Information Technology and Dynamics of Industry Structure

The UK IT Consulting Industry as a Contemporary Specimen

Kenneth L. Simons

Royal Holloway, University of London

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IT Revolutions and Firms

- Personal computers
  - Hobijn and Jovanovic (2001)
  - PC devalued old firms, gave value to new
  - Caused post-1972 stock market crash
  - Destroyed old firms
- Internet
  - Evans & Wurster (2000): *Blown to Bits*
  - Old businesses can be most vulnerable
  - Tremendous efficiency gains for firms that restructure advantageously
  - Example: Encyclopaedia Britannica
- IT benefits visible in firms
  - Brynjolfsson et al: 10× physical values

Modeling Revolutions

- Vintage capital & new technology
  - Reinganum (1983)
  - Incumbent, entrant compete to develop technology first (random, Nash)
  - Entrant innovates most for very major innovations
  - Including “drastic” innovations: if entrant succeeds, incumbent $\pi \leq 0$
- Implications for broader industry
  - Tushman & Anderson (1986)
  - In “disruptive” changes, entrants have advantage
  - Entrants most often use new technology
  - Entrants grow faster, exit less
  - New technology yields growth, survival

Revolutions Matter

- Affect who wins & who loses in competition
  - Incumbent and entrant strategies
  - Ramifications for competition policy
- As for firms, so for industries and nations:
  - Leapfrog versus linear development
  - “a business firm, an industry or an economy which is able to successfully utilize these global trends will eventually outperform its rivals.” (UNU conference May 2002)
  - [W]e should not be satisfied with merely catching up because this would not come up with competitive products... [L]eap forward based on our indigenous innovative capabilities. (Founder Computer chief designer, Lu 2000)

An Empirical Test

- Did the PC have a revolutionary impact in most industries?
- Is the internet having a similarly widespread impact?
- Test in one industry, which is a useful test case
- UK computer consultancies:
  - A leading industry in IT adoption, use
  - In a nation with high PC, Internet use
  - Hence impacts likely to be relatively apparent

Data

- Computer consultants in UK
  - *Computer Users Year Book*
    - Data published 1970-2001
  - Partial but substantial sample

    1980 - 948 firms, 1990 - 1489, 2000 - 1678
  - Names, addresses, other information used to match records over time
  - Multiple branches treated as 1 firm
  - Data on number of consultant employees, application areas
  - Ca. 1988 change in categories included, so pre-1988 often treated separately

About the Firms

- Consultancy services include:
  - Outsourcing & project management
  - Personnel management
  - Finance & accounting
  - Integrated business systems
  - Networks
  - E-commerce
  - Marketing
  - Top-level management strategy
- Most built custom software
- Size in full-time consultants (in 2000):
  - Largest: 3,260 full-time consultants
  - Top 10 averaged 1,656 (40% of full-time consultants in sample)
  - Mean: 29
  - Median: 5
- Largest were multinational, most national

Implications of Disruptive Technological Change

(cf. Tushman & Anderson 1986)

After the technological change:

1. Entry - Increases
2. New technology use - Greatest among new firms
3. Growth of new firms - Increases, relative to incumbents
4. Exit of new firms - Decreases, relative to incumbents
5. Growth of new technology users - High, relative to others
6. Exit of new technology users - Low, relative to others

Implications of Disruptive Technological Change

(cf. Tushman & Anderson 1986)

Results for PC/Internet

After the technological change:

1. Entry - Increases ?/?
2. New technology use - Greatest among new firms no/x2
3. Growth of new firms - Increases, relative to incumbents no/no
4. Exit of new firms - Decreases, relative to incumbents no/no
5. Growth of new technology users - High, relative to others no/insig.
6. Exit of new technology users - Low, relative to others yes/no

