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The UK electronics manufacturing industry 1997–2003: a case study of the effect of globalization

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The manuscript was received on 23 August 2004 and was accepted after revision for publication on 27 February 2006.

DOI:10.1243/09544054B13704

Abstract: Statistical data and information from industry interviews are used to build a picture of the implications of, and responses to, globalization in the key industry of electronics contract manufacturing in the UK. A comprehensive list of companies in the sector with associated employment and turnover data has been created from a variety of sources. Comparison of 2003 data with a 1997 dataset produces a unique longitudinal statistical picture of the industry over a period marked by the increasing influence of globalization. Total employment in the industry has decreased by 39 per cent from approximately 37 600 to 23 100 between 1997 and 2003. This breaks down into a decline in the printed circuit board (PCB) manufacturing subsector of 61 per cent, from 16 300 to around 6400, and a much smaller decline in the printed circuit board sub-contract assembly (PCBA) subsector of 22 per cent, from approximately 21 400 to 16 700. There has been a major shift in employment distribution away from large companies. Interview results indicate that the loss of large company capacity may have strategic implications for future technological capability. However, the UK is seen as a source of innovation and retention of strong engineering skills is key to bringing new products to the market.

Keywords: electronics manufacturing, employment statistics, globalization, offshore manufacturing, longitudinal study, contract manufacturing

1 INTRODUCTION

The current paper reports a study of the UK electronics manufacturing industry, in particular contract manufacturing service providers, over a period marked by the increasing influence of globalization. Contract electronics manufacturing (CEM) is of pivotal importance to wider manufacturing because the electronics content of consumer and industrial products continues to increase. For example the average electronics content of a modern car is 22 per cent by value [1]. In addition the results are of general interest as a case study of trends in mature, technology-based industries in western economies.

Electronics original equipment manufacturers (OEMs) are increasingly outsourcing the manufacturing of their products [2]. The main two types of

electronics contract manufacturing service providers are printed circuit board (PCB) manufacturers and sub-contract assemblers (PCBA). The PCB is the backbone of most electronic products, acting to support and make electrical interconnection between the electronic components attached to it. PCB manufacturers make the bare boards, to a design supplied by the customer. PCBAs attach electronic components to the board to make it into a functioning circuit.

In this study a unique longitudinal statistical picture was obtained by comparing data collected on PCB and PCBA companies in 2003 with the data collected in a 1997 survey of the same categories of company [3, 4]. To provide context for and to tease out factors underlying the statistical picture, interviews were carried out with senior managers of selected PCB and PCBA companies.

The background to the interviews was an opinion commonly voiced within the industry, at the time of the 2003 survey, that electronics manufacturing in the UK was in catastrophic decline. The electronics industry is notoriously cyclical but the

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perception was that there would not be a recovery for the UK industry from the then current downturn. The respondents were asked directly for their own view of the likely shape of the industry in the future and on the strategic implications of decline, and to identify factors promoting retention of manufacturing capacity in the industry within the UK. Complementary questions on the company itself were asked to provide background for the views expressed.

In the present paper the quantitative data from the two surveys and the qualitative data from the interviews are presented and compared. Conclusions are drawn on the strategic implications for the industry and wider UK manufacturing.

2 BACKGROUND

Data from a previous study [3] represent the situation in the third quarter of 1997. The study characterized the UK industry as a small number of high-profile companies supported by a large number of small companies. A concern was identified that the small companies would not be able to keep pace with the rapid rate of technological change in PCB/PCBA technologies. A complicating factor for the comparison of 1997 and 2003 data is the rapid decline of the global telecommunications and information technology sectors after a peak in about 2001. This is illustrated in Fig. 1, from which the volume of production by price for the whole of UK manufacturing and for the electrical and optical sector may be compared.

The market space for electronic manufacturing may be characterized by volume and product complexity as illustrated in Table 1. In general, low-volume, high-added-value products are more resistant to the trend to sourcing offshore because it is harder to compare like for like (reduced market transparency), and because they are less cost sensitive. However, a recent position paper issued by Intellect [5], a major UK electronics industry trade body, asserts that medium-volume electronics manufacturing in the UK is in the process of migrating offshore while high-volume electronics has already migrated. The approach suggested in the position paper is to concentrate on retaining design functions, rather than manufacturing capacity, in the UK.

2.1 Sub-contract assembly and electronic manufacturing services (EMS)

The trend in electronics manufacturing is away from vertical integration towards outsourcing of assembly of circuit boards, and increasingly to outsourcing of the entire manufacturing operation from design for

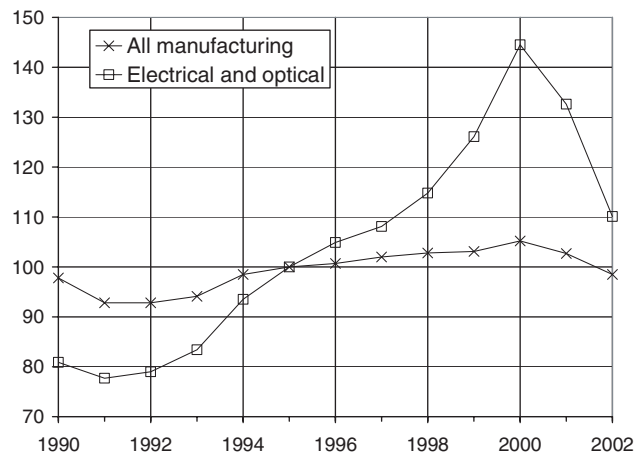


Fig. 1 UK index of volume of production by price (1995 = 100). (Source: Index of Manufacturing, Office of National Statistics, UK.)

