Information Technology and the Dynamics of Firm and Industrial Structure: The British IT Consulting Industry as a Contemporary Specimen

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The personal computer and the internet are often considered to have disruptive competitive impacts, causing upstart firms to overthrow incumbent market leaders. This paper uses the UK IT consulting industry as a test case to see whether such competitive impacts of the PC and the internet might so far have occurred in this specific industry. Findings regarding the entry, exit, growth, and technology-related areas of business for new entrants and incumbents over a period of three decades suggest that the PC and the internet did not have such a radical effect on market structure by the year 2001.

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Radical new "general-purpose" technologies are expected to have major economics impacts. Not only do they increase economic output, productivity, and welfare, but they are often theorized to have dramatic effects on firms and industries. Two recent technologies have received considerable attention: the personal computer and the internet. Hobijn and Jovanovic (2001) argue that when the rise of the personal computer became evident around late 1971 to early 1973, it triggered an abrupt fall in share prices of incumbent firms – yielding the stock market devaluation of the 1970s – and led to eventual waves of entry and exit economy-wide. Similarly, observers of the internet's impact on businesses suggest a radical and widespread transformation of firms that promises new business opportunities as well as the destruction of existing firms that fail to react to their changing environment. Evans and Wurster (2000), based on consultancy experience with the Boston Consulting Group, argue that the internet and other technologies for information diffusion are changing the bundles of goods and services best provided by independent firms, so that incumbent firms must radically adapt or lose their leadership to new firms.[2]

That information and communication technologies could have such an impact should be no surprise, given firms' huge ongoing investments in computers and networks and the resulting productivity gains and financial returns. In 1999, US firms invested some $510 billion in IT equipment and software, with upstream information technology-producing industries contributing about 8% of price-weighted US economic output for the year (US Department of Commerce, 2000). Indeed, firms' total investment in

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[2] The literature on general purpose technologies addresses various other aspects of the effects of new technologies. Among other literature, see Bresnahan and Trajtenberg (1995).

information technology may be as much as ten times higher (Brynjolfsson and Yang, 1997) when considerable co-investments in IT are considered. Relevant co-investments range from physical equipment to be used in conjunction with computers to training, organizational restructuring to take fuller advantage of new equipment and software, and managerial innovation to continually improve use of IT equipment and software.[3] US productivity growth has seemingly at least doubled since 1995, and the increase is commonly attributed to more and better use of information technologies.[4]

Understanding technological revolutions is extremely important, for firms, industries, and entire nations. Theory and industry observers alike indicate that radical technological change and the way it is put to use affects who wins and who loses. At the levels of firms and industries, knowledge of whether and how a revolution is occurring therefore affects incumbent and entrant strategies and competition policy. At the level of nations, "leapfrog" technology development models suggest – in contrast to linear models – that industries in an economy can leap directly to use of competitive new technologies. The flyer for a 2002 UN University conference propounds the view that "a business firm, an industry or an economy which is able to successfully utilize these global [IT and internet] trends will eventually outperform its rivals."[5]

How and why some firms, preponderantly entrants, capture existing markets is largely an open research question. Alternative theories have been proposed that could explain incumbents' loss of market leadership. The notion that incumbents might be less likely than entrants to adopt certain new technologies appears in vintage capital models of economic growth, R&D models such as Arrow (1962) and Reinganum (1983), and management of technology work by Tushman and Anderson (1986) and others. The latter work is of particular interest here because, while it does not present mathematical models, it nonetheless characterizes implications for entry, exit, technological change, and other market indicators for industries in which a large number of firms compete to put to use a new technology. Key theoretical concepts will be outlined below.

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[3] Brynjolfsson and Yang's (1997) estimate of intangible IT investments relies on stock market valuations to assess the intangibles, but Brynjolfsson indicates that estimates by other methods confirm the finding. Also, Brynjolfsson and Hitt (2000, p. 28) point to an empirical survey of resource planning projects that yields an even higher estimate of IT-related intangible investments.

[4] Brynjolfsson and Hitt (2000), in their valuable review of the literature to date on how IT is affecting organizational form and performance, show that macroeconomic measurement problems have been obscuring the contribution of IT to economic growth and even the overall rate of GDP growth.

[5] The chief designer of an internationally successful Chinese language printing system, developed by Founder of China, put it this way: "In high-tech areas, there are big lags between our country and advanced countries. Many new ideas and methods originate abroad…. However, we should not be satisfied with merely catching up because this would not come up with competitive products. It was inevitable that we would catch up for quite a long time. However, it was possible to leap forward based on our indigenous innovative capabilities." (Quoted in Lu, 2000, p. 132.) This contrasts with linear technology development (cf. Hobday, 1995).

Whether linear or leapfrog approaches can best succeed depends on the industry in question and the kinds of technological change ongoing. Technological changes that are disruptive or create entirely novel markets provide unusual opportunities for leapfrogging. In lower-income countries, pockets of specialized knowledge and skill may provide the crucial head start to succeed at developing an internationally competitive version of the new technology. Founder, for example, benefited from early university research as well as unusual access to talented engineering graduate students at China's leading university. Financial investments for new firm development, when directed according to these principles, need not be large and can be arranged in ad-hoc ways so long as the firm retains the right incentives and freedoms.

Did the personal computer really have impacts of the sort suggested by Hobijn and Jovanovic? Is the internet having such impacts now? This study investigates one specific industry to check for the sort of impacts predicted by theory to follow from disruptive technological change. The industry studied is UK computer consultancies, a service industry with high computer and internet usage. Firms are divided into incumbents and recent entrants, and further into users and non-users of the relevant technology. The measure of technology use is whether at a specific point in time firms advertise consultancy work addressing the technology. Hence the technology measure addresses whether they are positioned to use an area of technology as a core area of business, as in many previous studies of possibly-disruptive technologies.[6] If the PC and the internet have to date acted as disruptive technologies, this should be apparent as a shift in the relative survival and growth rates of new versus incumbent firms, and this shift should be associated with use of the technology.

The evidence indicates that the rise of the PC and the internet have not substantially increased exit or market leadership turnover among UK computer consultancies, nor given an advantage to firms that entered shortly after each technology emerged. This finding is, at least up to the present, counter to the notion that the PC and the internet have caused a shift in firm survival patterns to benefit innovative new firms. Although new firms have been slightly more likely to do business involving networking and the internet, entrants with these types of business have not been systematically more likely to grow and survive. Thus, at least in one IT-intensive service industry, the internet appears not yet to have had the sort of competitive impacts thought to stem from radical, disruptive new innovations.

Radical Technological Change and Competition

Tushman and Anderson (1986) argue that radical technological changes may be opportunities that new firms tend to exploit but to which incumbents tend to respond relatively badly or late.[7] They use this idea, based on implicit notions about the

[6] This paper and previous studies alike specify a category of technology that serves as a product type for the firm. Firms are responsible for the large numbers of innovations that put the technology to use through successful products. Christensen and Rosenbloom (1995) and Christensen (1997) measure whether a firm sells disk drives in a technological category corresponding to a hard disk size, and innovations by firms are the improvements needed to create competitively successful hard disks of this size. Henderson and Clark (1990) measure whether a firm sells semiconductor manufacturing alignment equipment using a particular means of alignment, and innovations by firms are the detailed work needed to make saleable alignment equipment of this sort.