Parametric Models

$$E_t = \exp(\beta_0 + \beta_1 T_t) + \varepsilon_t^E$$

$$\frac{\Pr[U_i = 1]}{1 - \Pr[U_i = 1]} = \exp(\upsilon_0 + \upsilon_1 R_{iY})$$

$$\log\left(\frac{S_{it+1}}{S_{it}}\right) = \gamma_0 + \gamma_1 R_{it} + \gamma_2 U_i + \gamma_3 \log S_{it} + \gamma_4 \log A_{it} + \gamma_5 T_t + \varepsilon_{it}^S$$

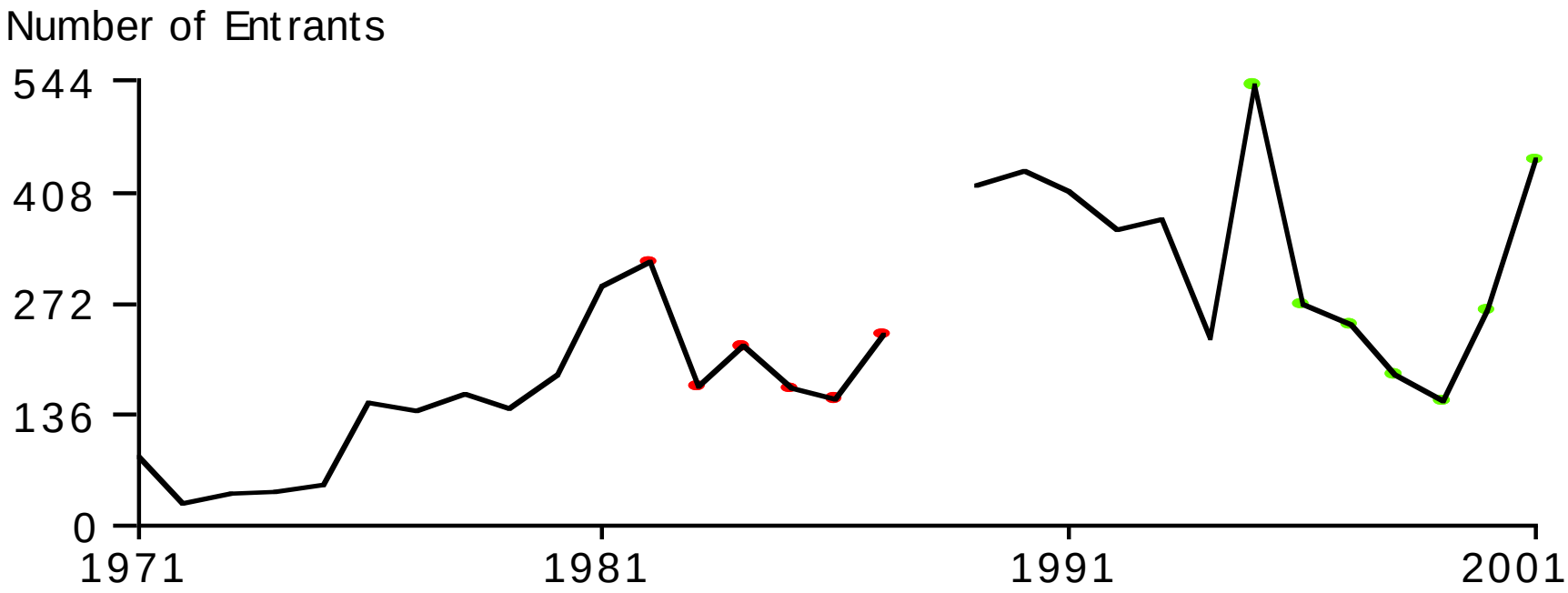
$$\frac{\Pr[X_{it} = 1]}{1 - \Pr[X_{it} = 1]} = \exp(\lambda_0 + \lambda_1 R_{it} + \lambda_2 U_i + \lambda_3 \log S_{it} + \lambda_4 \log A_{it} + \lambda_5 T_t)$$

E_t Entrants, year t
U_i User of technology dummy, firm i, in an early year Y with data
S_{it} Size (by employment), firm i year t
X_{it} Exit, firm i year t

T_t Technology impact dummy or proxy, year t
R_{it} Recent entrant dummy, firm i year t
A_{it} Age dummy, firm i year t

Disruptive technology implies: $\beta_1 > 0$; $\upsilon_1 > 0$; $\gamma_1 > 0$, $\gamma_2 > 0$, ($\gamma_5 > 0$); $\lambda_1 < 0$, $\lambda_2 < 0$, ($\lambda_5 > 0$)

Annual Entry of Computer Consultancies



Negative Binomial: Entry Before and After Rise of PC and Internet (SE in Paren.)

