MERGER AND TECHNOLOGICAL PROGRESSIVENESS:

THE CASE OF THE BRITISH COMPUTER INDUSTRY

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Merger and Technological Progressiveness : the case of the British Computer Industry [1]

One of the more persistent propositions in economics is that ascribed to Schumpeter relating the rate of innovation to size and market power. The argument is that the 'monopoly firm' will have a greater demand for innovations because its market power will increase its ability to profit from the innovation, and will also generate a larger supply of innovations because "there are advantages which, though not strictly attainable on the competitive level of enterprise are as a matter of fact secured only on the monopoly level' (Schumpeter {1942} p. 101).

In 1968, with the blessing of the Industrial Reorganisation Corporation, English Electric Computers Ltd., Plessey (computer division) and International Computers and Tabulators joined together to form the only existing British computer company of any size, International Computers Ltd. Prior to this date there had also been considerable merger activity in the industry involving the IRC. The merger sequence is displayed in Diagram 1.

In relation to this industry the IRC state in its first report, that this was a

> "sector which is of great importance to the country's export effort, where the pace of technical change is rapid and where there is intense competition from powerful companies in the U.S., Europe and Japan ..."

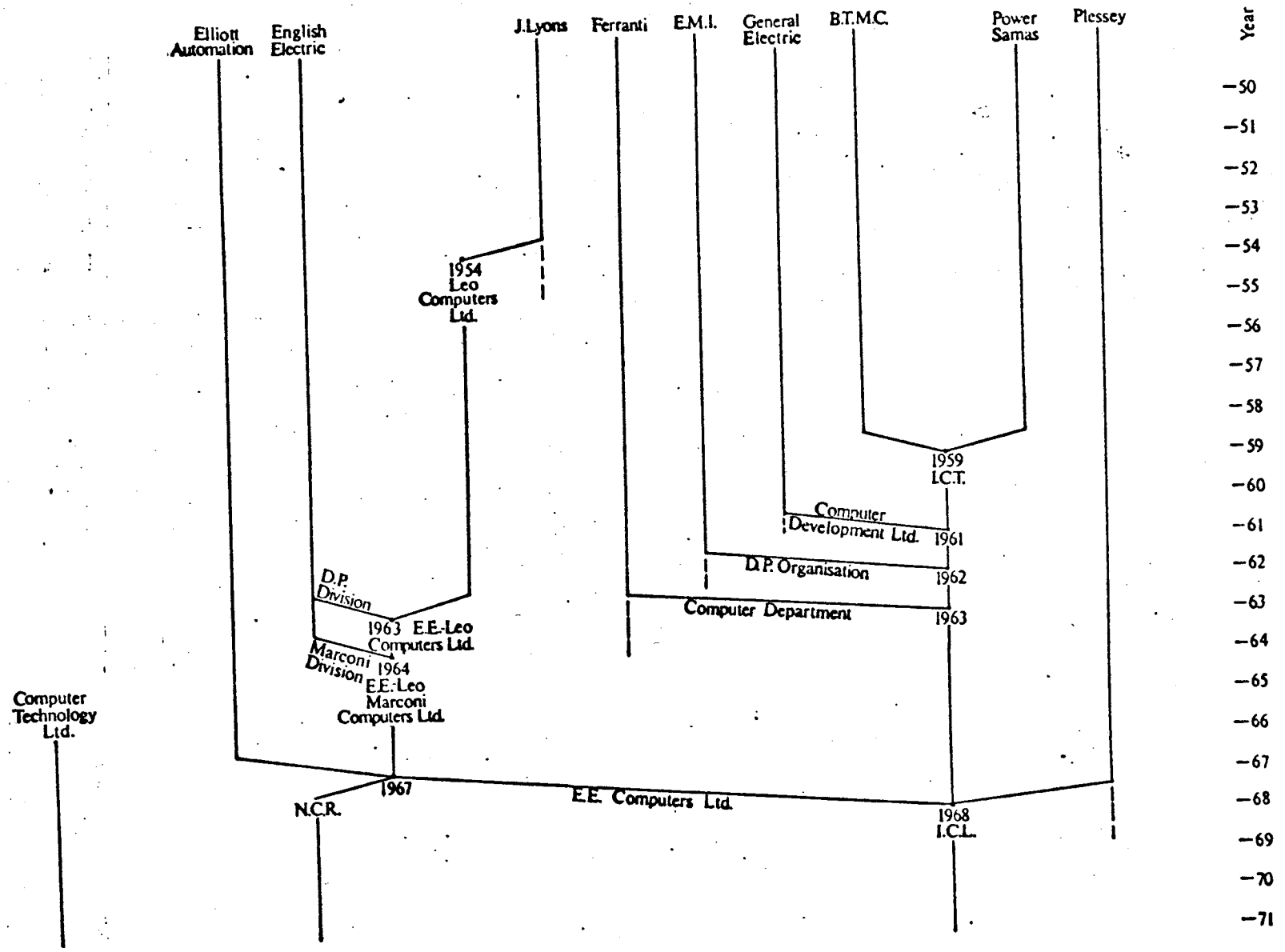
1. I wish to thank Norman Ireland, Keith Cowling, John Cubbin and other members of the University of Warwick Industrial Economics Workshop for comments on an earlier draft of this paper. This work was carried out under the asupices of a project on mergers financed by the Office of Fair Trading and was also supported by the Centre for Industrial, Economic and Business Research at the University of Warwick. The views presented herein however are purely those of the author and should not be taken as necessarily representative of those of these two bodies.