Studies of IT impacts have generally taken a different approach, asking whether in-house use of IT rather than direct application to products provided firms with productivity gains or other advantages. The measures of PC and internet application used here presumably are correlated with the degree of in-house use as well, but the direct application to areas of business in this study has several special ramifications. First, this may accelerate competitive processes regarding the technology and hence make it likely to observe impacts of the PC and the internet *earlier* than in most industries. Second, the exogenous technological progress in PCs and the internet may aid firms providing services related to the two technologies, hence tending to reinforce any advantage of entrants over incumbents. Third, if other firms in the economy benefit by using the PC and the internet, the higher growth and lower exit of firms buying PC- and internet-related services should again reinforce any advantage of entrants over incumbents.

[7] Tushman and Anderson argue that this behavior occurs only for major technological changes that are at odds with previous approaches, not for changes that involve the existing technological approaches in a more efficient or effective way. The changes considered in this study, the use of personal computers and

competencies of old and new firms in different technology areas, to draw out implications regarding entry, exit, market share, and other matters. In their view, radical technologies that are inconsistent with past technology are first commercialized largely by new entrants, with incumbents tending to exit after the introduction of the new technology. Consequently, entry and exit would be expected to rise temporarily upon the availability of the new technology, and large incumbent firms would be expected to contract unusually rapidly while small recent entrants would be expected to grow unusually rapidly. A similar view has been apparent in studies of many industries, including Majumdar (1982) and Schnaars (1994).[8]

Contrasting explanations exist as to why incumbent firms have failed to take advantage of the opportunities offered by major technological changes. Majumdar (1982), Tushman and Anderson (1986), and Anderson and Tushman (1990) seem to view the issue in terms of firms' core technological competencies, with firms not possessing the techniques and equipment needed to pursue the new technology unable to make the transition without a very high cost and indeed unable even to perceive the importance of the coming revolution. Henderson and Clark (1990) point to firms' R&D and engineering personnel, the people who deal with the technology most directly, and argue that these employees develop ways of thinking about the technology (both individually and as an organization) that are inconsistent with pertinent innovative approaches. Because of this limiting mindset, they fail to take advantage of the opportunities afforded by the new technological approach. Christensen and Rosenbloom (1995) point to firms' relationships with customers, and argue that incumbent firms tend to maintain their current technological approach because their customers demand products or services that initially can be best provided using the established technology. They fail to pay sufficient attention to the potential profits that could be obtained from new customers using the new technology, and they fail to realize that the new technology eventually may largely replace the old. Any of these reasons, along with others mentioned by Schnaars (1994), could be responsible for the sort of turnover of leading firms described by Tushman and Anderson (1986).

If radical technological changes act as these theories describe to cause market leadership turnover, several consequences should result. These hypothesized consequences provide a means to assess whether, to date, the internet is having large disruptive technological effects. The following competitive impacts would be expected in industries that begin to make use of the internet:

Consequence 1: Entry of new firms will increase following the technological change.

Consequence 2: The aggregate exit rate of firms will increase following the technological change.

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the advent of the internet as a medium for communication, appear in many ways to be radically different from the approaches previously in use, and have been labeled widely as discontinuities, thus fitting with the characterization given in the text for Tushman and Anderson's approach.

[8] Audretsch (1991) promotes a related view in which he divides industries into two categories, ones with "routinized" and "entrepreneurial" technological regimes. In industries with routinized regimes, established firms have an advantage in R&D, whereas in industries with entrepreneurial regimes, new firms have the advantage in performing and implementing innovations, and these differences affect firm survival rates.

Consequence 3: The exit rate of new firms will fall, and the exit rate of incumbent firms rise, following the technological change. The growth rate of new firms will rise, but the growth rate of incumbent firms fall, following the technological change.

Consequence 4: A greater percentage of new firms than old firms will use the disruptive technology.

Consequence 5: Firms using the disruptive technology will, *ceteris paribus*, have higher growth rates and lower exit rates than firms not using the disruptive technology.

These consequences are natural implications of a disruptive technology. Firms seek to take advantage of profit opportunities created by the new technology, causing more annual entry for a period following the advent of the new technology. Once new firms enter, they intensify market competition, eventually even overthrowing many or all of the incumbent market leaders. Hence the exit rate of all firms rises, at least eventually. The new firms, with the highest propensity to use the new technology, have a competitive advantage. Thus new firms have a higher growth rate and a lower exit rate relative to other eras, while incumbents disadvantaged by their outdated technology have relatively low growth and high exit. Technology, not newness, is the source of advantage, so these growth and exit consequences pertain to indicators of technology use as well as to newness. Consequences 2-5 above are similar to hypotheses 2, 5, and 7 of Tushman and Anderson (1986).[9]

Data

If PCs and the internet in fact are radical technologies that have already been causing radical changes in firm and industrial structure, the changes may be most easily detected in an industry in which usage of computers and the internet – and potential impacts on work organization – are unusually high. The computer consulting industry may be a better window on possible industry trends associated with computing and the internet than almost any other single industry. It is a service industry, and hence represents the majority (and much less studied relative to manufacturing) services component of the global economy. The service industries perhaps more than any others can take advantage of the IT revolution, because they tend to be less limited by physical

[9] A contrasting competitive pattern would result from reinforcing technology. For example, Jovanovic and MacDonald (1994) argue that exogenous radical technological changes may lead to a drop-off in the number of producers in an industry, with incumbent firms benefiting from an early-entry advantage. Klepper (1996) proposes a related model, involving large numbers of ongoing technological changes, in which some early market entrants grow large and dominate the market in the long run through their dominance of R&D. That such reinforcing technological changes are extremely important in many major industries is evidenced by a series of studies by Klepper and Simons (cf. 1997, 2000). These studies show that the common pattern of steady decline in number of companies in an industry, and eventual market concentration, is associated with lasting competitive advantage among a few early entrants that grow large. Moreover, the studies indicate that (at least in many industries) the leading firms dominate the R&D process for reinforcing technologies, and their R&D success is directly associated with greatly enhanced growth and likelihood of survival. Thus with reinforcing technology, incumbents rather than entrants tend to adopt the new technology and benefit in terms of growth and survival.

production methods than manufacturing, resource extraction, or agriculture. Computer consultants are among the leading adopters of computer equipment and novel work practices that work well with IT and communications technologies, and hence they may reflect impacts of IT, networking, and the internet earlier than firms in other industries.

This study relies on data compiled in VNU Business Publications' (1969-2001) annual industry directory, *The Computer User's Year Book*. The *Year Book* has tracked British computer consultants since its inception, and while it made no claim to be complete, it appears to have listed a large percentage of firms in the industry. It also provided detailed information about the firms including numbers of employees, fees per day of work, and types of business application. The annual lists reported in the directory were matched to determine the years when each firm was listed. Names and addresses of firms, among other information, were used to ensure that longitudinal records were properly matched over time. Multiple branches of a firm were treated as a single entity, not as individual establishments.