	PC		Internet			
	(1)	(2)	(3)	(4)	(5)	(6)
Year 1982-87 Dummy$_t$	0.621 *	0.145				
	(0.313)	(0.456)				
Year 1995-01 Dummy$_t$			-0.208	0.661		
			(0.186)	(0.424)		
Year 2000-01 Dummy$_t$					-0.183	
					(0.225)	
Internet Hosts$_t$ (10^8)						-0.120
						(0.224)
Real Mean Pr$_t$ (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

Dependent variable: Number of entrants in each year.
† p<.10, * p<.05, ** p<.01, *** p<.001

Local Likelihood Estimation

- Number of technology users u_t among n_t entrants in year t assumed binomial(n_t,r_t)
- Local weighted likelihood for each time τ:

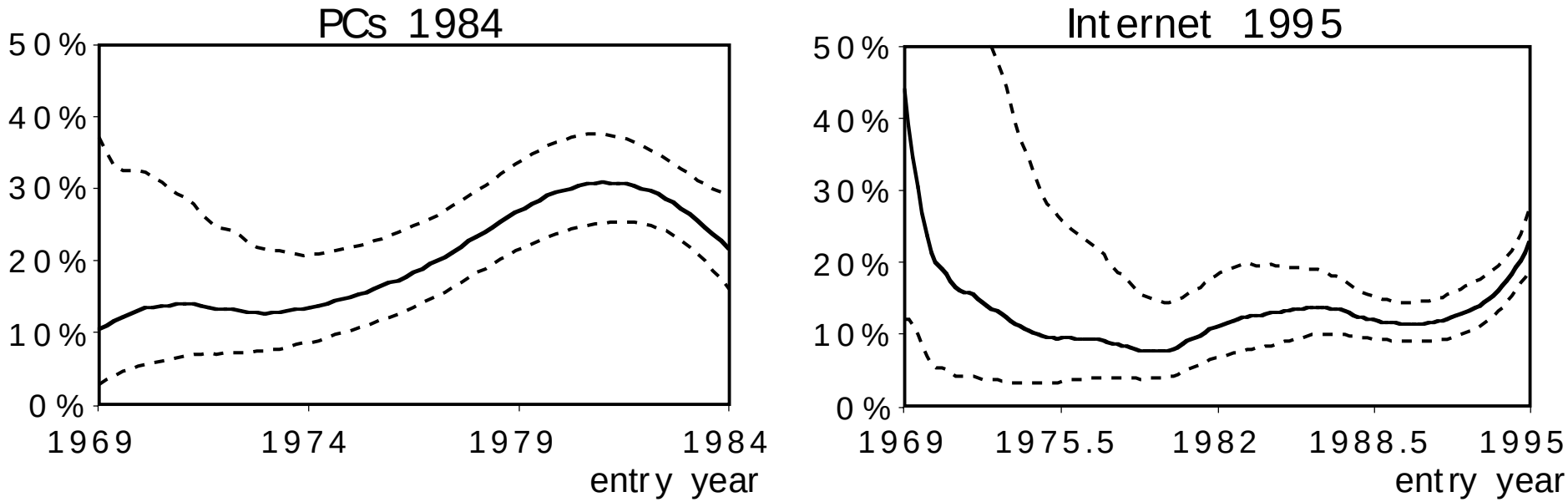
$$L_\tau = \sum_{t=\tau-b}^{\tau+b} \left(1 - \left|\frac{t-\tau}{b}\right|^3\right)^3 \binom{n_t}{u_t} r_t^{u_t} \left(1 - r_t\right)^{n_t - u_t},$$

