DEFINING HIGH TECHNOLOGY INDUSTRY: A CONSENSUS APPROACH*

Chris Thompson

Reasons are suggested for care over the definition of high technology industry. Some general approaches to definition are outlined, and a chronology of definitions is presented. Conceptual and practical problems with conventional choices are discussed, and a new consensus definition — drawn from a survey of current practice in the USA — is suggested as a complement to objective definitions. This is used to speculate upon high tech's potential role in the overall US employment problem.

Keywords: high technology, state programs, industrial policy, employment projections.

INTRODUCTION

The term 'high-tech' is today popularly applied to anything from computers to office decor. High tech consultants are available for advice on the aerodynamic properties of golf balls, egg-shell waste utilisation, and even chocolate engineering.[1] Originally intended to denote the application of the most advanced scientific techniques to the industrial production process, high technology has now become devalued, as Breheny *et al.* put it, into "no more than political glibspeak or property developer's advertising copy".[2] In the academic industrial location literature it is also used loosely, and can be synonymous with new, advanced,[3] emerging,[4] knowledge-based,[5] science-based,[6] or technology-intensive,[7] industry. It thereby ranks with longer-lived but equally malleable industrial metaphors like smokestack, footloose, and nationalised. Even among researchers who define it more specifically, there is still little agreement.

In this article, some reasons for concern over this problem are suggested. A variety of definitions of high technology are brought together, thereby extending earlier limited comparisons by Riche,

* The author wishes to thank the Wisconsin Alumni Research Foundation and the University of Wisconsin Madison Graduate School for financial support during the period of this research. Prof. Jack Huddleston and Tom Klak made helpful comments on an earlier draft. Officials in many States and Federal agencies kindly sent detailed information on their programmes: nothing in this article is to be taken as a statement of their policies. The author alone is responsible for any errors.

Hecker and Burgan,[8] Tomaskovic-Devey and Miller,[9] Langridge,[10] and Markusen, Hall and Glasmeier.[11] The statistical implications of each are then examined using US data for 1977 and 1982. Principles underlying these definitions are compared, and some conceptual and practical problems reviewed: because of these, a consensus definition will be suggested to complement the conventional objective definitions, and will be used to evaluate high tech's potential contribution to the broader US employment question.

THE IMPORTANCE OF DEFINING HIGH TECHNOLOGY

While it is not to be suggested here that a single definition of high technology be adopted for all studies, there are nevertheless several important reasons why any chosen or implicit definition should be detailed by the user, and why the implications of adopting any one definition *vis-a-vis* another should be understood. First, there is the current debate on the actual and potential contributions of this sector to the health of the Western economies. The popular media and many politicians have portrayed high technology — particularly the computing and biotechnology aspects — as bringing about the next industrial revolution by generating whole new industries and redressing poor competitiveness in traditional ones.[12] Such changes are anticipated to have repercussions for the rest of society: we are told "the age of the old industrial city could well be over",[13] to be replaced, perhaps, by university-industry production complexes,[14] and that "in comparison, traditional factors of industrial location are almost irrelevant".[15]

Debates rage, however, over more tangible outcomes for employment, cyclical stability, and trade competitiveness of the high tech sector. Premus, for example, argues that high tech has already begun to realise its promise, accounting for 75 per cent of the growth in jobs in manufacturing between 1955 and 1979.[16] Cremeans *et al.* further forecast that "although losses of employment in the smokestack sector during the recession are not expected to be recovered in those industries by 1987, employment gains in the high technology sector are expected to exceed those losses by a healthy margin over the 1979-87 period."[17] Others straightforwardly disagree: Browne claims "there are simply not enough high tech jobs to go around",[18] and Riche, Hecker and Burgan conclude that ". . . for the forseeable future the bulk of employment expansion will take place in non-high tech fields". Saxenian similarly argues that high tech's direct impact on employment will be limited, but adds that its longer-term secondary contribution through revitalising traditional industries, while promising, will not be unqualified.[19] Striking a compromise, Hekman,[20] Cordrey,[21] Flynn,[22] and Browne,[23] for example, suggest that high tech can become a success story at the local level for a limited number of areas offering the ingredients most sought by these firms. Contrasting claims are also made for high technology's ability to be recession-proof: according to Cremeans *et al.*, employment in the US high technology sector grew through the last recession by 217,000 jobs from 1979 to 1983, but Burgan emphasises that only in one very narrowly defined high technology group was employment performance better than in the non-farm business sector.[24] Disputes also exist about its role in promoting the international trade competitiveness of the US. An alluring notion is that high technology will allow industry to step up a gear in the process of cost-cutting innovation, which has always paid such dividends in the past: R. Kelly estimates that over 40 per cent of US manufactured goods exports are composed of technology-intensive products, compared with 25 per cent for the rest of the OECD.[25] Davis, however, asserts the reality to be that US competitiveness in this area has, in fact, been declining.[26]

Clearly, the researcher's ability to focus the issues in this argument and to devise validating studies is greatly influenced by the tools used to describe and measure the high tech phenomenon. This may be self-evident to many social scientists, but it is nevertheless emphasised here because some official views maintain otherwise. The US International Trade Administration, for example, in a study of US competitiveness in high technology industries, boldly asserts that "the conclusions developed from the broad data are not sensitive to the definition selected for high technology".[27] While this claim may be true over a limited range of similar definitions at the level of aggregate international flows, it is unlikely to hold across markedly varying definitions or at the disaggregated regional and local levels. The future course of democratic prosperity may well depend on academics picking up the challenge of constructively criticising the official generalisations a trusting public is offered.

The second reason for concern over definitions is that the early faith in high technology as the panacea for ailing economies, taken up by the popular media and politicians, has fostered a number of state government programmes to assist such industry.[28] It has been asserted that when entrepreneurs and investors find each other, possibly through such programmes, "everybody wins".[29] Weiss, however, ventures the more cynical suspicion that in the US "whatever relatively new industry these governments hope to attract automatically becomes high tech".[30] Similarly, Taylor in the UK remarks upon a "scramble by local authorities, by quasi-public agencies and by the private sector to make a Disraelian leap in the dark for the science and technological shore".[31] It is discomforting enough for the taxpayer to suspect that this shore does not exist, but even more depressing to believe that elected officials, having outfitted the expensive lifeboat, might not be able to recognise the shore when they see it.

High technology, through its preoccupation with innovation, is central to the continuing development of advanced capitalist societies. Schumpeter conceived of capitalism as a system offering tremendous rewards for the innovator, while extinction awaited others.[32] That such a ruthless dynamic has served Western society relatively well is thanks to the continuous flow of new entrepreneurs able to innovate where larger and hidebound vested interests fail, and to government actions which ameliorate the worst social consequences. High technology could be viewed as another opportunity — perhaps one of the few left — for renewing the system in this way. If so, it would surely be appropriate to ask whether official involvement in the process is beneficial, or whether it is helping assure a safe place among new ventures for established older interests which otherwise, by force of Schumpeter's creative destruction, would unavoidably be dislodged.

A necessary first step in such a judgement is being able to recognise high technology industry itself. A 1983 census by the US Office of Technology Assessment identifies over 150 state and local government initiatives and programmes in the US with at least some features directed towards high technology development. Most have been launched since 1980, and 38 of these in 22 states are specifically targeted on the creation, attraction, or retention of high technology firms.[33] Within these 38 programmes, 22 different types of services are identified, nine of which involve state finance in the form of investment capital or grants; another six involve state loans, and four are tax incentives. If the main precondition for efficiency in local public spending in general is accountability, then this implies having criteria for financial programmes which are explicit and defendable.[34] In this instance it would seem necessary to know to which industries, firms, or individuals such money is being offered, and why. This is underlined by one review of an "unsuccessful" high-technology programme, the New Jersey Office for Promoting Technical Innovation, which had attempted to encourage everything from basement inventors to sophisticated licensing arrangements.[35] The implication appears to be that OPTI would have had greater success with better targetting. Meanwhile, at the national level, there is also the debate over whether the plethora of such local business incentives really is beneficial to national production, or whether it merely succeeds in bidding up the public contribution to private location decisions and rewards particular groups in society.[36] The definition of high technology used to determine eligibility in different places will clearly determine the degree to which this set of subsidies is duplicative.