Table 1 Characteristics of the market space for electronic manufacturing (DTI, 1998)

	High complexity	Low complexity
Low volume: high uncertainty, significant interaction with the customer	Super value capital goods: defence electronics, avionics, science based – semiconductor equipment, equipment based – ECAD software tools, test equipment, telecommunications infrastructure	Jobbing or fashion goods: software, games
High volume: high automation	Fast-moving consumer goods: microprocessor fabs, computers and peripherals, OEMs	Commodities: memory fabs, sub-contract assemblers

manufacture, to procurement, test, delivery to the end customer, after sales service, and even recycling [6]. The term for such outsourced manufacture is 'electronic manufacturing services' (EMS). This term is replacing the older CEM and is seen to capture value-added engineering services in addition to assembly processes. The PCBA companies interviewed for this study all preferred to describe their activity as EMS.

3 METHODOLOGY

3.1 Justification of methodology

This study combines a quantitative survey of employment numbers with qualitative data from interviews with senior managers of representative companies in the survey group. In addition the employment data are combined with publicly available data on company turnovers to make an estimate of the total turnover of the industry in the UK.

Employment was chosen as the statistic for the quantitative study to describe the condition of the industry because it is strongly correlated with other measures such as turnover or sales figures, while being more readily determinable. Turnover figures are not reported by all companies, particularly smaller enterprises, and while some sales figures are collected by industry associations they are not made publicly available. By contrast in this study employment numbers at individual companies were obtained by a simple telephone survey. The employment figures were compared with those from a similar employment survey conducted in 1997 to produce a longitudinal statistical picture of the industry.

The potential use in the study of government data from the UK Office of National Statistics, indexed by standard industrial classification (SIC) codes, was investigated and ruled out early on. SIC codes are a hierarchical classification system for manufacturing activity and companies are required to classify themselves by choosing a code in their annual return to the UK regulator. The UK Office of National Statistics releases national economic data broken down by SIC code. The publicly available economic data are broken down at a level too high to be useful to the study. The lowest level of breakdown includes electronic manufacturing only as part of electrical and optical manufacturing, and these are the data presented in Fig. 1. However, the SIC coding system was found to be inadequate to identify companies of interest because it does not reflect closely the structure of the electronics industry (see subsection 3.2.1 below). Hence even if the National Office of Statistics were to release data broken down to a greater level of detail, it would not have been of use in the current study.

The quantitative study was supplemented with a qualitative study consisting of interviews with senior managers of companies across a spectrum of the industry. This was not intended to be a comprehensive survey but rather to provide the context for the statistical data. A relatively small set of interviewees was therefore chosen from companies representative of different segments of the industry. The reasons for the choice are given in more detail in subsection 3.3.1 below.

3.2 Quantitative study

3.2.1 Identification of companies

As complete a list as possible of all manufacturing sites in the UK currently undertaking PCB and PCBA activity was compiled. Companies were identified from a variety of sources, including the list from the 1997 study [3, 4], printed and online catalogues, trade magazines, and lists supplied by major trade

associations and industry contacts. Open access data sources included: The Electronics and Electrical Buyers Guide (CMP Data and Information Services); www.applegate.co.uk (online business directory); and the Electronics Manufacture and Test Contract Users Guide (UK trade magazine). Internet searches were also conducted for individual company websites.

The catalogue entries and websites of the companies were examined to categorize their activity as PCB, PCBA, both, or to exclude them from the list. Companies not actually manufacturing (e.g. agents) were rejected. Additionally capacity in vertically integrated companies used solely for their own products was not counted. Individual manufacturing sites for each company were resolved where possible and given separate entries on the list. The records of the companies on a commercial database (FAME, Bureau van Dijk Electronic Publishing) were also examined. This database derives mostly from firms' annual returns to the UK company registrar Companies House. An alternative approach of identifying companies from their SIC code on FAME was also tried. The codes were found to be not specific enough to identify a company's activity beyond being within the general area of electronics manufacturing, with over 7000 companies falling into this category.

3.2.2 Employment figures survey

A telephone survey of all sites that passed the vetting procedure was undertaken in April 2003 in order to obtain employment numbers for each site. It was found that this information was readily given in nearly all cases. An added benefit of the survey is a high level of confidence that most companies on the list were actually in operation in April 2003. Respondents were asked for the number of employees on-site, including part-time and contract workers, and to classify the activity undertaken on-site as PCB, PCBA, both, or neither. Where a site undertakes both PCB and PCBA, 50 per cent of the employee number given was attributed to the PCB activity and 50 per cent to PCBA. Advice from industrialists is that PCB is more labour intensive than PCBA, so the 50:50 split would tend to be an underestimate of the PCB numbers. However, the number of employees affected is small, at 7.8 per cent of the total 2003 figure.

3.2.3 Compensation for underestimation in the 1997 study

The coverage of companies in the sector in the 2003 study might be expected to be more complete than that for the 1997 study, because of improvements in electronic sources of information, in particular

the number of companies having websites on the internet and the growth in online databases. Evidence of this increase in coverage was given by the discovery of a small number of companies in 2003 which, on examination, were shown to have been in existence in 1997, but which had not featured in the 1997 database. It was not possible in these cases to obtain accurate employment figures for these companies, but it was clearly critical to obtain an estimate of employment within these firms to improve the accuracy of longitudinal comparison.

