

Pushing informationalized capitalism into science and information technology

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For at least a quarter of a century, the leadership of the developed market economies [DMEs], above all that of the United States, has insisted that 'computers, telecommunications, and the services which grow out of or depend on those technologies... are the critical industries for continued economic growth.¹ Policymakers have therefore consecrated themselves to the promotion of a newly informationalized political economy. This involved a dramatic redesign of the architecture of global capitalism. What provoked this phase-shift? What are its chief structural features? What, in particular, have science and technology contributed to this emerging, informationalized capitalism?

Let us clear the ground by stating straightaway that informationalized capitalism does not owe only to the development of powerful new technologies such as digital computer networks. Innovations in data processing, storage and distribution not only trace a continuing, albeit uneven, arc from the mid-19th century to the present, but are embedded historically in larger political-economic changes. To comprehend the present-day process of informationalization, I suggest, an appropriate starting-point is the global corporate profit slowdown which began around 1970. Associated with a secular build-up of surplus productive capacity, this stagnation came to afflict numerous core industries, from steel and automobiles to chemicals and textiles.

The result was to awaken corporate leaders to the idea that they needed to identify and develop new markets, and fast. This was hardly the first time that economic crisis engendered efforts to deepen and extend the market system – but the prominence accorded to information as a prospective solution was indeed unprecedented. This new focus grew from a historical confluence of factors: the growth of transnational companies with their own massively enlarged informational inputs and outputs, and with burgeoning needs for networked information among dozens or even hundreds of locations; the reciprocal development of information technologies capable of sifting, storing, sorting, sharing and – not least – measuring an increasing range of information streams in real time; the worldwide extension of specialized distribution systems for a succession of new cultural and informational commodities: books, musical recordings, film, television programs, and ultimately others; and the increasingly self-conscious application of an informational focus to a sweeping series of science and engineering problems.

Also crucial, and often unrecognized, was the huge scale on which information resources had already been developed, generally at government and community expense. Throughout the world there had been carefully nurtured local stocks of vernacular expertise – what Vandana Shiva calls 'people's knowledge'² – about farming and medicine and cooking and indeed about learning itself. In addition, throughout the developed market economies and to a lesser extent elsewhere, enormous and far-flung information systems and services had been built up as formally institutionalized programmes for education and training, scientific research, subsidized postal and electronic communications, and library services. If these collective information resources – a vast, multifaceted 'knowledge commons' – could but be broken up into for-profit proprietorships, an entire new realm for corporate-commercial exploitation might be established.

The stewards of an emerging informationalized capitalism thus formulated the objective of systematically enclosing the immensity of global culture and information on their own behalf. This required deploying the general calculus of the market as a governing principle, so that, whatever the social costs involved, as Frank Webster puts it, '[a]s a rule, information will... be produced and made available only where there is the prospect of its being sold at a profit, and it will be

produced most copiously and/or with greatest quality where the best opportunities for gain are evident. It follows that market pressures are decisive when it comes to determining what sort of information is to be produced, for whom, and on what conditions.’³

By the late 1990s, amidst the frenzies of the Internet investment bubble, it was widely accepted that, as one news report put it, ‘The business of America is... information.’⁴ As informational sites of value-creation were systematically developed, they cohered as a new central axis of the accumulation process. In 1997, the U.S. information industry reportedly generated \$623 billion in revenues.⁵ The global market for information and communications is much larger.⁶

For the transition to an informationalized capitalism involves far more than a narrow sector of media-based products.⁷ Across a vast and rapidly growing range of endeavour, disparate companies engaged in information production, organization, processing, storage, packaging, and distribution, constitute collectively a pole of growth for the market system. Indeed, information, to a greater or lesser extent, was emerging as an explicit component of each and every sphere of capitalist production. Specifying the contributions made by information businesses to overall capital investment, corporate profits, economic linkages with other industries, and waged employment, thus constituted a critical task for analysis. By accepting that, as Vincent Mosco suggests, the current stage of capitalism ‘draws all organizations into the orbit of the information business,’⁸ on the demand as well as on the supply side, we may comprehend the significance of the contemporary DME drive to reorganize the global political-economy.

