MEASURING THE FUTURE

Statistics and the information age

Ian Miles

If the information age is to be more than a slogan, we need to address the issue of how to measure its emergence, and how to assess developments within it. This may well pose challenges to our existing statistics-,since structural change can render established definitions and frameworks inadequate. So far, most discussion of this issue has been conducted within a tradition of counting up the 'information workforce'. This article argues for a different approach, focusing on the generation, diffusion and application of new information technology (IT). It considers how far available statistics can be used to throw light on IT-related developments, provides some examples of what these data tell us about possible future developments, and examines the implications for the future of statistical frameworks and statistical analysis itself.

Times of major social change and upheaval have often been times when efforts have been made to generate new statistics. The beginning of the modern era saw 'political arithmetic' and 'state-istics' emerging in the 17th and 18th centuries, as tools for policy analysis. The two major economic crises of 19th century Britain both saw statistical movements which led to the institutionalization of many methods of social and economic assessment, and the crises of the 1930s and 1960s kicked off contemporary social trends research and social indicators studies.[1] One motive for the efforts to produce new statistics in such turbulent times seems to have been related to the belief that it would be possible to step beyond limited partisan views of the changes that were under way, and provide a more 'objective' perspective from which to negotiate whatever transitions might be necessary.

Our current frameworks for accounting for economic development were largely formed immediately before and after World War II. The Systems of National Accounts were established, initially in the context of

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Keynesian economics, to provide information on the balance of resources and demand, and to help develop government economic policies which could aid postwar reconstruction and the avoidance of any repetition of damaging downturns which might become major depressions. These frameworks have recently come under attack from many quarters, however. They are criticized from green perspectives as failing to account for the impact of economic activities on the environment, from feminists for ignoring women's unpaid labour, from development activists for misrepresenting structural features of Third World countries, and so on.[2] Pressure for alternative statistics is growing, even as statistical agencies are finding themselves under pressure due to limited government financing in many countries —which in part reflects the success of the neo-conservative argument that free markets can look after themselves, and encouraging government to monitor events is liable to be a first step to allowing meddlesome government interventions.

Despite these difficulties, and despite the diversity of the criticisms of statistical systems that are now being raised, there are good reasons to consider the future of statistics—and statistics for the future. Just as earlier periods of turbulence have effected innovation in social and economic statistics, so the current transitions are liable to do so. Indeed, if statistical systems are not themselves developed to keep pace with changing times, we are liable to be left without adequate instruments to monitor the changing context. For instance, it is already widely conceded that statistical systems have lagged behind structural changes in industrial societies in that they have failed to keep track of the growth of the 'service economy': we have detailed data on minutely different branches of manufacturing industries whose employment and output have actually declined to very low levels in the West, while many important new producer services are swept up together in groups with titles like 'other business services not elsewhere conducted'. The United Nations has been proceeding to revise major statistical series so as to pay more attention to service industries, although it seems likely that many of these revisions will already be overtaken by the ongoing development of these sectors. The effort to take into account the emergence of the 'service economy' (already being discussed in the 1960s) is taking place even as many analysts have moved on to talking about the 'information economy' or Information Age (InfAge).

The present article concentrates on just one of the issues raised in the contemporary period—the statistical challenges posed by the InfAge. Perhaps paradoxically, despite the vast volumes of paper that have been devoted to celebrating or (less often) cautioning about this emergent socioeconomic structure, there is something of a dearth of statistical analysis of the issues raised. In part this is because current data are inadequate, and/or too slowly released to capture rapid change; but also there seems to be more interest in visionary exhortations about the InfAge than in close inspection of what trends and potentials are revealed by available data. This article draws on studies carried out for the Programme on Information and Communication Technologies of the UK's Economic and Social Research Council, and the expert group on Economic Impacts of Information Technology of the OECD's Information Computer Communications Policy group, to consider these issues. These studies involved extensive literature review as well as original analysis, and my gratitude goes to the numerous researchers who cooperated with the study (by sending in details of their own work, and by commenting on draft overviews) as well as to these sponsors.

What information economy?

The types of statistical issue to which we will be directed will depend on the kind of beast which we believe the emerging InfAge to be. The social scientific literature displays several quite distinct tendencies—including commentary to the effect that to talk of the InfAge is simply hyperbole, that there is far too much continuity in social and industrial structures and power relations to warrant the use of such a grandiose label. But many other commentators do argue that substantial change is under way, even if not all refer to the InfAge, the 'information economy', or the 'information society'. Some have placed emphasis on the role of new information technology (IT), while others try to identify shifts in socioeconomic structures ('regimes of accumulation'). However, when it comes to statistical analysis, a rather different approach has dominated. This focuses on information as such rather than on technological or organizational changes.

In a pioneering study, Machlup sought to marshal statistical evidence on the production and distribution of knowledge in the US economy.[3] His approach consisted of describing statistical evidence relating to various knowledge-generation and information-handling tasks—R&D, advertising, mass media and the like. This was elaborated on and modified in the studies of Porat[4] and many subsequent analysts, who aggregated the different categories of information work, to yield simple statistics summarizing the scale of such work (rather as the GNP summarizes the scale of formal economic activity).