The third reason why definition is important is geopolitical. The high technology sector was at the focal point of Washington's recent attempt to control the diffusion to Soviet-bloc nations of any technology with military applications, through the 1979 Export Administration Act.[37] This mandated the creation of a Militarily Critical Technology List so voluminous that it has been criticised as being a modern technologies list.[38] Any attempt to target a category of products for control in a trading system of fifteen free producing nations, each with its own views and national production interests, is bound to receive much criticism over the defined list of critical technology, even if the underlying principle of control is agreed upon. In the end, this measure duly became a source of public disagreement not only between the US and its allies, but also between the federal government and five of America's most prestigious universities, which had also been asked to observe restrictions.[39] As an Office of Technology Assessment (OTA) review of the Act found,

> . . .in the present environment, technology is complex, often intangible, widely diffused, and subject to swift change. Thus the difficulty of definition exacerbates the difficulties of control.[40]

A fourth factor of importance is the academic debate as to whether the high technology industry phenomenon is really new in the sense of being governed by different laws or processes than the old, and consequently whether new theoretical models are required. Oakey, for example, suggests that multiple, short, product life-cycles are more appropriate.[41] Scott points to the search for a *tabula rasa* on which to found new production complexes, rather than traditional evolution within existing industrial cores, as a distinguishing feature.[42] Precise, stable and comparable definitions are clearly necessary for measurements critical to study of such issues.

Finally, and more generally, if social scientists really expect to be able to play an important role as chroniclers and interpreters of change, and to be a part of society's coming to know itself, then it is important to have an awareness of definitions and the explicit and implicit values they contain. This is because often our *reaction* to the exceptional may be as interesting as the phenomenon itself, and as part of the reaction to high technology our very choice of definition may reveal something about what society really wants, or expects to find, on the yellow-chip road to Hall and Markusen's Silicon City myth.[43]

APPROACHES TO DEFINING HIGH TECHNOLOGY

Most studies involving high technology industry acknowledge the difficulty of definition and the several ways of proceeding. As Breheny *et al.*, Tomaskovic-Devey and Miller, and Langridge note, there seem to be four main approaches to resolving these problems before proceeding with a study. First, a formal definition can be omitted in favour of an implied understanding. Clearly, this approach does not solve the initial problem of identifying what is being discussed in a way amenable to analytic comparisons.

Second, an explicit, but still subjective, choice can be made of what is included in high technology. Oakey, for example, reports his summary data on 174 British and American high technology firms which were chosen because they were highly innovative and because accumulated expertise existed from previous research on these industries.[44] Similarly, Cremeans *et al.* base their conclusions on results from a judgementally selected sample. While this may be good enough for the purpose of the study in hand, it does pose problems of comparability and of value biases.

Third, a single industry, or a narrow group, can be selected for analysis, as was done by: Oakey with instruments;[45] Eckelmann with computers;[46] Hall, Markusen, Osborne and Wachsman with computer software;[47] Clifford with semiconductors;[48] OTA, Eckelmann, and Sanderson and Berry with robotics,[49] the ITA and Feldman with biotechnology;[50] and Paul with a group of these.[51] This approach allows deeper systematic investigation of what is likely to be a more internally consistent sample, and avoids the problem of delimiting a whole sector, but it does leave open the question of how far findings can be generalised to high technology as a whole.

Fourth, one or more explicit attributes which are believed to identify high technology can be postulated on the basis of theoretical belief about the phenomenon. From this attribute a practical index can be derived and applied to data on the whole spectrum of industrial types as laid out in an existing classification system — in the US usually the Standard Industrial Classification (SIC) or sometimes the Standard International Trade Classification (SITC). Of the four, this is the most scientific way to proceed, but care must be taken that circular argument is not the result. Flynn, for example, initially identifies high technology industry partly by a relatively high proportion of professional and technical workers, and yet later offers the finding that "statewide data indicate. . .the high technology industries. . .have a much higher percentage of their employment in professional and technical occupations."[52] Nevertheless, this applied index approach seems to have become conventional for high technology analysis, and the variants of it are outlined below, in approximate order of their development.

APPLIED INDEX DEFINITIONS OF HIGH TECHNOLOGY

Boretsky was probably the first to attempt a formal definition of high technology industries in this way, in 1971.[53] He included those which spend at least 10 per cent of their gross value added product on research and development (R & D), or which have at least 10 per cent of their total employment consisting of scientists, engineers and technicians (SE & T). The SIC code group he identified is often referred to as DOC1. He was followed by R. Kelly working for the US Department of Commerce's Office of Economic Research, who estimated R & D intensity from the value of R & D expenditures relative to shipments using 1968-70 data.[54] The average research intensity for all US manufacturing at that time (excluding SIC 1925) was 2.36 per cent of sales (f.o.b. plant). Initially Kelly included only those in the top quartile of intensity as high technology, but this was later expanded to cover all above-average industries in a definition often labelled DOC2. Aho and Rosen, working for the US Department of Labor's Bureau of International Labor Affairs, then used Kelly's method with more recent data on R & D and shipments, which they concorded to SITC codes to enable international trade comparisons.[55] Vinson and Harrington, in the Massachusetts Department of Manpower Development, selected all 3-digit industries whose share of SE & T employment in 1977 (or 1974 in some cases) exceeded the durable goods manufacturing share of 13.7 per cent.[56] This produced 14 manufacturing codes, to which they added space vehicles and guided missiles (SIC 376), and also six non-manufacturing industries from 1974 data.

By the end of the decade, high technology had become a media buzzword and both *Business Week* and *Scientific American* published their groupings.[57] The former identified high technology as one of five separate economies in 'restructured America', and using research by Data Resources Inc. listed 24 industries as high technology (though the basis for inclusion is not given). *Scientific American's* definition was based on employment of a high level of technical personnel. The two resulting groups are basically the same and cluster around computers, semiconductors, aircraft and instruments, except that *Business Week's* group also includes missiles, radio and TV equipment, ophthalmic goods, and watches and clocks. *Scientific American's* does not, but does include pharmaceuticals, which *Business Week's* does not.

Politicians and government offices also began to consider high technology at about this time. Premus prepared a study on the location of high technology firms for the US Congress Joint Economic Committee's Subcommittee on Monetary and Fiscal Policy, in 1982. He asserted that the important attributes identifying high technology industry are: that firms be labour-intensive rather than capital-intensive in their production processes; that firms employ a higher percentage of SE & T workers than other manufacturing companies; that they be science-based; and that R & D inputs be more important than in other manufacturing. A broad group of industries, using two-digit SIC codes, is thus defined, though the statistical limits of these critical features are not specified.[58]

More rigorous definitions of high technology have been devised and applied by Riche, Hecker and Burgan, working for the US Department of Labor's Bureau of Labor Statistics, in 1983.[59] They identify three groups of high technology industries (now often referred to as BLS1, BLS2 and BLS3), using three-digit SIC codes. BLS1 includes industries with a proportion of technology-oriented workers (engineers, life and physical scientists, mathematical specialists, engineering and science technicians, and computer specialists) at least 1.5 times the US all-industry average. BLS2 includes industries with a ratio of R & D expenditures to net sales of at least twice the all-industry average. BLS3 includes manufacturing industries with a proportion of technology-oriented workers equal to or greater than the average for all manufacturing industries, and a ratio of R & D expenditures to sales close to or above the average for all industries. This last group includes two non-manufacturing industries which provide technical support to high tech manufacturing. BLS1 is the broadest of these three and includes 48 three-digit SIC codes. BLS2 is the smallest, with only six.