$$r_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2$$

- b=8 chosen for adequate smoothing
- Usage rate r is quadratic near τ, allowing for non-monotonic trends
- At each τ, choose best fitting α_0, α_1, α_2;

$$\hat{r}_\tau = \hat{\alpha}_0 + \hat{\alpha}_1 \tau + \hat{\alpha}_2 \tau^2$$

Technology Use by Entry Date



Estimated probability of use and 95% confidence intervals
(maximum local likelihood estimates for binomial outcome)

OLS Regressions of Firm Growth, with Effects of PC and Internet
(Standard Errors in Parentheses)

	PC		Internet	
	(1)	(2)	(3)	(4)
Entrant 1982-87$_i$	-0.047 *	-0.021		
	(0.019)	(0.017)		
PC Apps. 1984$_i$		-0.032 †		
		(0.017)		
Entrant 1995-00$_i$			-0.004	-0.010
			(0.007)	(0.011)
Internet Apps. 1995$_i$				0.016
				(0.014)
Log Size (# of consultants)$_{it}$	-0.045 ***	-0.041 ***	-0.034 ***	-0.024 ***
	(0.004)	(0.005)	(0.002)	(0.004)
Log Age$_{it}$	-0.026 **	-0.018	-0.018 ***	-0.018 *
	(0.009)	(0.011)	(0.003)	(0.007)
Year 1982-87$_t$	-0.066 ***			
	(0.015)			
Year 1995-00$_t$			-0.001	
			(0.006)	
Constant	0.246	0.147	0.116	0.097
	(0.015)	(0.032)	(0.007)	(0.017)
N	6952	4214	15396	4727
Firms	1748	827	3736	1339
Restricted to years	1971-1986	1984-86 & 1988-00	1988-2000	1995-2000
Restricted to firms	all	present in 1984	all	present in 1995

Dependent variable: Growth rate[i,t] = log(total employment[i,t+1] / total employment[i,t])