Notes:

Pre 1949, I.B.M. and B.T.M.C. linked by Hollerith Franchise.

Post 1971, I.C.L., C.I.I. and C.D.C.(of U.S.) linked by 'Multinational Data', a company for the pooling of research interests.

(Dashes indicate that company continues in non-computer areas.)



It is reasonable to argue therefore that the main justification for the 1968 merger was on the grounds of technological progressiveness. It was felt that only as a merged industry could British computer manufacturing compete with its U.S. rivals on a technological level. In fact it can be argued that as the rate of technological progress in the computer industry has been so fast it is only by keeping up technologically that a firm can stay in existence. The benefits from technological change cannot be matched by any other competitive mechanism. This is further reinforced by the existence of increasing returns to scale in computer manufacture coupled with IBM's world market share of approximately 70% which makes the chance of any small company using price cutting as a successful competitive weapon very remote. (For further documentation of these points the reader is referred to Stoneman {1976} Chapter 5). One can further argue that if the British computer industry was to make inroads into the U.S. position of supremacy then it must be on the basis of technological superiority.

We therefore have a merger where the effects on the rate of technological progressiveness are of paramount importance in its evaluation. Moreover by investigating whether these benefits have been realised we can also gather some indication as to the appropriability of the views of Schumpeter. Our task therefore in the present context is to analyse to what extent the formation of ICL has enabled the British computer industry to advance technologically at a rate faster than it would have done.

The comparison that we are going to make is to relate the prices charged by British computer manufacturers for their machines to that charged by U.S. manufacturers for their machines to see whether over time their relative positions have changed. 1/ Now although price has many determinants it is felt that the underlying technology is the crucial one, thus any change in positions must relate to technological differences. When it comes, however, to the discussion of the results these other factors will be considered. Our prime objective therefore is to isolate changes in the relative prices of different manufacturers that we can ascribe to the merger activity in the U.K. computer industry. The U.S. companies for comparison were selected on the grounds of U.K. market share, thus excluding Univac and C.D.C., and current status, for although RCA and RXDS operated during the study period both had ceased computer manufacture by 1975. This left Burroughs, IBM, Honeywell and GE. The latter two merged in 1970, thus we can also investigate simultaneously the effects of this merger. (The methods used for comparison are such that no bias is introduced by the exclusion of now defunct companies).