The *Year Book* did not differentiate between consultancies and software houses in 1969 and 1970, nor did it indicate firms' numbers of employees or prices in those years. Therefore data are used from 1971 through 2001.[10] In 1988, the *Year Book* removed some types of software houses from the definition of consultants included in its lists, and added other types of consultancies, resulting in a structural break in the types of firms and services included. To lessen the impacts of this break, the (relatively few) firms that are indicated as having been software houses but that did not perform other types of consultancy have been excluded from analyses. The definition of consultancies included in the data has also broadened by a lesser degree at other points in time.

International consultancies make up a small percentage of firms in the sample. Only firms with offices in the United Kingdom have been retained in the data. The *Year Book* does not report market shares, but its figures on number of employees, available for most firms, provide information on the size distribution of companies. In 2000 the top ten full-time employers had 3260, 3000, 2500, 2000, 1500, 1000, 900, 900, 800, and 700 full-time employees respectively. This constitutes 40% of reported full-time employees in that year. The top ten in 2000 were all multinationals, six of them UK-originated. The bulk of the sample in contrast consists of small businesses. The mean and median numbers of full-time employees per firm in 2000 were only 29 and 5 respectively. It is such smaller, almost all UK-only, firms that have the largest effect in analyses of the data.

The number of firms included in the analysis totals 7,777. The sample begins with 84 firms in 1971, and the number rapidly rises to much larger counts: 285 in 1976, 508 in 1978, 731 in 1980, and 1067 in 1982. Thereafter the number of firms remains roughly stable through 1985, and falls to 919 in 1986 and 879 in 1987. The number then rises suddenly given the break in the definition of firms listed in the *Year Book*. In 1988, 1515 firms are included, and the number thereafter rises and falls irregularly. By 1993, 1933 firms are included; the number falls to 1593 in 1998 and then jumps to 1901 in 1999 and falls again to 1474 in 2001. These changes in sample sizes may reflect industry

[10] The year used is the year in which data were compiled and published, which is not always the same as the date printed on the cover. Up to 1983 the cover date matches the compilation and publication date, in 1984 the practice was adopted of putting the next year's date on the cover, and from 2000 both dates were given (cf. 2000/2001).

trends (indeed commentaries in the *Year Book* sometimes made this interpretation), although they could also reflect periodic shifts in data collection practices used to compile the *Year Book*.

Data on technology use, in terms of the application (business service) areas of firms, was collected from the *Year Book* in specific years. Measures were used to assess applications to personal (micro)computers and their most commonly used operating system, MS-DOS. The earliest year in which data seemingly could be reliably collected on use of personal (micro)computers was 1984, so for 1984 a dummy variable was recorded equal to 1 if the "machines covered" category for the firm indicated it dealt with issues regarding personal or micro computers and 0 if it did not.[11] The earliest year with a listing of companies addressing MS-DOS applications was 1987, so an MS-DOS dummy was constructed equal to 1 for firms handling MS-DOS applications in 1987 and 0 otherwise. Measures were also used to assess which firms addressed applications pertinent to the internet and computer networks more generally. The earliest year with a listing of firms having internet applications was 1995, and both internet and network dummies were constructed equal to 1 if a firm addressed that area of business in 1995 or 0 otherwise.

An index of mean price levels was computed from the fees charged by firms per day of consultancy services.[12] Most firms gave a range of list prices rather than a single number, and in these cases the minimum list price is used. Maximum price levels were not used because they often went unreported (c.f. "from £300 per day"), and because the maximum figures may be less reliable in that they pertained to specialized employees or wishful thinking. Table 1 reports median and mean fees charged per day of consulting work using the minimum list prices of firms in the sample.[13] Prices are discounted into 2001 £ using the Office for National Statistics' retail prices index.[14] The number of firms for which figures are available in each year, and the percentage of the sample composed by these firms, are indicated in the last two columns of Table 1. Comparisons may not be reliable between years up to 1987 versus 1988 onward, given the structural break in the data.

[11] Companies indicating that they dealt with various unspecified types of microcomputers, or with computers using the Intel chips used for personal computers, were coded as 1. Companies indicating that they dealt with various types of IBM computers were coded as 0 since they seemed at least primarily to deal with large-computer applications. Companies indicating that they dealt with "all" types of computer were coded as 0, since they did not profess particular applications to personal (micro)computers and, even if they dealt with them, presumably most often did so in a relatively limited role.

[12] Fees were collected at two-year intervals from 1971 through 1987, with two-year intervals used to reduce data collection expenses. Additionally 1984 fees were collected as part of the process of checks on the data during collection. With the reorganization of the *Year Book* for 1988, data in both 1988 and 1989 were recorded given the low frequency of reporting in 1988, and thereafter data were collected at two-year intervals through 1999, and data for 2000 and 2001 were added following publication. In a few cases, fees were reported per hour, week, or month, and fees per day were computed assuming 8 working hours per day, 5 working days per week, or 20 working days per month. The few instances where fees were reported in non-British currencies were excluded from price calculations.

[13] The figures are not weighted according to size of firm, because the available size figures are not always reliable for the sample's very large firms which would have the greatest influence on size-weighted means.

[14] Retail price indices were obtained from Central Statistical Office (1991, p. 7) and ONS dataset rpi1, "Retail Price Index: index numbers of retail prices 1948-2002", series CHAW. A retail price index, rather than service producer price index, was used for reasons of data availability back to 1971.

TABLE 1 ABOUT HERE.

Two additional variables are used in the analyses. First is a time series of the number of internet hosts worldwide. This is a measure of the size of the internet and is taken from the Domain Survey of the Internet Software Consortium.[15] Internet host figures have been interpolated where necessary to pertain to July of each year. Second, dummy variables are constructed for time periods of exogenous radical innovation equal to 1 in 1982-87 following the introduction of personal computers, or 1 in 1995-2001 for the rise of the internet, and 0 at all other times. The latter period coincides with the time when the number of internet hosts surpassed ten million.

Econometric Specification: Interactions between Entry, Growth, and Exit

Hypotheses relating radical IT changes to entry, exit, growth, and firm size can be analyzed using the following three-equation model:

$$E_t = f(T_t, ...) + \varepsilon_t \qquad (1)$$

$$\frac{dS_{it}/dt}{S_{it}} = g(S_{it}, T_t, ...) + \gamma_{it} \qquad (2)$$

$$\mathrm{Prob}(X_{it} = 1) = h(S_{it}, T_t, ...) \qquad (3)$$

Equation (1) concerns the number of entrants E_t at each time t. Entry is a function of recent exogenous technological change T_t, which equals 1 for a period after a major technological change and 0 at all other times. Control variables may be included, notably the industry mean price p_t, which serves as a measure of profit opportunity.[16] The random term ε_t allows for random variation in E_t, which will be assumed to follow a negative binomial distribution. Equation (2) concerns the growth rate in the size S_{it} of firm i at time t. Each firm's growth rate is assumed to be a function of S_{it}, T_t, and any controls. A normally-distributed random term γ_{it} is also included. Equation (3) concerns the probability of exit X_{it} by firm i at time t, where $X_{it} = 1$ if the firm exits and 0 otherwise. The exit probability is a function of the firm's size and of recent exogenous