Two other definitions have been developed by research contractors to the US Office of Technology Assessment.[60] Glasmeier, Hall and Markusen's original criteria were that industries and services exhibit a 2 per cent per annum growth rate in employment over a ten year period, coupled with a ratio of production workers to total employment 20 per cent below the national average. This encompasses 99 four-digit SIC codes,[61] and they have continued to use them in later work.[62] Armington, Harris and Odle defined high technology as having a minimum level either of professional, scientific and technical workers, or of R & D expenditures.[63] Their data were from the US Establishment and Enterprise Microdata files, developed at the Brookings Institution for the Small Business Administration. This definition covers 96 four-digit SIC codes, and, unlike the former, includes selected business services. Since both the Berkeley and Brookings definitions are based on four-digit SIC codes, they offer a finer distinction than the others.

Davis also followed the index approach in 1982, but added two sophisticated qualifications. First, he used the ratio of research and development expenditures to producers' shipments, including not only the funds spent by final producers, but also expenditures by producers of intermediate products used in the final product. This was done using the input-output technique to estimate the value of R & D incorporated in intermediate products, to be included as an indirect R

& D contribution in the final product. Second, he required that high technology industry should show a significantly greater intensity of R & D, rather than just an above average one: this point was reached at 8.2 cents of R & D per dollar of output. His work is sometimes referred to as the DOC3 definition.[64]

Another refinement was added by Lawson, who suggested that to be high technology, an industry must simultaneously exhibit the two criteria of greater than average concentrations of engineering and scientific skills and capabilities, and "accelerating rates of technological growth associated with zonation and evolution stages of their respective S-curves".[65] The latter she measured by trends in R & D scientists and engineers per 1000 employees within an industry from 1969 to 1977. This yielded 9 high technology industry groups across one two-digit and 17 three-digit SIC codes. Gandia, working for the Maryland Department of Economic and Community Development, has extended Lawson's logic to conclude that high technology can only ever be a dynamic concept, and hence stipulates that a positive derivative to the R & D activity curve should be the second criterion.[66] Tomaskovic-Devey and Miller suggest two definitions using "the various criteria that are offered by government and business groups", though they do not list sources.[67] One they call the Sci-Tech definition and it includes those industries with high levels (13.7 per cent or more) of SE & T workers in the labour force. The other they name the R & D definition and that includes industries with an above average intensity (9.6 per cent of investment) of R & D. Most recently of all in the US, Hosley and Kennedy of the Federal Reserve Board's Division of Research and Statistics selected in 1985 a small group of five industries for analysis, using a criterion of high growth.[68]

A few states in the US have commissioned definitions to guide their own programmes. For the Florida Department of Commerce, high technology industry denotes "knowledge-intensive manufacturing industries actively engaged in developing new products and processes".[69] Ten three-digit codes and one four-digit code are included in its list. Allen compiled a list of high tech SIC codes for a study of Colorado's industry which later guided that state's programmes, based on four common criteria (high percentage SE & T, high ratio of R & D expenditures to sales, high value-added products dependent on access to information and education resources) plus a fifth — having to use state of the art methods of production to survive.[70] This group of 46 four-digit codes includes chemicals and selected services. Arizona's Office of Economic Planning and Development has a list of 30 four-digit codes.[71] Texas, Maryland, and Wisconsin also have checklists based on SIC codes,[72] but Mississippi appears to be the only state where a group of SIC codes is enshrined in legislation.[73] Other states with no public financial programmes devoted to high tech have been able to allow more liberal interpretations: a common feature of these seems to be an absence of published details about the basis for the classification or the cut-off points used, since they appear more concerned with the convenience of end-use, rather than with the niceties of derivation.

In the UK, T. Kelly has developed a high-technology industry classification using three criteria: R & D expenditures as a percentage of output, rate of technological innovation, and a labour force bias towards administrative, technical and R & D workers.[74] He has identified nine British minimum list headings (MLH) in this way for a comparative study of high technology location in Scotland and East Anglia.[75] It is also used by Gould and Keeble, Keeble and Kelly, and Keeble.[76] The UK Department of Trade and Industry adopted an early operational definition based on specific goods, but its use was confined to answering Parliamentary questions.[77] A more formal definition has recently been devised for the same Department by Butchart, with 19 four-digit UK SIC codes based on R & D intensity (measured by the ratio of intra-mural R & D expenditure to gross industry output).[78]

STATISTICAL IMPLICATIONS OF DIFFERENT DEFINITIONS

The most striking feature to emerge from comparison of these 23 definitions is the large number of industries which could be defined as high technology. The range of SIC short titles mentioned in the definitions is 50 three-digit codes in the fifteen definitions primarily based on the three-digit level, and 108 four-digit codes in the seven definitions using primarily the four-digit level. Avoiding double counting through nested subdivisions, 50 three-digit codes and five unincorporated four-digit codes are covered. This all-inclusive group contained 18.2 per cent of all employees in the US in 1982, which was almost exactly the same share as it accounted for five years earlier. Only one out of the 50 industries — electric components and accessories (SIC 367) — receives universal affirmation as being high technology in the three-digit definitions, and only four out of the 108 product lines — electronic computing equipment (SIC 3573), radio and TV communication equipment (SIC 3662), semiconductors and related devices (SIC 3674), and electronic components nec (SIC 3679) — are chosen by all four-digit definitions.

There is considerable variation in the statistical picture drawn by the sub-sets represented in the different individual definitions. Business aggregates produced by each for 1982 are given in Table 1, where they are ranked by employment level.[79] The number of employees which could be included ranges from a minimum of 1.65 million (or 2.2 per cent of the US workforce) with the Federal Reserve Board's

Table 1

High Technology Employment and Growth in the USA, 1977-82

Definition*	1982 Employment Total (000s)	1982 Employment Share of US (%)	1977-82 Employment Growth (%)
Riche *et al.* (1983-BLS1)	11,400.2	15.3	15.0
Premus (1982)	7,488.7	10.1	6.5
Glasmeier *et al.* (1983)	5,488.7	7.4	17.1
Allen (1984)	5,637.2	7.2	27.0
Riche *et al.* (1983-BLS3)	5,212.5	7.0	20.3
Armington *et al.* (1984)	5,174.0	7.0	23.5
Vinson & Harrington (1979)	5,083.2	6.8	32.0
Mississippi (1984)	4,940.9	6.7	21.0
Gandia (1983)	4,759.6	6.4	26.6
Boretsky (1971)	4,052.4	5.5	18.4
Lawson (1982)	3,912.9	5.3	20.8
Kelly (1976)	3,676.8	5.0	20.0
Thompson (1987)	3,511.8	4.7	26.3
Davis (1982)	3,480.2	4.7	22.0
Tomaskovic-Devey & Miller (1983-II)	3,452.5	4.7	17.5
Dorsey (1985)	3,447.3	4.6	34.0
WDoD (1983)	3,437.2	4.6	31.4
Tomaskovic-Devey & Miller (1983-I)	3,386.6	4.6	21.6
FDoC (1983)	2,837.4	3.8	32.0
Business Week (1981)	2,836.4	3.8	30.8
Scientific American (1982)	2,675.0	3.6	31.6
Bootes (1985)	2,613.6	3.5	36.5
Riche *et al.* (1983-BLS2)	2,412.1	3.3	34.2
Hosley & Kennedy (1985)	1,654.5	2.2	37.5
All codes in the above	13,542.2	18.2	14.6
Total	74,297.3	100.0	14.4

* ranked by total employees.