A new capital-logic for telecommunications

In its technological aspect, this transition has involved volcanic shifts; the recent history of telecommunications provides a leading instance. ‘Services-related industries are information intensive,’ noted a Reagan-era official report, ‘and thus depend heavily on advanced communications and computer systems to provide necessary access to and transfer of information. The strong tie between the information and telecommunications sectors extends beyond the domestic sphere... to international market as well.’⁹ To further the objective of developing informationalized services for sale, the U.S., soon joined by other DMEs, struggled to actualize a radically altered global regime in telecommunications.

‘Private initiative is providing the expertise and guidance needed to develop the telecommunications and information sectors of developing nations,’ declared an Executive Branch document in 1983: ‘Greater efforts by the private sector will be mutually beneficial.’¹⁰ By this time, not coincidentally, the World Bank was beginning to profess concern for the ‘underprovisioning’ of telecommunications throughout the countries of the global South. ‘The allocation of resources to information and communication infrastructures in developing countries has been much less than market signals have called for,’ underscored a prestigious World Bank study.¹¹ National economic development was in turn undercut.

Laying the blame at the door of the government agencies which then controlled and managed telecoms throughout most of the world, the World Bank called for opening the sector to corporate-commercial investment. The same logic was applied to the developed market economies of Western Europe and Japan, which long had organized and operated their telecommunications systems as government ministries of posts, telephones and telegraphs.

In response there was launched the largest reorganization of productive assets in world business history, loosely synchronized to make over what had been an (often inadequate) public service into a corporate-commercial enterprise. Privatizations by the dozen were undertaken, with U.S. banks, law firms, accounting companies and PR agents typically awarded lucrative fees for their expertise in managing the process. And, sure enough, sectoral stagnation gave way to astonishing network build-outs using the most advanced digital technologies. For the first time, signals originating from any place and in disparate modes – voice, music, image, computer data – could be exchanged over a single multipurpose network infrastructure. ‘Everyone,’ it was widely asserted, would soon have access to the resources made available via telecoms.

But this accelerated system development was not undertaken out of charitable motives. It was intended both to open a huge new arena for corporate-commercial investment in its own right – by 2000, telecoms had become nearly a trillion dollar industry inclusive of network equipment sales as well as services – and to build out a newly crucial corporate-commercial infrastructure. Although recognition awaited the popping of the high-tech bubble, it did eventually dawn: Where

newly privatized telecom carriers became unprofitable, employees would be fired, less-profitable subscribers let go, and – as people from Brazil to Indonesia now know – system extension into poor neighbourhoods and rural regions would be terminated. The centre of gravity of the new infrastructure is proprietary; perhaps four-fifths of ‘the’ internet exists not as an open system accessible to individual users, but as controlled intra- and intercorporate networks.

The transformation of global telecoms, vital though it is, is just one face of what, from the start, was envisioned as a multifaceted process. Fully two decades ago, the U.S. crafted an overarching tenet of policy: it would ‘strongly oppose[] any actions that would interfere with the ability of producers and users to make optimum use of information as a productive resource.’¹² In this formulation, ‘producers and users’ of course means corporate, above all, transnational corporate producers and users of information.

Expropriating the knowledge commons

This doctrine engendered dramatic consequences for what is termed intellectual property. Laws of copyright, patents and trademarks are presented by U.S. state authorities as entirely beneficent: ‘Public policy aimed at protection of intellectual property is based on the desire to ensure a rich, diverse, competitive marketplace,’ asserts the USTR: ‘Copyright laws encourage... expressions of national culture’; ‘Patent laws encourage discovery and invention... while ensuring the freest possible public access to information...’¹³

But this boosterism is deeply self-interested. A top U.S. trade diplomat has conceded that, as late as the 1980s, ‘few of the world’s developing countries even had intellectual property laws...’¹⁴ Intense efforts were made to address this perceived deficit, as this obtuse field moved to the very front of global economic policymaking. The world in turn witnessed ‘...the greatest expansion ever in the international scope of intellectual property rights[,]’ as, during the 1990s, ‘dozens of countries strengthened their intellectual property laws and regulations (often under pressure from the United States).’ In addition to numerous regional trade and investment agreements, which rendered the protection of intellectual property a core concern, ‘the successful conclusion of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) as a founding component of the World Trade Organization (WTO) elevates recognition and enforcement of IPRs to the level of inviolable international commitment.’¹⁵