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[15] http://www.isc.org/

[16] In analyzing entry, and in other analyses not reported in the paper, the industry price index was used to proxy the effects of changing demand and labor supply. Price depends on industry-wide output Q_t, which depends in turn on the production of individual firms: $p_t = D_t^{-1}(Q_t)$, $Q_t = \sum q_{it}(S_{it})$, where $D_t^{-1}(\cdot)$ is the inverse demand function at time t and $q_{it}(\cdot)$ is a production function that may vary across firms and time. Price and firm sizes are observed, but not industry-wide output, so the relationship between p_t and Q_t will not be analyzed statistically. Q_t is affected by changing labor supply, since the availability of employees affects all firms' hiring and retention rates comparably at each point in time and hence affects total industry capacity. The price p_t per day of consulting is closely related to employee wage, since wages are the main component of firms' costs and firms must remain competitive with freelance consultants, and hence it is assumed that the percentage of firms' revenues going to salaries remains approximately constant over time and thus that p_t is a useful indicator of firms' profit opportunities.

technological change, as well as any controls. Exit will be modeled using a logistic model.[17]

Statistical analyses are carried out separately for the time periods before and after the structural change in the data. Analyses of entry exclude the year 1988, for which entry may result from change in the types of firms included. Analyses of exit exclude the year 1987, since firms that survived in 1987 might have been removed from the list in 1988 due to changes in classification. Analyses of growth likewise exclude comparisons between years before 1988 and later years.

Empirical Tests

Empirical tests of Consequences 1-5 of the radical technological change theories are carried out in order to test whether, and at what times and in what ways, the PC and the internet match with the predicted telltale processes stemming from technological change that benefits new firms over incumbents.

Entry

Consider first entry, which should increase following the technological change as stated in Consequence 1 of the theories. Table 2 presents count data analyses of the number of entrants in each year. The most straightforward count data model is the Poisson model, which parameterizes the arrival rate of firms and for which the dependent variable is the number of new firms that arrive in a one-year interval. The negative binomial model used here is a generalization of the Poisson model accounting for possible correlation in arrivals, measured by a parameter α.[18] In accordance with the Consequence 1 and equation (1) above, the arrival rate is allowed to depend on a dummy variable equal to 1 in periods following the introduction of the PC or the internet and 0 otherwise.

Table 2 presents estimates of the negative binomial model for the era in which the PC arose, 1971-87, and the era in which the internet arose, 1989-2001. The break in the two sample periods is chosen to correspond with the structural break in the data. The table reports coefficient estimates, with standard errors in parentheses.

TABLE 2 ABOUT HERE.

Did entry of new firms increase following the introduction of the personal computer? Column 1 of the table presents estimates of the coefficient of the year 1982-1987 dummy, a constant term, and the parameter α. The positive and significant estimate for the year 1982-1987 dummy indicates that indeed, more entry took place in these years than in previous years in the sample.[19] However, this interpretation may be misleading. Adding the real mean price index in column 2 to control for possibly changing profit

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[17] The three equations used here should not be confused with a simultaneous equation econometric system; they form a dynamic system of three equations that will be estimated independently.

[18] The negative binomial model therefore relaxes the Poisson model's implication that the mean number of arrivals must equal the variance.

[19] The fact that α is significantly greater than 0 confirms the appropriateness of the negative binomial model rather than the Poisson.

opportunities causes the coefficient of the year 1982-1987 dummy to fall substantially and become insignificant.

Did entry of new firms increase following the introduction of the internet? Columns 3-4 of the table present estimates analogous to those carried out for possible effects of the PC. In column 3, a dummy variable equal to 1 in the years 1995-2001, 0 otherwise, is used to parameterize the period when entry may have risen. In fact the coefficient estimate for this dummy is not only insignificant but negative, suggesting that entry may actually have been lower rather than higher following the spread of the internet. In column 4 when the real mean price index is added to the model, its coefficient estimate is negative – opposite the entry-attracting effect anticipated with greater profit opportunity – and the estimated coefficient of the 1995-2001 dummy becomes positive. The lesson is that time-specific covariates could be correlated with any number of industry trends and hence that conclusions regarding the specific causes of aggregate entry (or aggregate exit) must generally be tentative. Given the ability of time-specific covariates to pick up other industry trends, control variables that vary with time but not across firms are excluded from further analyses and it must be kept in mind that the aggregate entry and exit trends of Consequences 1 and 2 are susceptible to various time-specific causes.[20] In columns 5 and 6, alternative measures are used for when the rise of the internet might lead to a surge of entry by new firms: a dummy equal to 1 only in 2000-2001 is used in column 5, and the worldwide number of internet hosts is used to proxy when the surge would occur in column 6. In both cases the estimated coefficients of the impact times are insignificant and in fact negative, again contrary to Consequence 1.

Figure 1, which shows the number of new IT consultancies included in the data in each year from 1971 to 2001 excluding 1988, clarifies the reasons for the above estimates. The number of entrants remained low until the mid-1970s, averaging 40 firms per year in 1972-75, climbing to 156 firms per year in 1976-80, then rising to 293 in 1981 and 323 in 1982. Annual entry then fell back to an average of 159 firms per year in 1982-87, when the figure uses red dots to indicate the years immediately following the rise of the personal computer. Thus while annual entry was higher during 1982-87 than the *average* for previous years, the entry rates were in fact similar to those of the late 1970s through 1981. With the reorganization of the *Year Book's* listings for 1988, 842 new firms were included. Over the next five-year period, 1989-93, entry averaged 400 firms per year. The rise of the internet did not correspond to a rise in mean annual entry, although entry in 1995 and 2001 was relatively high. In 1994 the number of entrants had fallen to 230, and although the number rose to 541 in 1995, it fall back again to an average of 225 in 1996-2000. Only in 2001 was there a new increase in entry, with 450 new firms. Thus the evidence is consistent with (a) a possible brief slight increase in entry in 1982 and 1995, (b) the possibility that entry was triggered by the technological changes but was delayed for at least five years or so after the technological change, or (c) increases in entry that happened to be obscured by time specific trends such as demand shifts.

[20] Controlling for the mean and median price indices in other models reported in the paper in some cases affects the sign of time period estimates and rarely recent-entry dummies, but this does not alter the overall conclusion of the paper.

FIGURE 1 ABOUT HERE.

Technology Use

If the PC and the internet are disruptive technological changes in that they provided an advantage to new entrants over incumbents, the slower adoption of the technology by incumbents should be apparent in adoption rate data. For each of the four technology use measures collected, therefore, compare recent entrants and incumbents with regard to their use of each technology application in specific years. Table 3 reports the percentage of entrants in 1982-87 versus earlier entrants that dealt with personal (micro)computers in 1984 and MS-DOS in 1987. It also reports the percentage of entrants in 1995 versus earlier entrants that dealt with the internet in 1995 and likewise computer networks in 1995.

TABLE 3 ABOUT HERE.