Source: Statistics aggregated from US Department of Commerce, Bureau of the Census, *County Business Patterns, 1982, United States,* USGPO, Washington DC, 1985 and earlier years.

definition, to 11.4 million (or 15.3 per cent of the workforce) with the Bureau of Labor Statistics's first definition — a difference factor of 6.9. The 23 different possible employment estimates average 4.30 million with 15 of them producing an employment total of between 3 and 5.5 million. The extremes also differ by a factor of 7.1 for payroll; establishments totals vary by much more at a factor of 24.5, though this is brought down to a similar level (7.5) if BLS1, the broadest definition, is excluded. Employment growth from 1977 to 1982 was only 6.5 per cent in the Premus group of high technology codes, which is less than half the all-industry growth rate of 14.4 per cent. The range across the other definitions was 22.5 per cent, from 15.0 per cent (BLS1) to 37.5 per cent (FRB). Generally it seems that growth figures increase down the Table, implying that the definitions which were relatively more restricted in the employment they included were also more successful at isolating areas of growth: in particular, the Federal Reserve Board's choice of growth as a criterion manifests itself in the result.

CONCEPTUAL AND PRACTICAL PROBLEMS WITH THE DEFINITION OF HIGH TECH

Definitions using the SIC-based applied index approach do offer objectivity (through measurement), flexibility (through choice of index and cut-offs), a fineness to distinction (through the detailed breakdown inherent to the SIC), and maximum use of other existing data tabulated by SIC code when following up on the behaviour and characteristics of the high technology industry thus identified. However, they are also susceptible to some problems.

First, there is the problem of choosing a quantitative measure of the underlying notion about high technology, since indices themselves are not free from definitional problems. Research and development, for example, is not a clear-cut concept with standard measures.[80] Lawson points out that differences in total research expenditures may reflect inter-profession salary differentials and the varying costs of R & D-related equipment rather than the volume of usable research delivered for the money.[81] Some industries contract out R & D, thereby lowering their R & D employment rate. Further, as Kelly notes, accounted research spending is being observed at the margin, and does not measure accumulated research expenditures of previous years (and of other firms and industries) already embodied in the starting materials.[82] Nor does it measure the background level of technological wisdom already in the public domain. Most chosen indices are concerned with occupational categories, R & D expenditures, and their ratios to selected employment, shipments, value-added, or output totals: some of this data is obtained from trade and occupational sources, rather than employment and industrial surveys, and applying it to industries arranged by SIC classification may be possible only at the level of broad industrial groups, or with arbitrary trimming. Lawson further points out that values of shipments are very sensitive to the intermediate transactions.

Second, there is little theoretical basis for suggesting the appropriate cut-off points for high and low ratios obtained with the chosen index. Quartiles and averages are simple, yet arbitrary. Davis's significant-step method seems the most appropriate,[83] but either way, in practical terms the researcher is still often faced with fine distinctions between low ratios. Flynn, for example, finds that although professional and technical jobs account for a greater share of employment in high technology than in traditional industries, they are still in the minority, with blue collar and clerical jobs forming the majority in high-tech industries: the proportion of skilled technician workers never exceeded 11 per cent in her high tech sample.[84]

Applying the critical cut-off on the chosen criterion as an industry-wide average implies further assumptions about the degree of homogeneity within an industrial group, and introduces a third problem associated with use of the SIC coding system for such an exercise. The SIC is largely a product-oriented way of classifying different industries: activity is broken down into major industry groups at the two digit level, with the third digit identifying sub-groups within an industry, and the fourth a specific product line.[85] The level of code used in the definition of high technology thus carries implications for whether industries or products are the objects of classification.[86] It also determines the fineness with which activities can be separated, and this is crucial if broadly related industries are performing differently. For example, employment within the SIC code 35 (machinery except electrical) grew 12.5 per cent in the five year period between 1977 an 1982. However, employment in its sub-category SIC 351 (engines and turbines) declined by 9.8 per cent over the same period, and that in a finer division, SIC 3511 (turbines and turbine generator sets), dropped 19.7 per cent. Another four-digit code in the 35 group, SIC 3533 (oil field machinery), meanwhile grew by 89.5 per cent. Even within the same four-digit code, there are likely to be further variations in the use of high technology among individual firms, as Beaumont found.[87]

A fourth conceptual problem arises from the SIC's emphasis on product rather than process distinctions, and its fixed nature in the face of individual diffusion. The popular and instinctive way of defining high technology stems from the way it is directly experienced, that is through the novelty and sophistication of the product. Although this has been the approach used by some researchers, the economic geographer is more often trying to identify something with connotations of fast growth and rapid innovation, in which scientific research and development plays a pivotal role; that is, factors of the process with which the sophisticated products are made. Features of process might be only marginally related to the features of product by which industries are conventionally arranged. As the OTA points out, modern agriculture and forestry rely heavily on chemicals and sophisticated scientific management techniques, and yet are omitted from nearly all high technology lists.[88]

The key features of high technology *qua* process are its continuous change and its apparent ability to revolutionise production across the board. But the cutting edge, having cut, moveth on. As Flynn points out,

> While the textile industry is often referred to as mature or traditional today, it represented high technology a hundred years ago. Similarly, industries considered high technology today, such as computers, information processing, robotics or powdered metals, may or may not be the high technology of tomorrow.[89]

Even yesterday's high technology, which might be thought merely standard today, could yet be re-incorporated in tomorrow's frontier group. For example, most researchers might describe the manufacture of television sets as a routine activity and no longer high tech. However, the advent of chips, home computers, satellite dishes, and fibre optic transmission, has brought about new production requirements and turned the humble box into an intelligent window. Given this, how should an establishment which now manufactures both new and conventional types of TV sets be classified?

It thus seems relatively easy to present a definition of high technology for a specific time, so long as it is taken to include a small group of research intensive industries that manufacture new, sophisticated, technology intensive products — that is, only those at the cutting edge. It also implies that researchers taking the approach of single industry studies are on firmest ground. If, however, the definition is broadened to include any industry adopting new processes or products coming from the smaller group, but not necessarily itself contributing to further research and development — which is certainly a temptation as it is this secondary area in which many expect the true employment and economic benefits to show up — then it would be possible to include autos, textiles and even the shoe industry. For even though these would be intuitively classified as traditional industries, they too are becoming modernised with computer-aided design and robot production techniques.

Further minor problems arise after a definition has been chosen and applied. These include errors in reporting,[90] and unexplained changes in an existing definition.[91] Finally, there is also a problem of comparability. Breheny *et al.* note that the occupational composition criterion cannot be universally applied outside the US. For example, the current source of occupational data in the UK (the Census of Production) does not cover the service sector. As they further point out, high tech in any case may have specific realisations varying by host economy. The Berkeley researchers assumed high technology creates, and therefore can be defined by, higher than average employment opportunities, but in the UK, in spite of the apparently vibrant spread of high tech, only one manufacturing MLH could meet the same employment growth criterion. Langridge analysed UK manufacturing MLHs in terms of output growth, capital to labour and capital to output ratios, and occupational composition ratios, and found that "nothing conclusive" emerged. Only his ranking in terms of output growth successfully identified a satisfying high tech group.[92]

BEYOND THE OBJECTIVE DEFINITIONS

This review of problems indicates there is a variety of definitions to choose from, and that the question of best definition will always depend on the theoretical conception of high technology adhered to, the data available, and the objectives of the particular study in hand. Future research might adopt either of two types of definition for high technology industry. First, a fixed definition in which the industry groups originally defined as high technology can be considered the benchmark group. Tracking change with such a definition will then indicate not only that particular group's performance, but also the degree to which it has become more or less important for the whole economy over time. Second, a moving or relative definition in which an index could be chosen (such as R & D expenditures and/or SE & T employment), all industries periodically remeasured against it, and the cut-off point continually updated according to the changing distribution. Tracking this definition would then show how the industrial and product composition of the defined high tech group changes over time.