Paralleling their successes in telecoms, U.S. trade law negotiators thus ‘ensure[d] that the vast majority of our trading partners have passed modern intellectual property laws and are improving their enforcement of these laws.’¹⁶ As a result, for the first time, a true global regime has been established to legally constitute private property rights in information. India had notably used import substitution policies together with socially-oriented intellectual property laws to establish itself ‘as the world’s forerunner in the manufacture of generic drugs and as a result maintained an affordable price structure’; more recently, like scores of other poor nations, it began to acquiesce to the radically different, proprietary, corporate-commercial regime.¹⁷

This process involves expropriation of vernacular knowledges, relying on different forms of intrusion: local informants as well as high-tech methods like satellite imagery of natural resources. In 1990, estimated world sales of medicines derived from plants discovered by indigenous peoples amounted to \$43 billion; and at least one quarter of the drugs prescribed in the US employed natural compounds derived from plants, most of which stem from vernacular applications.¹⁸ The consequences of this expropriation for local populations are characteristically severe.

Additional results are also evident. Worldwide licensing and royalty payments, for example, increased from \$6.8 billion in 1976 to more than \$60 billion in 1995.¹⁹ The lion’s share of the bounty flows to the already powerful; the 50 largest developed country-based transnational corporations accounted for more than one-quarter of all corporate patents granted in the US, 1990-96.²⁰

Inasmuch as it comes to centre on ‘intellectual property,’ informationalized capitalism carries fearsome implications for the longstanding tension between democratic politics and the capitalist market. Years before the attacks of September 11, 2001 established a basis for an increasingly authoritarian trend in the United States, the centre of informationalized capitalism, economist Michael Perelman made the following prescient suggestion:

‘The policing of this intellectual property propels modern capitalist police power to unparalleled

heights... protection of the commodity status of information requires more intrusive protection of property rights than other commodities do... In effect, the protection of informational property rights often requires personal information about those who might want unauthorized access to that information... We can be certain that the police powers of the information economy will be stronger than anything we have yet experienced.'²¹

Strengthened oversight and control thus go hand-in-hand with the enlargement of information markets. Augmented and extended intellectual property laws, applied to a rapidly growing array of new and existing information commodities, are a major component of this change. Several important kinds of knowledge sharing, such as education and training, have recently become increasingly 'tradeable,' as they are progressively reconstituted as commercial, on-line products. But the economic role of such services is expected to become ever more important. US services exports totalled \$255 billion in 1999, while cross-border services all told accounted for more than one quarter of world trade, about \$1.4 trillion.²²

Crafting transnational rules for GATS

A third axis of political-economic change has, accordingly, gained in importance – stemming from the need to craft transnational trade and investment rules for this burgeoning services sector. '[W]e will seek the broadest possible cross-border market access in services,' writes a top US negotiator, '...moving on to the professions, distribution, and much more – to realize the potential for firms to offer a full range of services over the telecommunications network.'²³

Initiatives within the World Trade Organization including, in particular, a hoped-for General Agreement on Trade in Services (GATS), are at the forefront here. Again developing out of efforts made during the 1980s,²⁴ the GATS – a proceeding launched in 1995 – extends existing international trade law to services. GATS, states the US representative, 'is the first multilateral, legally enforceable agreement covering trade and investment in services. The GATS is designed to reduce or eliminate governmental measures that prevent services from being freely provided across national borders or that discriminate against locally-established service firms with foreign ownership.'²⁵

But this attempt again possesses as its precondition radical institutional change. With relatively unimportant qualifications, it obligates states to acquiesce to the legal and thus the social redefinition of fields as diverse as education and library services²⁶ as 'industries,' so as to accommodate competition by foreign as well as domestic market suppliers - as well as to bind themselves to the already-mentioned regime of 'trade-related intellectual property rights' which would make any potentially profitable form of vernacular or public-service provision fair game for corporate-commercial expropriation. An unusually candid US report in the mid-1980s conceded that 'liberalization of trade and investment in the services will, in at least some industries, benefit primarily the small number of large firms with substantial overseas activities.'²⁷

This attempt, both complex and contested, may be reined-in and perhaps even repelled. But it represents not merely another garden-variety attempt at self-aggrandizement by the DMEs, but instead a third vital component in the framework for regenerated market development.

