RESEARCH REPORT

1. Background: The Economic Cycle and Economic Growth

The business cycle is a fact of economic life. Although economists disagree over its length and causes, business cycles can potentially influence the growth process: positively, through the creation of new opportunities; or negatively, by reduced demand and through disrupting businesses' access to capital and factor markets. These processes may be potentially significant in new technology sectors where risk is high and product development can be long and protracted. Thus macroeconomic volatility has the potential to influence the level of technological development – or more specifically, it will influence the potential to exploit technological opportunities and may influence long-run economic growth.

In most conventional economics the phenomena of economic growth and the business cycle are analysed independently: business cycle theorists analyse detrended data and consider the trend as exogenous; whereas growth theorists focus on understanding long-run deterministic growth trend using equilibrium models. Some recent developments in economic theory, however, have called into question this traditional division between the business cycle and economic growth: we have seen the emergence of the real business cycle literature; the development of endogenous growth models; and the concept of hysteresis where short-term shocks have persistent impacts.

Most of the studies which have shed light on the relationship between the short and the long-run have been based on theoretical models or aggregate macroeconomic data. The empirical evidence based on international comparisons is mixed. Using a sample of ninety-two countries Ramey and Ramey (1995) find that countries with higher volatility have lower growth, and a similar result is found by Fatás (2002). De Hek (2002) suggests a negative relationship between long-run growth and uncertainty due to the impact on the productivity of knowledge creation. Conversely, Kormendi and Meguire (1985) find a positive relationship between economic fluctuations and growth. Other studies have provided more ambiguous results: Jones, and Manuelli Stacchetti (1999) argue that the relationship between volatility in fundamentals and growth can be either positive or negative. Similarly, Stiglitz (1993) has argued that there are both benefits and costs for economic downturns: the positive effects are through the incentives provided for firms to increase their efficiency whereas there negative effects through reduced expenditure on R&D. Importantly, Stiglitz concludes that the long-run losses are likely to be far more significant than any temporary gains from cost cutting.

The UK economy has shown a high degree of volatility since the Second World War; with volatility increasing after 1973 but becoming relatively more stable since the early 1990s (Kitson, 2004). Economic growth has been below trend since 2001 and this has allowed this study to analyse whether this slow down, and the contemporaneous geopolitical shocks, have influenced the development of two technology-based industries in the UK.

2. Objectives

The aim of the project was to consider how changes in the macroeconomy and shocks influence managerial behaviour and corporate strategy. Furthermore it considered how such behaviour and actions may affect competitiveness and long run growth. The project, therefore, aimed to inform on the microfoundations of macroeconomics. By focussing on two key high-technology sectors in the UK economy - aerospace and biotechnology – the project aimed to consider whether the development and commercialisation of technology was influenced by short-term economic fluctuations. The project intended to produce results that would be of relevance to managers and policy makers. The results would of course be contingent on the nature and extent of macroeconomic and other changes that took place during the study period (see section 3 below).

3. Methodology

The project used 'real time' case studies to analyse how companies were responding to changing economic conditions and shocks. This approach allowed tracking of the behaviour of the firms every 2-3 months using interviews with the companies in the sample combined with other data sources which provided details on corporate activities and finance (such as the Aerospace Market Observatory, Biocentury and Factiva). The benefit of such a methodology was that it allowed relevant issues to emerge and provided first hand information on causality that is unavailable in aggregate data and it generated a close familiarity with the firms and their circumstances.

The industries in the study have a high degree of innovation and R&D activity, and both serve international markets. Furthermore, product development in both takes a long time – an average of 15 years. There are, however, important differences between the industries. Aerospace is a more mature industry with a small number of dominant companies. Biotechnology is a young industry (or sector) with a large number of small firms – many being concentrated in the Cambridge area (the study area).