However, neither of these gets round the problem of 'high' being discernible only against a particular background. In this event, perhaps it would be better to recognise this explicitly by having a definition based on just that: let high technology be defined as whatever people think it is. In this way those industries which do mean the most to a society would be tracked, and if the group was periodically updated, it would again show how the industrial and product composition of the defined high tech group changes over time. This approach would have the theoretical virtues of always highlighting the contemporary high tech group, and of allowing for Markusen *et al.'s* product-profit cycle explanation, whereby

". . .every industry was once high tech". It would also probably have the practical advantage of not including the large SIC 371 (motor vehicles and equipment), which in the Riche *et al.* BLS1 definition makes it difficult to distinguish high technology group employment from conventional manufacturing, and results in Detroit being cast as the high tech dynamo of the US.

The social perception of what constitutes high tech in present day America was uncovered by a survey of 26 federal offices and 135 state agencies and programmes concerned with high tech. This asked for their operational definition of the term in their everyday work.[94] Nine federal and twelve state definitions based on the SIC system were found. Within these, thirteen three-digit and 35 four-digit codes are mentioned by a majority of definitions (that is, more than four federal and six state definitions). In the latter group of 35, 31 codes are already accounted for within the majority three-digit codes, which leaves only four unincorporated codes. These thirteen three-digit codes and the four unincorporated four-digit codes could thus be thought of as the most consistently-recognised high technology group of industries, and are suggested here as a third type of definition, a consensus one. Of course, it is not certain the individual definitions were independently derived, nor do they constitute all possible varieties of definition throughout society. They have not been weighted by how many people make use of each, and the method implies fusing industry- and product-based approaches because of the mix of three- and four-digit codes, Nevertheless, this is a group of codes about which there has been the most agreement among US experts, and which can be suggested as a complement to the objective definitions of Riche *et al.,* which are currently gaining the widest acceptance in the US.

Table 2 shows business aggregates for this consensus group, arrayed by US SIC code. High technology industries by this definition accounted for 3.51 million employees in the US in 1982, or 4.7 per cent of the workforce. They worked in 0.5 per cent of establishments for 6.8 per cent of the total US payroll. Jobs in this group increased by 26.3 per cent in the five years from 1977 to 1982, which was almost double the growth rate for all US industry. Few of the 17 codes are individually very large: only electronic components and accessories (SIC 367) accounts for more than 0.05 per cent of US establishments. Only four codes contain more than half of one per cent of total US employees: these are communication equipment (SIC 366), aircraft and parts (SIC 372), electronic components and accessories (SIC 367), and — far behind these three — office and computing machines (SIC 357). Nevertheless, all 17 codes account for a greater than proportional share of payroll, and some have exhibited spectacular employment growth. The largest absolute growth from 1977 to 1982

Table 2

US Business Aggregates for 17 Consensus High Technology SIC Codes

SIC Code	Short Title	Establishments		Employees		Payroll	
		1982 (no.)	1977-82 (%)	1982 (no.)	1977-82 (%)	1982 ($000's)	1977-82 (%)
283	Drugs	1,213	7.25	169,840	6.23	4,078.353	60.77
2869	Industrial organic chemicals, nec	582	9.60	112,126	4.80	3,211.190	57.58
351	Engines & turbines	312	4.70	118,870	−9.77	2,840.990	27.30
357	Office & computing machines	1,934	63.07	402,513	61.26	9,681.006	144.25
3622	Industrial controls	834	32.59	68,175	12.20	1,329.662	69.08
365	Radio & TV receiving equipment	928	−14.63	73,746	−19.92	1,303.297	19.34
366	Communication equipment	2,398	15.23	607,296	35.21	14,151.150	105.61
367	Electronic components & accessories	5,026	41.54	526,626	36.53	9,843.704	106.01
3693	X-ray apparatus and tubes	212	29.27	43,515	163.98	995.114	292.58
372	Aircraft & parts	1,323	21.60	541,027	26.17	14,457.920	91.06
376	Guided missiles, space vehicles, parts	103	−3.74	164,791	32.28	5,131.563	101.82
381	Engineering & scientific instruments	851	12.42	53,160	12.73	1,036.556	56.11
382	Measuring & controlling devices	2,360	29.03	232,720	23.08	4,723.714	84.38
383	Optical instruments & lenses	544	12.86	42,536	58.18	893.893	130.75
384	Medical instruments & supplies	2,493	13.89	141,823	14.86	2,545.680	70.90
386	Photographic equipment & supplies	729	4.74	111,331	−0.70	3,169.089	65.55
7391	Research & development laboratories	2.717	34.97	101,686	33.92	2,611.072	104.19
	Total	24,559	23.92	3,511,781	26.30	82,003.930	90.85
	Rest of US industry	4,609,401	6.39	70,785,471	13.81	1,117,355.273	60.68
	Total US industry	4,633,960	6.47	74,297,252	14.35	1,199,359.203	62.43

Source: Statistics aggregated from US Department of Commerce, Bureau of the Census, *County Business Patterns, 1982, United States,* USGPO, Washington DC, 1985 and earlier years was in the same four. The largest relative job gains were in X-ray apparatus and tubes (SIC 3693), which grew by 164 per cent, office and computing machines, with 61.3 per cent, and optical instruments and lenses (SIC 383), which grew by 58.2 per cent. However, employment in seven out of the 17 codes did not grow by as much as the 13.8 per cent increase for the rest of US industry, and three high technology codes actually manifested a decline: radio and TV receiving equipment (SIC 365) went down by 19.9 per cent, engines and turbines (SIC 351) by 9.8 per cent, and photographic equipment and supplies (SIC 386) by 0.7 per cent. The absolute aggregate job loss for these three codes, however, was only 31,993, or about one lost for every 24 jobs gained in this high tech group overall.

This performance does not look so helpful, though, in the larger context. At its 1977-82 rate of growth, the US labour force as a whole would add 12.5 million people between 1982 and 1987, and another 13.8 million between 1987 and 1992. The total of unemployed, which grew by 3.7 million between 1977 and 1982, would at that period's rate be 16.3 million strong by 1987. Although neither of these trends is likely to persist at exactly the 1977-82 level because of the unique demographically-driven characteristics of the period and the impact of economic recovery, it is a fact that even if 1972 or 1977 pre-recession levels of unemployment are regained, this would still leave 4.9 to 7 million Americans out of work. Added to this is the potential threat to any of the 15 million machine-operating, assembly, and labouring jobs posed by the spectres of de-industrialisation and foreign assembly.[95] Against this backdrop, direct high tech employment appears to be falling short of Cremeans *et al.'s* optimistic forecast: at the 1977-82 rate of individual code employment growth, the consensus high tech group will have added slightly more than 1 million new jobs by 1987, and only a further 1.4 million by 1992. The implicit hope of trading one lost manufacturing job for one new high tech job is thus unlikely to be realised, and the contribution of this sector to job-saving is more likely to rest, as many have already speculated,[96] in the reinvigoration of traditional industry to meet foreign competition. Assuming Miller's 'ripple effect' ratio of one high tech job generating three to seven others, the aggregate job equation is brought into the envelope of possible balance, depending on assumptions about the rest of the economy.

CONCLUSION

This review, comparison, and new definition have several implications for the four concerns outlined at the start of the paper. First, it is indeed possible to come to a variety of contradictory conclusions, depending on which definition is employed. By the Federal Reserve

Board definition, high tech is generating jobs at three times the rate of the rest of the economy, but under the Joint Economic Committee definition, high tech is performing at less than half the national average. The trends shown by the consensus group of high technology industries, though, support Riche, Hecker and Burgan's conclusions about high tech continuing to be "a small slice of the employment pie", rather than Cremeans *et al.'s* optimistic forcast.