Porat and his followers draw distinctions between different types of information work. One distinction is between work in the primary information sector, whose outputs are information products, and the secondary information sector, which produces information inputs to production of non-information goods and services. (Just as all jobs have informational components, so it is hard to imagine a product that lacks them—the tricky task is to identify products whose primary role is informational). Another distinction is between information producers, processors, distributors and infrastructure workers—which describes how different occupations are servicing information, but says little about what it is being applied to. The categories of work subsumed under the different headings are often extremely heterogeneous: information producers, for example, range from chemists, optometrists and civil engineers to stockbrokers, composers and programmers. (Journalists, meanwhile, are information distributors, along with newspaper boys and girls; and photographers are regarded as infrastructure workers!) Many studies have charted what, in most countries, has been for a long period a striking growth in information work as a share of all employment.[5] Not all the subcategories of information worker grow over time: while it would be interesting to have more investigation of these varying trends, most attention has been directed to comparing aggregates. It might be unkindly suspected that the popularity of the Porat approach reflects the appeal of being able to flourish a single estimate of the scale of the information sector, which can be relatively easily produced by reworking existing employment and/or national account statistics.

The global growth of information work as revealed by these studies is certainly impressive. The impression is created that social demand for increasing amounts of information is driving change, but the basis of this demand remains unspecified. Information and knowledge activities are clearly shown to be of considerable scale—and thus, presumably, importance—in our societies. But what changes are taking place in the role and processing of information? Is it plausible that the growth paths of so many highly varied classes of information work share a common explanation? Why should we deduce that these trends constitute a new phase of socio-economic development?

This approach sheds little light on such questions. For one thing, these data only deal with those types of information work that are specialized activities. Such specialization may involve completely new information activities. Or it may reflect a change in the location of information activities—for example, certain types of information processing being relocated from manual or other jobs. They may be relocated through new international divisions of labour, such that information work is not fully captured in national data.[6] Perhaps more important at present is the trend in the division of labour identified (and deplored) by Braverman[7] and researchers who followed in his wake: it involves less the growth of information work than the compartmentalization of such work away from other activities. This will involve new information flows—the traditional integration of information within the worker's head is replaced by machine monitoring and office communications, and the new information tasks of supervising groups of workers may be added. One might deduce that although new specialized information workers are becoming visible, if they perform in a more efficient manner, the total volume of information work might even be reduced! The picture is actually more complicated than this (even if we put to one side the various critiques of Braverman's analysis): in practice, new locations and means of integrating information are almost certain to give rise to new opportunities for using information, so what happens may be quite indeterminate.

Assessing the number of information workers, then, is not the same as describing or accounting for the role of information in economic life. Economies have throughout history relied on information processing as an integral part of their functioning; what makes advanced industrial economies different in this respect is the secular growth of specialized information work. Since all jobs, however deskilled they are, require the worker to engage in some information processing, the application of IT to industry (eg robots) can affect all classes of workers—production workers as well as the information workforce. The statistics on information work which we have been discussing, then, are likely to provide only the roughest guide to identifying the areas of work where IT is likely to be applied. In our own work we have found evidence that computer expenditures in UK manufacturing sectors are actually strongly correlated with the numbers of white-collar workers in the different sectors, but this may well apply to early generations of computers, and be less true for other microelectronics-using devices.[8]

Technology, society and statistics

The question was raised above as to why we should deduce that a long-term trend in information work should be treated as if it constitutes a new era warranting a term such as 'information economy'. Several other approaches to socioeconomic change do, in contrast, point to structural changes which do represent a new development within industrial societies. Here we focus on the 'neo-Schumpeterian' approach to distinguishing between epochs of economic development based on technological revolutions,[9] rather than on the 'post-Fordist' and 'regulation' approaches which put more weight on organizational change at the firm or societal levels.[10] The intention is not to minimize the importance of organizational change, nor to imply that it is a simple consequence of technological change.

This article thus takes up the statistical implications of understanding IT-related aspects of the InfAge. The 'neo-Schumpeterian' argument is that the new technologies represent more than a further step in the steady evolution of information activities, and in the slow process of application of technologies of all types to information processing. A vast range of changes is under way in our use of information: these are made possible by (rather than being caused by) the development of new IT, based on the cheapening of programmable information-processing power enabled through microelectronics. This revolutionary core technology can be applied in ways that effect a transformation of the economy—to create new systems of production and consumption, variously referred to as a new regime of accumulation or mode of development,[11] or as a new technoeconomic paradigm, a new technological system or a new sociotechnical system.[12] While the emphasis of these approaches varies, they share in common the notion that a structural change is taking place in industrial economies as they enter a new phase, which we here term the InfAge.

While in many respects the task of thinking about statistical needs is made easier by focusing on the IT-related aspects of the InfAge, there are still several problems posed. Even defining new IT is contentious. Since the IT revolution has largely been based on the cheapening and increased performance of the core technology of microelectronics, it might seem reasonable to say that any devices that use this heartland technology are IT. But this would focus only on the hardware—what about the software and services that are required to realize the utility of IT, by enabling it to be programmed? And if we allow anything using microelectronics to be counted as IT, this opens the floodgates, as more and more products of different kinds come to incorporate chips—not only computers and communications systems, not only audiovisual products and robots, but all kinds of transport equipment and household appliances (indeed, 'smart buildings' themselves), and even such trivia as musical birthday cards and computerized jogging shoes!

A definitional step forward involves discriminating between four classes of product (by which we mean both goods and services):

(1) heartland IT products (microelectronics, etc);
(2) the core IT products, which use the programmability and information-processing power of this heartland technology to deliver general-purpose information-processing functionality as their main output—ie most

computers and telecommunications equipment and services;
(3) IT-using products, which may incorporate dedicated chips and embedded computers, or be controlled through telecommunications or other means, but whose main functionalities will often involve effecting physical, chemical or biological changes (eg moving things, maintaining them, changing people's physical health status etc);
(4) Non IT-using products.