The estimation is based entirely on the data from the 1997 and 2003 studies. The 1997 dataset is treated as a representative sample of all the CEM companies existing in 1997. The change between 1997 and 2003 in the total numbers employed by these companies (or their successors) is obtained from the 2003 dataset. The total number of employees at all companies existing in 1997 can then be extrapolated from the change in employment in the sample. The derivation of the equation used for the estimation is presented below.

It is assumed that the percentage change between 1997 and 2003 in the total number of employees at the companies in the 1997 dataset, is the same as the percentage change in the total number of employees at all CEM companies existing in 1997. This assumption may be written as

$$T_{1997}^L/T_{1997} = S_{1997}^L/S_{1997} \quad (1)$$

where T_{1997}^L is the true number of employees lost from the CEM industry between 1997 and 2003, T_{1997} is the true total of employees employed in the industry in 1997, S_{1997}^L is the number of employees lost between 1997 and 2003 from manufacturing sites owned by companies identified in the 1997 study, and S_{1997} is the total number of employees at companies identified by the 1997 study, in 1997.

Now the total number of employees employed in CEM companies in 2003 is just the total number in 1997, less the number of employees lost, plus the number of new jobs created at new companies, i.e.

$$T_{2003} = T_{1997} - T_{1997}^L + N \quad (2)$$

where N is the total number of employees at new companies set up after 1997.

Finally by substituting for T_{1997}^L in equation (2) and re-arranging, the following is obtained

$$T_{1997} = \frac{(T_{2003} - N)}{(1 - S_{1997}^L/S_{1997})} \quad (3)$$

Equation (3) was used to estimate the total employment in the industry in 1997.

Manufacturing sites were classified by examining company records on FAME and company websites. The histories of companies were traced, where necessary, to determine whether a particular manufacturing site belonging to a company in the 1997 dataset was still in operation. New companies were considered to be those operating under both a new name and from a new geographical site. For example, sites formerly belonging to liquidated companies, but still operating under a new name, were not considered to be new. Where companies were still operating but had moved away from PCB/PCBA activity the jobs were considered to be lost.

3.2.4 Estimation of turnover

Smaller companies in the UK do not have to supply turnover figures in their annual returns. There were figures for 21 per cent of sites having 49 employees or fewer, and figures for 52 per cent of sites having 50 employees or more. A power law was fitted by least-squares to the available turnover versus site size by employee number data, for each activity type, as shown in Fig. 2. The PCB (PCBA) power

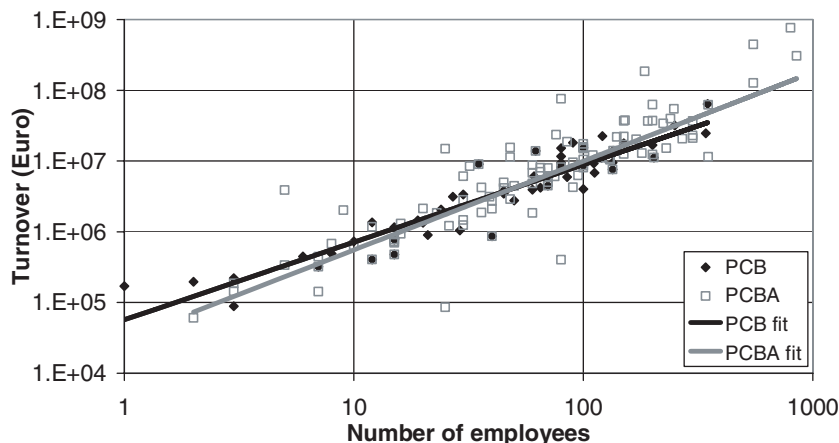


Fig. 2 Graph of company declared turnover figures versus employee numbers from the 2003 study by activity type. The lines are power law fits

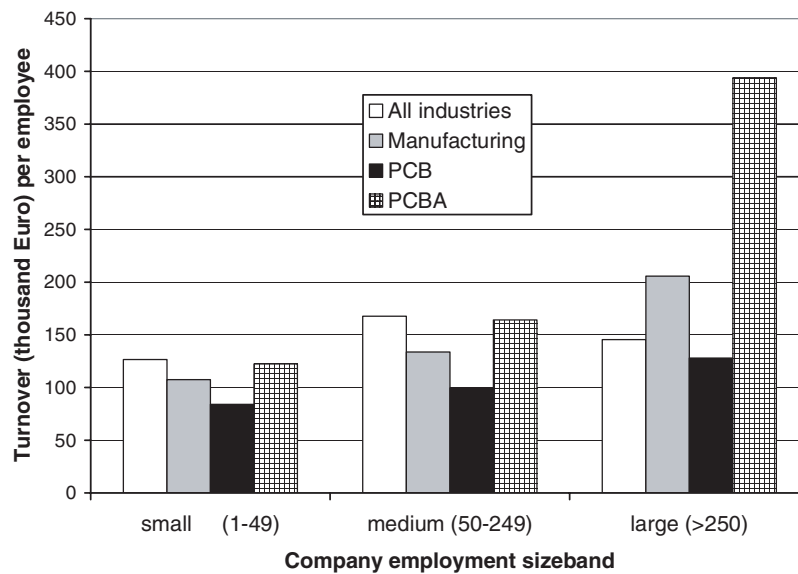


Fig. 3 Turnover per employee for various categories of UK company

law fit was used to estimate a figure for companies undertaking PCB (PCBA) activity and not declaring their turnover.

