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## Industry structure, procurement and innovation in the UK defence sector

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# Working Paper Series

## Industry Structure, Procurement and Innovation in the UK Defence Sector

Andrew D James  
Peter Hall

Manchester Business School Working Paper No 553

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## **Abstract**

There is agreement within industrial organisation economics that an inverted U-shape relationship exists between the level of competition in an industry and the level of innovation in that industry. Thus, when consolidation changes the level of competition in an industry we might expect this to have implications for the level of innovation in that industry. The key question for our paper is whether the sort of relationship found to hold, on average, across all of manufacturing industry applies in the specific case of the defence industry. We note that the defence industry has unusual structural characteristics and in particular a single (monopsony) buyer on the demand side that can determine the number of competitors in the industry by imposing regulatory barriers to entry, use its contract terms to control the profits that companies make, and support industry innovation through funding R&D by industry and in its own research facilities. We present data on changes to the structure of the UK defence industry and patterns of innovation, 1989-2007. We note in particular that industry consolidation has been accompanied by a steep decline in industry's own funded defence R&D (an input measure of innovation). We argue that this may be explained in part by changes in industry structure but that industry competition is not the whole story. We argue that another part of the explanation relates to public policy: changes in the level of demand, procurement reform and the changing character of demand have all played a part in reducing both the opportunities and incentives for defence industry innovation. We also offer a third explanation, namely that changes in the nature of defence innovation may themselves in part have driven consolidation. We conclude by considering the concerns of UK policy makers about the decline in industry's own funded defence R&D and the policy options that may be open to them.

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# **INDUSTRY STRUCTURE, PROCUREMENT AND INNOVATION IN THE UK DEFENCE SECTOR**

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## **ABSTRACT**

There is agreement within industrial organisation economics that an inverted U-shape relationship exists between the level of competition in an industry and the level of innovation in that industry. Thus, when consolidation changes the level of competition in an industry we might expect this to have implications for the level of innovation in that industry. The key question for our paper is whether the sort of relationship found to hold, on average, across all of manufacturing industry applies in the specific case of the defence industry. We note that the defence industry has unusual structural characteristics and in particular a single (monopsony) buyer on the demand side that can determine the number of competitors in the industry by imposing regulatory barriers to entry, use its contract terms to control the profits that companies make, and support industry innovation through funding R&D by industry and in its own research facilities. We present data on changes to the structure of the UK defence industry and patterns of innovation, 1989-2007. We note in particular that industry consolidation has been accompanied by a steep decline in industry's own funded defence R&D (an input measure of innovation). We argue that this may be explained in part by changes in

industry structure but that industry competition is not the whole story. We argue that another part of the explanation relates to public policy: changes in the level of demand, procurement reform and the changing character of demand have all played a part in reducing both the opportunities and incentives for defence industry innovation. We also offer a third explanation, namely that changes in the nature of defence innovation may themselves in part have driven consolidation. We conclude by considering the concerns of UK policy makers about the decline in industry's own funded defence R&D and the policy options that may be open to them.

# **INDUSTRY STRUCTURE, PROCUREMENT AND INNOVATION IN THE UK DEFENCE SECTOR**

## **1. INTRODUCTION**

In this paper, we investigate the implications for innovation of the changing structure of the UK defence industry since the end of the Cold War. As elsewhere in the world, structural change in the UK defence industry has largely taken the form of consolidation, usually through mergers, acquisitions and divestments, which has reduced the number of firms competing with each other within the industry. Industrial organisation economics suggests that there is a relationship between the level of competition in an industry and the level of innovation in that industry. Thus, we might expect that defence industry consolidation has had an impact not only on production and cost efficiency using the existing technology but for dynamic efficiency flowing from the innovation that leads to the generation of new products and the introduction of new technology. While there may be a “Schumpeterian trade-off” between efforts to achieve both forms of efficiency, our focus in this paper is on the latter, dynamic efficiency implications.

The paper is structured as follows. In Section 2, we review economic analysis that suggests industry-wide innovation has an inverted U-shape relationship to the level of competition in the industry. Consolidation will change the level of competition and is thus predicted to have implications for innovation. The defence industry, however, has unusual structural characteristics, in particular a single (monopsony) buyer on the demand side, and we note that this might affect the applicability of standard industrial organisation economics theory. In Sections 3 and 4 we present evidence on changes to the structure of British defence industry and changing patterns of innovation, 1989/90-2007. In Section 5, we argue that the observed changes in defence industry innovation may be explained in part by changes in industry structure but industry competition is not the whole story. We argue that the policy decisions of the Ministry of Defence have played an important part in reducing the opportunities and incentives for innovation in the UK defence industry. We also introduce another and complementary argument: that innovation may have played a part in changing industry structure. Section 6 considers

the concerns of UK policy makers and the policy options that may be open to them. Section 7 concludes.

## **2. INDUSTRY STRUCTURE AND INNOVATION IN CONDITIONS OF MONOPSONY**

The structure of the defence industry has changed significantly since the end of the Cold War. This structural change has largely taken the form of consolidation, usually through mergers, acquisitions and divestments. The timing and character of consolidation has differed between the major arms producing countries but the effect has been to reduce the number of firms competing with each other within the industry.

### **2.1 Industry structure and innovation**

Industrial organisation economics suggests that there is a relationship between the level of competition in an industry and the level of innovation in that industry. Early economic theorising in the area tended to focus on the potential value of monopoly for innovation.<sup>1</sup>  
<sup>2</sup> Single-firm supply enabled and protected by high barriers to entry brings with it the potential of profits higher than those available in markets shared among many firms with low or no barriers to entry and exit. The barriers to entry bestow advantages not only of market power reflected in high profits but also, relatively speaking, of size, experience, and the potential of survival. Monopolists, it was argued, not only had profit to invest in innovation but were large enough to withstand inevitable set-backs, experienced enough to make well-informed decisions, and had the prospects to raise capital if they wished to. The implication was that in markets where entry was less restricted and competition more fierce, the prospects for innovation might be undermined.

In more recent times, it has become clear that monopoly is neither necessary nor sufficient for higher-level innovation performance. Monopoly is not necessary since, in industries comprising more than one firm, individual firms have proved to have enough market power to generate internal funds to innovate. Further, while capital market

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<sup>1</sup> Schumpeter, J.A. (1954), *Capitalism, Socialism and Democracy* (4<sup>th</sup> edition), London, Allen and Unwin.