The 'IT revolution' involves both the development of potentials in category (1), and the application and diffusion of these potentials in categories (2) and (3)—which will be reflected in greater volumes of (2) in investment and consumption, and higher proportions of IT components in the products featured in (3) (though, as we see, miniaturization and cost reduction of IT may make statistical assessment of this difficult). As is implied, this offers approaches to developing indicators of the 'informatization' or IT-intensity of different sectors, activities, occupations and products.

Many loose ends are left in this brief account,[13] and in some respects this is as it should be, since there is still little agreement as to the best ways to conceptualize IT. New statistical systems should, ideally, allow for experimentation with alternative aggregations of their subcategories. Scope should be left for future developments, too, rather than freezing things around our current experiences: for instance, it is quite possible that optronics will at some point displace microelectronics from its leading role in IT, so we would like to be able to redefine category (1) in this case—and, since this might be associated with quite distinctive patterns of IT use, we should be able to modify categories (2) and (3) accordingly. The pace of change is such that it is important to avoid closure of debate: 'flexibility', one of the watchwords of the InfAge, should be applied to statistical systems, avoiding premature commitment to rapidly obsolescing classifications.

More headaches are caused by the *software dependency* of IT. IT's programmability requires programmes—which allows for information to control devices, and for information to control information processing. This is the basis for the high levels of flexibility associated with IT products. Software and computer services have been a steadily growing share of the total price of IT systems and a wide variety of new telecommunications services has been created in recent years. Finally, a large number of new information products, ranging from online databases to optical publishing, are becoming well established: many of these will be classified as service activities. The problem is that our statistics have long been weak in dealing with services activities: but these are now becoming critical factors in IT application and economic performance, and critical aspects of the InfAge. As we see below, the use of IT by service industries has also tended to be neglected in statistical analyses, which have concentrated far more on IT applications in manufacturing—even though service users are particularly important.

There is a marked imbalance in the literature on the InfAge: despite a proliferation of prescriptions and grand visions, and a deluge of detailed (but generally localized) case studies of technological and organizational change, there are relatively few efforts to bring statistics to bear on relevant developments. Now, there are certainly reasons to exercise considerable caution in applying available statistics. Technological and organizational change are bound to involve some difficulty for statistical analysis. It takes time for new occupations, sectors and commodities to be identified, and many interesting new activities are hidden away in 'miscellaneous' and 'not elsewhere specified' categories, as mentioned. Difficult problems arise from the blurring of established boundaries as organizational structures change, as different sectors converge with hybrid technologies (computer communications, for instance, or telecommunications, broadcasting and publishing). And doubts are currently being cast on how far existing measures of productivity and investment cope with time-saving and software-based activities. Technological change is associated with other difficulties, too, which we consider below.

But if we want to identify the scope for improvement in statistical systems, and, indeed, see how far we can already chart out the contours of the emerging InfAge, we need to examine existing statistics before making pronouncements about their inadequacies. For one thing, these inadequacies might be less important, or more easily overcome, than we would imagine: we might be able to deduce substantial results from statistical analysis if we bear the inadequacies in mind in our interpretations; and, in any case, these data are the best that we have, and we cannot expect them to change overnight, since there are strong pressures for continuity in statistical series.

Reporting for the InfAge

A recent study which scrutinized UK data and data sources has been published by the British Library.[14] The study described seven areas of data dealing with all aspects of the production, diffusion, application and implications of IT hardware, software, services and systems. It set out to cover a broad range of data, mainly from official and academic sources. While these were found to be the most substantial and reliable sources in the UK, some trade and press sources were found to be useful, together with a few consultancy studies which avoid the general problems of this genre. (These problems include, especially, high prices and/or restrictions on use which effectively remove them from the public domain; and limited details of their methods of data production, so that their claims are difficult to validate.)

A primary conclusion of this study was that a great deal of statistical data about IT actually does exist in the UK. Subsequent work for the OECD demonstrates that the same is true for many other industrial societies although the different responses to IT in different countries makes the comparability of these data much more limited than we would wish. The data are typically spread, however, over a wide range of sources—government agencies, consultancies, trade organizations and academic research institutions, etc. They are published in a variety of books, journals, conference reports, etc. To bring these together in one place proved a large but educative task—it might prove valuable in other countries, too.

The UK study set out to provide a critical review of data and data sources, and we are not aware of such an enterprise being undertaken in other countries. However, we do have examples of impressive efforts to develop statistical reports on IT developments in several countries—rather similar to the social reports which bring together social indicators, but with an IT focus.

An excellent example of these is the set of Swedish reports *Data Om Informationsteknologin i Sverige*.[15] These are profusely illustrated with graphs, charts and tables, making it easy for information to be located and absorbed by decision makers and accessible to the general public, with accompanying text mainly taking the form of a commentary on the data presented. The main chapters cover: (1) 'People and technology' (2) 'Diffusion'; (3) 'Telecommunications'; (4) 'Trade'; (5) 'Labour markets'; (6) 'Education'; (7) 'Research and development'; (8) 'Work environment'; (9) 'Databases and security'.

A significant feature of these reports is the extent to which they draw on workforce survey data as a way of discussing the diffusion of IT, and its experience in everyday working life. We discuss these data further below. The reports present a variety of cross-national comparative data on the 'information workforce', exports and imports of electronic products, levels of diffusion of telex and telephones etc.