Science and technology as new sites of accumulation

How, finally, are additional informational sites of value-creation being identified and prepared for corporate-commercial exploitation? Here, we must credit crucial developments in science and technology.

Two basic trends may be carried over from David Dickson's insightful study²⁸ of the 1980s. First, sustained by huge research and development expenditures, science has become a direct and potent contributor to informationalized capitalism – what Tessa Morris-Suzuki some years ago termed a 'perpetual-innovation economy.' Second, science has become a force for continued uneven development, perhaps even for a new imperialism. A third essential trend also must be mentioned: that the science that is driving informationalized capitalism, interestingly, itself is increasingly a product of an informationalized intellectual apparatus.

Computer science – a field that literally did not exist half a century ago – has today become a central node in this process of intellectual and social transformation. However, an informational plane, or aspect, decades in the making, today claims dominion far beyond computer science. The scientific imagination at large has been gripped by informational metaphors, which have

grown influential, even decisive, in directing inquiry. Alongside computer applications, the information-processing capabilities of living genes and the 'programming' of inert materials are especially privileged sites of current scientific advance. Two converging fields, biotechnology and nanotechnology, which increasingly also intertwine with the other sciences, operate at the atomic and molecular level, but harbour dramatic applications for great swaths of productive enterprise: agriculture, agronomy, medicine, pharmaceuticals, environmental science, computers and, not least, manufacturing.

Indeed, for peasants and small farmers, developments in biotechnology have already figured in a profound social displacement, as corporate export-crop agriculture employing laboratory-produced seeds bears down on existing farming practices. By 2002, biotech crops produced by the top five producing nations – South Africa, China, Canada, Argentina and, with a commanding lead, the U.S. – were planted on no fewer than 144 million acres.²⁹ Nanotechnology, promising to build replicable products and machines literally atom-by-atom, can be expected to have a comparable impact.

These and other science-based industries establish new frontiers, new sites of accumulation, for informationalized capitalism. They are nurtured in turn by billions of dollars in annual research investment.

A substantial, though declining, share of this pyramiding R&D expenditure is borne by the U.S. military. For half a century, indeed, the U.S. investment in science and technology has been credited with providing an indispensable basis for its unrivalled military power. Thus, as one analyst underlines, 'The pace of innovation, which is the foundation for revolutionary advances in defence technologies, is not accidental. Political and military authorities in...the U.S. government... are deliberately investing tens of billions of dollars in advanced technologies.'³⁰ Military support for the 'electronic battlefield' and for the 'Star Wars' strategic defence initiative, extending on into today's 'infowar,' has generated significant R&D revenue streams. Not only digital computers, but the very field of computer science itself came into being largely under US military auspices.³¹

Today, biotechnology, nanotechnology, and an array of other commercially promising scientific endeavours receive substantial funds from military agencies, as well as from other government departments. Efforts to bolster the national 'cyberinfrastructure' for research, for example, obtain funding from the US National Science Foundation, whose budget – atypically for a nonmilitary agency – has increased tenfold (nominal dollars) over the last thirty years, to \$5 billion by 2003.³² NSF's coordinating role over basic science, though vital, claims a mere fraction of the total U.S. expenditure for research and development: about \$265 billion by 2000, up from \$169 billion in 1994.³³

Behind this outlay, greater than the gross output of many countries, revealing changes are being wrought in the organization of scientific labour. Consider the employment profile of scientists working fulltime in the US early in the post-war epoch. During 1956-58, a survey of around 170,000 fulltime employed scientists and engineers – of an estimated 250,000 such scientists and engineers in the country – almost half were employed by private companies or were self-employed, the rest either worked in universities, government agencies or non-profit institutions.³⁴ In 1999, in contrast, the number of fulltime employed scientists and engineers in the US had skyrocketed, to around 3.3 million. And private industry had become the largest employer of such labour,³⁵ not surprisingly, as from 1979 forward corporate R&D outlays surpassed those of the Federal Government (between 1964 and 2000, the US Government share in R&D funding fell from 66.8% to 26.3%).³⁶