Effecting Comparisons

Our task is to look at the movements of relative prices over time, but one of the major problems with this exercise as regards

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1/ I wish to thank Diane Ellwood and Warren Ho for their invaluable help in the preparation and manipulation of the data.

computers is that machines vary considerably in their 'size' or 'quality' What we therefore have to do is adjust for quality. The procedure we have used is related to the 'hedonic' or 'characteristics' approach to quality adjustment as propounded by Griliches {1971}. This method suggests that each computer can be reduced to several basic characteristics (in the present case cycle time and maximum store) for each of which, in a given sample, we can estimate, usually by the regression of actual price on characteristics, a shadow price (equal to the regression coefficient). The sum of the values at these shadow prices of the characteristics of a given computer represent its quality. By dividing 'price' by 'quality' we have a measure for each machine of price per unit of quality that can be used for comparison purposes.

In the present case we have defined the sample over which to estimate shadow prices as all IBM machines introduced between 1960 and 1975. Thus for all machines we can estimate a 'quality' index which is the price of a machine as if it were to have been introduced by IBM - the IBM equivalent price. Obviously for IBM machines the actual price is going to equal the IBM equivalent price apart from the 'white noise' taken account of in the error term of the regression. If therefore we perform our exercise for the machines of other manufacturers comparing their price to their IBM equivalent price it is equivalent to looking at the prices of their machines relative to IBM machines after adjusting for quality differences. This is what we shall be doing.

To be specific, to obtain the shadow prices for our quality measure we ran equation (1) across all IBM machines introduced between

1960 and 1975. [1/] It might be noted that we are working on the assumption that the IBM shadow prices are constant over time.

$$\text{Log } P = \alpha + \beta_0 \text{ Log } C + \beta_1 \text{Log } S + \sum_{i=1}^{16} B_i D_i + u \qquad (1)$$

P = price in f'000

C = cycle time in μ secs.

S = maximum store in '000 bits

D_i = dummy variables for year of introduction

The early results led us to the form in equation (2) as our

$$\text{Log } P = \underset{(-3.37)}{-0.393 \text{ Log } C} + \underset{(45.40)}{0.706 \text{ Log } S} + \underset{(6.22)}{0.804G} \qquad (2)$$

$$N \geq 45, \quad F = 119.1 \quad DW = 1.67$$

'quality' equation, where t statistics are in brackets and G is a dummy variable reflecting whether the machine was introduced in the 1960-1964 period (when it is 1) or not (when it is 0). This way of representing the effect of time was chosen as only the dummy variables for the period 60-64 in (1) were significantly different

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1/ All data is from CCL {1962-1974}, IDC {1961-1974}, Shirley {1969} and Smythe {1970, 1975}. All logs are to base ten.

from zero when 1965 was included in the constant. This also fits in well with the discussion of technological change in Stoneman {1976}, where major changes in technology are related to the generation concept. The constant is excluded as its inclusion led to an estimate not significantly different from zero. With the regression coefficients from (2) we estimated for the machines of all manufacturers $\hat{\text{Log}}\ P$, which we call the I.B.M. equivalent price, i.e. the price of the machine as if it were to have been introduced by I.B.M.

Results

As explained above, the analysis proceeds by the use of the 'I.B.M. equivalent price'. In our regressions we use the variables

Log P = $\log_{10}$ of actual price

$\hat{\text{Log}}\ P$ = $\log_{10}$ of the predicted I.B.M. equivalent price

1960-1975 = year time dummies

I.C.T. etc. = manufacturer dummies

and what we are seeking is some indication of an improvement in the performance of the British industry post I.C.L. formation. To test for this we have regressed across all machines, equations of the form [1/]

$$\text{Log } P = \alpha + \beta\ \hat{\text{Log}}\ P + D_1 \ \ldots \ D_n$$

on different data bases. In Table 1 equation 1 we show the results of

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1/ These regressions are best termed descriptive regressions.

fitting this form across all manufacturers (except I.B.M. of course). The time dummies do not show any significant[1/] pattern and only the G.E. manufacturer dummy is significant. (Its positive sign indicates that G.E. machines were more expensive than those of other manufacturers). The significant constant and term in $\hat{\text{Log P}}$ imply that the prices of other manufacturers' machines relative to those of I.B.M. vary with size of machine.