The assistance of the relevant trade associations -Society of British Aerospace Companies (SBAC) and the Eastern Regions Biotechnology Initiative (ERBI) - was very important in facilitating access to the companies in the study. The initial intention was to track eight companies in each sector. It was not possible to obtain the agreement of eight aerospace firms to participate in the level required by the study – some firms refused and others firms in the sector would not have been comparable to the seven firms that did participate as they are the largest 'prime' contactors in the sector (see Appendix B). A positive change was made to the study by tracking more companies in the biotechnology sector: 14 (see Appendix C) which was six more than in the original proposal, although one of those firms (B10) failed during the period. In addition, to the main firms in the study (and in addition to the original proposal), 24 other organisations were interviewed in order to help verify the findings, benchmark the results and evaluate industry developments (these included industry associations, providers of finance and industry intermediaries – see Appendix D). It should also be noted that the last round of interviews were completed in November 2004 - this was

later than originally envisaged and reflected the difficulty of fitting in with the schedules of all the sample.

4. Results

The section provides a brief summary of the economic changes and geopolitical shocks during the study period and provides a short analysis of the key findings.

4.1 Economic Changes and Geopolitical Shocks

The growth of the UK economy remained positive throughout the study period (2002Q1 to 2004Q4) and this was a continuation of a long period of sustained growth with the last quarterly fall in GDP occurring in 1992Q2 (see Kitson, 2004). Although the overall economy did not suffer a deep business cycle trough, growth was below trend throughout the period. Inflation remained within the Bank of England's target range and there were only small changes in interest rates: the Bank's Repo rate was 4% at the start of the study period and remained at that rate throughout 2002. It was followed by modest reductions in 2003 and increases in 2004 to a peak of 4.75%. The effective exchange rate (which is a weighted basket of currencies) was reasonably stable during the period but there were significant changes in the sterling-dollar exchange rate with sterling appreciating by 27% against the dollar.

One of the most prominent features of the period was the depressed state of equity markets. The UK stock market had fallen by more than 20% from a peak in mid-2000 to the start of the study period - it then stabilised in early 2002 before falling again and subsequently showing a modest recovery from early 2003. There was, however, greater variation in the valuations of technology-based firms. Overall, the valuation of technology-based firms fell by approximately 75% from their peak in 2000 to the start of the study period; they continued to fall until early 2003 before showing a modest recovery. The fall in the valuation of the biotechnology sector exceeded that of the overall technology sector - with a fall of 80% from a peak in early 2000 to the start of the study period. This decline continued, with the valuation falling by 50% from 2002Q1 to 2003Q1 before showing a modest revival (Goldman Sachs, 2004).

Additionally, there were major economic impacts of the series of geopolitical shocks that occurred during, and immediately preceding the study period. First there was the 9/11 terrorist attack in 2001; followed in October by the invasion of Afghanistan; conflict with Iraq culminated in the invasion in March 2003 with instability remaining in that area; and a global SARS (severe acute respiratory syndrome) epidemic between November 2002 and July 2003.

4.2 Sectoral Responses to Economic Change

Although the UK economy was growing moderately during the period there were major contractions in the sectors studied. Output in the UK aerospace sector fell in 2002 followed by a modest increase in 2003. There was an 18% fall in exports in 2002 followed by a modest 2.6% increase in 2003. Similarly, there was a 20.3% fall in employment in 2002 followed by a modest increase of 4% in 2003. This reduction in employment took place in all of the aerospace firms in the study with the exception of firm A1. R&D increased in both 2002 and 2003 (at an average rate of 14.3%) with R&D intensity averaging 12.3% of turnover. The firms in the study did however, re-evaluate the R&D expenditure strategy in light of downturn in the sector and there

were reductions in expenditures on activities that were considered to have distant or uncertain returns.

Most indicators also suggest a fall in the output and employment of UK biotechnology firms during the study period but there are, however, two important caveats. First there are data limitations, as technology firms are not classed within the standard industrial classification system. Second, most biotech companies have yet to bring products to market, so usual measures of output are not applicable. In 2003, there were only 10 products produced and sold by UK biotech firms compared to 194 in development (Ernst &Young, 2003).