A rather different IT report is the *Informatization White Paper* published annually by the Japan Information Processing Development Centre (JIPDEC), dealing mainly with trends in suppliers and users of IT products. The 1989 edition,[16] for example, reviews IT activities ('informatization') over the 1980s, including topics as various as government IT policies, computer crime, and consumer use of IT. It is notable for its development of indicators of informatization, assessed in terms of expenditure per person working in various (highly aggregated) industrial sectors from 1981 to 1986, with projections for 1988 and 1991. Three main classes of data are considered—expenditure on computer hardware, on computer software (maintenance and development expenses, since packaged software sales are relatively low in Japan), and on telecommunications. Trends in IT use are depicted by means of plotting the evolution of each informatization index along an axis, so as to yield a triangular plane for each year considered; the slope of this plane will change as different elements grow at different rates (for example, it is projected that telecommunications expenditure will grow at a more rapid rate than the other elements). Such comparative mapping of IT costs can reveal tendencies—and possible bottlenecks—in IT utilization.

Statistics from suppliers are used to examine IT markets, eg to estimate the numbers and value of computer systems in operation in quite detailed sectors of the economy, and to plot diffusion curves for computers of various types. Other data in this report cover such topics as: expansion plans; expenses classified in terms of personnel, equipment, etc; numbers of personnel in various categories, and expenditures on various types of training; applications of computer systems; and use of various telecommunications and online services; etc. IT activities in Japan thus emerge as being extremely well documented. However, many of the data derive from surveys of computer users only—and presumably these will be mainly larger IT installations. The data tell us little about the scale of non-usage of IT: it would have been helpful to have supplied more background information on the economic sectors discussed within which to situate these trend analyses.

With the continued diffusion of small IT systems across the economy, it may be questioned how valid such traditional user surveys (which form an important part of the data from trade sources in all countries) are for examining the wider contours of the InfAge.

A few brief points about user surveys should be made here. Such surveys can be particularly valuable for telling us about patterns of IT use, as long as we interpret the results in the light of what we know about the characteristics of the user population (and how it is, and may be, changing). One important facet of the InfAge's high software-dependence is the blurring that takes place between software-producing and software-using sectors. The computer services sector, and trade in packaged software, are (fairly) well charted; but patterns of software use and production across the whole economy remain less visible. Even in countries like the UK, where packaged software plays a much greater role than in Japan, a great deal of software is produced in-house by 'user' organizations, with only a small fraction of this becoming a traded commodity. User organizations in the UK are believed to employ about half of all IT professionals in the UK;[17] accordingly, Brady surveyed computer establishments, and was able to document what types of software (eg systems, development, general applications, industry-specific applications) are obtained by what means (packages, bespoke production, in-house), from what sources (staff, hardware manufacturers, software houses, dealers etc) for what types of equipment (mainframes, minis, micros).[18] The results indicate, for instance, that in-house production is more common for applications-oriented programs (especially industry-specific ones), and for mainframes.

User surveys are also especially important when we are dealing with activities that are still fairly uncommon. Thus we examined the use of new telematics services in a sample of IT establishments in the UK. The use of these services is sufficiently rare for a general survey to be extremely cost-ineffective; and, indeed, the results indicated that some of the services about which there is most industry discussion—for example electronic data interchange—have yet to find a firm footing in the UK, with the exception of intense use in certain sectors. Data communications are still overwhelmingly being used for intra-corporate communications; voice telephony dominates when it comes to interorganizational interchanges. Problems with connectivity and standards were extremely important obstacles to these visions of the future being rapidly realized.[19]

User surveys are not very useful, however, for telling us about broad patterns of diffusion of IT across the economy and society as we enter the InfAge. Trends among major users—eg those with mainframe computers or large IT installations—may provide evidence as to where we will all be moving in the future. But the vanguard is not always followed, especially when technologies are changing as well as cheapening. For example, some growing users are side-stepping mainframes, instead finding that microcomputer networks can carry out many of the functions that are desired. To gain more of a view of average circumstances, as well as advanced practices, we need to look at more general data on whole populations of households, firms and the like. The diffusion statistics that are available tell us some interesting things both about the InfAge, and about the limitations of available data themselves.

Diffusion of IT

There have been numerous examples of how specific IT applications (eg robots, office equipment) are diffusing across establishments, firms and sectors. Such studies often pose difficult definitional issues (what is a robot? a flexible manufacturing system? a word processor?); these are not just a problem of rapid technological change, but also reflect suppliers and traders appropriating 'up-to the minute' labels to glamorize their products. Most of these survey studies cover only manufacturing or else even more restricted sectors; and most concern hardware, the use of software and services being rarely addressed. There are too many studies to provide a comprehensive review here, so we will simply focus on some highlights.