Disaggregating we look at Honeywell/G.E. in equation 2. The significant G.E. dummy again appears but now the non-significant constant and the coefficient on $\hat{\text{Log P}}$ not different from unity implies that the Honeywell prices are very close to those of I.B.M. An inspection of the time dummies as they stand indicates very little except possibly a change in sign post 1967. This is taken account of in equation 3, where although the constant is not significantly different from zero the dummy (1960-67) is significantly different. The reasonable R^2 and the significance pattern implies a worsening in Honeywell performance with respect to I.B.M. post 1967, such that pre 1967 Honeywell prices were lower than those of I.B.M. but with machines introduced post 1967 it came into equality with I.B.M. No evidence can be found that Honeywell/G.E. performs better than Honeywell before the merger but the pre-merger Honeywell pattern seems to be dominant.

When we turn to Burroughs' machines (equation 4) there is a different pattern emerging. The constant is now significant, the coefficient on $\hat{\text{Log P}}$ is no longer unity and no significant pattern can be attributed to the time dummies. Improvements with respect to I.B.M.

1/ In all the Tables significance at the 95% level is indicated by an asterisk.

Table 1

$$\text{Log } P = \alpha + \beta \text{ Log } \hat{P} + \sum_i \gamma_i D_i$$

	All manufacturers		Honeywell G.E.		Honeywell/G.E.		Burroughs		British	
	coeff.	t	coeff.	t	coeff.	t	coeff.	t	coeff.	t
	1		2		3		4		5	
Constant	0.849	4.790*	-0.167	-0.664	0.064	0.325	1.439	5.590*	1.453	5.865*
Log $\hat{P}$	0.665	11.496*	1.037	10.173*	1.060	10.94*	0.497	3.976*	0.462	5.187*
1960	-0.206	-0.594	*				*		-0.464	-1.253
61	-0.465	-1.357	-0.471	-1.585			*		*	*
62	-0.015	-0.068	-0.075	-0.253			-0.180	-0.578	-0.272	-0.739
63	-0.002	-0.016	0.434	1.837			-0.275	1.156	-0.150	-0.684
64	-0.329	-2.473*	-0.187	-1.168			-0.410	-1.111	-0.532	-2.475*
65	*		*				*		*	
66	-0.202	-1.551	-0.236	-1.545			*		-0.323	-1.548
67	-0.278	-1.695	-0.575	-2.456			*		-0.177	-0.767
68	-0.117	-0.861	0.128	0.769			-0.345	-1.243	-0.137	-0.593
69	-0.015	-0.114	0.305	1.531			-0.174	-0.524	-0.081	-0.383
70	-0.256	-1.643	-0.273	-1.663			*		-0.047	-0.172
71	+0.121	-0.770	0.310	1.512			-0.092	-0.284	+0.073	0.277
72	0.262	1.921	0.308	2.149*			-0.018	-0.062	0.127	0.338
73	-0.242	-1.525	0.108	0.530			-0.871	-2.387*	0.162	0.538
74	-0.291	-1.339	*				*		-0.359	-1.383
75	-0.199	-0.749	*				*		-0.017	-0.052
60-64										
60-66										
60-67					-0.282	-2.196*				
60-68										
70-75										
I.C.T.										
I.C.L.										
Ferranti										
Leo										
E.E.										
Eliott										
G.E.	0.278	2.341*	0.510	4.799	0.487	4.519*				
British	0.101	1.182								
Honeywell	-0.151	-1.694								
R^2	0.677		0.835		0.697		0.887		0.664	
$\hat{R}^2$	0.629		0.780		0.681		0.813		0.561	
N	146		57		57		24		65	