Second, if job replacement is achieved in aggregate, then it is the distributional questions — occupational and geographic — which will come to the fore. Thus, the local impacts of this sector are likely to command most attention in the future, and hence the state and local programmes will be of most interest. Attention needs to be focussed on what are the important locational factors for particular high tech industries, and the extent to which state programmes really are targetting the next wave of winners within high tech, or have instead allowed high tech programmes to become part of the general industrial subsidy. At a higher level, this becomes a question of whether the US political and constitutional apparatus will overtly allow positive discriminatory policies among industries in the way the Japanese high tech development thrust is practised now,[97] and in the way the French planning system proved was so successful for post-war modernisation.[98] If competition from Japan cannot be the fortuitous Sputnik of the 'eighties and generate an orchestrated response from the independence-minded economy, then the question needs to be raised of whether a US industrial policy based on the Pentagon-spending multiplier can be relied on to fill this vital role instead.

Third, the variety of performance levels within the consensus high tech group implies that valuable new industrial production secrets are not being generated equally in all high tech industries, and that the political and administrative difficulties of draconian export restrictions could be replaced by a more concentrated, less controversial, and thus probably more effective effort on a smaller group of selected industries and products.

Fourth, attempts to derive the general logic, laws and processes underlying this sector on the basis of revealed patterns will be contingent on the definition used. Indeed, the fact that there are already so many definitions on offer indicates a lack of agreement over even the basic concept of high technology which has to underlie the choice of representative measures. Several models could be candidates for theory, including: the conventional discussions of innovation by Schumpeter, Mansfield *et al.*, Freeman, and Telser;[99] Oakey's attempt to fit industrial change into the product cycle, Markusen's profit cycle, or the attempted fusion of both into the product-profit cycle of Markusen *et al.*;[100] the communications-driven hierarchical structuring of space put forward in the structural-realist model of Walker;[101] or the non-equilibrium approach of Storper.[102] Further articulation and testing of these is obviously necessary in the light of unfolding trends.

Finally, the definitions do indicate something about the interest of the parties involved. Wisconsin (America's Dairyland, as the auto license plates remind us) is the only state to include livestock services (SIC 0751) in its checklist of high technology companies. The Defense Department's Militarily Critical Technology List, meanwhile, is over 900 pages long and remains to this day a classified document, making it extremely difficult to prosecute wilful evasion of export control. It does seem, therefore, that high tech is a case of "by our definitions shall ye know us".

Objective definitions will always be limited, as they must be underpinned by a notion of 'high techness' which can only spring from the social context, and because they usually have to be based on data series which only imperfectly reflect key production processes. It may be useful to recognise this explicitly by also tracking a consensus definition grounded in social thought, such as the one suggested here, alongside the conventional objective definitions. The ancient Greek word *teknos*, which is the root of our word technology, originally meant art — a phenomenon unarguably the product of particular times and places and thus consciously used to interpret cultures. In the modern era, technology has come to connote instead a technical, rational, scientific, culture-free force, driving the supposedly inevitable and unidirectional engines of progress, whose sole dimension of variability is the rate at which they turn. Only by restoring the former, industrial-culture interpretation alongside the rational one will we truly come to understand what high tech means, and thus have any hope of consciously steering it towards desired goals.

NOTES AND REFERENCES

1. 'Real specialists', *San Francisco Chronicle Business Extra,* 8 July 1985, p. 19.
2. M. Breheny, P. Cheshire and R. Langridge, 'The anatomy of job creation? Industrial change in Britain's M4 corridor', in P. Hall and A. Markusen (eds), *Silicon Landscapes,* Allen and Unwin, London, 1985, p. 120.
3. G. Eads and R. Nelson, 'Government support of advanced civilian technology', *Public Policy,* 119, 3, 1971, pp. 405-27.
4. H. Giersch, *Proceedings of a Conference on Emerging Technology at Kiel Institute of World Economics,* JCB Mohr, Tubingen, 1981; and S. Miller, *Emerging Technologies and Their Implications for Mid-America,* Stanford Research International, Menlo Park, California, June 1984.
5. C. Freeman, *The Economics of Industrial Innovation,* MIT Press, Cambridge, Mass, 1982.

6. E. Deuterman, 'Seeding science-based industry', *Federal Reserve Bank of Philadelphia Business Review,* 1966, pp. 7-15.
7. R. Kelly, *Alternative Measurements of Technology-Intensive Trade,* Staff Economic Report, OER-ER-17, Office of Economic Research, International Economic Policy and Research, Office of the Assistant Secretary for Policy, US Department of Commerce, September 1976.
8. R. Riche, D. Hecker and J. Burgan, 'High technology today and tomorrow: a small slice of the employment pie', *BLS Monthly Labor Review,* November 1983, pp. 50-8.
9. D. Tomaskovic-Devey and S. Miller, 'Can high-tech provide the jobs?', *Challenge,* 26, 2, 1983, pp. 57-63.
10. R. Langridge, *Defining 'High-Tech' for Locational Analysis,* Discussion Paper in Urban and Regional Economics, series C, no. 22, Department of Economics, University of Reading, January 1984.
11. A. Markusen, P. Hall and A. Glasmeier, *High Tech America: the What, How, Where and Why of the Sunrise Industries,* Allen and Unwin, Boston, 1986.
12. 'America rushes to high technology for growth', *Business Week,* 28 March 1983, p. 87.
13. T. Taylor, 'High technology industry and the development of science parks', in P. Hall and A. Markusen (eds), *Silicon Landscapes,* Allen and Unwin, London, 1985, chapter 9.
14. J. Rees and H. Stafford, 'High technology location and regional development: the theoretical base' in *Technology, Innovation, and Regional Economic Development,* US Office of Technology Assessment Report no. OTA-STI-238, USGPO, Washington DC, July 1984a, appendix A; A. Scott, 'Empirical observations on industrialization and urbanization in Southern California', Annual Trewartha Lecture to the University of Wisconsin-Madison Geography Department, 26 March 1985; B. Moore and R. Spires, 'The role of high technology complexes and science parks in regional development', paper presented at an OECD Seminar on Science Parks and Technology Complexes in Relation to Regional Development, Venice, 3 June 1986.
15. P. Hall, 'The geography of the fifth Kondratieff cycle', *New Society,* 26 March 1981, pp. 535-7.
16. R. Premus, *Location of High Technology Firms and Regional Economic Development,* Staff Study Prepared for the Use of the Sub-Committee on Monetary and Fiscal Policy of the Joint Economic Committee, Congress of the United States (97th Congress, 2d Session), USGPO, Washington DC, 1 June 1982.
17. J. Cremeans *et al.*, 'Structural change in the US economy: 1979-87. High technology versus smokestack industries', in US Department of Commerce, *1984 US Industrial Outlook,* USGPO, Washington DC, 1984, pp. 39-45.
18. L. Browne, 'Can high tech save the Great Lakes States?', *New England Economic Review,* November/December 1983, pp. 19-33.
19. A. Saxenian, 'Let them eat chips', review of E. Rogers and J. Larsen, *Silicon Valley Fever: Growth of High Technology Culture,* Basic Books, New York, 1984, in *Environment and Planning D: Society and Space,* 3, 1, 1985, pp. 121-7.
20. J. Hekman, 'The future of high technology industry in New England: a case study of computers', *New England Economic Review,* January/February 1980, pp. 5-17; and 'Can New England hold on to its high technology industry?', *New England Economic Review,* March/April 1980, pp. 35-44.
21. J. Cordrey, 'Developing a community's high technology resource base: the Dayton case', paper to the 91st Annual Meeting of the Ohio Academy of Science, Ohio State University, 23-25 April, 1982.
22. P. Flynn, 'Lowell: a high technology success story', *New England Economic Review,* September/October 1984, pp. 39-49.