4.3 Managerial and Entrepreneurial Responses to the Economic Change

How did management respond to the changing economic conditions and geopolitical shocks? First it should be noted that the managerial structures of the firms varied considerably between the two sectors reflecting their different ages and sizes. A simple contrast can be drawn between 'managerial' driven firms in aerospace and 'entrepreneurial' driven firms in biotechnology. In the context of the two sectors in this study, both the entrepreneurial and managerial functions involve risk taking – but in the more entrepreneurial driven biotechnology sector there is more risk taking because of a less structured and more uncertain set of possibilities (Bearse 1982) and because the entrepreneurs bear final responsibility for decisions (Gasse, 1982; Knight 1921).

Management and entrepreneurship are increasingly being analysed as dynamic processes, moving through different dimensions, contexts and constraints (Baron and Shane (2005); Vohora, Wright and Lockett (2004). There has, however, been little analysis of how macroeconomic fluctuations may influence critical junctures and the development of core competences in firms.

4.3.1 Entrepreneurial Responses in Biotechnology

One of the consistent findings was that most biotechnology entrepreneurs believed that the majority of macroeconomic variables had only a negligible impact on their firms and almost never influenced important decisions they made, particularly about the development and commercialisation of science. The reason for this is the emergent nature of the biotechnology industry in general and the long gestation time for each firm to develop products. The vast majority of these firms are engaged in commercialising basic biological sciences which take around 10-15 years to develop before coming to market and which cost an average of $800 million to develop (diMasi, 2001). Due to this long gestation time and because only around 4% of pre-clinical biotech products actually make it through the regulatory process (PhRMA, 2002), very few biotech products have yet been brought to market, even by firms in the UK which comprise the most developed group of biotech firms outside the US (see above).

Yet, all the entrepreneurs reported that one economic variable has had a very important effect on biotech firms: the change in stock market valuations and the impactions for biotech financing. The repercussions of the fall in the stock market were a collapse in exit rotes for financiers (mainly venture capitalists), a radical fall in the valuations of biotechnology firms (some of the firms in the sample were valued at less than the value of their cash assets), and limited finance for product development.

What was the effect of the bursting of the financing bubble on the entrepreneurial process within biotech? A binary distinction can be made between those firms dependent on the capital markets for future viability and those with other means of cash generation. **If a firm had large enough cash reserves and revenue streams for several years' worth of cashburn for its development programme, then it felt relatively insulated from the changes in the capital markets**. The two largest case study firms were within this category. Firm B7 had a self-sustaining revenue stream from a portfolio of marketed drugs (pharmaceutical products acquired in the late 1990s). Firm B5 had raised a large amount of cash and had a joint venture with a large US biotech which was financing a large amount of its development costs. The development programmes of these firms were therefore largely unaffected by the changes in the capital markets and instead, according to their CEOs, they were largely dictated by their technology and business needs.

Those firms facing prospective liquidity constraints responded in a variety of ways. **First, they tried to generate finance through increasing revenue streams.** This was to help finance research but was also considered important to signal to financial markets that the firm was a revenue generator. One firm pursued a strategy of building up recurring revenue streams through acquisition, and another firm in the sample acquired developed drugs from a large pharmaceutical company.

A second approach was to reduce cashburn. The so-called 'discipline of expensive hard to get money' was considered an impetus to improve efficiency. This involved reducing headcount, the number of projects and attempting to reduce costs from the supply chain. But in some cases it was considered that there were technological constraints, or a minimum efficient scale, which limited the extent of feasible cost reductions (it is particularly difficult to reduce the cost of drugs in clinical trials – except by terminating the programme).