are not noticeable. Similar conclusions can be drawn with respect to British machines (equation 5). We thus seem to have two groups of manufacturers, I.B.M. and Honeywell and Burroughs and British, the main difference being how prices relative to I.B.M. vary as size of machines vary (more on this below). However we must investigate the British sector further (this being our main concern). In Table 2 a number of regressions covering the British sector are presented. Equation 1 adds manufacture dummies to Equation 5, Table 1. The constant and $\hat{\text{Log}}$ P are again significant as is the Ferranti dummy. In the time dummies there seems to be a change in sign post 1967 although no real significance attained by these dummies. As can be seen from equation 2 a significant first generation dummy can be introduced also giving us a significant Elliott dummy. The significance and sign of the first generation dummy indicates some worsening post 1964. The addition of a dummy to cover I.C.L.'s formation (allowing a 2 year gestation lag) 1970-1975 (equation 3) does not affect these results but is insignificant. The only hint of any change in performance by I.C.L. over its forerunners is the change in sign (from negative to positive) of the post 1967 dummies in equation 1 implying a worsening of performance. This is made explicit in equation 5. However even if we drop all time dummies there is no real improvement in the performance of the I.C.L. dummy (equation 4). In fact relative to Elliott (although not I.C.T. or E.E., or other firms especially Ferranti) I.C.L. was performing worse.

The main worry with these results is that the British and Burroughs results indicate prices very different from those of I.B.M. Thus in Table 3 we have another set of regressions where we constrain

Table 2

$$\text{Log } P = \alpha + \beta \hat{\text{Log}} P + \sum_i \gamma_i D_i$$

British Sector only

	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
	1		2		3		4		5	
Constant	1.473	6.435*	1.247	8.516*	1.256	8.403*	1.193	7.931*	1.217	6.363*
$\hat{\text{Log}}$ P	0.435	5.496*	0.509	7.693*	0.505	7.410*	0.499	7.267*	0.524	7.113*
1960	-0.195	-0.563								
61	*	*								
62	0.028	0.084								
63	-0.206	-1.062								
64	-4.20	-2.063*								
65	*	*								
66	-0.172	-0.887								
67	-0.094	-0.433								
68	0.035	0.156								
69	0.253	0.751								
70	0.317	0.808								
71	0.422	1.104								
72	0.489	1.088								
73	0.523	1.292								
74	-0.017	-0.045								
75	0.397	0.094								
60-64			-0.217	-2.389*	-0.217	-2.366*				
60-67					0.045	0.387				
70-75									-0.172	-1.266
I.C.T.										
I.C.L.	-0.304	-0.940	0.022	0.192	-0.003	-0.030	0.101	0.906		
Ferranti	0.688	3.052*	0.639	2.931*	0.642	2.919*	0.500	2.288*		
Leo	0.228	1.214	0.257	1.465	0.257	1.457	0.257	1.414		
E.E.	-0.135	-0.906	-0.081	-0.718	-0.079	-0.698	-0.078	-0.663		
Eliott	-0.257	1.914	-0.321	-2.882*	-0.320	2.854*	-0.337	-2.923		
R^2	0.685		0.714		0.714		0.685		0.561	
$\hat{R}^2$	0.652		0.678		0.673		0.652		0.547	
N	65		65		65		65		65	

the coefficient on $\hat{\text{Log}}$ P to unity by making the dependent variable Log P - $\hat{\text{Log}}$ P. 1/ Starting with Honeywell in equation 1 we see the same pattern as above (not surprising given the coefficient on $\hat{\text{Log}}$ P) with a worsening position post 1967 and a G.E. dummy showing higher prices for G.E. machines. In equation 2 we introduce the 60-67 dummy explicitly to show the change in performance. In equation 3 Burroughs is covered, but as is to be expected this equation has a lower R^2 than that found above (although not strictly compatible). The significant constant implies prices higher than I.B.M. but the time dummy pattern shows no real improvement vis a vis I.B.M. over time at the 95% level however a number of dummy's are significant especially post 1968. This is illustrated in equation 4 where the 60-67 dummy is significant at 90% and the constant loses significance. However the difference in R^2 or $\hat{R}^2$ between 3 and 4 is quite large, indicating perhaps that 3 is better and no real improvement over time has been apparent.

Equation 5 covers British machines where we have a significant constant but no significant dummies (British machines continually higher priced than I.B.M. machines). In equation 6 two dummies for time are used only the first generation dummy being significant. The 70-75 dummy must of course overlap strongly with the I.C.L. dummy (only I.C.L. machines are introduced 70-75) its removal in equation 7 giving us a very marked improvement in the I.C.L. dummy. (In all these equations it might be noted that R^2's are low). In equation 7 we get the first

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1/ These regressions are equivalent to an analysis of variance.