23. L. Browne, 'Conflicting views of technological progress and the labor market', *New England Economic Review,* July/August 1984, pp. 5-16.
24. J. Burgan, 'Cyclical behavior of high tech industries', *BLS Monthly Labor Review,* May 1985, pp. 9-15.
25. R. Kelly, *The Impact of Technological Innovation on International Trade Patterns,* Staff Economic Report ER-24, Bureau of International Economic Policy and Research, US Department of Commerce, USGPO, Washington DC, December 1977.
26. L. Davis, 'New definition of 'high-tech' reveals that US competitiveness in this area has been declining', *Business America,* 18 October 1982, pp. 18-23.
27. *An Assessment of US Competitiveness in High Technology Industries,* International Trade Administration, US Department of Commerce, USGPO, Washington DC, July 1983.
28. *State Activities to Encourage Technological Innovation: an Update,* report by the California Commission on Industrial Innovation for the National Governors' Association Task Force on Technological Innovation, 1120 N Street, Suite 1201, Sacramento, California 95814, February 1982; US Office of Technology Assessment, *Census of State Government Initiatives for High-Technology Industrial Development,* Technology, Innovation, and Regional Economic Development Project Background Paper OTA-BP-STI-21, Congress of the United States, USGPO, Washington DC, 1983a; US Office of Technology Assessment, *Technology, Innovation, and Regional Economic Development Background Paper No. 2: Encouraging High Technology Development,* Report No. BP-STI-25, Congress of the United States, USGPO, Washington DC, February 1984b.
29. S. Moser, 'The great high tech treasure hunt', *Management Focus,* Peat, Marwick and Mitchell, September/October 1984, p. 17.
30. M. Weiss, 'High technology industries and the future of employment', in P. Hall and A. Markusen (eds), *Silicon Landscapes, op. cit.,* pp. 80-93.
31. T. Taylor, 'High technology industry and the development of science parks', in Hall and Markusen, *op. cit.,* pp. 134-143.
32. J. Schumpeter, *Capitalism, Socialism, and Democracy,* George Allen and Unwin, London, 1976.
33. US Office of Technology Assessment, *op. cit.,* 1983a.
34. F. Layfield, *Local Government Finance: Report of the Committee of Enquiry,* Command 6453, HMSO, London, 1976; R. Jackman, 'Does central government need to control the total of local spending?', *Local Government Studies,* 8, May/June 1982, pp. 75-90.
35. US Office of Technology Assessment, *op.cit.,* 1983a.
36. B. Harrison and S. Kanter, 'The political economy of states job creation business incentives', *Journal of the American Institute of Planners,* 44, 4, 1978, pp. 424-35.
37. US Office of Technology Assessment, *Technology and East-West Trade, An Update,* Report No. OTA-ISC-209, Congress of the US, USGPO, Washington DC, May 1983b.
38. *Transfer of United States High Technology to the Soviet Union and Soviet Bloc Nations,* US Senate Committee on Governmental Affairs Hearings before the Permanent Sub-Committee on Investigations, US Senate, 97th Congress, 2nd Session, USGPO, Washington DC, 4-12 May 1982.
39. These were: Stanford, CalTech, MIT, Cornell, and California. See 'State secrets', *Scientific American,* 246, 4, 1982, p. 70.
40. US Office of Technology Assessment, *op. cit.,* 1983b.
41. R. Oakey, *High Technology Small Firms: Regional Development in Britain and the United States,* St. Martin's Press, New York, 1984.
42. A. Scott, *op. cit.*
43. Hall and Markusen, *op. cit.*

44. R. Oakey, *op. cit.*
45. R. Oakey, *High Technology Industry and Industrial Location: The Instruments Industry Example,* Gower, Hants, England, 1981.
46. R. Eckelmann, *High Technology Industries: Profiles and Outlooks — The Computer Industry,* International Trade Administration, US Department of Commerce, USGPO, Washington DC, April 1983.
47. P. Hall, A. Markusen, R. Osborn, and B. Wachsman, 'The American computer software industry: economic development prospects', *Built Environment,* 9, 1, 1983, pp. 29-39.
48. J. Clifford, *High Technology Industries: Profiles and Outlooks — the Semiconductor Industry,* International Trade Administration, US Dept. of Commerce, Washington DC, April 1983.
49. *Exploratory Workshop on the Social Impacts of Robotics: Summary and Issues — a Background Paper,* US Office of Technology Assessment Report No. OTA-BP-CIT-11, Congress of the US, USGPO, Washington DC, 1982; R. Eckelmann, *High Technology Industries: Profiles and Outlooks — The Robotics Industry,* International Trade Administration, US Department of Commerce, USGPO, Washington DC, April 1983; S. Sanderson and B. Berry, 'Robotics and regional development', in J. Rees (ed.), *Technology, Regions, and Policy,* Rowman & Littlefield, New Jersey, 1986, chapter 8.
50. International Trade Administration. *High Technology Industries, Profiles, and Outlooks: Biotechnology,* US Department of Commerce, USGPO, Washington DC, July 1984; M. Feldman, 'Biotechnology and local economic growth: the American pattern', in Hall and Markusen (eds), *op. cit.,* pp. 65-79; M. Feldman, 'Patterns of biotechnology development', in P. Brotchie *et al.,* (eds), *The Future of Urban Form: The Impact of New Technology,* Croom Helm, Beckenham, Kent, England, 1985, pp. 93-107.
51. J. Paul, *High Technology, International Trade and Competition: Robotics, Telecommunications, Computers, Semiconductors,* Noyes Publications, Park Ridge, New Jersey, 1984.
52. Flynn, *op. cit.,* pp. 41-2.
53. M. Boretsky, 'Concerns about the present American position in international trade', *Symposium on Technology and International Trade,* National Academy of Sciences, Washington DC, 1971.
54. R. Kelly, *op. cit.*
55. C. Aho and H. Rosen, *Trends in Technology-Intensive Trade,* Economic Discussion Paper No. 9, Bureau of International Affairs, Office of Foreign Economic Research, US Department of Labor, National Technical Information Service, Springfield VA, October 1980.
56. R. Vinson and P. Harrington, *Defining High Technology Industries in Massachusetts,* Policy and Evaluation Division, Department of Manpower Development, State of Massachusetts, September 1979, p. 5 and Table 4.
57. 'Special issue: America's restructured economy', *Business Week,* 1 June 1981, pp. 55-100; *Scientific American's List of High Technology Industries,* quoted in Wisconsin Department of Development, *Special Report: Wisconsin, The High Tech Decision,* 1982 (P.O. Box 7970, Madison WI 53707).
58. R. Premus, *op. cit.*
59. Riche, Hecker and Burgan, *op. cit.*
60. US Office of Technology Assessment, *Technology, Innovation, and Regional Economic Development,* Report No. OTA-STI-238, Congress of the United States, USGPO, Washington DC, July 1984a.
61. A. Glasmeier, A. Markusen, and P. Hall, *Defining High Technology Industries,* Working Paper 407, Institute of Urban and Regional Development, University of California, Berkeley CA 94720, March 1983.
62. A. Markusen, P. Hall, and A. Glasmeier, *High Tech America: the What, How, Where and Why of the Sunrise Industries,* Allen and Unwin, Boston, 1986.