<sup>2</sup> Galbraith, J.K. (1957), *American Capitalism: The Concept of Countervailing Power* (Revised edition), London, H.Hamilton.

imperfections mean that prospective innovators are treated unevenly (the experienced, large and profitable favoured over start-ups, SMEs and the yet-to-be-profitable), the range and depth of financial institutions facilitate innovation-related investments of varying degrees of risk in many market environments<sup>3</sup>. Monopoly is not sufficient for innovation if: (1) the firm is unwilling to innovate (through its owners' risk-aversion, preference for distributed dividends, or laziness) or, (2) is unable to because of lack of financial resources. A monopoly may not have the internal funds available to invest in innovation, for example, if its market is contestable, i.e. open to the threat of "hit-and-run entry" which, in turn, obliges it to price at a non-profit-making level<sup>4</sup>.

Given the importance of profit in generating or attracting funds for innovation, it makes sense to focus as much on the degree of competition associated with a market structure as on the structure itself. While increasing competition can act in principle both as a driving-force behind innovation and an impediment to resourcing it, there is a general presumption that as increasingly fierce competition reduces firms' profits it will at some point result in declining industry-level innovation. That said, there is an emerging consensus based on empirical observation that if an industry moves from a starting point of very low-level competition to a higher level, innovation may initially increase. *This gives rise to the notion of an inverted U-shape relationship between the fierceness of competition and innovation performance* (See Fig 1).

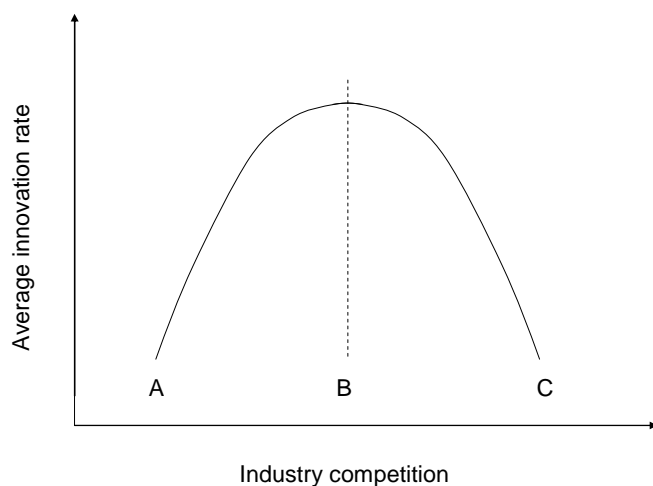
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<sup>3</sup> Capital markets should not be regarded as imperfect just because they deny potential innovators funds to invest: lending institutions may legitimately be risk-averse or simply exercising good judgement based on their experience. Capital market imperfections may arise, however, if lenders are poorly informed or are informed less well than potential borrowers.

<sup>4</sup> Baumol, W.J., J.C. Panzar and R.D. Willig (1982), *Contestable Markets and the Theory of Industry Structure*, New York, London: Harcourt Brace Jovanovich.



**Figure 1: The inverted U-shape relationship between industry competition and innovation**



To explain the initial range, AB, traditional arguments in the literature of industrial organisation drew attention to the potential benefits of oligopoly: market structures with few enough players for the conduct decisions of one to have an influence on outcomes for its rivals. Scherer, for example, observes:

“Oligopolists have most of the advantages attributed to a monopolist. Their ability to suppress price competition increases organizational slack and permits a longer run decision-making horizon.... In addition, because sales at tacitly collusive prices are profitable, oligopolists have an incentive to try increasing their market shares by maneuvering on non-price dimensions - e.g. through product innovation”.<sup>5</sup>

He goes on:

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<sup>5</sup> Scherer, FM (1980). *Industrial Market Structure and Economic Performance*. Second Edition. Rand McNally: Chicago: p.426.

“The rapidity of innovation increases with the number of firms, and ... sellers with small market shares are more likely to trigger a rapid pace of innovation than dominant firms, though the latter may retaliate vigorously”.<sup>6</sup>

Others have argued that since all firms in modern competition are driven, to some extent, to seek new and better products and processes, increasing the number of firms may raise the probability of discovery or increase the intensity of search and thus increase the rate at which successful innovation outcomes are achieved<sup>7</sup>. Evolutionary theorists argue that increasing the breadth and intensity of search is valuable for generating variety, and requires the selection mechanism of competition to sort out what is best fitted for the existing market environment. More competition is thus always better than none, both from the point of view of increasing the rate of market experiments and that of identifying what will succeed in the market<sup>8</sup>. Finally, Aghion *et al* point out that while an increase in industry competition reduces the profit firms receive, they will still spend more on innovation, if they expect their profits in the more competitive environment to *fall by less if they innovate than if they do not*. It is the *difference* that matters. In a growing industry and starting from sufficiently low levels of competition, Aghion *et al* argue that firms may increase their innovation spending as conditions become more competitive<sup>9</sup>.

The range BC can be explained by noting that increased competition reduces the market power of individual firms and, with it, their profits - and to such an extent that profit-hungry innovation investment falls. In a seminal analysis, Dasgupta and Stiglitz argue that the simultaneous increase in competition and decline in industry-wide innovation can be explained by differences in “technological opportunity”.<sup>10</sup> <sup>11</sup> Technological

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<sup>6</sup> Scherer, FM (1980). *Industrial Market Structure and Economic Performance*. Second Edition. Rand McNally: Chicago: pp.428-9.

<sup>7</sup> Geroski, P.A. (1990), “Innovation, technological opportunity and market structure”, *Oxford Economic Papers*. 42(3): 586-602.

<sup>8</sup> Metcalfe, JS (1998). *Evolutionary Economics and Creative Destruction*. London: Routledge.

<sup>9</sup> Aghion, P, N.Bloom, R. Blundell, R.Griffith, P. Howitt (2002), “Competition and innovation: An inverted U relationship”, National Bureau of Economic Research Working Paper 9269, Cambridge, MA.

<sup>10</sup> Dasgupta, P. and J.E. Stiglitz (1980). “Industrial structure and the nature of innovative activity”, *The Economic Journal*, 90 (358): 266-293.

opportunity is reflected in the extent to which additional innovation investment spending yields benefit (profit) to the firm and can vary from industry to industry and one long period to another. Where or when technological opportunity is relatively rich (poor) and the benefits from increasing innovation-related spending thus relatively high (low), industry structure will be characterised by higher levels of industry concentration and higher levels of industry-wide R&D and innovation. To the extent that lower levels of industry concentration imply higher levels of competition and lower firm-level profits, the argument suggests that variations in technological opportunity are sufficient to explain why more competition will be associated with less innovation. The model of Aghion et al points the same lesson but through a different mechanism. Here, as the industry becomes progressively more competitive, profits are driven down absolutely by so much that the negative impact on innovation overwhelms any positive influence noted earlier from the differential impact on innovation versus non-innovation.