Table 4

$$\text{Log } P - \hat{\text{Log}}\, P = \alpha + \sum_i \gamma_i D_i$$

	Honeywell/G.E.		Honeywell/G.E.		Burroughs		Burroughs		British		British		British		British	
	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t	Coeff.	t
	1		2		3		4		5		6		7		8	
Constant	-0.085	-0.733	0.007	1.24	0.871	2.847*	0.042	0.426	0.484	1.826	0.359	3.076*	0.359	3.087	0.213	2.9111*
1960	*				*				0.229	0.463						
61	-0.466	1.587			*				*							
62	-0.057	-0.192			-0.423	-0.978			-0.205	-0.413						
63	0.402	1.848			-0.519	-1.587			-0.291	-1.032						
64	-0.178	-1.137			-1.246	-2.880			-0.465	-1.572						
65	*				*				*							
66	-0.237	-1.566			*				-0.179	-0.638						
67	-0.594	-2.621*			*				-0.162	-0.517						
68	0.101	0.684			-0.699	-1.863			-0.027	-0.082						
69	0.301	1.530			-0.985	-2.628*			-0.201	-0.418						
70	-0.273	-1.676			*				-0.471	-0.860						
71	0.292	1.482			-0.653	-1.743			-0.036	-0.066						
72	0.314	2.222*			-0.644	-1.924			-0.230	-0.362						
73	0.092	0.465			-1.237	-3.502			-0.185	-0.323						
74	*	0.465			*				-0.327	-0.598						
75	*				*				-0.701	-1.227						
60-64											-0.260	-2.06*	-0.260	-2.064		
60-67			-0.281	-2.975*			0.299	1.947*								
70-75											-0.121	-0.07				
I.C.T.									*		*				*	
I.C.L.									-0.211	-0.450	-0.288	-1.727	-0.359	-2.572*	-0.212	-1.953*
Ferranti									0.391	1.212	0.397	1.321	0.397	1.326	*	
Leo									0.162	0.593	0.215	0.884	0.215	0.887	*	
E.E.									-0.278	-1.294	-0.236	-1.531	-0.236	-1.536	*	
Elliott									-0.370	-1.913	-0.379	-2.454*	-0.379	-2.463*	-0.342	-2.522*
G.E.	0.503	4.859*	0.485	4.733												
R^2	0.623		0.311		0.604		0.147		0.342		0.247		0.239		0.109	
$\hat{R}^2$	0.510		0.285		0.392		0.108		0.641		0.155		0.161		0.080	
N	57		57		24		24		65		65		65		65	

indication that I.C.L. machines are an improvement over its forerunners vis a vis I.B.M. although not significantly different from Elliot machines. This conclusion can still be stated at a 90% level of significance if we remove all other time dummies and manufacture dummies apart from Elliott (equation 8). At last we have isolated an improvement effect due to I.C.L.

To summarise, in these regressions we have only been able to find a slight hint of any change in the performance of the British industry post merger and then in equations with low R^2 and no account taken for any gestation period for improvements in machines. The major theme running through the results is that the British industry over the last fifteen years has at least managed to keep pace with the American companies especially I.B.M. but there is no strong evidence that the merger activity has led to any change in its relative performance.

Interpretation

In the interpretation of the result that the British industry has managed to hold its own in terms of price relative to the American companies we must face a number of problems :

a) What should the counter factual be?
b) Is our quality measure reasonable?
c) Are the price/quality relations a good measure to use?