Studies of microelectronics in manufacturing processes (ie excluding office/administrative applications), using a consistent methodology have been replicated in a number of countries.[20] These studies agree on several main points:

- The rate of diffusion is rapid—from a very low base in the late 1970s to a majority of establishments by the late 1980s. For instance, in the UK, the proportions of establishments using microelectronics, both in process and product innovation cases, more than doubled in the first half of the 1980s: as early as 1985, then, almost 50% of British factories were estimated to be using microelectronics in processes, and, by 1987, 59% of factories, accounting for 82% of manufacturing employment, were. Process applications are more common than product applications (the comparable figures for which were 13% of establishments (53% of employment) in 1985 and 1987). Product innovations are common in electronics, but also in other machinery and engineering branches, and in automobiles.
- Diffusion rates vary considerably by industry. Process applications are more common in industries which handle relatively more tractable material, and whose products have a higher information content—electronics, machinery and printing, for instance, as opposed to clothing, textiles etc. In 'flow' industries (eg chemicals) programmable logic control of processes is common; in engineering where batch production is more the norm, numerical control machine tools and computer-aided design; robots in automobile industries; etc. Most IT applications to date are stand-alone systems: integrated central control systems are used relatively rarely although they are becoming more important.
- As with many other innovations, so with IT: diffusion is most common in larger establishments, in foreign-owned firms, and in leading regions of countries.
- Difficulty in accessing sufficiently skilled staff is the most commonly reported problem with these innovations—from a management perspective. The employment changes associated with the new technologies are ambiguous, with both increases and decreases reported: net decreases in process innovation tend to outweigh (generally) more positive changes associated with product innovation. But these changes are small compared to the total changes in manufacturing employment, and this type of establishment survey methodology only deals with 'direct effects', having

nothing to say about the indirect relations of innovation at one establishment with other establishments.

Similar general results have been reported in studies of Canadian manufacturing, but from Canada also comes one of the few detailed studies of IT use by services (a survey in 1989 of establishments with over 20 employees). This study examined existing and planned use of 12 types of office equipment and five telecommunications technologies.[21] The results of the study indicate high diffusion of many of the IT-based systems studied. PCs and related systems for accessing computer power (online terminals and minicomputers) are widely diffused, of course (88% use computerized financial systems, 56% inventory control, 50% order entry, and significant growth is expected for other applications like desktop publishing, now just below 30% penetration). 89% of establishments use fax. But 40% of respondents are now using local area networks (LANs), with another 17% having plans to do so in the next three years; 30% use private electronic mail; and 19% use electronic data interchange (EDI). Of course, diffusion rates varied across services. Major users are communications, wholesale trade, finance and insurance, transport, business services, real estate and the retail trade; accommodation, and food and drink are at the bottom. IT applications do not all diffuse in a parallel fashion, however. While communications, finance, and business services are clearly overall the most heavy users, they do not lead in every single technology studied—for example, wholesale trade leads in computerized order entry. As practically every study confirms, larger firms tend to make greater use of IT systems; and, again, foreign-owned firms tended to be more advanced in IT use (eg 44% use E-mail as opposed to 28% of Canadian-owned firms).

Apart from such establishment-level surveys, there are two other valuable data sources which can tell us about IT diffusion. First is official statistics of expenditure and employment, most notably the input–output tables. Recent UK Census of Production studies provide information on computer hire, expenditure, and employment across (non-service) sectors; these are the source of our assertion that there is a strong correlation between IT investment and white-collar employment in these sectors.[22] Input–output analysis brings together data on the interchanges between different industries into an arrangement of data which allows for versatile analysis. We can assess the purchases from IT-related sectors by other parts of the economy, calculate the contribution of these sectors to the final output of other sectors, and so on.

Input–output data have been used in the UK, the USA (and in as yet unpublished studies of Germany) to examine IT diffusion. Roach[23] worked with data provided by the US Department of Commerce which allow calculation of the IT component of each industry's capital stock (ie stock of investment goods) from the 1950s to the 1980s. The trends depict, for instance, chemical, electrical equipment and transport equipment becoming far more IT-intensive than other manufacturing sectors. Even more interesting, non-manufacturing industries held over 80% of the IT capital stock in 1985; it is highly concentrated in (service) industries dealing primarily with information—precisely those sectors where fewest data from diffusion studies or official statistics are available! The IT revolution is not only progressing rapidly; it is particularly intense among certain service sectors, though other services are laggards. Ironically, however, services are treated in a gross aggregation in the tables, both as producers and users of IT. The tables are not very helpful as to software and computer services, as opposed to computer and telecommunications equipment.

The same problems apply to UK input–output data.[24] The results of our UK analyses give a very similar picture to Roach's for the USA[25]—around 80% of IT (computers and telecommunications hardware) investment comes from services sectors of the economy, for instance. Likewise, the IT share of plant and machinery investment (around 25% in 1984—having grown from under 20% in 1979) is very similar to that cited for the USA in 1985 by the Office of Technology Assessment.[26]

Table 1 presents these data at a high level of aggregation. As well as the share of each sector's investment in IT, we present two 'comparative IT investment intensity ratios'. With a ratio less than one, an industry is accounting for a smaller share of IT spend than its share of total fixed capital investment expenditure; with one greater than one, it is accounting for a greater share of IT spend than its share of total fixed capital investment. This provides useful insights into where IT is being applied most heavily.

These results confirm the importance of service sectors as IT-using sectors. They are dominant users, and a greater share of their investment is in IT. If there is an 'IT revolution', it is particularly marked in services—sectors that have by and large been relatively unaffected by earlier technological revolutions. (As we can see, however, the telecommunications service sector is responsible for the high consumption of telecommunications equipment by services.)[27] These data throw up numerous questions as to the ways in which IT is being applied in different parts of the economy. The InfAge currently involves very heterogeneous patterns of development in different areas.

TABLE 1. COMPARATIVE IT INVESTMENT INTENSITY RATIOS, 1984.