The work of Aghion et al is important for our purposes because, in the empirical test of their model, they find a strong inverted U-relationship between their measure of innovation and their version of industry competition when they examine the experience of nearly 14,000 firms in a large range of industries across most of British manufacturing for the period 1968-1997.<sup>12</sup> It is considerable interest that when the modelling is extended to include entry and threat of entry as alternative measures of competition, the same inverted U-relationship seems to emerge.

## **2.2 Defence industry consolidation and innovation**

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<sup>11</sup> Dasgupta, P. and J.E. Stiglitz (1980). "Uncertainty, industrial structure and the speed of R&D", *Bell Journal of Economics* 11(1) (Spring), pp1-28.

<sup>12</sup> Aghion et al use a version of the Lerner Index to calculate their measure of industry competition and a citation-weighted patent count to capture innovation performance. The Lerner Index is price minus marginal cost over price. Since marginal costs are hard to observe, the authors use a version of it that is operating profit (net of depreciation and provisions) minus the financial cost of capital all divided by sales. Their index of industry competition is found by subtracting from 1 the arithmetic average of the Lerner Indices for firms in the industry. In conditions of fierce competition, no firm makes any profit, all have a Lerner Index of zero, and the industry-level index reaches a maximum of 1. As competition becomes less fierce and some firms make profit, so the value of their Lerner Index rises and the industry competition index falls to lower levels. In general, the metrics for industry competition could include measures of industry concentration *per se*, and/or measure of the height of barriers to entry. Metrics for innovation could include R&D spending (an input measure), patents, innovations or levels and changes in total factor productivity.

The key question for our paper is whether the sort of relationship found to hold, on average, across all of manufacturing industry applies in the specific case of the defence industry.

The defence industry has unusual structural characteristics, in particular a single (monopsony) buyer on the demand side (the national Ministry of Defence) and this might affect the applicability in this case of the general analysis. The monopsony buyer of defence equipment has particular needs for and views about innovation and the power to influence the competitive conditions under which its suppliers operate. Government can determine the number of competitors in the industry by imposing regulatory barriers to entry; it can directly affect the level of demand; it can indirectly affect the level of competition in the industry by the way it structures programmes and distributes business among the firms; it can control the profits that suppliers make through the terms and conditions of its contracts; and, it can support industry innovation through funding R&D by industry and offering access to the knowledge base and experimental facilities of government research laboratories. Equally, of course, it may choose to do none of these things.

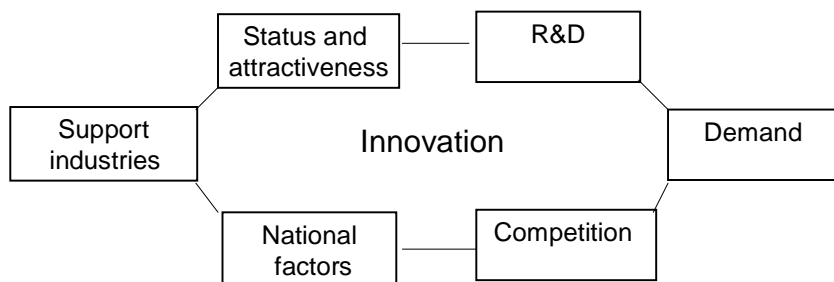
This leads us to another point, namely that competition is only one of a number of factors that drives innovation. David Teece criticises industrial organisation economics for its preoccupation with market power and argues that whilst competition and rivalry are important there are other factors that influence the rate and direction of innovation. The extent of vertical integration, organisational culture and values and the nature and extent of a firm's external linkages may all play a part.<sup>13</sup> In their study of the US fixed-wing military aircraft industry, Birker et al extend Porter's "competitiveness diamond" to identify six factors that drive innovation (see Figure 2). The nature and amount of competition is arguably the most important driver, they say, but other factors are significant: national factors and in particular the availability of human resources, physical resources, knowledge, capital and infrastructure; the status and attractiveness of the

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<sup>13</sup> Teece, DJ (1996). "Firm organization, industrial structure, and technological innovation". *Journal of Economic Behavior & Organization*. 31: 193-224.

sector to potential employees; the character of support industries such that innovation in military aircraft is in part influenced by the competitive posture, innovativeness and financial health of the industry supply chain; the composition and level of R&D funded and conducted by government and industry; and, demand conditions in terms not only of total demand but how that demand is distributed across products and industry segments and also the sophistication and insistence on quality of the buyer.<sup>14</sup>

**Figure 2: The six drivers of innovation in the US fixed-wing military aircraft industry**



(Source: Birkler et al, 2003)

### 2.3 Previous studies

The consequences of industry consolidation for innovation in the defence sector have been the subject of considerable academic and policy attention in the United States. Kovacic and Smallwood argue that many of the mergers that occurred in the US defence industry in the early 1990s featured acute tensions between claimed efficiencies (in terms of cost savings) and the weakening of competition as a procurement discipline. They express particular concern about the implications for innovation commenting that:

<sup>14</sup> Birkler, J, Bower, A, Drezner, J, Lee, G, Lorell, M, Smith, G, Timson, F, Trimble, W and Younossi, O (2003). *Competition and Innovation in the U.S. Fixed-Wing Military Aircraft Industry*. RAND: Santa Monica, CA.

“The main potential hazard of mergers is the danger that technological competition will diminish, and that specific technologies may become entrenched as the one or two remaining suppliers freeze out innovative design approaches that threaten their vested interests or defy conventional wisdom”.<sup>15</sup>

Mark Lorell observes that increased innovation in combat aircraft has occurred at times of increased demand, emergence of new component technologies and significant changes in military threat perceptions and buyer performance and capability requirements. Larger numbers of experienced and credible prime contractors are more likely than lower numbers of competitors to promote the greater competition to innovate that leads to new technology eras. Equally, in most cases, the key innovations that have led to radical change have come from firms who were not the dominant players at the time. These second-rank firms were often willing to take greater technological and financial risks in a bid to displace the dominant market leaders and revolutionary innovations have rarely come from the dominant firms of the time. In addition, higher levels of demand promote new entrants and much greater competition among contractors to innovate. A limited number of dominant credible contractors combined with high barriers to entry may reduce the incentives for competition to innovate, even during periods of rising demand.<sup>16</sup>

Birkler et al conclude their study of competition and innovation in the US fixed wing military aircraft industry by arguing that there were potentially serious questions about the level of competition and innovation in a future environment that may be dominated by one or two credible prime contractors in fixed-wing combat aircraft.<sup>17</sup>

Unfortunately, there has been little or no academic discussion of the impact on industry level innovation of changes in the structure of the UK defence industry. This is despite

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<sup>15</sup> Kovacic, WE and Smallwood, DE (1994). “Competition policy, rivalries, and defense industry consolidation”. *Journal of Economic Perspectives*. 8 (4): 91-110.