The table shows that recent entrants made greater use of the new technologies than incumbents as their areas of business, corresponding with Consequence 4 of the theories of disruptive technology. However, the differences in usage rates were quite small. For PCs in 1984 and MS-DOS in 1987, the percentages of firms advertising applications to the technology were almost identical for entrants and incumbents, and only for MS-DOS was the difference even marginally statistically significant using Fisher's exact test. The percentages were more noticeably different, and statistically significant, for the internet and computer networks in 1995, but even then the incumbent usage rate was nonetheless over half that of recent entrants. This does not seem to signal a huge disparity in incumbent versus entrant firms' adoption of the new technologies, although perhaps a noteworthy difference has arisen for internet applications.

Growth and Exit

Consequences 2, 3, and 5 of the theories pertain to growth and exit. Consequence 2 implies an increase in the aggregate exit rate following the introduction of a disruptive technology. Therefore, in statistical analyses the exit rate will be allowed to shift after 1982 for the PC or 1995 for the internet (even with the inclusion of dummy variables indicating recent entry because the recent entry variable may be only a partial measure of which firms should have lower and higher exit). A corresponding shift in the mean growth rate of surviving firms might be expected to accompany a shift in the aggregate exit rate, and hence a comparable time-period effect will be included in growth analyses. The shift is allowed through inclusion of time period dummies, equal to 1 in 1982-87 or 1995 to date and 0 in other years.

In all analyses firm age and size are included as control variables since both are well known to be correlated with plant and firm growth and exit rates, especially at relatively small sizes and young ages (cf. Evans, 1987; Dunne, Roberts, and Samuelson, 1989; Geroski, 1991). Age is proxied by the number of years the firm has been in the sample (1 in the firm's first year in the sample). Size is measured by the number of full plus part time consultants employed by each firm. In analyses of exit, a dummy variable is also included equal to 1 for the minority of firms without size data and 0 otherwise; in analyses of growth all firms included have size measures since the size data are required

to construct the measure of growth. Experimentation with alternative transformations indicated that the logarithms of size and age yielded relatively high explanatory power, and specification of a nonparametric age effect – through inclusion of dummy variables corresponding to specific age categories – did not yield a significant improvement in model fit. Therefore the logarithms of these size and age measures are included as control variables.

After controlling for the effects of age and size that pertain to firms at all times, entrants after the introduction of a new disruptive technology should have relatively high growth and low probability of exit. This outcome is expressed by Consequence 3 of the theories. Therefore a dummy variable is included equal to 1 for entrants in 1982-87 or 1995 to date and 0 for firms that entered previously.

Table 4 reports OLS regression estimates of determinants of firm growth rates from each year to the subsequent year. Table 5 reports logistic regression estimates of determinants of firm exit rates from each year to the subsequent year. The first column in each table, column 7 or 13, pertains to the basic model of impacts of the PC. The estimates in column 7 indicate that the mean growth rate of surviving firms actually decreased significantly, and the mean growth rate of post-technology entrants was actually significantly lower than that of incumbents at a similar age and size. This is contrary to Consequences 2 and 3 of the theories and therefore suggests that the PC did not act as a disruptive technology in this industry. The estimates in column 13 indicate that the exit rate was significantly higher in 1982-87 than in previous years, but also that the exit probability of post-technology entrants was actually significantly higher than that of incumbents at a similar age and size. While the increased aggregate exit rate fits with the notion that the PC was a disruptive technology for the industry, the increased exit rate of recent entrants again suggests that the PC did not act as a disruptive technology in this industry.

TABLES 4 AND 5 ABOUT HERE.

In columns 8 and 9 of Table 4, and columns 14 and 15 of Table 5, dummy variables are included to assess Consequence 5 as it pertains to the PC. In columns 8 and 14 the dummy variable is 1 for firms with personal (micro)computer related applications in 1984, 0 otherwise, and growth and survival are assessed in all years from 1984 on among all firms present in the sample in 1984. In columns 9 and 15 the dummy variable is 1 for firms with MS-DOS related applications in 1987, 0 otherwise, and growth and survival are assessed in all years from 1987 on among all firms present in the sample in 1987. With both of these technologies the estimates of the recent entrant dummies remain qualitatively similar to the estimates in columns 7 and 13. In both cases, firms' application of the new technology is estimated to have an insignificant and in fact negative relation to future growth, contrary to the idea that the PC was a disruptive technology. Regarding exit, firms' application of the new technology is estimated to decrease the probability of exit, insignificantly for the personal (micro)computer and significantly for MS-DOS, consistent with the idea that the PC was a disruptive technology. The findings for application of these technologies thus do not even clearly support the idea that later entrants would have benefited from using the new technology, even if they had used it more frequently than incumbents, which they did not.

The remainder of each table pertains to impacts of the internet. Columns 10 and 16 pertain to the basic model of impacts of the internet, and hence provide the means to assess Consequences 2 and 3. The estimates in column 10 indicate that the mean growth rate of surviving firms did not change significantly and if anything decreased after the rise of the internet, and the mean growth rate of post-technology entrants was likewise insignificantly different and if anything lower than that of incumbents at a similar age and size. This is contrary to Consequences 2 and 3 of the theories and therefore suggests that the internet did not act as a disruptive technology in this industry. The estimates in column 16 indicate that the exit rate was significantly higher in 1995-2000 than in previous years, but that exit by post-technology entrants was not significantly lower than exit by incumbents at a similar age and size. While the increased aggregate exit rate fits with the notion that the internet was a disruptive technology for the industry, the lack of a significantly lower exit rate for recent entrants again casts doubt on the disruptive internet idea.

Internet and network applications by specific firms are addressed in columns 11-12 and 17-18. In each case the technology application dummy variable is 1 for firms with relevant applications in 1995, 0 otherwise, and growth and survival are assessed in all years from 1995 on among all firms present in the sample in 1995. With both of these technologies the estimates of the recent entrant dummies remain qualitatively similar to the estimates in column 10, but in the exit analyses the recent entry dummy is actually estimated to have a significant positive relation to exit, opposite Consequence 3. In both cases, firms' application of the new technology is estimated to have an insignificant impact on growth and exit, and in fact the estimate for network applications in column 18 suggests that firms applying the technology experienced relatively high exit, contrary to the idea that the internet was a disruptive technology.

To aid diagnosis of the apparent lack of advantage of post-technology entrants in growth and exit rates, Figures 2 and 3 exhibit the changing median size and percentage survival of successive cohorts of entrants. In Figure 2, entrants in nearby years have been grouped into cohort of 3-5 years each; this makes it easier to see patterns in changing median firm sizes that would otherwise be obscured. Small numbers underneath the curves equal n – 1969, where n is the last year of entry included in the cohort. The earliest group of entrants, in 1969-72, is therefore reported with the tiny symbol 3 and has a curve colored blue for easy identification. Subsequent cohorts are 1973-76 (7), 1977-81 (12), 1982-84 (15 shaded red), 1985-87 (18 shaded red), 1988-91 (22), 1992-94 (25), 1995-97 (28 shaded green), and 1998-2001 (32 shaded green). Because the vertical axis is logarithmic, a given growth rate has the same slope at any point on the graph, facilitating comparisons of growth rates. The outstanding impression from Figure 2 is that the median early entrant remained much larger than later entrants and that this trend did not reverse after the rise of the PC and the internet. Even the rates of growth in median firm size for the early entrants was reasonably high in the PC and internet eras compared to other firms. Among other cohorts of firms the median size remained small and may even have contracted slightly during the mid-1990s (the bigger contraction in 1998 is presumably due to the *Year Book*'s reorganization of the data). And the evidence suggests that the relatively late entrants, colored red and green for the PC and internet eras, did little or no better at growth than entrants in other eras.