In targeted fields, the corporate takeover of science was even more striking. Over three-quarters of computer scientists (BS, MS, PhD), for instance, were employed by private industry in 1999. Educational institutions continued, however, to employ a plurality (48%) of life scientists,³⁷ although the corporate share of investment in U.S. biomedical research increased from around 32% in 1980 to 62% in 2000.³⁸ Perhaps even more important, the social character of universities – ostensibly public or quasi-public institutions – underwent radical alteration. By 2000, one-fourth of U.S. university-based medical researchers received funding from drug companies; and around two-thirds of the nation's academic institutions held stock in start-up companies that sponsor research performed at the same university.³⁹ And of course, the results of scientific labour were increasingly held as private property, as pharmaceutical companies, among many others, 'spend heavily to create and test a patentable product, but then incur minimal reproduction costs.'⁴⁰

Another qualitative shift merits emphasis. As recently as 1983, research and development investment by the services sector of the U.S. economy was very small, under 5 percent of total R&D expenditures; the manufacturing sector dominated R&D spending. By 1999, non-manufacturing industries provided 36% of overall R&D funding – around \$66 billion – though this proportion continues to fluctuate.⁴¹ The altered focus of the research endeavour again expresses the core economic role of information services.

The reorganization of scientific labour constitutes a global, rather than merely a national, phenomenon, but it shows no sign of curtailing uneven development. Because it is shaped by an encompassing process of capitalist transnationalization, indeed, science both expresses and contributes to deepened inequality within the world economy. Some 80% of the world's R&D and a similar share of its scientific publications come from the developed nations;⁴² while less than 5 percent of the world's publicly accessible databases in 2002 were produced in Asia, Africa, the Middle East and South America.⁴³ But the circuits of science that feed a transnational informationalized capitalism are themselves fed by streams of labour drawn from the global South. The leading example of this is the 'brain drain,' a hot political issue two or three decades ago, but today something that hardly appears to merit comment, at least within the DMEs. Rather than learning to address local needs and local problems, a million students a year continue to depart poor world countries to attend tertiary schools in the DMEs, where they are set to work on an agenda loosely set by corporate-commercial proprietors, and often find work in a research complex increasingly dominated by capital. Big transnational companies may even relocate teams of scientist-employees back to cheap-labor countries, such as China and India, relying on new network systems to coordinate and manage R&D across increasingly dispersed and far-flung sites.

The Internet bubble is finished, but the transition to informationalized capitalism continues. Will the pole of growth that is being created prove sufficient to pull the market system out of its economic crisis? Or, on the other hand, has that crisis, originating in a secular renewal of economic stagnation in manufacturing industries, not already leapt into telecoms and information – the heartland of informationalized capitalism, and the very sector that was supposed to bail out the system from its earlier difficulties? This is the key question, from which all subsequent analysis must begin.

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Notes

1. U.S. Cong, House. 96th Cong 2d Sess., House Report No. 96-1535, 'International Information Flow: Forging A New Framework,' 32d Report by the Committee on Government Operations. 11 December 1980. USGPO, 1980: 42.
2. Vandana Shiva, *Biopiracy: The Plunder of Nature and Knowledge*. Boston: South End, 1997.
3. Webster, *Theories*: 81.
4. Randolph E. Schmid, 'Information a \$623-Billion Industry in '97, U.S. Says,' *LAT* 25 Oct. 1999: C3.
5. Including establishments engaged in producing and distributing information and cultural products; providing the means to transmit or distribute these products as well as data or communications; and processing data. U.S. Census Bureau, *United States 1997 Economic Census Information Geographic Area Series. EC97551A-US*. Washington, D.C.: October 1999.
6. David Pringle, 'Information Technology Market Is Seen Posting Modest Rebound,' *WSJ* 1 March 2002: B3.
7. Dan Schiller, 'From Culture to Information and Back Again: Commodification as a Route to Knowledge,' *CSMC* March 1994: 102.
8. Vincent Mosco, *The Political Economy of Communication: Rethinking and Renewal*. London: Sage, 1996: 152.
9. US Cong, Senate. 98th Cong 1st Sess, S Print 98-22, Committee on Commerce, Science and Transportation. 11 March 1983. 'Long-Range Goals in International Telecommunications and Information: An Outline for U.S. Policy.' [NTIA Report] Washington, D.C.: USGPO: 1983: 5.