<sup>16</sup> Lorell, M (2003). *The U.S. Combat Aircraft Industry, 1909-2000*. RAND: Santa Monica, CA.

<sup>17</sup> Birkler, J, Bower, A, Drezner, J, Lee, G, Lorell, M, Smith, G, Timson, F, Trimble, W and Younossi, O (2003). *Competition and Innovation in the U.S. Fixed-Wing Military Aircraft Industry*. RAND: Santa Monica, CA.

the considerable consolidation that it has experienced since the end of the Cold War and growing public policy concerns about the decline in industry funding of defence R&D. In the following sections, we present evidence on changes to the structure of British defence industry and changing patterns of innovation since the end of the Cold War.

### 3. THE CHANGING STRUCTURE OF THE UK DEFENCE INDUSTRY

#### 3.1 Prime contract awards

One illustration of the dramatic change in the structure of the UK defence industry is provided by an analysis of the companies receiving prime contract awards. Table 1 lists the largest suppliers to the UK Ministry of Defence by value of prime contract awards in 1990-91 and 2005-06 and the nationality of those suppliers. The table shows significant changes in the UK defence market and two main points arise. First, there has been a significant change in the companies in the contracts list. Few of the companies who were listed in 1990-91 were still there fifteen years later. Second, the supplier base is more international: in 1990-91, the only foreign-owned company was the Westland Group; by 2005-06, U.S., Italian, French and European transnational companies played an important role.

**Table 1: Value of prime contract awards to private sector companies 1990-91 and 2005-06 (with nationality of foreign owned companies)**

| 1990-91           |   | 2005-06           |   |
|-------------------|---|-------------------|---|
| Contract awards   | Contractors   | Contract awards   | Contractors   |
| Over £375 million | British Aerospace<br>GEC<br>Rolls Royce<br>VSEL<br>The Weir Group | Over £500 million | BAE Systems<br>Finmeccanica (Italy)<br>General Dynamics (US)<br>QinetiQ Group |
| £151-375 million  | Babcock International<br>British<br>Telecommunications            | £250-£500 million | Babcock International<br>EADS (Europe)<br>EDS (US)                            |

|  |  |  |  |
|--|--|--|--|
|  | Dowty Group<br>Ferranti International<br>GEC Siemens<br>GKN<br>Hunting Engineering<br>Racal Electronics<br>Thorn EMI<br>Vickers<br>Westland Group (US) |  | Halliburton (US)<br>Lockheed Martin (US)<br>Raytheon (US)<br>Rolls Royce<br>Serco Group<br>Thales Defence (France) |
|--|--|--|--|

(Source: UK Defence Statistics 1991 and 2006)

### 3.2 Structural change in the industry

Structural change in the UK defence industry has largely taken the form of consolidation and Figure 3 shows the process of mergers, acquisitions, joint ventures and divestments that has led to the emergence of three of the UK's leading defence contractors.

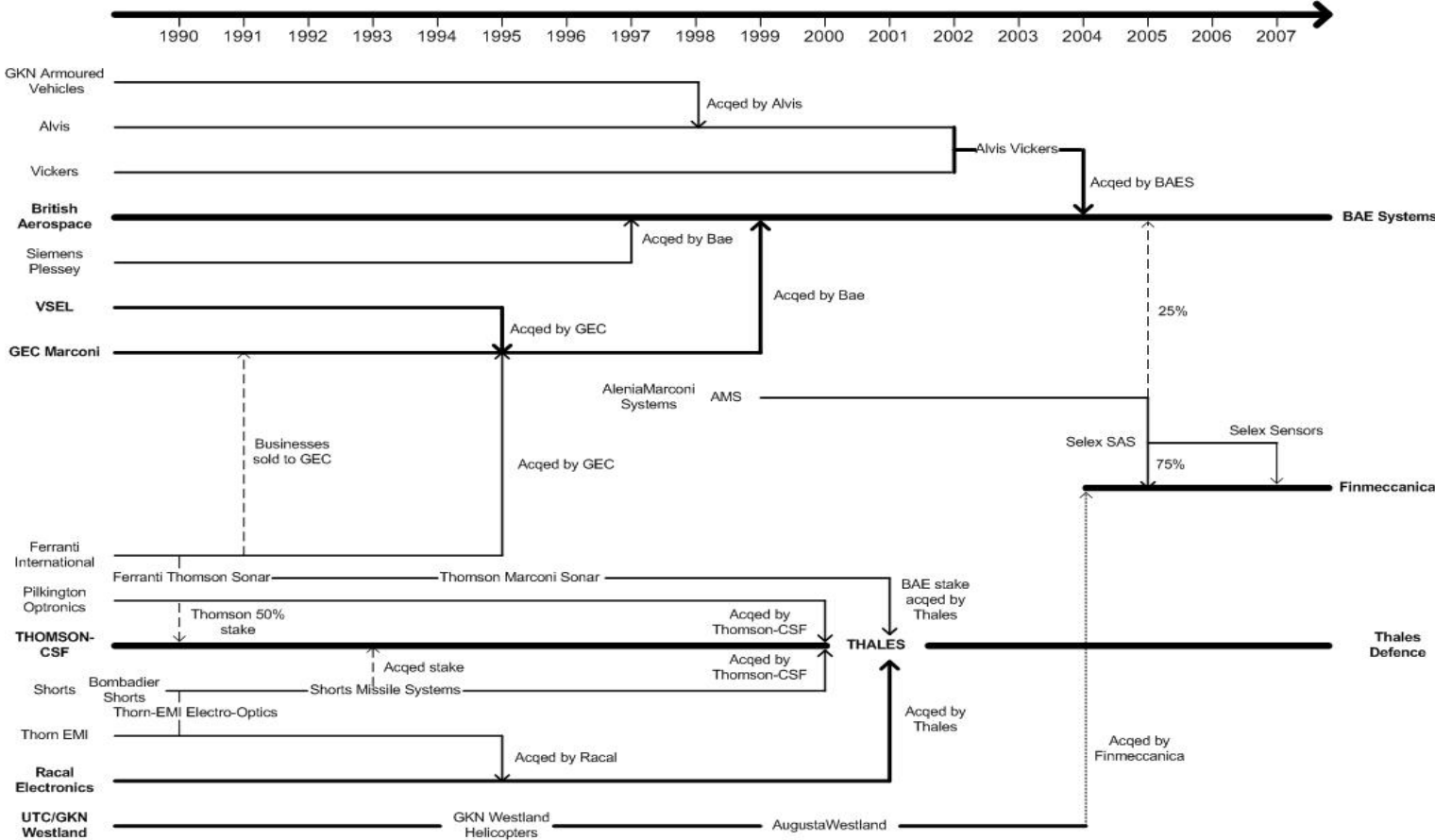
The 1990s saw a number of medium sized defence contractors (such as Racal, Ferranti and Alvis) and divisions of diversified engineering firms (such as Dowty and GKN's armoured vehicles division) exit the market through divestment of their defence businesses or merger.