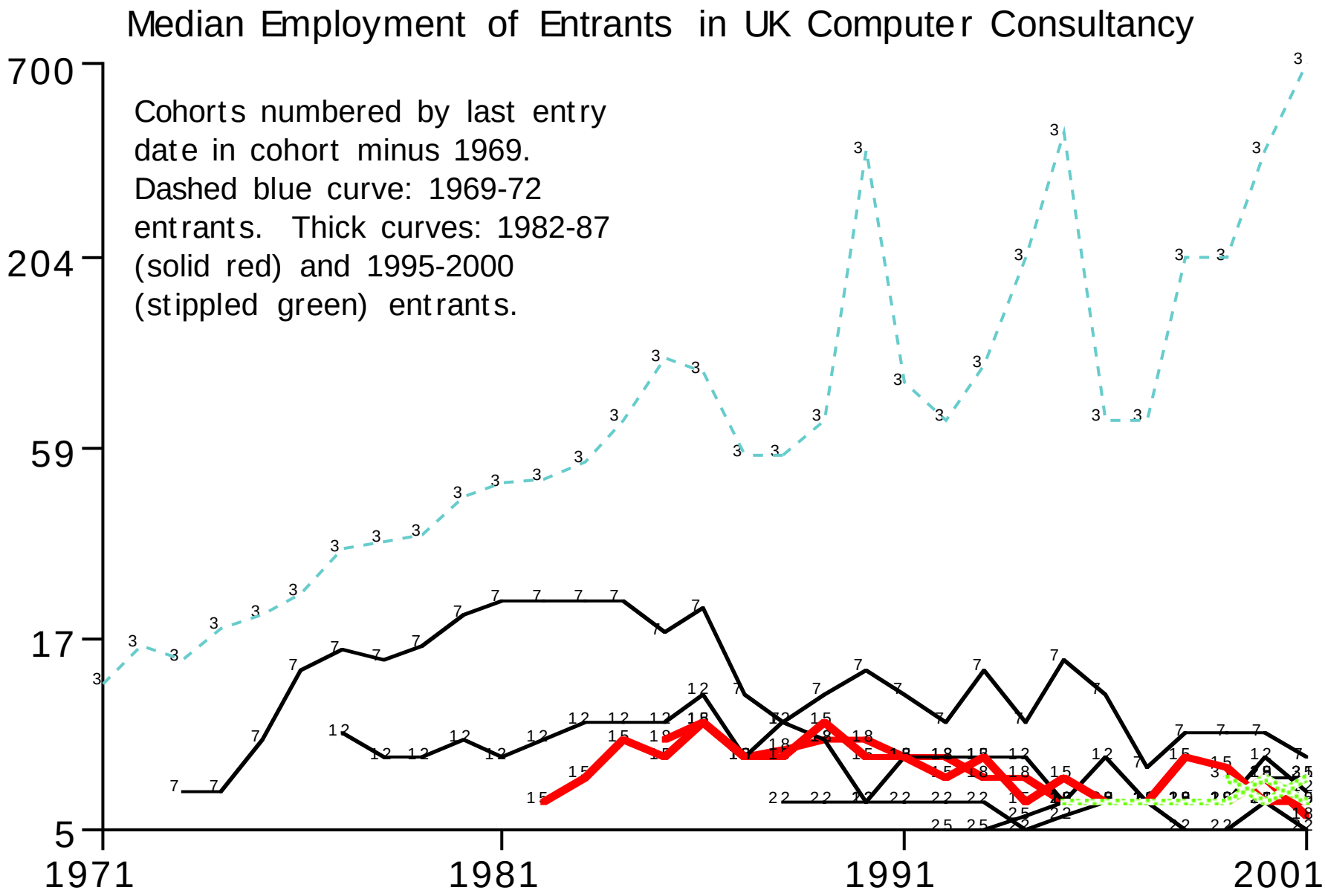
†$p < 0.10$, * $p < 0.05$, **$p < 0.01$, ***$p < 0.001$