A third approach was to alter the business model in response to the demands of the financial sector in order to obtain finance, albeit on considerably less favourable terms than during the height of the bubble. The traditional model of private equity funding for biotech was for firms to receive up to four years' worth of capital and if the targets for technology development had been successfully met, then further funding would be allocated for the next development stage. The change in financial markets affected how venture capitalists (VCs) invested and what firms did in response. With the drastically reduced opportunities to exit from their investments through an IPO (initial public offering) or trade sale, the VCs needed to conserve the cash burn of their investments. It became apparent from the firms we were tracking that they were responding to the changing needs of the VCs and altering their business models.

The fall in valuations and the lack of prospective exits caused VC to continue financing companies with later stage technologies that were closer to market. These were perceived to be lower risk with greater potential for an eventual exit. The private biotech firms responded by dropping their earlier stage technologies to concentrate on later stage products nearer to revenue. The decrease in appetite for risk in the markets has skewed the technology value further from early stage towards later stage. Additionally, the changes in financial markets resulted in VC financing shifting from the less proven model of platform technologies to the more proven model of drug development.

The difficulties in raising finance resulted in changing labour requirements in the firms in the sample. The remaining entrepreneurs all needed to devote much of their time and energy to raising cash from the markets. Due to the highly capital intensive nature of biotech and its dependence on external financing, the growth in biotech company formation also created a 'monster that needed feeding' with massive shortfalls at the industry level between the biotech industry's ongoing cash needs and the capital supply from the money markets. Those firms whose management was primarily with a scientific and technology background felt ill-suited and resented such tasks and the response of one firm (B6) was to replace their CEO who had a science background with a manager with marketing expertise from a large supermarket chain. The VCs also responded by external expertise and advice to help the firms that they were financing to reduce costs and cashburn.

There is evidence that UK entrepreneurs are less effective than US entrepreneurs in raising finance. Although many US companies were also running out of capital - for instance, with 60 US-listed companies with less than 1 year's worth of cash and 125 US-listed companies with 2 years' worth of cash or less - proportionately more US companies were more successful in raising cash, especially for the very largest amounts. Although there were many factors at work, many in the industry believed that US firms were much more prepared and proactive in re-inventing themselves to raise the maximum amount of cash possible. This is one reason why US firms raised nearly six times more cash than European firms in 2000. In contrast, amongst the UK sample there was evidence firms were not maximising their opportunities when the capital markets were open.

The retrenchment in financial markets has created a funding problem for the biotechnology industry. It is estimated that in 2004 there is a one billion Euro funding shortfall among European bioscience companies, of which 50-70% lies in the UK (BIGT, 2004). There has been much research highlighting that structural financing gaps exist for high technology firms in the UK (Lockett, Murray and Wright, 2002; HM Treasury, 2003a) and in other industrialised countries like the US (Wessner 2004). **Our research suggests that such financing gaps increased during the downcycle – and this may have permanent impacts on the commercial exploitation of such technologies.**

4.3.2 Managerial Responses in Aerospace

Managers in the aerospace industry, unlike those in biotechnology, were acutely aware of the business cycle and macroeconomic changes (particularly the exchange rate). But, as with biotechnology, changes in financial markets are important in influencing corporate performance. The main mechanisms were changes in the company's share price (in particular the falls in early part of the study period). The firms in the sample wished to signal to financial markets that they were responding to the difficult trading conditions and the geopolitical shocks. These firms developed a set of strategies for resilience through learning lessons from previous recessions – such as the aerospace recession of the early 1990s. This, combined with the maturity and size of the firms in the sector, meant that the sector was far more stable than in the biotechnology sector.

The tracking of the aerospace firms in the sample suggests the companies developed two critical strategies in dealing with the business cycle. The first was to be proactive in avoiding as much of the cycle as possible. The second was to use the cycle to pass

through difficult changes to achieve longer-term objectives. A third, adopted by only one company, was to ensure that the business cycle did not have any adverse impact on long-run capacity or competences.

All of these firms engaged in extensive scenario planning due to the uncertain nature of the industry. Some of the firms realised it was better not merely to react to market downturns once they occurred but that it was possible to avoid many of their cyclical risks by developing strategies to try and avoid the cycle.