Sectors: *code*	*content*	**PCINVCOM**	**PCINVTEL**	**CITIIRCOM**	**CITIRTEL**
1–3	Agriculture, forestry, fishing	0.6	0.1	0.13	0.02
4–11	Extractive sector	1.7	3.5	0.37	0.87
12–25	Manufacturing	4.1	4.0	0.92	1.00
26	Construction	0.5	1.4	0.10	0.35
27–45 (less 36)	Services (excluding leasing)	5.7	4.6	1.26	1.15
27–45 (less 36, 37)	Services othen than telecommunications (and excluding leasing)	5.8	1.8	1.28	0.45

Source: Calculated from input–output data, 1984.

Definitions:
PCINVCOM = % of sectoral investment in computers
PCINVTEL = % of sectoral investment in telecommunications equipment
CITIIRCOM = comparative IT investment intensity ratio for computers
CITIRTEL = comparative IT investment intensity ratio for telecommunications equipment

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This should make us cautious about using the term 'post-industrial society'. The InfAge involves the application of technology within services on a large scale. Services are, in some respects, being industrialized—the InfAge may be a more industrial society, a super-industrial or meta-industrial society, rather than a post-industrial one. However, our understandings of industrialism are being rethought as 'post-Fordist' industrial organization brings many attributes of services to manufacturing. Thus, smaller and more customized production runs, just-in-time systems and the like, resemble services' traditional characteristics of varied output and close supplier–client relationships. Increasingly it becomes inappropriate to consider manufacturing and services as contrasting sectors; they are becoming more alike and they are becoming more integrated. From 'manufacturing *v* services' and 'manufacturing or services', attention needs to shift to 'manufacturing and services'. Debates as to whether we are deindustrializing or moving to a post-industrial society are misleading: the question is, what combinations of manufacturing and service activities are crucial in the information economy. The integration of sectors is likely to be the key element in future growth, both quantitative and qualitative.

Other aspects of the InfAge

Diffusion studies have attracted much effort and attention, but they are not the only types of statistic that we can locate. The UK study reviewed data and data sources in a number of other areas, and we can summarize the main conclusions as follows.

R&D

Many statistics were located covering: (1) pure research and science (including data on employment and expenditure, as well as 'output' measures such as bibliometrics); (2) government financial support for R&D in general, and for specific programmes of research; (3) industrial R&D funding and activity; and (4) studies of innovation as indexed by patenting and other measures. R&D activities are often classified in these data, however, in ways that make it difficult to identify specifically IT activities—although innovation data do demonstrate the growing significance of these activities. The IT hardware-producing sectors are relatively well covered in R&D statistics. Software and related activities have traditionally not been classified as R&D (they may appear in research programmes, however); this weakness is recognized by the OECD, which is considering appropriate revisions to its Frascati manual for R&D measurement.

Production of IT

The relative emphasis of statistics on hardware, as opposed to software and services, again appears here. We have relatively detailed data on the employment, output and trade of IT equipment-producing sectors (following the definitional discussion above, these are taken to be the 'heartland' semiconductor producers, and the 'core' IT firms—also the most intensive direct users of the output of the 'heartland'—computer and telecommunications equipment manufacturers). Regular official publications cover these, together with related branches of activity, such as electrical instruments, radio and electronic capital goods etc. Statistics are less detailed on the computer services sector, and on some aspects of telecommunications services; newer services are proving a problem for official and unofficial statisticians alike.

Work and employment

Official occupational classifications define a large number of IT-related jobs (eg programmer, systems analyst, telecommunications manager, data entry operative), although independent studies (eg of skill shortages) have added many new categories. Official employment data are more generally reported by industrial group; censuses that could yield detailed information on the distribution of IT occupations are infrequent. Many diffusion studies have been motivated by concern with employment issues.[28] Specialized studies have tackled pay and recruitment; and by-product statistics cover a variety of education and training themes. But apart from case-study research, analysis of organizational change associated with IT is relatively rare. There are several surveys of worker attitudes to, and industrial relations around, IT-related change: researchers appear rather surprised by the relative lack of conflict, and find their worst fears realized by the general absence of workforce participation in IT decision making. The UK studies here have mainly been conducted by establishment-level surveys; we consider below an alternative approach.

Final consumption

Official and especially market surveys provide statistics on the diffusion among consumers of a number of types of IT product, especially home computers (which are widely diffused in the UK). Few sources go beyond the mere fact of purchase to provide information on patterns of use—the predominant use of home computers is for entertainment (video games). With the development of new ranges of IT-based products, and the use of microelectronics within many familiar items of household equipment, the analysis of consumer use of IT clearly requires more detailed academic studies.

Social implications

There are three topics where statistics have been developed to any extent. Social attitudes to IT have been assessed by opinion poll and attitude survey on various studies, including some international comparisons. These studies, in the UK and elsewhere, while not very impressive as to the style, scope and depth of questioning, do consistently suggest generally high levels of acceptance of IT, especially among younger people, with some reservations concerning application of technology to all areas of everyday life, and mixed reactions as to unemployment, retraining etc. Data protection and privacy statistics are produced by the UK's Data Protection Registrar, on databases holding personal data, their purposes, and organizations' knowledge of the scope of data protection law and their responsibilities under it. There is little structural analysis of organizations holding such information, and the related topic of interchange of non-stored information between organizations and between IT-based and non-IT-based retrieval systems. Computer crime is an area whose scale is hotly debated; victims may often seek to minimize the problem, while some experts may exaggerate it. The few surveys that do exist suggest that the prevalence of serious fraud is less than is often believed, but they are limited in scope and methodological adequacy.