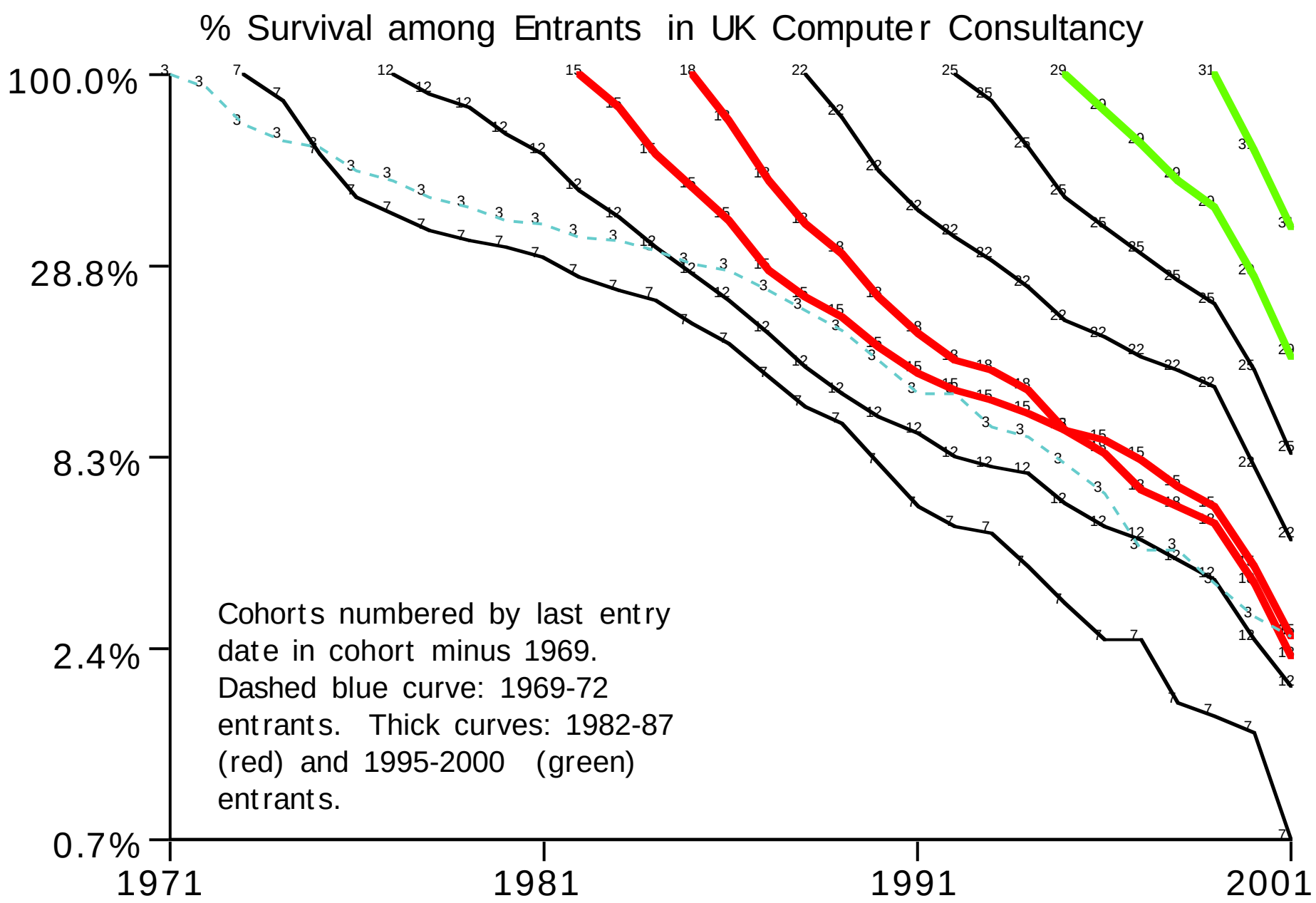
Logistic Regressions of Firm Exit with Effects of PC and Internet
(Standard Errors in Parentheses)