10. US Cong, Senate. 98th Cong 1st Sess, S Print 98-22, Committee on Commerce, Science and Transportation. 11 March 1983. 'Long-Range Goals in International Telecommunications and Information: An Outline for U.S. Policy.' [NTIA Report] Washington, D.C.: USGPO: 1983, 21.
11. Robert J. Sanders, Jeremy J. Warford and Bjorn Wellenius, Telecommunications and Economic Development. Baltimore: Published for the World Bank by Johns Hopkins U P, 1983: 279.
12. Long-Range Goals: 22.
13. USTR, 'Protection of Intellectual Property Rights The WTO TRIPS Agreement,' at www.ustr.gov/sectors
14. Ambassador Charlene Barshefsky, 'The Networked World Initiative: Trade Policy Enters A New Era,' Federal Communications Bar Association, Washington, D.C., 23 October 2000: 3.
15. Keith Maskus, 2001: 1.
16. Ambassador Charlene Barshefsky, 'The Networked World Initiative: Trade Policy Enters A New Era,' Federal Communications Bar Association, Washington, D.C., 23 October 2000: 3
17. Pradip N. Thomas, 'Copyright and Emerging Knowledge Economy in India,' Economic and Political Weekly XXXVI, 24 (16 June 2001): 2150, 2154.
18. World Bank, Knowledge for Development: 38.
19. World Bank, Knowledge for Development: 29.
20. World Bank, Knowledge for Development: 1999: 28.
21. Michael Perelman, Class Warfare in the Information Age. New York: St. Martin's Press, 1998: 80-82.
22. USTR Fact Sheet 12/14/00: 1-2.
23. Ambassador Charlene Barshefsky, 'The Networked World Initiative: Trade Policy Enters A New Era,' Federal Communications Bar Association, Washington, D.C., 23 October 2000:7.
24. See Karl P. Sauvart, International Transactions In Services: The Politics of Transborder Data Flows. Boulder: Westview Press Atwater Series on the World Information Economy No. 1, 1986.
25. USTR Fact Sheet, 'WTO Services – US Negotiating Proposals,' 12/14/00: 2.
26. John W. Berry, 'WTO and GATS: The Challenge to Libraries,' American Libraries 33 (5) May 2002: 7.
27. OTA, Trade in Services Exports and Foreign Revenues, Summary. Washington, D.C.: USGPO [No. 052-003-01049-6] 1986: 13.
28. David Dickson, The New Politics of Science. New York: Pantheon, 1984.
29. Scott Miller, 'EU Official Calls for Trace in Biotech Dispute,' WSJ 31 Jan 2003: A8.
30. William C. Martel, 'Technological Foundations of Military Power,' in William C. Martel, Ed., The Technological Arsenal: Emerging Defense Capabilities. Washington: Smithsonian Institution Press, 2001: 257-9 and Introduction: xii.
31. Kenneth Flamm, Creating the Computer. Washington: Brookings Institution, 1988: 78-9.
32. Executive Office of the President, OMB. Historical Tables: Budget of the U.S. Government Fiscal Years 2002. Table 4.1 Outlays By Agency 1962-2006, 71.
33. NSF Science and Engineering Indicators 4-6.
34. NSF, American Science Manpower 1956-58: A Report of the National Register of Scientific and Technical Personnel. NSF 61-45. Washington, D.C.: USGPO, 1961: 17.
35. US National Science Foundation, Scientists and Engineers Statistical Data System 1999: Table C2, 'Employed U.S. Scientists and Engineers, by level and field of highest degree attained, sex, and employment sector: 1999.'
36. NSF Science and Engineering Indicators 2002: 4-18, 4-9.
37. US NSF, Science and Technology Indicators 2002: 3-10.
38. 'Study Says Academic Research Is Tainted by Drug-Industry Ties,' WSJ 22 Jan 2003: D2.
39. 'Study Says Academic Research Is Tainted by Drug-Industry Ties,' WSJ 22 Jan 2003: D2
40. Merrill Matthews, 'The Pharmatech Industry in the New Economy,' PfizerForum.com, retrieved 28 January 2003 from <http://www.pfizer.com>

41. US NSF, Science and Engineering Indicators 2002: 4-20; 6-18.
42. World Bank, World Development Report 1998-99: Knowledge for Development. New York: Oxford UP 1999: 27.
43. Martha E. Williams, 'The State of Databases Today: 2003,' in Gale Directory of Databases 2003. Vol 1: Online Databases. New York: 2003: xxiv-xxv.