FIGURES 2 AND 3 ABOUT HERE.

In Figure 3, the percentage of firms surviving in each cohort is plotted against calendar time.[21] Because separate curves are plotted for entrants in every year, effects associated with firm age can be clearly distinguished from effects associated with calendar time. As in the previous figure, curves are reported with small numbers that identify the cohorts; each numbers equals the cohort's entry date minus 1969. Thus the first cohort, entering in 1969, is numbered 0, and subsequent cohorts are numbered 1, 2, …, 31. Curves for the earliest entrants, in 1969-72, are colored blue. Curves for entrants in 1982-87, immediately after the rise of the PC, are colored red. Curves for entrants in 1995-2000, immediately after the rise of the internet, are colored green. Because the vertical axis is logarithmic, a given exit rate has the same slope at any point on the graph, facilitating comparisons of exit rates. The very early cohorts seem to have had slightly lower exit rates than other firms, but otherwise the exit rates appear to have been similar across cohorts, given the similar slopes of the curves. Neither during the PC era, nor during the internet era, nor any time in between did the exit rates of recent entrants abate relative to the exit rates of incumbents. From 1999 to 2000 and again from 2000 to 2001, the exit rates of all firms increased, but this period of high exit affected all cohorts alike, the only possible exception being the low exit of the very earliest entrants (for which sample sizes were in any case small); the more recent entrants did not have any advantage in these two most recent years just as they did not have any advantage earlier. All cohorts of firms appear to have suffered alike, and recent entrants did not appear to benefit from the PC nor from the internet.

Conclusion

This paper has focused on one industry, the UK computer consulting industry, as a means to probe disruptive technology theories regarding how the PC and the internet may have impacted firm size and industry structure through the competitive process. The study intentionally focused on an IT-driven (and IT-driving) industry that may experience changes in the competitive process earlier than other IT-related industries. The competitive consequences of radical, disruptive technological change have been characterized by several theories that predict a resulting change in competitive leadership. This study searched for the telltale signs of such a competitive reversal due to disruptive technology, in the 1980s for the personal computer and in the 1990s up to 2001 for the internet.

The findings do not match the telltale signs expected if the PC and the internet have been disruptive technologies. Entry was not much greater following the introduction of PCs or of the internet. Entrants in 1982-87 had nearly the same rates of application of PC areas of business as incumbents, and entrants in 1995 had higher but not enormously higher rates of application of internet- and network-related areas of business. Examination of the growth and exit rates of recent entrants versus incumbents, and of firms that did versus did not apply the technology to their business markets,

[21] In case of gaps in firm's records, the change in percentage survival is calculated each year among firms present in the panel in that year; i.e., the percentages are Kaplan-Meier survival estimates.

indicated that even where entrants applied a technology more than incumbents, they did not benefit from the technology application in terms of growth and exit.

These findings are limited to one industry, but nonetheless add substantially to the small existing research base about IT impacts on firm and industry structure.[22] The focus on a single industry might be avoided by studying multi-industry data panels, as Hitt (1999) and Brynjolfsson and Hitt (2000) do to find evidence of falling firm sizes associated with greater IT use. However, multi-industry panels may conflate industry life cycle effects with the phenomenon of study unless such effects are accounted for; this bias is complicated to address and has not been fully addressed in existing studies of IT and industry structure. Case studies provide means to probe why and how new technologies have their effect, but to date such studies of the internet have been limited to a small number of firms, obstructing systematic study of whether and why corporate leadership turnover is spurred by the internet or other disruptive technologies. Thus hopefully this study will contribute fruitfully to the emerging stream of research on ramifications of computers and the internet for firm and industry structure.

Will the internet have major effects on market structure in future? Such future changes are possible, but perhaps they will not have the form indicated by theories of disruptive technology causing market leadership turnover. Indeed, the chairman of CMG, the largest full-time employer among UK IT consultancies in 2000, writes about the e-commerce opportunity that:

> "This is a very significant integration challenge and one that favours the breadth of skills, resources and experience that companies such as CMG can offer. Indeed, the majority of major organisations are already turning to well-established systems integrators for this work, rather than newer so-called Internet integrators." (CMG Annual Report, 2000, p. 7.)

This interpretation coincides with Porter's (2001) argument that the internet will not change the dynamics and strategies of business competition, but merely intensify them and make current strategic concerns all the more relevant. The truth is still a matter to debate, as attested by the pages of letters in response to Porter's *Harvard Business Review* article, but at least so far the PC and the internet do not seem to have had the sort of disruptive technology impacts described by theories of corporate leadership turnover.

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[22] Two useful studies of the adoption of new IT technologies by firms are Fabiani, Schivardi, and Trento (2001) and Bertschek and Fryges (2002).

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Table 1. Trends in real median and mean fee per day of IT consultancy work, at minimum list prices, UK, 1971-2001

Year	Fee, real £ per day median	Fee, real £ per day mean	Sample size N	Sample size % of firms
1971	274	304	10	12%
1973	274	261	16	14%
1975	203	223	47	28%
1977	263	285	233	58%
1979	306	318	451	74%
1981	348	335	733	77%
1983	357	369	820	76%
1984	389	387	831	77%
1985	403	425	813	77%
1987	510	517	620	71%
1988	405	459	628	41%
1989	451	455	891	56%
1991	422	454	1006	63%
1993	431	465	1278	66%
1995	465	483	1119	64%
1997	440	489	1115	68%
1999	472	495	1242	65%
2000	458	496	973	58%
2001	495	496	766	52%

Table 2. Negative Binomial Analyses of Entry Before and After the Rise of the PC and the Internet (Standard Errors in Parentheses)

	PC		Internet			
	(1)	(2)	(3)	(4)	(5)	(6)
Year 1982-87 Dummy$_t$	0.621 *	0.145				
	(0.313)	(0.456)				
Year 1995-2001 Dummy$_t$			-0.208	0.661		
			(0.186)	(0.424)		
Year 2000-2001 Dummy$_t$					-0.183	
					(0.225)	
Internet Hosts$_t$ (100 millions)						-0.120
						(0.224)
Real Mean Price$_t$ (100£)		0.437		-2.814 *		
		(0.330)		(1.281)		
Constant	4.736	3.434	5.918	18.854	5.850	5.844
	(0.186)	(0.993)	(0.136)	(5.897)	(0.108)	(0.115)
α	0.373 ***	-1.079 ***	0.108 ***	0.079 ***	0.113 ***	0.116 ***
	(0.125)	(0.336)	(0.043)	(0.032)	(0.045)	(0.046)
N	17	17	13	13	13	13
Years	1971-1987	1971-1987	1989-2001	1989-2001	1989-2001	1989-2001

† p<.10, * p<.05, ** p<.01, *** p<.001 (for α, based on likelihood ratio test versus Poisson model)

Table 3. Application Areas of Incumbents and Entrants

Application	% with Application Area: Recent Entrants	% with Application Area: Incumbents	Sample Sizes: Recent Entrants	Sample Sizes: Incumbents	p-val.
PCs 1984	25.7%	23.4%	522	559	.397
MS-DOS 1987	34.9%	29.1%	587	292	.094
Internet 1995	22.4%	13.0%	541	1204	$2x10^{-6}$
Network 1995	32.7%	18.4%	541	1204	$1x10^{-10}$

Recent entrants are entrants in the years 1982-84 for microcomputers in 1984, 1982-87 for MS-DOS in 1987, and 1995 for the internet and networks in 1995. Incumbents are all other firms. The p-value is reported using Fisher's exact test, and pertains to the difference in probability of having the application area for recent entrants versus incumbents.