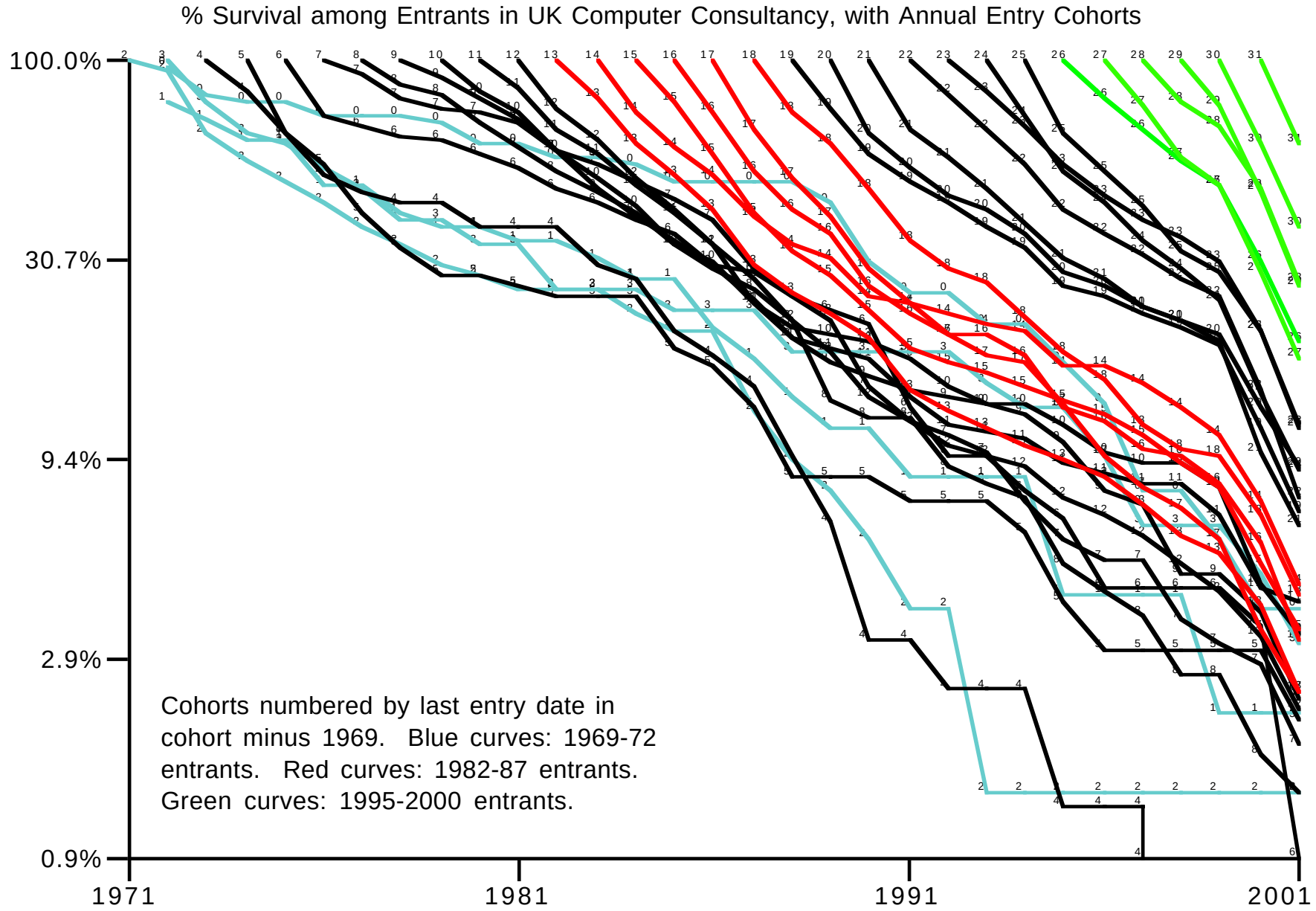
	PC		Internet	
	(5)	(6)	(7)	(8)
Entrant 1982-87$_i$	0.202 *	0.066		
	(0.090)	(0.085)		
PC Apps. 1984$_i$		-0.158 †		
		(0.087)		
Entrant 1995-00$_i$			-0.017	0.195 **
			(0.039)	(0.069)
Internet Apps. 1995$_i$				-0.002
				(0.086)
Log Size (# of consultants)$_{it}$	-0.122 ***	-0.048 †	0.009	-0.028
	(0.024)	(0.027)	(0.014)	(0.026)
Log Age$_{it}$	-0.277 ***	-0.180 ***	-0.218 ***	0.085 *
	(0.047)	(0.052)	(0.019)	(0.043)
No Size Data$_{it}$	0.241 *	0.264 *	0.133 **	0.136
	(0.101)	(0.122)	(0.051)	(0.100)
Year 1982-87$_t$	0.396 ***			
	(0.082)			
Year 1995-00$_t$			0.327 ***	
			(0.038)	
Constant	-1.378	-1.186	-1.235	-1.599
	(0.076)	(0.154)	(0.042)	(0.108)
N	9287	5654	22019	6614
Firms	2359	1081	5630	1745
Restricted to years	1971-1986	1984-86 & 1988-00	1988-2000	1995-2000
Restricted to firms	all	present in 1984	all	present in 1995

Dependent variable: Exit[i,t] = 1 if firm i was in the data in year t but not in t+1 nor any subsequent year, 0 otherwise

†$p < 0.10$, * $p < 0.05$, **$p < 0.01$, ***$p < 0.001$


Median Employment of Entrants in UK Computer Consultancy
Cohorts numbered by last entry date in cohort minus 1969. Dashed blue curve: 1969-72 entrants. Thick curves: 1982-87 (solid red) and 1995-2000 (stippled green) entrants.
700
204
59
17
5
1971
1981
1991
2001


% Survival among Entrants in UK Computer Consultancy
100.0%
28.8%
8.3%
2.4%
0.7%
1971
1981
1991
2001
Cohorts numbered by last entry date in cohort minus 1969.
Dashed blue curve: 1969-72 entrants. Thick curves: 1982-87 (red) and 1995-2000 (green) entrants.