The review revealed that much of the data that have been produced are surprisingly underutilized. Relatively few researchers seem to have attempted to see just how much can be extracted from available sources. The available data certainly are limited. They emphasize hardware as opposed to software and services; computer rather than telecommunications; manufacturing (and within that, in production processes) rather than services (and administrative work) use of IT; diffusion rather than applications and experiences. But there are evident uses to which thay can be put.

In a more international context, we have been highly impressed by a series of comparative studies undertaken by Nordic countries using Labour Force Survey data. These studies allow for analysis of IT diffusion among occupations as well as industries and regions,[29] study of pattern of use of IT at all of these levels of analysis, and assessment of the experience of technological change among the workforce. Finland, Norway and Sweden have extended their Labour Force Surveys to address such issues. These studies tell us how many workers are experiencing IT in their daily work. Indeed, some of these studies estimate how much use is being made of IT in terms of hours per day. In any case, we can develop indicators of IT-intensity of sectors based, for example, on the proportion of total employees, or of employees of particular types, working directly with computers (or other IT equipment) in their jobs. And by comparing IT use across occupations as well as sectors, we can gain further information on the types of application to which IT is put.

These studies enable us to inspect the proportions of the members of occupations of various kinds, in different sectors, who are using computer equipment. Similar patterns are displayed across the three countries. Again, we see that there has been a rapid diffusion of IT (revealed in the Swedish time-series data): the introduction of computers is rapidly affecting growing numbers of jobs—in the five years since the mid-1980s, the share of Swedish workers using computers grew from about 20% to about 30%, and growth trends since the early 1960s seem to show an exponential increase in the numbers of workers using computers (with take-off occurring since the late 1970s).[30] Sectorally, the studies confirm other data sources in showing IT concentration in specific industrial sectors, showing that financial industries are particularly high IT users. Occupationally, computer use emerges as being concentrated in administrative and clerical jobs—though quite large proportions of several other occupations are also computer users. The Swedish data show that word processing is the application showing most rapid growth between 1984 and 1989, but it still lags behind use of terminals (customer services, registers etc), and administrative systems (book-keeping, personnel, invoicing etc), and the use of dedicated terminals (EPOS, teller terminals etc). The survey tells us the proportions of users making use of stand-alone and networked PCs (networking is particularly high in finance and research, stand-alone PCs in research and construction), and also how many users make use of the terminals and PCs (one user only is most common).

One Finnish study[31] is also worthy of mention, not least because it represents a striking large-scale survey study of the implications of IT for working conditions (we should, before seeking to generalize from the results, recall that this concerns the introduction of IT in the early 1980s). The study asked many detailed questions about the trends in employment at the workplace, the levels of training given for the use of IT, the types of equipment used, and the workers' evaluations of the changes in the quality of their jobs. Essentially, the results would seem to support what has sometimes been called the 'polarization hypothesis'. In contrast to claims that the use of IT results in a general deskilling or upgrading of jobs, this viewpoint argues that, whether through managerial choice or other factors, it is frequently the case that the result is a differentiation between the best and worst jobs, with a variety of 'middle-range' jobs disappearing.

For *blue-collar workers* whose numbers were declining, the trend was for the content of work to become more demanding with more opportunities for promotion and training. Growing job satisfaction was reported, though so were increased stress and social conflict. For *lower white-collar workers*, whose numbers were growing, the content of work was becoming more fragmented and repetitive, and less independent (this is reminiscent of the idea of 'industrialization of service work'). While decreased job satisfaction, growing mental stress and social conflict were reported, so too were better opportunities for training. Finally, for *upper white-collar workers*, labour demand was also growing, with more opportunities for promotion and training. There was no obvious difference in work content or satisfaction, though criticism of working conditions becomes more marked. Thus, while IT is not replacing office workers, it would seem, in the early 1980s in Finland, at least, to be associated with some polarization between lower- and upper-level jobs (with the lower white-collar jobs becoming more like blue-collar jobs).

Such Labour Force Survey data provide a powerful way of inspecting both the diffusion of IT, and the implications of its application for the workforce. As such they represent powerful statistics for analytic purposes, and the pioneering Scandinavian studies could usefully be emulated elsewhere. The methodology employed in such studies might be reviewed by national statisticians with a view to assessing whether cost-effective additions to ongoing national surveys might be made.

Technological challenges to statistics

IT has continually improved in performance, to dramatic extents, since the invention of the semiconductor systems on which chips are based. The resulting lowering of prices and increase in utility facilitates the wide diffusion of IT. But it means that today's latest 'computers' are very different from those purchased 10 years ago—I have a pocket-sized computer that is much more powerful than the first desktop machine I purchased a decade ago—and, furthermore, the variety of different types of computer available has mushroomed. This has led to various simple classifications being generated (eg supercomputers, mainframes, minis, micros and embedded computers). But the pace of change still causes problems, with current devices in even the lower categories functionally superior in many respects to devices in higher categories a decade or so ago, and there is no reason to expect a slow-down in this trajectory of increasing performance in reducing scale. Similar problems confront many other ITs and IT-using technologies. This makes it difficult to be sure that one is comparing like with like, rendering comparisons over time especially problematic, though even cross-sectional comparisons may involve different classes of equipment.