The most significant transaction for the competitive landscape of the UK defence market was the 1999 acquisition of GEC Marconi by British Aerospace that led to the creation of BAE Systems. During the 1990s, UK government defence industrial and procurement policy had sought to sustain the GEC Marconi-British Aerospace duopoly as a means of maintaining a level of credible competition in the UK defence market. The formation of BAE Systems created a firm that had a central role on almost all major UK defence programmes from nuclear submarines to fast jet combat aircraft and (with its acquisition of Alvis Vickers) armoured fighting vehicles.



There were also a number of new entrants including Finmeccanica, Thales, EADS, General Dynamics and QinetiQ. In most cases, these were new owners rather than new entrants in the strict sense of the term. The entry of QinetiQ was the product of the privatisation of the greater part of the UK government's defence research establishments. The entry of foreign firms such as Finmeccanica and Thales was through the acquisition of existing UK defence businesses or buy-outs of UK partners in established defence joint ventures. This process was encouraged by the UK government in part as an attempt to create a credible competitor to BAE Systems.

**Figure 3: The consolidation of the UK defence industry and the emergence of BAE Systems, Finmeccanica and Thales**



### 3.3 Consolidation

The overall effect of these structural changes has been to reduce the number of firms competing with each other within the industry although the extent of competition within industry sub-sectors does differ. Table 2 lists the companies in the UK defence industry that have what the Ministry of Defence describes as platform systems level capability. This shows that there are single UK sources of platform systems level capability in some segments. In the case of fast jet combat aircraft, this has been the case for several decades. In the case of armoured fighting vehicles, this has been the product of consolidation over the last decade - from five or more prime companies (GKN Defence, Alvis, Vickers Defence Systems, RO Defence and Marconi Defence Systems) to one - BAE Systems Land Systems. In other segments, particularly C4ISTAR, there are a significant number of UK based companies with platform systems level capabilities.

**Table 2: Companies with platform systems level capability (2006)**

| Sector  | Company  |
|---|--|
| Fast jet combat aircraft & maritime patrol fixed wing | BAE Systems  |
| Helicopter  | AgustaWestland UK<br>Eurocopter  |
| Strategic airlift (C-130)                             | Marshall of Cambridge  |
| Submarines  | Babcock Naval Services Ltd<br>BAE Systems<br>KBR (including DML)                       |
| Complex surface warships & Royal Fleet Auxiliary      | Babcock Engineering Services Ltd<br>BAE Systems<br>KBR (including DML)<br>Thales<br>VT |
| Armoured Fighting Vehicles                            | BAE Systems  |
| Complex weapons                                       | MBDA (UK)  |

|                      |  |
|----------------------|--|
|                      | Raytheon Systems Limited<br>Thales<br>BAE Systems UWS  |
| Non-embedded C4ISTAR | BAE Systems, Thales, EADS, General Dynamics, Lockheed Martin, Northrop Grumman, Raytheon, Selex Communications, VT Communications, Ultra Electronics, BT, EDS, Fujitsu, LogicaCMG, QinetiQ |
| CBRN                 | Smiths Detection<br>General Dynamics UK<br>SERCO Assurance<br>EDS  |

(Source: Ministry of Defence, Defence Industrial Strategy, 2005)

#### 4. THE CHANGING PATTERN OF INNOVATION IN THE UK DEFENCE INDUSTRY

We now turn to consider changes in the pattern of innovation in the UK defence industry using R&D spending as a proximate measure of innovation in the UK defence industry.<sup>18</sup>

##### 4.1 Defence R&D trends

Let us begin by looking at the trend changes in overall UK defence R&D spending since 1989. Figure 4 shows all defence R&D conducted in the UK by performer and the first point to emphasise is that total defence R&D spending has fallen dramatically in real terms since the end of the Cold War. Defence R&D fell by half in real terms between

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<sup>18</sup> We fully recognise and accept that R&D is an input measure for innovation and is also an incomplete and imperfect representation of innovation performance. R&D is a “traditional indicator” of innovation that captures “only a limited amount of the innovation and innovative potential that exists in the UK” (Harris, M., P. Nightingale and V. Acha (2006), *The Innovation Gap: Why Policy Needs to Reflect the Reality of Innovation in the UK*. London, NESTA (National Endowment for Science Technology and the Arts), Research Report (October). That said, aerospace and defence, together with pharmaceuticals, account for over half of the R&D performed by the UK’s top 750 companies (*ibid*, p20), suggesting that R&D may be more important as a driver of innovation in defence than in many other sectors of industry.

1989 and the low point in defence R&D spending in 2003 and despite an increase in recent years it was almost 40 percent lower in 2005 than it was in 1989.