% Survival among Entrants in UK Computer Consultancy, with Annual Entry Cohorts
100.0%
30.7%
9.4%
2.9%
0.9%
1971
1981
1991
2001
Cohorts numbered by last entry date in cohort minus 1969. Blue curves: 1969-72 entrants. Red curves: 1982-87 entrants. Green curves: 1995-2000 entrants.

Sensitivity Tests

- Alternative specifications:
  - Alternative technology measures: MS-DOS applications 1987 and network management & design 1995
  - Firms with 5+ full-time consultants in 1st year of analysis (1984 for models 1&5)
  - GDP growth, or services GDP growth
  - Price index (consultancy fee per day)
  - Size and age categories (19 categories added)
  - Internet impacts beginning 1999, or proxy using internet hosts
  - Recent entry measure using firm entry time (and entry time squared)
- Robust lack of disruptive effects
  - Late entry not associated with significantly lower exit or higher growth, except:
  - With internet from 1999 (or hosts), slight exit but not growth advantage
  - In 1 permutation, significant exit advantage but growth disadvantage

Interpretation - Part 1

- No late-mover benefits caused by PC or internet in UK IT consultancy
  - Firms did put PC- and internet-related technologies to use
  - But benefits varied with time, market niche, and work practices
    - Recall Goldfarb (2001) on the test-case GPT, electrification
  - Large firms did not suffer
  - Indeed, new pure e-commerce consultancy sector shrank: need traditional IT consultancy skills

The E-Commerce Opportunity:

“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.)

Interpretation - Part 2

- In all industries, consultants' expertise suggests why PC and internet rarely cause entrant advantage
  - PC not a panacea
    - Large central computers cheaper, more effective for many uses
    - PC network administrative costs 10x hardware costs; mainframes improved just as PCs did
    - Some firms switched to PCs, then back!
    - cf. Bresnahan & Greenstein (1996)
  - Internet tools increasingly available
    - Early adoption or in-house software development thus yields fleeting benefits
    - 2001 survey for manufacturers suggests available tools best suit large firms

Interpretation - Part 2 cont.

- Constant need for <u>many</u> kinds of IT improvements
  - PC and internet applications just two of many continuing IT improvements by firms
  - E.g., internal networks, data management, including customer databases
  - Don’t ignore the others & focus on one!
  - cf. Klepper & Simons (1997)
- General purpose technology delay?
  - GPT literature suggests effects after a long delay; could this apply to competitive disruption?
  - But for PC and internet, above reasons suggest no delayed competitive disruption
  - PC: Among UK IT consultancies, no delayed competitive disruption
  - Internet: Dot.com firms an early example - failed despite enormous investments

Conclusions

- Among UK IT consultants, PC and Internet did not disrupt competitive order
  - Incumbents used PC and Internet as core business areas, nearly as frequently as new firms
  - New firms did not experience enhanced growth relative to incumbents
  - New firms did not experience reduced exit
  - Technology users did not do better than non-users
- Among all industries, reasons why PC and Internet should be limited in their disruptive effects

Policy Advice

- Firms
  - Don’t panic - Don’t assume late entrants have a miraculous advantage
  - Invest steadily in pertinent IT software and hardware
    - Mainframes sometimes necessary
    - If setting up new PC networks, note continuing high maintenance costs
  - Buy third-party software if possible
    - In-house development very expensive
    - New software tools will be developed
    - Encourage development to fit your needs
- National governments
  - Leapfrogging based on IT not a quick fix
  - Would require especially creative solutions
  - Infrastructure helps (don’t prolong development - no late entry advantage)