Table 4. OLS Regressions of Growth Rate in Total Employment, with Effects of the PC and the Internet (Standard Errors in Parentheses)

	PC (7)	PC (8)	PC (9)	Internet (10)	Internet (11)	Internet (12)
Year 1982-87 $Dummy_t$	-0.066 *** (0.015)					
Entrant 1982-87 $Dummy_i$	-0.047 * (0.019)	-0.021 (0.017)	-0.040 * (0.019)			
PC Apps. 1984 $Dummy_i$		-0.002 (0.037)				
DOS Apps. 1987 $Dummy_i$			-0.011 (0.016)			
Year 1995-00 $Dummy_t$				-0.001 (0.006)		
Entry 1995-00 $Dummy_i$				-0.004 (0.007)	-0.010 (0.011)	-0.010 (0.011)
Internet Apps. 1995 $Dummy_i$					0.016 (0.014)	
Network Apps. 1995 $Dummy_i$						0.019 (0.012)
Ln Age_{it}	-0.026 ** (0.009)	-0.018 (0.012)	-0.033 * (0.016)	-0.018 *** (0.003)	-0.018 * (0.007)	-0.018 * (0.007)
Ln Size (# of $consultants)_{it}$	-0.045 *** (0.004)	-0.040 *** (0.005)	-0.030 *** (0.005)	-0.034 *** (0.002)	-0.024 *** (0.004)	-0.024 *** (0.004)
Constant	0.246 (0.015)	0.136 (0.033)	0.169 (0.047)	0.116 (0.007)	0.097 (0.017)	0.095 (0.017)
N	6952	4214	3126	15396	4727	4727
Firms	1748	827	556	3736	1339	1339
Years	1971-1986	1984-86 & 1988-00	1988-2000	1988-2000	1995-2000	1995-2000

† p<.10, * p<.05, ** p<.01, *** p<.001

Table 5. Logistic Regressions of Exit with Effects of the PC and the Internet
(Standard Errors in Parentheses)

	PC			Internet		
	(13)	(14)	(15)	(16)	(17)	(18)
Year 1982-87 $Dummy_t$	0.396 *** (0.082)					
Entrant 1982-87 $Dummy_i$	0.202 * (0.090)	0.060 (0.085)	0.261 * (0.115)			
PC Apps. 1984 $Dummy_i$		-0.151 (0.176)				
DOS Apps. 1987 $Dummy_i$			-0.217 * (0.099)			
Year 1995-00 $Dummy_t$				0.327 *** (0.038)		
Entry 1995-00 $Dummy_i$				-0.017 (0.039)	0.195 ** (0.069)	0.194 ** (0.069)
Internet Apps. 1995 $Dummy_i$					-0.002 (0.086)	
Network Apps. 1995 $Dummy_i$						0.006 (0.077)
Ln Age_{it}	-0.277 *** (0.047)	-0.194 *** (0.054)	0.039 (0.090)	-0.218 *** (0.019)	0.085 * (0.043)	0.085 * (0.043)
Ln Size (# of $consultants)_{it}$	-0.122 *** (0.024)	-0.042 (0.027)	-0.010 (0.031)	0.009 (0.014)	-0.028 (0.026)	-0.029 (0.026)
No Size Data $Dummy_{it}$	0.241 * (0.101)	0.281 * (0.121)	0.184 (0.177)	0.133 ** (0.051)	0.136 (0.100)	0.138 (0.100)
Constant	-1.378 (0.076)	-1.203 (0.158)	-1.915 (0.274)	-1.235 (0.042)	-1.599 (0.108)	-1.601 (0.108)
N	9287	5654	3978	22019	6614	6614
Firms	2236	1081	697	5630	1745	1745
Years	1971-1986	1984-86 & 1988-00	1988-2000	1988-2000	1995-2000	1995-2000

† p<.10, * p<.05, ** p<.01, *** p<.001

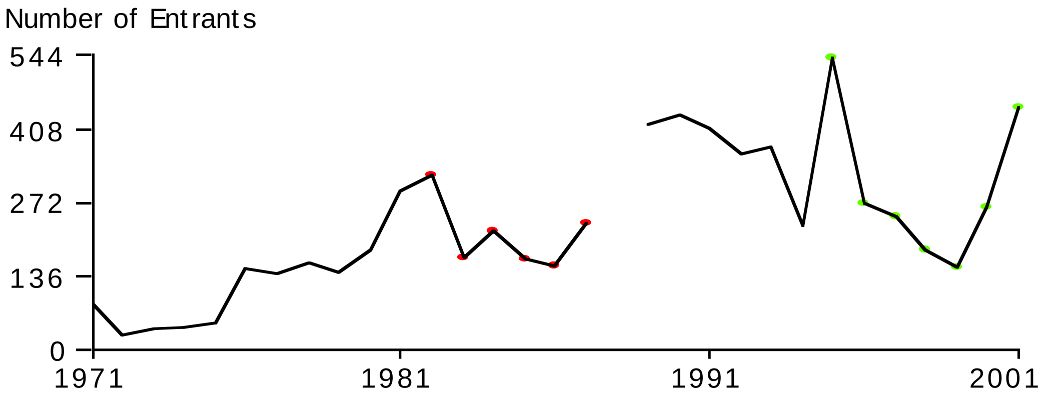


Figure 1. Annual Entry of UK Computer Consultancies (firms per year). Colored dots emphasize specific years: red for 1982-87, green for 1995-2001.

Figure 2. Median Employment Over Time in Successive Cohorts of Entrants in UK Computer Consultancy