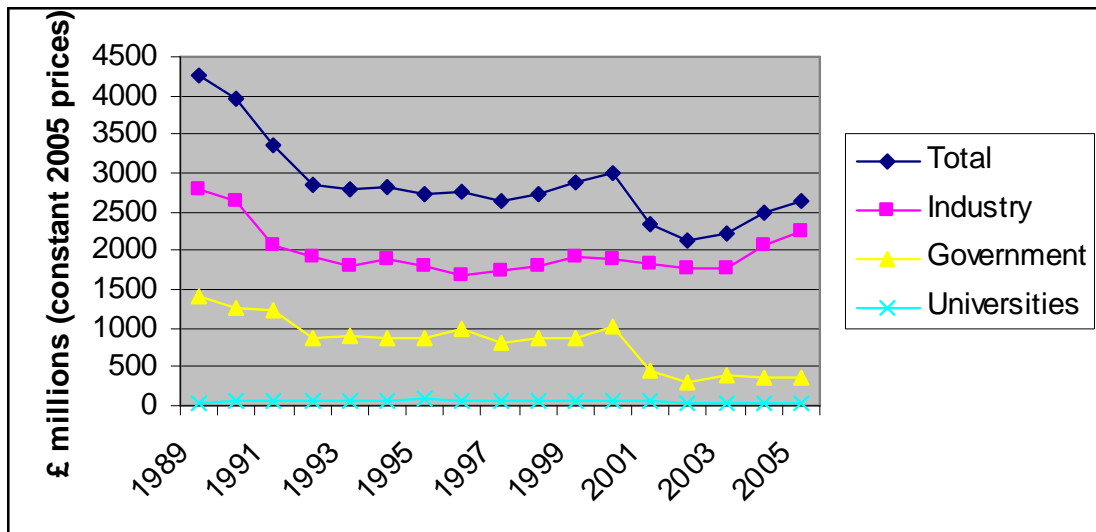
Defence R&D conducted by government in its own defence research establishments accounted for around one-third of all UK defence R&D until the privatisation of the government's defence research establishments in 2001. Defence R&D conducted in the government research establishments fell by almost 40 percent in real terms between 1989 and 1994 and after recovering slightly it was still 27 percent lower in 2000 when compared with 1989. The sharp decline in 2001 is explained by the privatisation of the defence research establishments to form QinetiQ at which point defence R&D conducted by QinetiQ was reclassified as industry R&D and government conducted R&D fell significantly.

Defence R&D performed by industry represents the largest share of defence R&D conducted in the UK (around two-thirds of UK defence R&D prior to the formation of QinetiQ). The value of defence R&D performed by industry also fell dramatically between 1989 and 1996 by 39.5 percent. Despite an increase in later years, defence R&D conducted by industry in 2005 was still almost 20 percent below its 1989 level.<sup>19</sup>

**Figure 4: Defence R&D conducted in the UK by performer 1989-2005**

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<sup>19</sup> Universities conduct only a modest amount of defence R&D in the UK and will not be considered here.



(Source: Office of National Statistics <http://www.statistics.gov.uk/>)

#### 4.2 Defence R&D performed by UK industry

The figures discussed so far relate to the value of defence R&D performed by industry rather than the sources of funds for that R&D. Figure 5 looks in more detail at defence R&D in UK businesses and shows the changes in the sources of funds for defence R&D in UK businesses between 1989 and 2005.

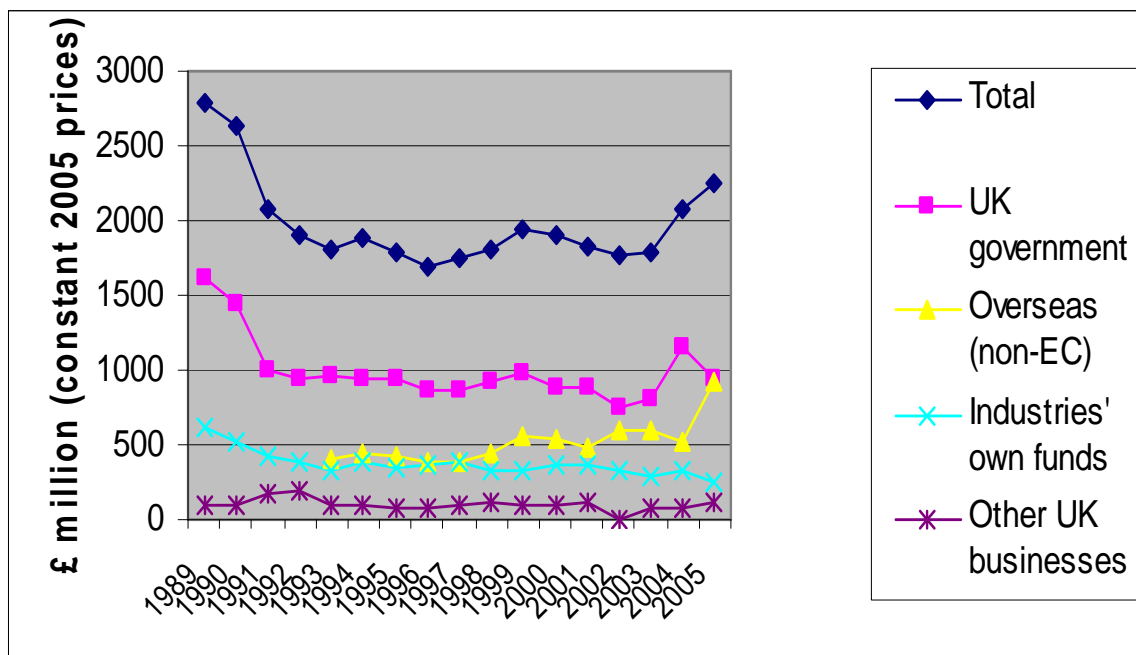
This shows that industry's own funded R&D has always been a relatively small share of the defence R&D conducted by UK businesses and that it saw a remarkable decline between 1989 and 2005. In 1989, industry's own funded defence R&D accounted for 20% of its R&D - by 2005 this had fallen to a little over 11%. In 1989 industry funded defence R&D worth £610 million (in 2005 prices). By 2005 this had fallen to a little over £250 million. This represents a dramatic decline of almost 60% in real terms between 1989 and 2005. This is all the more remarkable when we remember that all defence R&D spending was around 40 percent lower in 2005 than it was in 1989. Industry R&D spending also fell by considerably more than defence procurement spending during the same period.

While the UK defence industry may have been funding substantially less R&D from its own sources there has been a striking increase in the importance of funding from

overseas. Overseas sources of funding for defence R&D conducted by UK companies has more than doubled since 1993 to reach £927 million in 2005. Overseas sources have increased from 22% to 41% of funding of defence R&D in UK businesses. Whilst there is no further information available from the CSO as to the precise sources of these funds we may speculate that this reflects the growing importance of international collaborative projects (particularly the Joint Strike Fighter) as well as increasing efforts by UK companies to obtain research contracts from foreign governments (particularly the United States). The statistics do not indicate European Commission funding as being important.