The first strategy was to develop a portfolio of activities that were driven by different cycles to create a company less vulnerable to one industrial or technological cycle. Company A6 reduced cyclical risk by utilising its competency in high precision engineering to structure itself around four divisions with largely unrelated sets of economic drivers: aerospace, medical equipment, sealing solutions and industrial divisions. Furthermore, Company A6 was also attempting to lower its cyclical risk by selling into a wide spread of markets which were perceived to have differently phased business cycles.

Furthermore, in order to minimise exchange rate risk A6 was attempting to design out the volatility by sourcing to "match revenues and costs in the same currency as far as is possible". Hence its 50% of US sales is now matched by 50% of production in the US. A6 is attempting to reduce uncertainty, lower its risk profile to improve its credit ratings and thereby to achieve better and cheaper access to capital. The behaviour of the exchange rate is very important for all firms in the sample as most aerospace products are priced in dollars. All of the firms used complex hedging strategies to deal with exchange rate fluctuations and uncertainty. The recent weakness of the dollar, however, has put pressure on profit margins and it has led to a variety of corporate responses. First, it has accelerated the search for acquisition targets in the US - this will help both in matching revenues to currency and the acquisition of American technology (which is often both leading edge and difficult to acquire). Second, it has increased pressure to reduce costs. Company A1 is attempting reduce its cost base by 1.5 billion Euros by 2006, particularly through rationalization of its supply chain.

Company A5 has also pursued a strategy of diversification. It has been lowering its dependence on the aero engine market and diversifying into the marine and industrial turbine markets. It was able to achieve much of this diversification by leveraging its aerospace technology and it argued 'the rationale behind that was a desire to broaden the business so that these kinds of swings could be offset by a more stable business'. Similar to Company A6, A5 argued that its risk profile was further reduced by its spread of markets. Although UK-based, by the end of the study period, 80% of its sales, 60% of its R&D and 40% of its employment are outside the UK.

The second strategy was to reduce the risk attached to their revenue streams by changing revenue models. Traditionally revenue was based around selling high value equipment. Yet the highly volatile nature of this market meant that even when times were buoyant there was a high degree of uncertainty about future revenues. Many of these firms, therefore, were moving to an emphasis on service and aftermarket revenues which are much more recurring and stable.

Company A5 has been one of the most aggressive firms in pursuing a strategy to maximise aftermarket revenues - these have increased by 60% over the past five years. Similarly, Company A3, the world's largest helicopter manufacturer, calculate that for every pound spent on procurement of a helicopter the customer will spend two pounds fifty over the lifetime of its operation. Underlying this strategy has been the development of a comprehensive services capability so that they can also offer their customers a complete service including training, monitoring and repair and maintenance. This is fundamentally changing the nature of their business and the skills of the people that they employ, because they are now more service-orientated.

In a highly cyclical industry such as aerospace it is impossible to avoid the business cycle. These firms in the sector put considerable efforts into increasing their preparedness using intensive forecasting of industry demand and scenario planning (the experience of the first Gulf war was used to model the possible impact of the second conflict in Iraq) to create contingencies so they would be quick to respond. Firms also used these adverse external events and made a 'virtue of necessity' in order to push through organisational change: these tended to fall into two types: 'burying bad news' and 'pushing through change'.

The 'burying of bad news' was a strategy used by a number of the companies in the sample. In effect, management believed that change was necessary because of excess capacity within the industry but considered that timing of the changes, in particular closure of capacity and redundancies, would be made easier by in the context of external events. Company A1 is a large aerospace systems manufacturer that had a division manufacturing regional aircraft ranging from 19-seat turboprops up to 100-seat jets. Any decision to end the manufacture of passenger planes in the UK would be politically sensitive - however, within two months of 9/11, it announced that it was closing down that division. It has continued with a process of rationalisation which would have 'less palatable' if the sector had not suffered from significant shocks. Similarly, company A2 announced the closure of one of its major production facilities shortly after 9/11.