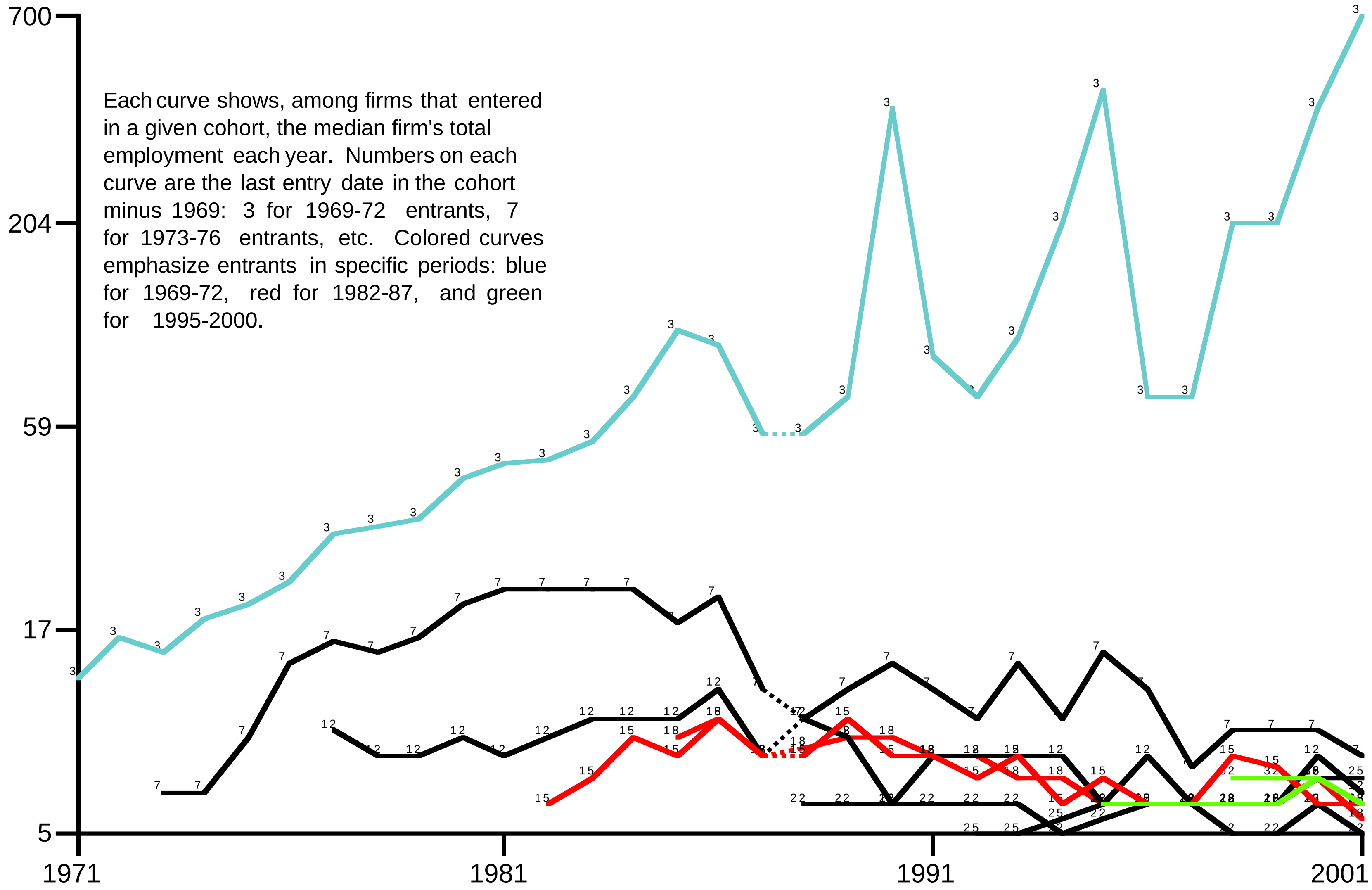
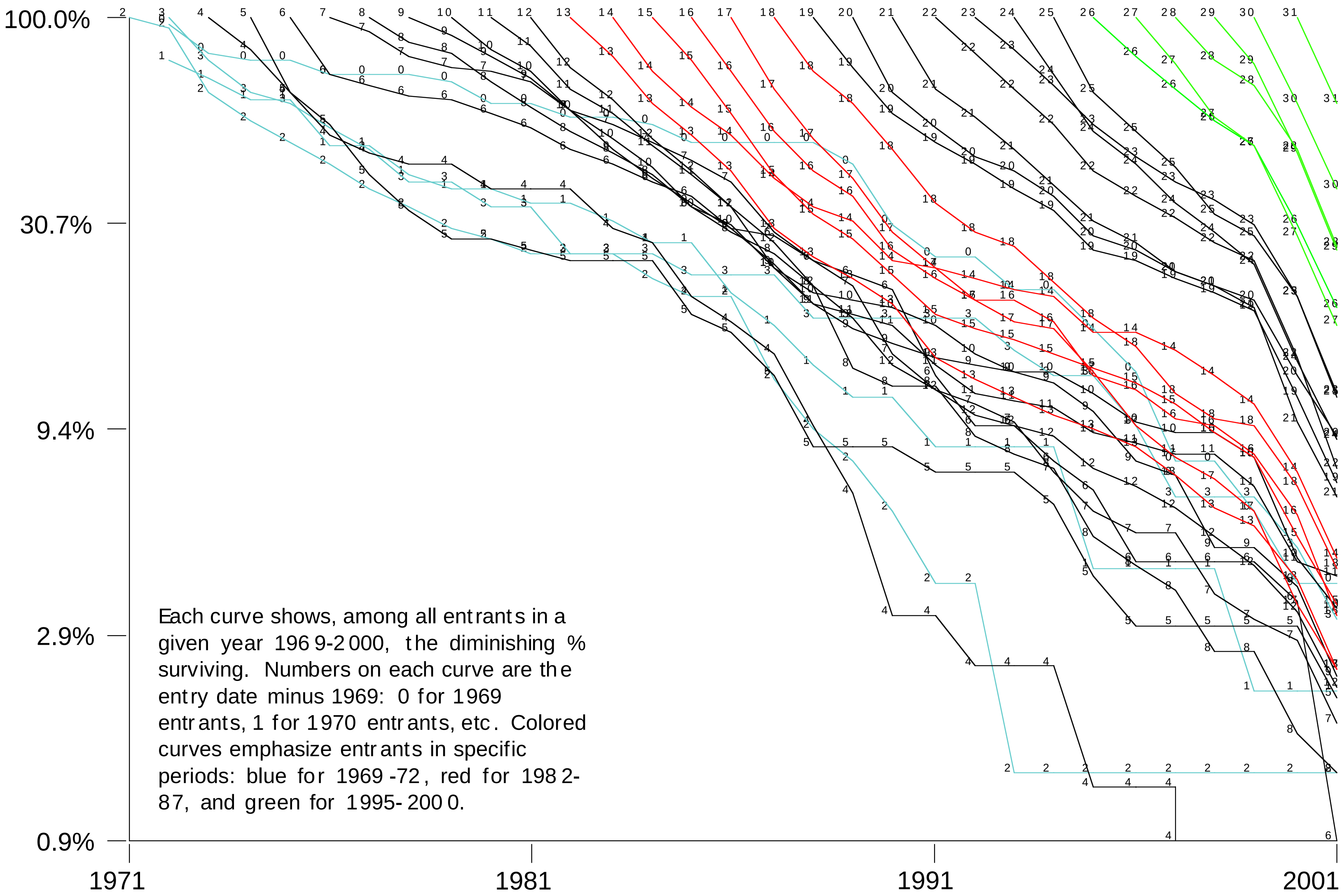


Figure 3. Survival Over Time of Successive Cohorts of Entrants in UK Computer Consultancy



Each curve shows, among all entrants in a given year 1969-2000, the diminishing % surviving. Numbers on each curve are the entry date minus 1969: 0 for 1969 entrants, 1 for 1970 entrants, etc. Colored curves emphasize entrants in specific periods: blue for 1969-72, red for 1982-87, and green for 1995-2000.