At the same time, UK government funding for defence R&D conducted by UK businesses has declined. In 1989, UK government funding accounted for 58% of defence R&D - by 2005 it had fallen to 42%. Indeed, by 2005 overseas funding was on par with UK government funding. In some part, this is likely to reflect a shift in UK government funding - rather than funding defence R&D directly some defence R&D is being funded by the UK government through international collaborative programmes such as the Joint Strike Fighter. However, in large part the decline in UK government funding reflects the steep decline in UK government defence R&D since the mid 1980s.

**Figure 5: Sources of funds for defence R&D in UK businesses (1989-2005)**



(Source: Office of National Statistics <http://www.statistics.gov.uk/>)

## 5. DISCUSSION

In Section 2, we reviewed work from the industrial organisation economics literature that seeks to understand how an industry's changing structure and competition may help explain changing levels of innovation within an industry. We raised the question of whether this theory holds in the specific case of the defence industry with its unusual (monopsonistic) characteristics. In Sections 3 and 4 we described the changes in the structure of the UK defence industry since the late 1980s and noted the steep decline in innovation funded by the UK defence industry.

### 5.1 Industry structure and changes in defence industry innovation

Can an explanation for the dramatic decline in industry funded defence R&D be found in the inverted U-shape relationship between industry structure and innovation postulated by industrial organisation economics theory?

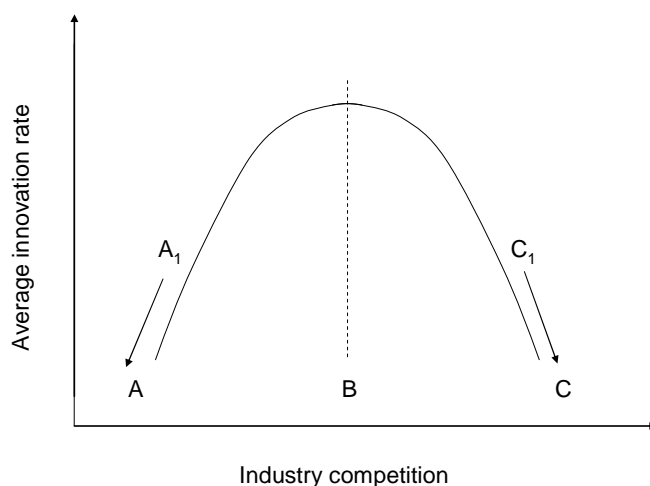
If the inverted U-shape applies here, a fall in industry innovation is predicted to occur under one of two scenarios: (a) starting at a moderate to low level of competition,



industry structure then changes to bring about a yet-lower level of competitive pressure (in Figure 6, a shift to the left from  $A_1$  towards A); (b) starting at a moderate to high level of competition, industry structure changes to yield even more intense competition among firms (in Figure 6, a shift to the right from  $C_1$  towards C).

Suppose first that we cannot calibrate the model to say at what intensity-level of competition, relative to that associated with peak innovation performance, the industry was operating at the start of our period of observation. However, if we can say something about the direction in which the level of competition in the industry moved, and if we accept that an inverted U-shape relationship holds in the UK defence industry, we could infer from that, and the observation that innovation fell, whether it was in 1990/1 at the left-hand side of the peak or the right. On the other hand, we have to be open to the logical possibility that at the same time as industry innovation fell, intensity of competition increased (decreased) from an observably low (high) initial level of competition. In that event, we would have evidence that the inverted U-shape hypothesis did not hold in this case.

**Figure 6: Industry structure and changes in defence industry innovation in the UK**



Comparing the groups of prime contractors, the number of companies awarded major contracts in the British defence industry fell slightly over our period of analysis - from 16 to 13. But “the defence industry” is, like all “industries” a construct and it is of at least as great interest to disaggregate it into its component parts<sup>20</sup>. If we do that, we discover from Table 2 that in three sub-sectors (i.e. fast jet combat aircraft and maritime patrol fixed wing; strategic airlift; armoured fighting vehicles) it would have been impossible for conditions to have moved from less to more internally competitive since in 2006 there was only one firm. There were also low numbers of competitors in helicopters (2) and submarines (3), and in the remaining sectors, two with 4, one with 5 and one (non-embedded C4ISTAR) with 15. Of these, helicopters and submarines had become no more competitive in terms of firms performing MoD work. But this is a very mixed bag and it seems possible that some sub-sectors (in particular non-embedded C4ISTAR) may have become more competitive rather than less.<sup>21</sup> Clearly, it would be dangerous to put down observed changes in R&D to changes in industry structure alone. *But a possible explanation for what we observe may be that scenario (a) above applies to some, possibly most sub-sectors, scenario (b) to perhaps one sub-sector, and that the joint impact of changes in both groups is sufficient to explain the observed decline in overall R&D.*

## **5.2 Non-structural explanations: the role of government**

Changes in industry’s own funded defence R&D may be explained in part by changes in industry structure and competition but competition is not the whole story. The level of demand, procurement reform and the character of demand have all played a part in reducing both the opportunities and incentives for defence industry innovation and explain in part the observed decline in industry’s own funded defence R&D. Let us consider each in turn.

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<sup>20</sup> Kovacic and Smallwood (1994) do something similar in their analysis of competitiveness in US defence industry.

<sup>21</sup> The picture is complicated by the fact that sub-sectors can be defined in different ways. On the other hand, however sub-sector boundaries are drawn, it remains quite possible for competition to have decreased in some cases and increased in others and to yield the same overall result.

The *level of demand* reduced the opportunities and incentives for defence industry innovation. There are simply fewer new defence equipment programmes and programmes have been cancelled or delayed. Thus, there are fewer opportunities for industry to innovate and less incentive for industry to invest in its own R&D directed at existing or anticipated UK MOD requirements. This cannot be the whole story, however, because industry's own funded R&D has fallen more sharply than UK defence procurement spending. Equipment spending fell by 21% in real terms between 1990-2000. Industry's own funded R&D fell by 28% during the same period.

*The Levene procurement reforms* introduced in the 1980s had the effect of reducing incentives for industry innovation. A shift from cost-plus towards fixed price contracts sought to shift programme risk from the MOD to the prime contractor and had the effect of reducing industry's incentive to pursue high risk-high return radical technological innovation.<sup>22</sup> Simultaneously, government commitment to "value for money" achieved, wherever possible through competition, reduced industry opportunities for earning more-than-normal profit in the production phase. This is a critical point because we have noted how economic theory emphasises the importance of profit in generating or attracting funds for innovation. The balance between risk and reward on UK defence contracts has been an issue of on-going concern for the UK defence industry.