Organisational change is notoriously hard to achieve successfully (Clark, 1994). Many of the firms in the sample found that the global crisis in aviation gave them the opportunity and the impetus to re-engineer their operations**. Firms made a 'virtue of necessity' by using these market conditions to improve their operational efficiency by implementing process improvements and rationalising the supply chain**. Company A1 implemented such changes but it differed from the others in the sample in one notable way: it kept its employment levels constant and made no redundancies. A1's forecasts about its market position were more optimistic than those of the others in the sample but it was also very concerned about losing skills and competences if it reduced its workforce. This illustrates that there can be a variety of corporate responses to economic fluctuations and changes.

Assessment

Much of the literature on corporate risk management has focused on managing financial risk (see Froot, Stein and Scharfstein, 1992). And the behaviour of the aerospace firms in the sample is consistent with other studies (see Culp and Miller, 1999) that find most large firms use a variety of hedging procedures to reduce financial risk. Yet the notion of reducing risk has other dimensions including the

passing of risk down the supply chain (including the risk of technological development) and diversification to reduce the impact of different market cycles. The latter suggests that at least some diversification provides some insulation from shocks and is contrary to much of the literature that suggests that diversification has an adverse impact on corporate performance (eg Berger and Ofek, 1995; Lang and Stulz, 1994; Servas, 1996).

4.3.3 Sectoral Comparisons

The impact of economic change was apparent in both sectors studied. It particularly it influenced young firms in the biotechnology sector who were at 'critical junctures' in their development and required finance to grow. Many of these firms did not have the competences to cope easily with the changes in financial markets. The companies in the more mature aerospace sector had 'learned' to cope with change and uncertainty and had developed competences and capacity to deal with such factors.

4.4 Other Issues

The tracking of the companies revealed a number of other important issues that influence corporate performance.

4.4.1 The Importance of Location

The issue of location and the clustering of economic activity have been highlighted as important factors in local and national economic performance (HM Treasury 2001, 2003b, 2004a; and Porter, 2003). Such factors have been considered of particular importance for high technology activities, and improving links to the science base has been identified as crucial for improving long-run growth (Lambert 2003). In aerospace, location was seen as largely being a result of historical factors and links to the science base were largely well developed and independent of geography. Conversely**, location and the clustering of activities are seen as important for the biotechnology firms** which were located in the Cambridge area. But the perceived locational advantages had little to do with links to the local science base or with links to other firms in similar lines of business. Few of the firms in the sample had, or were developing, relationships with other biotechnology firms in their region or sub-region. Similarly, none had strong existing links with Cambridge University even if they had been spun-out from the University (this is consistent with the low level of collaboration with higher education establishments identified in other studies see Kitson and Wilkinson 2003; and Frenz, Michie and Oughton, 2004). There were links with other higher educational establishments but these were global in nature reflecting the very specialised expertise required for the development of specialised technologies (expertise which might only be available in one or two establishments globally).

Location for biotech firms was - and is - important for other reasons. First, because it was perceived to improved access to finance – a Cambridge location (or literally a CB postcode) provided credibility and the mainly London-based VCs would travel to Cambridge. It should also be noted that the development of a critical mass of biotechnology firms in the Cambridge areas has also now led to the development of locally based VCs (this is consistent with the analysis of Baxter et al (2004) that the development of cluster-based high technology industries requires the support of local intermediaries and support institutions). Second, the size of the Cambridge biotechnology cluster had facilitated the development of a local supply chain

providing specialised inputs (wet labs, lab cleaning, etc). Third, there is the importance of the local labour market – simply put, research staff are more willing to work for a Cambridge-based enterprise than one located elsewhere. The riskiness of biotechnology entrepreneurship is associated with unstable employment which can be mitigated by the prospect of being reemployed in same local labour market – a prospect which is higher because of the large number of firms engaged in similar activities. Furthermore, there is a psychological impact of working in a labour market with others of a similar disposition and skill set - it is 'normalising the abnormal' (CEO, Firm B9). Also, the characteristics of the local employment led to a process of 'residential preference' – simply, those working in biotechnology liked living in Cambridge and its environs.