Often, statisticians are less interested in the physical presence of so many units of technology, let alone the extent to which it is being used, than in the amount of money being expended on the technology in question. This is problematic in the IT field, where performance trends are also reflected in the prices of equipment (with software and services notoriously lagging behind—and thus becoming progressively larger components of total IT system costs). As the 'bits per buck' available have steadily increased in data processing, transmission and storage systems, so a given sum of money purchases more IT power and (often) functionality. This means that expenditure levels are not a good surrogate for other measures of IT hardware and software. Thus, while we can chart a growing IT-intensity of industry, by comparing the ratio of IT to other plant and machinery investment, the increased centrality and criticality of IT in production is likely to be even larger.

One solution to such problems has been adopted by a number of researchers. This is to develop 'technometric' measures, which take into account the changing capacity of IT. The problem is that IT is evolving along numerous dimensions simultaneously: how can these be combined (or should they be combined at all) to weight measures of expenditure or installed stock?

This topic has attracted growing attention, not least because different ways of dealing with the issue have substantial effects on estimates of economic performance. Mishel reports that a change in the way in which computer prices were assessed in the USA, so as to take into account performance changes, doubled estimates of manufacturing output growth![32] The development of technometric measures is worth considerable effort, but caution is required in moving to new statistical procedures. Indicators of individual dimensions of IT improvement in applications settings are certainly worth constructing. Automatically aggregating these to give summary indicators is more problematic, since different uses of IT may well place more emphasis on different features of the systems. New applications and modes of application are being established for core IT and IT-using products, and IT is continuing to expand into new areas—word processing, desktop publishing, hyper- and multi-media etc, for example. Innovators respond to varying trends in the costs of data storage, transmission, manipulation etc, by developing their products so they make more or less use of these particular attributes.

Furthermore, IT systems are *configurational*, as digital information is capable of being shared between different devices in information networks. Quite possibly the move toward 'systemation', bridging the islands of automation (only isolated parts of the overall production process have been to date reorganized using IT), may be crucial to future IT developments. Some surveys demonstrate that such a trend is under way: but it creates more measurement headaches, as the power made available by an IT device becomes a function of the network into which it is integrated. While it is thus misleading to count devices as if they were isolated, or as elements of networks, the statistical identification of networks (eg how do we demarcate their boundaries, when my desktop PC can be connected to devices in any continent, at any time?). A given number of individual computers may be stand-alone systems, nodes of a complex network structure, or even (as has been suggested by some computer scientists), elements of a hypercomputer which aggregates the spare capacity of individual computers to form a (spatially dispersed) supercomputer.

Conclusions

The lack of empirical analysis of the diffusion of IT and the diversity of IT applications is remarkable. More attention should be devoted to establishing just what data are available for analysis, and to bringing these data together in accessible form (but not uncritically!). We have noted a number of lacunae in statistical data: these will need to be addressed if we are to get a better grasp on the InfAge. Perhaps the most obvious gaps to fill are those which could be handled by extension of familiar approaches: for instance, analysis of new IT services, on IT use in services, and on the actual experience and output of IT applications, as opposed to their mere diffusion. Other issues demand more experimental studies of appropriate statistical methods. Such experimental approaches might be carried out by both official and non-official agencies, working from a variety of perspectives, so as to establish the practicality and means of obtaining useful systematic information on IT-related topics.

As the discussion of technometric studies—another area where more effort is required—confirmed, IT development poses considerable challenges and headaches to statistical analysis. IT is, ironically, part of the solution: it is increasingly possible to release data rapidly in electronic form, to experiment with different ways of aggregating raw data, to develop 'satellite accounts' which articulate more or less closely with the established statistical frameworks, to carry out 'what if' analyses to inspect the consequences of different assumptions, and so on. While many of us find statistical minutiae tedious, the implications of some statistical decisions being made today are far-reaching, both in their consequences for interpreting familiar economic indicators, and in the opportunities and limitations which are posed for analysis of the InfAge.

But applying IT to statistics is not enough—even if, as we have argued, many data remain underutilized. Mobilizing the necessary financial and human resources to carry out such analyses, and to produce new data, is also required, and it is no easy task. Problems have been caused by limitations on public expenditure, both for official statistics and for academic research—in the UK this has undoubtedly led to some demoralization of both statisticians and social scientists. After an upsurge of surveys in the early 1980s, there seems to have been a diminution of interest in IT diffusion in many countries, for example. This means that most of the statistical studies that have related IT to issues of employment and working conditions remain fixated on early generations of IT. IT and the InfAge are moving targets, and we are in danger of having our viewpoints on both shackled by obsolete categories of analysis. The InfAge is liable to lack basic information on itself.

But precisely because we are dealing with moving targets, we need to be cautious in the way in which statistical resources are committed to the subject. There is no point in throwing away statistical systems that have been painstakingly developed over decades, and thus losing abilities to engage in over-time analyses, if we are simply adapting to immediate and volatile circumstances. What is necessary at present is to encourage new and experimental studies to be carried out in parallel with established analyses, to develop 'satellite accounts' and methods of 'IT accounting',[33] and to promote debate and dialogue between researchers on these topics within and between countries.

The future of statistics is not altogether bleak. There are many straws in the wind to suggest that the intellectual tasks are now being recognized. As merely two examples, I would cite the Office of Technology Assessment's study *Statistical Needs for a Changing US Economy*,[34] and the very interesting studies on bringing together official and survey data into an IT accounting framework carried out in Germany.[35] The OECD has been acting as an important forum for statisticians and other concerned parties to discuss similar issues. While the leads and lags in the process are highly uncertain, we can be sure that future years will see considerable accommodation of our statistical systems to confront the requirements and challenges of the InfAge. The sooner work is begun on this task the better.

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