We consider each of these in turn. The counter factual is always a problem, in the present case it would be tempting to say that

the performance of the British industry post 1968 without mergers would have been (relative to the U.S. companies) as it was pre 1968 and thus the merger made no difference. This however is too simple. The four factors affecting the rate of innovation can be summarised as technological opportunity, competitive pressures, efficiency in R & D and financial resources available. Technological opportunity was not a barrier to innovation post merger because (as we argue below) I.B.M. appears to undertake protective R & D (developing unmarketed innovations) and as their perceived performance is the same as the British industry better performance was a possibility for the British industry. Thus technological opportunity was not a barrier to faster progress, and our initial impression is not affected. On the competitive pressure side, it must be argued that the main competitors pre and post 1968 were the U.S. companies so the merger made no difference here. The initial impression again is not affected. Thus if our counter factual is going to be at all different to the pre 1968 performance the arguments must rest in the last two areas. The reason for supposing that the pre 1968 performance projected forward does not represent a fair counter factual are that :

1) The cost of developing a range of fourth generation machines (e.g. ICL 2900 series) to replace those of the third (e.g. ICL 1900 series) is much greater than that required to replace the second generation machines.

2) The funds for this development of fourth generation machines are of a size (estimated for ICL at £160m. 1/) that they have in the

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1/ Computer Weekky 12.7.73.

British case to come from the British Government. 1/ It is not really conceivable that the U.K. government would have supported the efforts of a number of U.K. companies all attempting to develop new machines. Only once it merged could the government support be forthcoming. It must be in this area that the merger is of prime importance. At the same time it must also be the case that only in the merged firm could the British industry hope to obtain a return on R & D expenditure of any reasonable size. The non-merged industry as a whole would have to have had higher total R & D to generate the same results, and even with the same efficiency as the merged company, competing against the U.S., could not have expected a much larger market share and thus no larger current profits from which to finance and obtain a return on R & D.

Unfortunately we are not able to isolate 'the advantages which, .. are as a matter of fact secured only at the monopoly level', specifically any increase in efficiency of the research process with greater size. We have however argued that only at the merged level could the U.K. computer industry continue to show its pre-1968 performance.

1/ Between 1968 and 1975 ICL received £50.4m. from the British Government and the benefit of a 'Buy British' government procurement policy.

The second area of contention we raised earlier was as to the strength of our quality measures. The main point one must make here is that we have excluded any software performance indicators. This is primarily on the grounds of data shortage. The main problem with this omission is that there is an opinion in this industry that IBM software is better than that of other companies. This may lead to bias in the results. To counter this however, a) the cycle times used in our regressions require software backing thus some software performance is included, b) post 1968 the amount of software supplied by manufacturers with their machines has changed (they 'unbundled') so that in later years much less was supplied and, c) much of the software is peculiar to each user. All in all therefore it is felt that any bias introduced would be minimal.

The last point to discuss is the crucial one. Are price/quality comparisons a good method to use? This essentially requires an answer as to whether changes in prices are totally due to technological change, and/or does any technological change take place that is not reflected in prices?

Taking this latter point first, there is some indication that IBM undertakes protective R & D, i.e. it invests sums in order to develop new technologies that will only be marketed when it is challenged by a competitor. The evidence for and reasoning behind this phenomen is further discussed in Stoneman {1976}. The true extent of this expenditure cannot be accurately gauged but it does throw doubt on our results as to the success of the ICL merger.

Returning to the bigger question of whether technological change will be reflected in prices, if it is not then it must be reflected in profits. However we run into the problem that many factors affect profits not the least being scale economies, differential wage levels, prices paid for inputs etc. Moreover with multinational companies there are great difficulties in sorting out profit centres. We cannot therefore perform a meaningful exercise of comparative profitability over time. However, in Table 4 some data (taken from Extel) on Profit/Turnover ratios is presented. Realising all the difficulties the performance of ICL in terms of profitability seems to have stood up quite well with respect to the U.K. operations of I.M.B. and Burroughs. We can argue from these figures that the performance of ICL found above was not the result of profit reduction, nor were IBM and Burroughs taking increased profits from technological advance, although the absolute levels of the Profit/Turnover ratio is lower in the British sector.