To validate this method of estimating turnover, turnover per employee statistics broken down by company sizeband are presented in Fig. 3, for all UK companies and UK manufacturing sector companies [7], and for the PCB and PCBA companies of Fig. 2. Both the PCB and the PCBA subsectors follow the trend for manufacturing-based companies of increasing turnover per employee with increasing company size. However, the trend is more marked for the PCBA subsector, hence the use of separate power law fits in the estimation procedure. The methodology was reviewed by an industrial steering board to the study, comprising senior industrial figures, who considered the difference in the turnover per employee trends for the PCB and PCBA subsectors to reflect the fact that PCB manufacture is more labour intensive than PCB assembly.

3.3 Qualitative study

3.3.1 Selection of interviewees

As is described in the results section below, analysis of the statistical data in this study shows strong shifts in the distribution of employees between large and small companies, and between the PCB and PCBA subsectors. In addition, as has been stated in section 2 above, the pressure towards moving manufacturing offshore is expected to be greatest for high-volume production, i.e. larger companies. The perspectives of companies were therefore expected to differ according to their size. In order

to capture this, interviewees for the qualitative study were selected from small, medium, and large companies. One PCB and one PCBA company in each sizeband was chosen, again because companies in the two subsectors might be expected to have different perspectives, and because the economic fortunes of the two subsectors seen in the results of the statistical study have been markedly different. The choice of company within each class was guided by an advisory board to the study, comprising senior industrial figures, to ensure the company chosen could reasonably be expected to exhibit features representative of a large number of companies in its category. The interviews were carried out with senior managers of each company selected. All targeted companies agreed to be interviewed.

3.3.2 Interview structure

The interviews were targeted at answering the following research questions.

1. What have been the changes in the industry over the period 1997 to 2003? Is the perception of *catastrophic* decline, and pessimism over the future of the sector, justified?
2. What are the strategic implications for the wider UK manufacturing industry of the loss of onshore skills and capability in electronic manufacturing?
3. What factors are there promoting survival and growth of onshore capability in electronic manufacturing?

As has been stated in section 3.1, the interviews were seen as providing qualitative data to

complement the picture generated from the statistical data. In particular, the interviews served the purpose of ensuring that no major factors or developments over the period under study, that could influence the interpretation of the quantitative data, had been missed.

The interviews, lasting approximately an hour, were semi-structured and followed the protocol presented in Appendix 2. The interviewees were asked directly for their perceptions of the current state of the industry to address research question 1. Research questions 2 and 3 were addressed by a direct question on the interviewee's opinion of the likely future shape of the industry after emergence from the downturn described in section 2. Further data to address all research questions were elicited by a set of questions systematically covering factors affecting the interviewee's business. The factors were:

- (a) suppliers;
- (b) location;
- (c) customers;
- (d) technology changes;
- (e) offshore manufacture;
- (f) skills.

Each interview was attended by two researchers. The interviews were carried out on company premises and were recorded with the subject's consent. A written record was made from the recording for subsequent analysis.

3.4 Exchange rate

An exchange rate of 0.7 GBP to 1 Euro is used in this work.

4 QUANTITATIVE RESULTS

4.1 Numbers of manufacturing sites identified

The total number of manufacturing sites in the 2003 dataset was 402. A total of 142 sites undertaking PCB activity were identified, belonging to 138 companies. It should be recalled here that a single company may have more than one manufacturing site, and that one site may undertake both PCB and PCBA activity. There were 294 PCBA sites identified, belonging to 290 companies. For the 1997 dataset there were 334 sites, consisting of 169 PCB sites belonging to 165 companies and 188 PCBA sites belonging to 187 companies. The far larger number of sites identified in 2003 compared with 1997, despite the intervening manufacturing recession, is further evidence that there was an under-sampling in the 1997 study.

Table 2 Estimates of total employment in the industry in 1997

	S_{1997}	T_{2003}	S_{1997}^L	N	T_{1997}
Best estimate for T_{1997}	24 775	23 103	10 053	734	37 644
Estimate for T_{1997} assuming $N = 0$	24 775	23 103	10 053	0	38 879

4.2 Estimate and accuracy of estimate for 1997 employment figure

The total number of employees identified by the 1997 study, S_{1997} , was 24 775. The total number of employees identified by the 2003 study, T_{2003} , was 23 103. The total number of employees lost from sites identified by the 1997 study between 1997 and 2003, S_{1997}^L , was 10 053. The number of employees in 2003 at companies identified as having started up after 1997, N , was 734. These figures are summarized in Table 2. Inserting these figures in equation (3), the estimate for the total employment in the industry in 1997, T_{1997} , obtained is 37 644. This implies that 34 per cent of employees in the industry in 1997 were missed by the 1997 study.

The major probable influence on the accuracy of the estimate for total employment in 1997 is the efficacy of the procedure by which manufacturing sites and companies in the 2003 list were classified as new, i.e. having started up between 1997 and 2003, rather than existing in 1997 and having been missed by the 1997 study. In fact the size of any error from this source is likely to be small. Setting $N = 0$ in equation (3), i.e. assuming no new companies started up between 1997 and 2003, yields an estimate for T_{1997} of 38 879, only 3 per cent higher than the best estimate above.

