread adoption of new products and services may be costly in terms of the markets that fail to develop. In other words, "efficiency" in data telecommunication pricing might have the unintended consequence of reducing the productivity of IT equipment that would be even less well utilised for both local and long-distance data communication.

Classical policy issues: competition and regulation

The foregoing section indicates that, from the viewpoint of formal economic analysis, the issues of central concern in the twentieth century in regulating telecommunication industries may continue into the twenty-first (Mansell 1999). It is clear that the traditional public utility rationale for state control or regulation has been transformed by technological and institutional change. Nonetheless, issues related to pricing and to service quality as well as interconnection are likely to re-emerge due to the industrial economics of many of the ICT industries.

The breadth and depth of transformation in telecommunications markets in particular will be profound. It is possible that, over time, such changes may create competitive conditions resembling other product and service markets. However, to imagine that these conditions will immediately follow from reforms designed to enhance competition, such as mandated interconnection and privatisation, is a highly optimistic assessment.

There is little doubt that traditional models for the social regulation of telecommunication services as practised in the PTT era are no longer appropriate. Nor can one conclude that alternative models such as the UK's efforts to foster specific competitors to the dominant network operator are suitable in other contexts. At present, both the rationale and operational goals of regulation in those markets that have liberalised are uncertain and indistinct. This is not surprising given the extent of the reforms being undertaken.

The principal value of academic research in this environment is to provide a critical assessment and broader range of debate than would follow from a political or regulatory policy-making process. For example, we already can detect profound changes in the market structure at a global level in the provision of the international telecommunication infrastructure. The argument that competition policy at the level of the EU, the US, or Japan has duly considered all of the implications of these changes is dubious. In an academic context it is appropriate to discuss openly the opportunities and problems that might emerge from these changes in a way that cannot be achieved in public policy forums. This is the advantage that academic research enjoyed in the years prior to the current reforms and it is surprising that this capability is, on the whole, being allowed to lapse in many countries.

The new policy agenda: access, infrastructure, and standards

The issue of 'universal access' was one of the principles underlying the original social control of telecommunications. Many believe that these issues have largely been resolved (although there is solid empirical evidence to the contrary) and are reluctant to extend the "universal access" agenda to the new configuration of ICTs. At the same time, there is a growing "public access" constituency asking how exclusion may be reduced and inclusion enhanced by making existing social institutions such as libraries and schools key access points for the "networked knowledge" resources of the Internet.

The requirements to achieve such a "public access" infrastructure have only begun to be addressed (Mansell and Steinmueller 2000). It is not only the creation of suitably placed "termination" points for Internet connections, but also the financing of equipment, maintenance, and skills acquisition that present serious social issues for the twenty-first century. Ignoring these issues will not make them go away but will widen the gaps between the information "haves" and "have nots", lessening the cohesion within society and creating new divisive political agendas.

Serious study of these issues requires a careful examination of existing received wisdom such as the gender and age bias in current patterns of utilisation of "networked knowledge" resources. It does not follow that these patterns reflect differential capabilities or, even, necessarily interests in the potentials offered by ICTs generally or the Internet in particular. The general mystification of these new technologies, which has been part of the marketing appeal for particular classes of users, has long passed its potential usefulness. It is timely to re-assess how and where advances can be made in extending access to those whose everyday

employment is not intimately involved with these technologies.

As we begin to think about the Internet in terms of a broad vehicle of cultural expression and inclusion, it is useful to rethink some of the issues surrounding technical compatibility standards. There has been considerable value in having the incentives of proprietary standards in the promotion of new tools and techniques for software creation and many of these incentives should continue. It is, however, increasingly important to examine the consequences of public investments in information and knowledge creation that require all of these tools to be accessible. In many cases the ICT community (and the software community in particular) has, itself, been very progressive in providing the tools for accessing information created through the use of proprietary tools and techniques.

It is nonetheless appropriate for public authorities in the educational, cultural, and research policy areas to consider the issues of public access to information, particularly information created using public funds, with a view towards ensuring that access is maintained without being "bound" to particular proprietary tools. Implementing such a policy will require a renewed examination of the standards-making process (which is, at the international level, supported through government involvement) to ensure that methods for "interconnection", conversion of, and access to information continue to develop. Standards should also facilitate the viability of cultural, political, and social expression using the evolving "networked knowledge" infrastructure without requiring the "commodification" of these activities.

Conclusion

The breadth of the agenda identified in the preceding pages indicates the extent of the challenge we face in the social sciences in upgrading our research to deal with the emerging reality of the knowledge-based society. Very few countries have taken this challenge seriously in the funding of their social science research. The consequence of this is that relatively few young social scientists are developing the expertise or experience necessary to address the challenges that society will face in coming years involving the use of ICTs. For those who have developed this expertise and experience (often through circuitous and unconventional career paths) there is far more work than they can possibly undertake and an ever-growing set of issues that businesses and governments want to be addressed quickly. The absence of structural funding to create centres of excellence in this area remains the central problem as almost all of the issues identified above involve a degree of inter-disciplinarity or specialisation that is not easily accommodated within the existing social science disciplines. Good research in this area almost always involves the construction of stable research teams combining expertise, the systematic collection of data (which, unfortunately, ages rapidly), and strong links between academics and forward-looking businesses. Hopefully, each of these will come to be in greater supply in the coming years.

Note

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