Table 4. Profit/Turnover ratio

Year	ICL	IBM(UK)[1]	IBM	Burroughs Corporation	Burroughs Machines Ltd.[1]
1965	x	x	.269	.074	.155
1966	x	x	.248	.110	.177
1967	x	x	.243	.152	.118
1968	x	.274	.271	.137	.167
1969	.060	.281	.275	.132	.244
1970	.067	.292	.268	.150	.224
1971	.078	.212	.248	.144	.177
1972	.022	.196	.259	.146	.053
1973	.065	.194	.268	.165	.053
1974	.061	.176	.271	.168	.028

1. Covering the British subsidiary of the U.S. parent companies.

Source : Extel. All profits are pre-tax. Honeywell is excluded because its profit and turnover figures include a large non-computer element.

Although it is felt that there are no major objections so far to our analysis that stand up to rigorous inquiry it could be suggested that our results need further support. Two areas of approach open up :

a) The analysis of patent data

b) An analysis of market share data

A detailed investigation of patent applications is not really feasible for the 1960-1975 period, and even if it were there must be some qualification to any results because it is not really clear whether patents are an input or an output of the research process and thus whether they represent a good indicator of success in research and development. However there is a very significant quote by ICL that indicates that the British industry's performance with regard to patents has been the equal of IBM's.

> "we have been able for many years successively to renew our patent agreement with IBM on the basis of no payment. We have been able to persuade them that we have sufficient value in patents to justify them making available to us all their patents without money being exchanged". (SCST {1970}, para. 874 p.157).

The final indicator of performance that we can look at is market shares. One would expect that the company with technological superiority could increase its market share. In Table 5 some data on market shares is presented. The problem with drawing any conclusions on the basis of this data are that the U.K. government has a 'Buy British' policy (although one can get over this problem by data disaggregation) and that compatability is of over-riding importance in

computer selection. This latter point at the simplest level means that if a firm has an IBM machine with IBM based software, its computing costs are much lower if that software can be used on the next machine purchased, and thus it has an incentive to buy an IBM compatible machine.

Table 5. Market Shares.

	Year % market shares by notional value					
Manufacturer	1966	1967	1968	1969	1972	1973
ICL (ICT, E.E. etc. pre 1968)	34.4	32.4	41.0	49.4	34.7	32.9
IBM	43.2	42.5	23.4	27.7	38.4	39.7
Burroughs	3.9	1.3	6.4	3.0	3.9	3.7
Honeywell	5.8	6.9	5.4	7.9	7.0	7.0
Others	12.7	16.8	23.8	12.0	16.0	16.7

Sources : Various reports of the Department of Trade and Industry to the Select Committee on Science and Technology 1969-1974.

These figures of course show year by year variation but no strong trends on which to base any conclusions.

The overall conclusion that the main body of work and these peripheral comments imply is that the U.K. computer industry has been able to hold its own against the U.S. companies. It should however be

noted that this must be modified to take account of any possible protective R & D taking place in the non-U.K. sector. We have argued that this performance could not have been maintained if the British industry had not merged in 1968. However perhaps of as much significance is that this performance has been achieved in a situation where IBM spends more on R & D than ICL's total turnover. 1/ The efficiency of their R & D process is therefore of commendable quality.

1/ ICL's R & D expenditure between 1969 and 1971 was £45m. in 1969 IBM spent $288m., in 1970 $300m., its budget for 1972/3 was $500m.

BIBLIOGRAPHY

C.C.L. (62-74) Computer Consultants Limited, British Commercial Computer Digest, 1962-1974. Pergamon Press.

Griliches (1971) Z.Griliches, Price Indexes and Quality Change, Harvard University Press, Cambridge, Mass. 1971.

I.D.C. (61-74), International Data Corporation, Computers and Automation, 1961-1974.

Schumpeter (1942), J.A.Schumpeter, Capitalism, Socialism and Democracy, Harper, New York, 1942.

S.C.S.T.(1970) Select Committee on Science and Technology, U.K.Computer Industry, Vol. II, H.C.272 (Session 1969-70). H.M.S.O.1970.

Shirley (1969), D.Shirley, Choosing a Computer, Business Publications Limited, London, 1969.

Smythe (1970, 75), C.Smythe, Choosing a Computer, Business Publications Limited, London, 1970, 75.

Stoneman (1976), P.Stoneman, Technological Diffusion and the Computer Revolution, D.A.E. Monograph No.25, Cambridge University Press, 1976.