Equation (3) was only used in the estimate of the *total* number of employees in the industry. The relative *proportions* of numbers of employees in the PCB and PCBA sectors, and in each of the company employment sizebands, found by the 1997 study are used in the comparisons between 1997 and 2003 presented below. From the estimate above, the 1997 study appears to have covered 66 per cent of employees in the industry. Therefore, the assumption that the proportions of numbers of employees found by the 1997 study was representative of the industry as a whole seems reasonable.

4.3 Comparison between 1997 and 2003

The 2003 employment totals for the industry may be compared with the estimated totals for 1997 in Fig. 4. The headline figure is that total employment in the industry has decreased by 39 per cent from around 37 600 to approximately 23 100 between 1997 and 2003. This aggregate figure is mostly accounted for

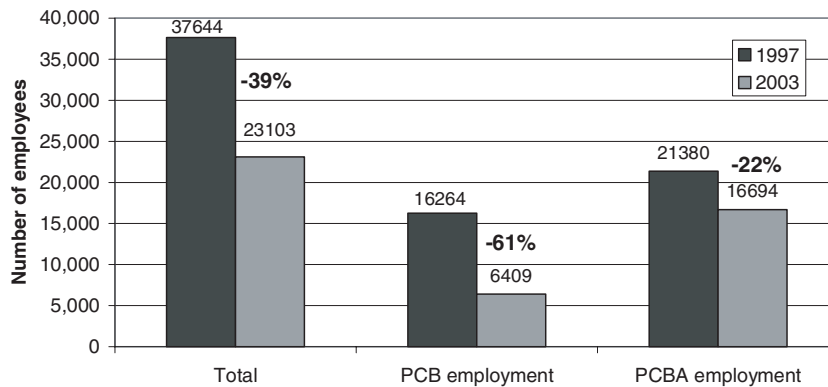


Fig. 4 Change in electronic manufacturing employment 1997–2003

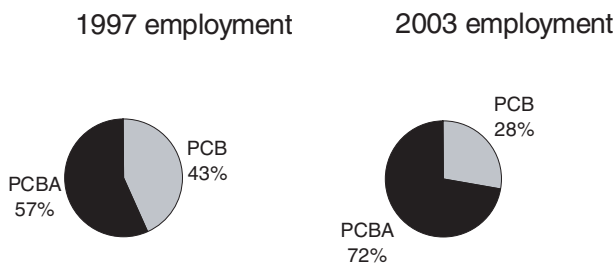


Fig. 5 Distribution of employment between PCB and PCBA sectors

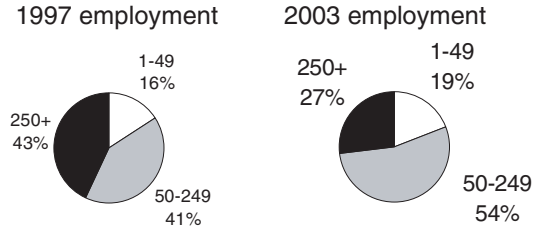


Fig. 6 Employment distribution by size of site (number of employees at site)

by a decline in PCB employment of 61 per cent, from around 16 300 to approximately 6400. As a consequence the distribution of employment between the PCB and PCBA sectors has shifted from close to equal in 1997, to PCBA employing more than double the numbers in PCB in 2003, as shown in Fig. 5.

The PCBA sector by contrast has experienced a much smaller decline in employment of 22 per cent, from around 21 400 to 16 700. This is despite large, high-profile reductions in the UK capacity of major EMS multinationals such as Celestica and Solectron since 1997. In fact there has been a shift in the whole industry in employment distribution away from large sites (250 employees or more) as the majority employer in 1997, to medium sites (50–249 employees) as the majority employer. The shift can be seen in Fig. 6. This trend to smaller company sizes is a matter of strategic concern for the UK, as voiced by the interview respondents

and described in the qualitative results section of this work.

4.4 Estimated turnover for 2003

The total turnover estimated for the whole industry in 2003 is €4.0 billion, of which €0.6 billion is from PCB activity and €3.4 billion from PCBA activity. Figure 7 also shows the contributions from sites of different sizebands by employee number. The majority of sites for which turnover has been estimated are those of 49 employees or fewer, and the contribution to the total turnover from such sites is small at about 8 per cent. By far the greatest contribution is from companies having more than 249 employees, at 58 per cent of the total. The loss of large companies therefore has a disproportionate effect on the total turnover of the industry, as reflected in the turnover per employee statistics in Fig. 3. It should be noted that the true figures for turnover corresponding to activity actually taking place in the UK are likely to be smaller than those in Fig. 7, because published turnover figures do not discriminate between onshore and offshore activity. An example is PCB companies offering offshore procurement as reported in section 5 below.

5 QUALITATIVE RESULTS

5.1 Companies interviewed

Over the period of March–June 2003, interviews were carried out with senior managers of one small, one medium, and one large PCB company, and similarly for PCBA companies, making six interviews in all. Brief profiles of the companies interviewed are presented in Table 3. ‘Box build’ for the PCBA medium company refers to manufacture of fully integrated systems or subsystems incorporating assembled PCBs.