4.4.2 Government Policies

A number of Government policies were implemented or expanded during the study period and had an impact on the firms in the two sectors. The one mentioned by all firms in the sample was R&D (research and development) tax credits. **All the firms identified R&D tax credits as a help to their activities (albeit complicated in its implementation especially for small firms) but all indicated that it had no direct impact on their research and development activity.** The benefit of the tax credit was that it improved cash-flow or net profits – or in the case of most biotech firms it reduced their effective cashburn rate. But all of the firms indicated that their decision to develop a technology or to increase R&D was not directly influenced by the tax credit as the product development period was so long and the benefit of the credit was perceived to be small in relation to the full development costs. Currently, the analysis of the impact of R&D tax credits has provided mixed results (see Hall and Van Reenan 2000 for a review of the evidence). The UK Government intends to review the impact of R&D tax credits in 2005 (HM Treasury, 2004), the results of this study suggest that such an evaluation should include an analysis of the mechanisms through which firms may benefit from such tax credits and whether such benefits generate a change in R&D behaviour. For instance, the tax credit has allowed some firms in biotechnology to spread their funds further which allowed them to continue R&D despite the lack of new external finance – this may have provided a net boost to aggregate R&D but not through the mechanism initially envisaged.

A policy issue which was increasingly highlighted by most of the biotechnology firms throughout the study period was the tax treatment of high technology spin-outs from Universities. The changes to the tax rules in 2003 created an immediate income tax and National Insurance charge on the value of shares owned by the biotechnology entrepreneurs in the study, although these firms were generating very low, or zero, revenues. The firms in the study highlighted the large disincentive effect of this policy change, particularly in high-technology industries characterised by high risk, volatile valuations and very long development periods The discontent within the industry, and other sectors, has very recently led to a reversal of the policy and a consultation process in 2005 (Inland Revenue, 2004).

The most prominent public policy concerns for many of the firms in aerospace were the shifts in defence procurement policy. There have been a series of initiatives and shifts since 1997 with an initial focus on 'cheaper, faster and better' and 'better value for money' (Taylor, 2003). It is not appropriate here to discuss the costs and benefits of putting increased emphasis on cost as the driver of procurement

policy. What is apparent from the study, however, is that the shifts in policy emphasis created uncertainty in the industry which is probably not conducive to long-term development of the sector.

Uncertainty and lack of clear information also characterised the firms' evaluation of science and technology policy – although those in aerospace were more effectively linked into the science base. All the aerospace firms maintained their links with Universities and research establishments throughout the study period. The impact of the difficult trading conditions was to delay the strengthening of such links and to focus resources on research and collaboration with nearer-term potential. The firms in both sectors, although more so in aerospace, were aware that there was an increasing policy focus on science, links with Universities and that the Regional Development Agencies (RDAs) were an increasingly important agent of policy. There was, however, confusion as to what such changes in policy focus meant for the firms in the sample. This was particularly apparent for the biotechnology firms who perceived that there were a plethora of policy initiatives that were difficult to access, and that it was difficult for smaller firms to develop links with the local science base.

4.5 Discussion of the Research

This section briefly highlights the implications of the research for macroeconomics, policy and management.

4.5.1 Implications for Macroeconomics

There is considerable discussion and dispute concerning the microfoundations of macroeconomics. This study suggests there were a variety of corporate responses to many of the macroeconomic and industrial changes observed in the sectors studied. This suggests that there should be caution in interpreting empirical regularities in macroeconomic models as the final impacts may be the aggregation of many different responses (on this see Kitson, 2005).