63. C. Armington, C. Harris, and M. Odle, 'Formation and growth in high-technology firms: a regional assessment', US Office of Technology Assessment *op. cit.,* 1984a, appendix B.
64. L. Davis, *Technology Intensity of US Output and Trade,* Office of Trade and Investment Analysis, International Trade Administration, US Department of Commerce, Washington DC, 1982; 'New definition of high-tech reveals that US competitiveness in this area has been declining', *Business America,* 18 October 1982, pp. 18-23.
65. A. Lawson, 'Technological growth and high technology in US industries', US Bureau of Industrial Economics, *Industrial Economics Review,* 1, 3, 1982, pp. 11-18.
66. D. Gandia, 'Defining high tech', unpublished draft paper to the Maryland Department of Economic and Community Development, May 1983.
67. Tomaskovic-Devey and Miller, *op. cit.*
68. J. Hosley and J. Kennedy, 'A revision of the Index of Industrial Production', *Federal Reserve Bulletin,* 71, July 1985, pp. 487-501; J. Hosley, personal communication, 31 July 1985.
69. *Interstate Comparisons of High Technology Industry Employment,* State of Florida Department of Commerce, Division of Economic Development, Bureau of Business Assistance, Tallahassee, Florida, 1983.
70. G. Allen, *Emerging High Technology Companies Based on Colorado's High Technology Industry Survey,* Business Research Division, Graduate School of Business Administration, University of Colorado, Boulder, Colorado 80309, 1984.
71. G. Bootes, personal communication with the Economic Research Specialist, Office of Economic Planning and Development, 1700 West Washington, Phoenix, Arizona 85007, 17 July 1985.
72. H. Dorsey, personal communications with the Texas Economic Development Commission, July 1985; Gandia *op. cit.; Special report: Wisconsin, the High Tech Decision,* 1982, and *Special Report: Wisconsin, the Technology for the 80s,* 1983, both by Wisconsin Department of Development, Business Development Services (P.O. Box 7970, Madison WI 53707).
73. *An Act to Provide Tax Incentives and Financial Assistance to Advanced Technology Business,* Mississippi Legislature, House Bill No. 145, by Rep. Hall, Ways & Means, Regular Session, New Capitol Building, 400 High St., Jackson MS 39201, 1984.
74. T. Kelly, The Location, Organisation, and Regional Impact of High Technology Industry in the UK, unpublished paper, Department of Geography, University of Cambridge, 1983.
75. T. Kelly, *The Location and Spatial Organisation of High Technology Industry in Great Britain: Computer Electronics* (PhD Thesis, Department of Geography, University of Cambridge, 1983).
76. A. Gould and D. Keeble, 'New firms and rural industrialization in East Anglia', *Regional Studies,* 18, 3, 1984, pp. 189-201; D. Keeble and T. Kelly, 'New firms and high technology industry in the United Kingdom: the case of computer electronics', in D. Keeble and E. Wever, *New Firms and Regional Development in Europe,* Croom Helm, London, 1986, pp. 75-104; D. Keeble, 'Entrepreneurship, high technology industry and regional development in the United Kingdom: the case of the Cambridge phenomenon', paper presented to a seminar on Technology and Territory: Innovation Diffusion in the Regional Experience of Europe and the USA, Instituto Universitario Orientiale, University of Naples, 20-21 February 1987.
77. R. Woods, personal communication with the UK Department of Trade and Industry, London, 6 July 1985.
78. R. Butchart, 'A new UK definition of the high technology industries', *Economic Trends,* 400, February 1987, pp. 82-8.
79. *County Business Patterns, 1982, United States,* US Department of Commerce, Bureau of the Census, CBP-82-1, USGPO, Washington DC, 1985 and earlier years.

80. A. Rubenstein, 'Economic evaluation of R & D: a brief survey of theory and practice', *Journal of Industrial Engineering,* 17, 11, 1966, pp. 615-20; UNESCO, *The Measurement of Scientific and Technological Activities,* Paris, 1969; H. Kleinman, *Indicators of the Output of New Technological Products from Industry,* report to the US National Science Foundation, National Technical Information Service, US Department of Commerce, Washington DC, 1975; OECD, *The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Experimental Development,* Paris, 1981.
81. Lawson, *op. cit.*
82. R. Kelly, *op. cit.*
83. Davis, *op. cit.*
84. Flynn, *op. cit.*
85. *Standard Industrial Classification Manual, 1972 (with 1977 update),* US Office of Management and Budget, Washington DC.
86. The four-digit codes which are not included in the majority of four-digit definitions, but which are buried inside a three-digit code in the majority of three-digit definitions (presumably because the relative coarseness does not allow separation) are: turbines and turbine generator sets (SIC 3511), internal combustion engines nec (SIC 3519), typewriters (SIC 3572), phonograph records (SIC 3652), cathode ray television picture tubes (SIC 3672), and electronic connectors (SIC 3678). The implication is they are falsely included at a three-digit level. Conversely, the four-digit codes appearing in the majority of four-digit definitions, but which are not covered by the three-digit codes in the majority of three-digit definitions, are: industrial controls (SIC 3622), industrial organic chemicals nec (SIC 2869), X-ray apparatus and tubes (SIC 3693), and R & D labs (SIC 7391). The implication here is they are falsely omitted by a three-digit level of definition.
87. J. Beaumont, *The Location, Mobility and Finance of New High Technology Companies in the UK Electronics Industry,* unpublished study, UK Department of Industry, South East Regional Office, November 1982.
88. US Office of Technology Assessment, *op. cit.,* 1983a.
89. Flynn, *op. cit.*
90. For example, Vinson and Harrington's Table 4 has electrical industrial apparatus (SIC 362) incorrectly labelled as 372. The OTA in 1984a printed on p. 120 Armington *et al.'s* SIC code for small arms as 3486 when its actual number is 3484. A. Markusen, *Defense Spending and the Geography of High Tech Industries,* Working Paper No. 423, Institute of Urban and Regional Development, University of California, Berkeley CA 94720, 1984, on p. 35 allocates organic chemicals (misc) the code 2866 instead of the correct 2869, and radio, TV communications the code 3622 instead of 3662. These are easy transcription errors to make in the course of several drafts of typing.
91. For example, *US High Technology Trade and Competitiveness,* International Trade Administration, Office of Trade and Investment Analysis, US Department of Commerce, Staff Report DIE-01-85, USGPO, Washington DC, February 1985, includes SIC codes 287 and 351 in DOC1 (Boretsky's 1971 definition), whereas its earlier report, *An Assessment of US Competitiveness in High Technology Industries,* July 1983, does not. The ITA also includes SIC 361 (electric distributing equipment) in its version of DOC2, but this was in the non-technology intensive category in Table 4 of R. Kelly's original work. Tomaskovic-Devey and Miller and Flynn disagree over what is included in the Massachusetts definition: the former include SIC codes 281, 282, 351 and 372, which the latter omits, while the converse holds for codes 348, 363, 364, 365, 369, 379, 384, 385 and 387.
92. Langridge, *op. cit.*
93. Markusen, Hall and Glasmeier, *op. cit.*
94. C. Thompson, 'Definitions of high technology used by state programs in the USA: a study of variation in industrial policy under a federal system', *Environment and Planning C: Government and Policy* (forthcoming, 1987).

95. J. Grunwald and K. Flamm, *The Global Factory: Foreign Assembly in International Trade,* Brookings Institution, Washington DC, 1985.
96. Saxenian, *op. cit.*
97. S. Zucker, C. Deutsch, J. Hoerr, N. Jonas, J. Pearson, and J. Cooper, *The Reindustrialization of America,* The Business Week Team, McGraw-Hill Book Company, New York, 1982.
98. S. Cohen, *Madern Capitalist Planning: The French Model,* University of California Press, Berkeley, CA 94720, 1977.
99. E. Mansfield, J. Rapoport, A. Romeo, E. Villani, S. Wagner, and F. Husik, *The Production and Application of New Industrial Technology,* W.W. Norton, New York, 1977; Freeman, *op. cit.;* L. Telser, 'A theory of innovation and its effects', *Bell Journal of Economics,* 13, 1, 1982, pp. 69-92.
100. A. Markusen, *Profit Cycles, Oligopoly and Regional Development,* MIT Press, Cambridge, Mass, 1985; Markusen, Hall and Glasmeier, *op. cit.*
101. R. Walker, 'Technological determination and determinism: industrial growth and location' in M. Castells, *High Technology, Space and Society,* SAGE Urban Affairs Annual Reviews, 28, Beverly Hills CA, 1985, pp. 226-64.
102. M. Storper, 'Technology and spatial production relations: disequilibrium, interindustry relationships, and industrial development' in Castells, *op. cit.,* pp. 265-83.