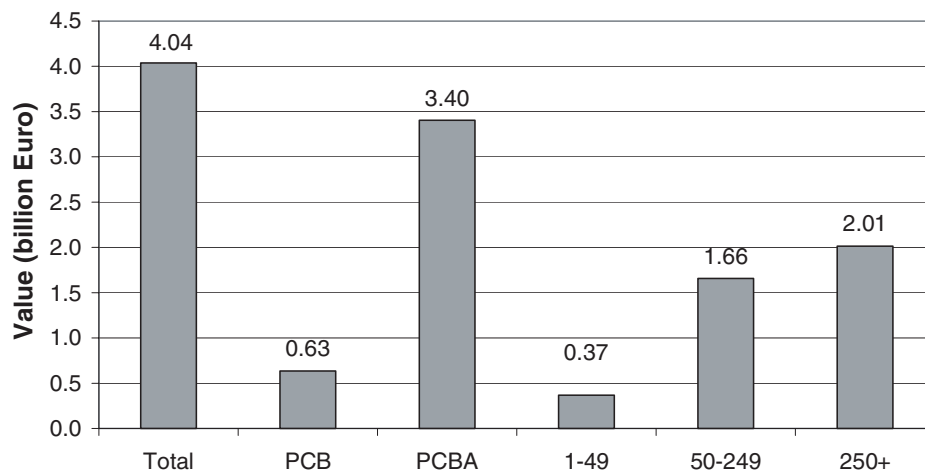


Fig. 7 Estimated turnover figure for the industry and contributions from: the PCB sector, the PCBA sector, sites of 1–49 employees, 50–249 employees, and more than 249 employees

Table 3 Sketches of the companies interviewed for the study

PCB small	27 employees London commuter belt
PCB medium	Specializes in prototyping for R&D 70 employees/€8.1M turnover English East Midlands Long-established company Offers offshore procurement from a factory in China
PCB large	542 employees/€41M turnover Three locations English Midlands and Northwest Non-standard materials/ low volume and medium volume
PCBA small	28 employees/€2.9M turnover English East Midlands Concentrates on exporter customers
PCBA medium	150 employees/€29M turnover English Midlands Complex box build low volume, e.g.: mass spectrometers
PCBA large	350 employees/€1261M (in 2001) turnover Two English Midlands locations Part of large multinational

5.2 Major themes

The interview responses can be grouped in four major themes that are closely linked to the research questions:

- underlying structural factors: the economic facts of life acting to drive production offshore or to retain it (research questions 1 and 3);
- current situation: the current situation of the industry as perceived by the respondents (research question 1);
- implications of current trends: strategic issues for the UK industry if current trends continue (research question 2);
- survival and growth factors for the UK onshore capability (research question 3).

5.3 Underlying structural factors

The comments in this section all come from the PCB respondents. Turnaround time, or the time a customer waits between ordering and receipt, emerged as one of the major criteria for determining whether manufacturing takes place in the UK or overseas. Eight days was quoted as the turnaround capability for offshore procurement from a factory in China. One respondent said that a 48 h turnaround capability from China would make the company's onshore manufacturing untenable, and that there is little to retain manufacturing onshore other than turnaround time and cost. Customer service, for example, can be undertaken by agents, who have low overheads. In addition, while there is no longer a large premium on the faster turnaround from onshore manufacture, there are additional costs owing to compliance with environmental legislation. On the other hand there are perceived risks of loss of intellectual property (IP) in manufacturing in the Far East.

5.4 Current situation

5.4.1 PCB sector

Two of the three respondents quoted a decline in the number of companies in the sector from 400–450 companies to 120–150 between 1997 and 2003. The figure in 2003 is close to the estimate from the survey reported here. A decline in turnover from €640M to €214M was also quoted. The turnover for 2003 estimated in this study, of €688M, is much larger. Sixty per cent of UK business is said by interviewees to have gone abroad. The UK market is segmented into four large (by UK standards) players and seven medium players, with the rest being small.

Interviewees said that most PCB companies are owner managed, employ fewer than 70 people, and have turnovers in the range €2.9M–€4.3M. This view is consistent with the survey results.

5.4.2 PCBA sector

Comments in the PCBA sector focused on the reduction of the UK capacity of large EMS multinationals. The two with the largest UK capacity are Celestica and Solectron, and both have been downsizing. Most recently, in the second quarter of 2004, Celestica announced closure of one of its UK sites [8]. One respondent compared the recent loss by Celestica in the UK of €71M of Sun Microsystems business with the turnover of three medium-sized PCBA companies. An estimate was given of 350 EMS companies having turnovers more than €0.36M. The figure is larger than the figure of 298 PCBA sites identified in the current survey, but possibly includes companies excluded for not assembling PCBs on-site. It is notable that all the PCBA respondents preferred, or aspired to, the description EMS for their company's activities.

5.4.3 PCB and PCBA sectors

Two of the PCB companies observed that there is no more room for efficiency savings in onshore PCB manufacture, so that companies can no longer compete on price alone. In fact most of the respondent companies have a strategic approach to customer selection. Several of the smaller PCB and PCBA companies believed that larger companies had suffered from over-investment to meet demand for telecommunications products before the market downturn.

Two of the interviewed companies in the PCB sector offer offshore procurement. Prototyping, design for manufacture, and testing are handled in-house with the facility to manufacture on-shore to cover any short-term hiatus in delivery. One of the companies perceived their 20 per cent mark-up to be much less than the historical agent mark-up. An eyewitness described the factory of a southern Chinese supplier as being well run and tidy and producing to high quality, but as discharging effluent directly into a stream in contradiction of its documented policy. The Chinese operation is more labour intensive, having four to five times the number of employees as the UK company for the same turnover. The large PCBA company organizes manufacturing on a global scale. The UK site undertakes 'gateway activity', taking a new product through the prototype stage and placing it for volume manufacture with a sister site in a low-cost region.