The analysis of the short-term impact of shocks on growth has focused on labour market impacts (see Ball, 1997; and Blanchard and Summers, 1988). This study suggests that important transmission mechanisms may operate in financial markets. In particular, the study of biotechnology indicates finance gaps are highly cyclical – and that the failure to acquire finance may prevent the commercialisation of technology. This may have an impact on long-term growth although it will be difficult to quantify precisely the impact with technologies that can take in approximately 15 years to develop.

4.5.2 Implications for Policy

The problem of finance gaps for high technology businesses has been identified by policymakers (HM Treasury, 2003b). The cyclical nature of such gaps (highlighted above), however, has not yet been recognised. Uncertainty about policy developments and lack of clear information is perceived as a problem for the firms in the study. The importance of credibility and transparency are recognised as essential components in monetary policy – such concepts could be more effectively applied to other areas of economic policy.

The development of high-technology clusters is a prominent aspect of recent industrial and regional policy. This study indicates that importance of location for the

Cambridge biotechnology cluster is mainly based on labour markets and financial factors, not inter-firm collaboration or links with science base. Clusters may be important for long-term growth but analysis should be based on what firms do - not just where they are. Similarly, the future analysis of R&D tax credits should consider how it influences corporate strategy and behaviour in addition to evaluating measures of R&D.

4.5.3 Implications for Management

The firms in the aerospace sectors were resilient to the shocks that affected the sector and they demonstrated various strategies for reducing the cycle and using it to implement change. The evidence from some of the firms suggested that diversification may have insulated the impact of variable cycles. This could be interpreted as being contrary to much of the strategy literature that emphasises reliance on core competences (Hamel and Prahalad, 1994). Alternatively, it could be considered as an extension of such an approach focusing on the core competence of the management of technology across different products and (related) sectors.

The most important issue facing managers and entrepreneurs in biotechnology is access to finance. This problem is cyclical but is likely to persist as the sector is primarily dependent on a VC sector whose institutions and practices were developed for an alternative technology (ICT) with a much shorter product development period. One strategy to ameliorate this problem is the employment of specialists with knowledge of finance and marketing.

5. Activities

Kitson attended over 20 conferences during the study period and Primost has attended 10 during this period; and presentations were made at some of these events (see 6 and 7 below).

6. Outputs

The initial research and analysis has produced three book chapters and the final research will be disseminated via academic journals and conference presentations (see section 2A above). In addition, research from the project was used for a film produced by the Cambridge-MIT Institute (CMI) ('Cultures of innovation: biotechnology and the race for success'). Academic presentations based on the research have been given at:

- Queen Mary College, London, December 2001
- Euroma, Copenhagen, June 2002
- Wake Forest University, North Carolina, USA, September 2002
- London Metropolitan University, December 2003
- Oxford, Programme Conference, 28-29 June 2004
- Stanford Centre, Oxford, November 2004

7. Impact

The film described above was shown at the Cambridge-MIT Institute's National Competitiveness Summit in London in November 2002 to approximately 150

delegates. It has been used and distributed by DTI and will be made available on the CMI website.

Policy consultation and advice based on the project has been given to:

- DTI Electronics Innovation and Growth Team, October 2004
- HM Treasury (representatives from the Enterprise, Productivity and Science and Industry Teams), December 2004

Research results have been disseminated to various user groups in the business community including:

- Peregrine Summit (IT), September 2002
- Rolls Royce (aerospace), October 2002
- NTT DoCoMo (telecommunications) June 2003
- JR Tokai (railways) November 2004

The research has also been used in a newspaper article ('The bad news about our addiction to foreign goods' The Guardian, March 1 2004).

8. Future Research Priorities

There are a number of areas where further research may be pursued:

- International comparisons – is there evidence of similar processes in other countries, particularly regarding the impact of finance on management practices and the commercialisation of technology?
- Industrial comparisons - is there evidence of similar processes in other technology-based industries such as electronics and nanotechnology?
- Links between the science base and business – analysis on the extent, nature and benefits of such links

Appendix A

References

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