Most of the respondents, including the large PCBA company, reported that big companies are seeking the business of smaller companies. One interviewee

stated that this was not the case even one year previously. In the PCB sector all respondents expressed concern at the reduction in the supplier base. This point is discussed in more detail in section 5.5.

5.5 Implications of current trends

5.5.1 Loss of large companies

Several issues were raised concerning the strategic impact on the UK manufacturing capability of the loss of large companies. The large PCB company respondents expressed concern regarding a sector composed mostly of small companies, because small PCB companies lack the resources for the investment required to keep up with future developments in PCB technology and also do not have sufficient depth of technical knowledge to service large OEM customers. Defence and avionics customers are demanding and difficult for small companies to service.

In the PCBA sector, the complete outsourcing of manufacture means increasing requirements for post-manufacture and end-user services such as repair and end-of-life. Again, these are difficult for small players to supply. One respondent stated that OEMs like their business to be less than 25 per cent of the turnover of their EMS provider for reasons of security of supply. In practice this means a minimum turnover of €17M. The large PCBA company claimed their competitive edge to be advanced technology and engineering expertise, and related a case of a customer who moved from their existing EMS provider in order to take advantage of the advanced technology capability of flip-chip assembly. The large PCBA company also works closely with assembly line equipment manufacturers, and acts as a beta (pre-market release) testing site for new equipment.

Some specialist skills are in short supply, e.g. radio frequency (RF) engineers. A company needs a certain level of business to justify retaining specialist skills, although in an outsourcing model such skills can be bought in from specialist design houses. The background of many of the interview respondents was in the large, vertically integrated UK electronics sector OEMs such as GEC. With the disappearance of such companies in mind, the large PCB company respondents expressed concern as to where the next generation of engineers will come from. The company has identified universities as critical in this issue, and is already establishing partnerships for research and development.

5.5.2 Reduction in supplier base

Concerns about the reduction in the supplier base were identified by all the PCB sector respondents.

The suppliers have reduced in number through consolidation and often now have no UK base and are run from a base in mainland Europe. Offshore supply was seen as a strategic risk although no cases of interruptions of supply were identified. Technical support from chemicals companies is vital to PCB manufacture. The chemicals must be tested daily and any problems resolved quickly to avoid loss of production. The reduction in the number of sales representatives was seen as a loss of technical expertise available to a PCB company. A major chemicals supplier confirmed in a private conversation that the number of their sales representatives in the UK had dropped from 14 to 3. Chemicals companies also have a technology transfer role, for example in alerting PCB companies to, and helping them implement, new processes to comply with the recent European environmental directives on electronics waste and elimination of lead [9, 10]. It was also perceived that the focus of supplier companies is on low-cost manufacturing areas, and that Europe is not a priority.

5.5.3 Other issues

Concern was expressed at the idea that design could be retained in the UK even if manufacturing moves substantially offshore. It was believed that design would eventually follow. In the PCBA sector one respondent was of the opinion that an upturn in the market would see Far Eastern competitors lose interest in smaller-batch-size UK business, so that smaller companies may be forced to source onshore. The supply chain for offshore sourcing is also difficult to handle and may not be the cheapest option when a full cost analysis is made. This point is also made in the Intellect position paper [5] already referred to.

5.6 Survival and growth factors

A few niche areas are seen as likely to remain in the UK. Defence and avionics will remain for strategic and political reasons as has been previously stated. The respondent from the medium PCBA company specializing in complex box build said that their customers like the comfort factor of geographical proximity. This is because of the inevitable teething problems encountered in transfer of manufacture to the service provider. The respondent also said that product integration with complex electromechanical parts is hard to source offshore. Computer server customization, also referred to as 'last touch to customer', is now a significant and growing part of the activity at the site of the large PCBA company. The basic servers are made in low-cost areas, but there are many customer-specified options that

have to be configured in the UK because of the short lead times (five days) demanded by customers. An interesting detail in the military sector is offset trading. Offsets are onshore percentage of manufacture requirements placed by an ordering government on OEMs winning military contracts. Multinational EMS providers can switch production between sites to fulfil offsets to the advantage of its OEM customer, and the large PCBA site interviewed has an employee handling such arrangements almost full-time.

The large PCBA company has signalled a corporate commitment to retaining UK capacity. The UK is seen as a source of innovation and a UK presence enables early contact with high technology start-ups. The company invests engineering staff time in new products, to take them from concept to readiness for mass manufacture. The large PCB company operates a factory serving small OEMs for the same reason. It was notable that all three PCBA companies have a commitment to a strong in-house engineering capability. The large PCBA company also cited its UK recycling capability as a competitive advantage.

6 DISCUSSION

A discussion of the results with reference to the research questions is presented after each research question below.

Research question 1: What have been the changes in the industry over the period 1997 to 2003? Is the perception of catastrophic decline, and pessimism over the future of the sector, justified?

There has been a substantial loss of capacity of 61 per cent by number of employees in the UK PCB sector between 1997 and 2003 according to the survey. This figure roughly corresponds to perceptions in the industry, although much larger company numbers for 1997 were quoted by the interview respondents. The discrepancy is possibly attributed to the respondents actually recalling company numbers from an earlier period than 1997. Advanced technology was not viewed by the smaller PCB companies as enabling PCB manufacture to stay in the UK. The factors enabling them to retain business appeared to be turnaround time and batch sizes. The larger PCB company did have a technology-oriented strategy but claimed this to be unique in Europe.

In the PCBA sector perceptions of decline focused on the reduction in UK capacity of the large EMS multinationals. Despite this the actual sectoral loss of capacity as found by the statistical survey was a relatively modest 22 per cent in employee numbers.

Research question 2: What are the strategic implications for the wider UK manufacturing industry of

the loss of onshore skills and capability in electronic manufacturing?

The loss of capacity discussed above has been accompanied by loss of supporting infrastructure such as chemical suppliers. The statistical survey identified a shift in employment distribution overall towards medium-sized companies. The trend to smaller companies has implications for the strategic capabilities of the UK industry. In particular large companies often have more advanced technology and the resources to invest in equipment and engineering knowledge. This capability is of importance to small start-ups seeking to commercialize new product concepts. Concern was expressed by one company as to where the next generation of engineering talent will come from, since much of the current generation of senior engineers gained their experience in large companies. On the related issue of retaining design in the UK even if manufacturing moves substantially offshore, the scepticism found in the interviews is echoed in a recently published study of opinion in the wider UK manufacturing industry [11].

Research question 3: What factors are there promoting survival and growth of onshore capability in electronic manufacturing?

Nearly all of the companies interviewed appeared to be satisfied with their levels of business and business strategies. All respondents expressed a strong commitment to customer service, and most described a targeted approach to customer selection, rather than accepting orders indiscriminately. Commonly respondents expressed an aim of being close to the customer so as to gain early engineering input into new product designs. The markets served are mostly domestic. Only the large PCB company has an export strategy, focused on the European market. The small PCBA company targets domestic customers whose markets are overseas.

7 CONCLUSIONS

Total employment in the UK contract electronic manufacturing industry has decreased by 39 per cent from approximately 37 600 to 23 100 between 1997 and 2003. The biggest loss in capacity between 1997 and 2003 has been in the PCB manufacturing subsector, declining by 61 per cent by number of employees. The figure is in broad agreement with the findings on perceptions from industry interviews. The loss in the PCBA subsector has been much less over the same time period, at 22 per cent by number of employees. The interview data indicate that the major factors retaining capacity in the UK for the PCB subsector are turnaround

time and cost. Over both sectors there has been a major shift in employment distribution away from large companies. The loss of large company capacity may have strategic implications for the UK electronic manufacturing sector and wider manufacturing industry. These include reduction in the indigenous supplier base, and possible lack of investment resources to keep up with changes in technology.

Industry expectations are that some application areas of electronic manufacturing will stay in the UK. These include the strategic sectors of defence and avionics, configuration of network servers, and complex and low volume products such as mass spectrometers. The UK is seen as a source of innovation, and retention of strong engineering skills is key to bringing new products to the market.

ACKNOWLEDGEMENTS

The research presented here is part of the STRATEC project funded by the EPSRC via Loughborough University's Innovative Manufacturing Research Centre (GR/R64483/01). The authors would like to thank members of the STRATEC steering board namely Frank Coultard, Intellect; Martin Goosey, Rohm and Haas Electronic Materials; and Nick Jolly, DTI. The authors are also very grateful to a number of industrialists within the PCB and electronic manufacturing services industry for their time and opinions. Finally the authors would like to thank Sarah West and Rachel Cherry for helping to compile the data.

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APPENDIX 1

Notation

CEM	contract electronic manufacturing
EMS	electronic manufacturing services
IP	intellectual property
M	million
N	number of employees at new companies
OEM	original equipment manufacturer
PCB	printed circuit board manufacturer (manufacturer of bare boards)
PCBA	printed circuit board sub-contract assembler (assembler of components on to circuit boards)
S_{1997}	number of employees identified in 1997 study
S_{1997}^L	number of employees lost from companies identified in 1997 study between 1997 and 2003
SIC	standard industrial classification
T_{1997}	true number of employees in the CEM industry in 1997
T_{1997}^L	true number of employees lost between 1997 and 2003 from the industry
T_{2003}	true number of employees in the CEM industry in 2003

APPENDIX 2

Interview protocol

Introduction

- Brief introduction to the project by interviewer.
- Purpose of interview, confidentiality.
- Interviewer asks interviewee to describe their personal history and role in the company.

Company

- Would you describe the structure of the PCB industry and where [interviewee's company] fits in?
 - Sizes of companies, type and batch size production capabilities.
 - Who are you competing with? Has this changed? Have you had to change to attract this business?
- What influence does your location have?
- Would you describe your customers and your relationships with them?
 - Industries/sectors supplied into.
 - Geographical distribution.
 - Short term/long term.
 - Technology transfer, measures for locking in customers.
- Would you describe your customers and your relationships with them?
 - Geography, technology transfer.
- What kinds of investments are principally required?
 - Training, equipment, R&D.
- How important are technology changes and innovation to your business?
- What would you describe as your competitive edge?

Trend to offshore manufacture

- Is [interviewee's company] in competition with offshore manufacturers for volume? If so what brings customers to [interviewee's company] rather than going offshore?
- What is the long-term future for [interviewee's company] with regard to the trend to offshore manufacture?

Industry trends

- What changes have you seen in the industry in the past few years?
- What do you expect the industry to look like after the end of the current manufacturing recession?
 - Telecoms?
- What is the long-term future for the industry in the UK?
 - Retention – small batches, design, prototyping
- What technological changes do you see affecting the industry in the next 5 years?