Equally, perhaps some of the decline in own funded R&D can be explained by the *character of demand*. In their US study, Birkler et al emphasise the importance of the sophistication and insistence on quality from the buyer and how: "The composition of demand shapes how firms perceive, interpret, and respond to buyer needs".<sup>23</sup> The experience of several high profile technology failures (Nimrod in the 1980s and Bowman in the 1990s) has made the MOD risk averse when it comes to technological innovation and there has been an emphasis within MOD on mature technologies rather than radical

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<sup>22</sup> Equally, there are good reasons to argue that the Levene reforms may have increased incentives for process innovation as prime contractors sought to improve efficiencies in their R&D and manufacturing activities. At the same time, it may have increased incentives for prime contractors to shift some of the responsibility (and risk) for innovation down the supply chain.

<sup>23</sup> Birkler, J, Bower, A, Drezner, J, Lee, G, Lorell, M, Smith, G, Timson, F, Trimble, W and Younossi, O (2003). *Competition and Innovation in the U.S. Fixed-Wing Military Aircraft Industry*. RAND: Santa Monica, CA: p.54.

technological innovations. The Levene Reforms were accompanied by cuts in UK defence R&D. The MOD made clear in its 1987 Statement on the Defence Estimates that it would no longer fund “gold plated” technological solutions that required the funding of new R&D programmes. Instead, the defence industry would be expected to seek off-the-shelf technological solutions wherever possible either from the civilian sector or (more likely) from teaming with foreign firms to access technology developed overseas. Taken together, the effect of these policy changes appear to have been to reduce the incentive for innovation in the UK defence industry.

### **5.3 Innovation to industry structure: “reverse flow causation”?**

While we have focused mainly on arguments relating industry structure to innovation, we must also be open to possibility that any observed relationship between the two could equally well be the result of causation flowing from innovation to structure rather than (or more likely as well as) from structure to innovation.

Business investment in innovation can have several effects with structural implications. If undertaken by incumbents, it can raise barriers to entry against potential entrants and/or create and sustain competitive advantage for individual firms, positioning them to grow at the expense of others, and perhaps take them over. If undertaken by outsiders, it can provide a means of entry that would not be possible otherwise.

We know that the cost, complexity and risk associated with defence innovation has increased dramatically over time and that this has been one of the drivers of consolidation. If large multidivisional and multiproduct defence companies are better able to spread the costs and risks of innovation then perhaps what we have seen is innovation driving consolidation. In the case of the UK defence industry, many medium sized companies came to the conclusion during the late 1980s and early 1990s that increasing R&D costs and risks combined with declining market opportunities meant that they either had to grow (through acquisition) or exit (through divestment). Many chose the latter and redirected their capital (and innovation efforts) into the civil arena.

On the other hand, the non-UK companies that have taken their place have done so on the back of successful investment in defence-oriented innovation undertaken overseas. In particular, we have in mind US companies such as General Dynamics, Lockheed Martin and Raytheon. We have noted how the Levene Reforms signalled a growing demand on the part of the MOD for off-the-shelf solutions that involved lower development risk and less need for MOD R&D funding of new technologies. Consequently, the 1980s and 1990s saw MOD award contracts to overseas firms offering relatively stronger innovation track records. The scale of US defence R&D spending relative to Europe meant that US companies were particularly well positioned to access the UK market.

The impact on the level of competition in the industry is ambiguous. The changes included a fall in the number of players in the industry suggesting a reduction in competition. Simultaneously, it led to an increase in the exposure of incumbents operating in the UK to outsiders.

## **6. POLICY ISSUES**

Our analysis suggests that changing industry structure may be necessary to understand the decline in industry's own funded R&D but it is not sufficient. In part, the MOD as monopsonist has reaped what it has sown: in particular, the Levene procurement reforms had the effect of reducing the opportunities and incentives for industry defence R&D investment and the risk-reward balance appears to remain a disincentive to industry investment. The level of industry funded defence R&D is a matter of policy concern to government.<sup>24</sup>

### **6.1 Does the decline in industry's own funded R&D matter?**

Let us begin by considering whether government should care about the decline in own funded R&D in the defence industry. The main reason why it may matter is that the decline in own funded R&D may reduce diversity within the UK defence innovation system. Diversity is enhanced where the defence industry is willing and able to generate its own ideas and propose new solutions to MOD. This is most likely to occur where

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<sup>24</sup> Ministry of Defence (2006). *Defence Technology Strategy*. Ministry of Defence: London.

industry funds its own R&D independent of MOD. If industry is becoming increasingly dependent on funding from MOD or overseas defence programmes (as the data suggests) then the capacity of the defence innovation system to generate new ideas may be impaired. This is important because the MOD's ability to generate technological innovation itself has been severely reduced by the privatisation of QinetiQ (its former defence research establishments) and the MOD defence R&D budget is being cut in favour of budgets supporting the operations in Iraq and Afghanistan.<sup>25</sup> It is also important because the MOD's Defence Industrial Strategy sets out a vision of the future where: "as industry sees that we are able to insert new capability rapidly as technology develops, it will be motivated to invest its own resources, alongside our research, to help us understand the opportunities and offer unsolicited proposals for improving our capability".<sup>26</sup> There is little evidence that such a situation has existed over the last two decades.

Against these arguments there are some good reasons to question whether MOD ought to be concerned about the decline in own funded R&D. Industry's own funded R&D has always represented a relatively small share of UK defence R&D spending and within that the figures for own funded defence R&D are dominated by a small number of large prime contractors.<sup>27</sup> This raises the question of whether MOD is wise to focus its policy attention on prime contractors. We know that the role of primes is increasingly as systems integrators with responsibility for the management of architectural innovation, suppliers are increasingly responsible for design, development and production of key sub-systems and components are sourced from globalised commercial suppliers. If significant innovation now occurs at all levels of the supply chain as well as at the prime contractor level then this suggests that the focus of policy attention needs to shift towards the supply chain. Equally, there is recognition that the broader science and technology base beyond the traditional defence-industrial-scientific complex has the potential to play an important

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<sup>25</sup> Select Committee on Defence (2007). *The Work of the Defence Science and Technology Laboratory and the Funding of Defence Research*. Eighth Report HC84. The Stationery Office: London.

<sup>26</sup> Ministry of Defence (2005). *Defence Industrial Strategy*. Ministry of Defence: London: p.63.

<sup>27</sup> The data does not allow us to break it down by company but we know from the DTI's R&D Scoreboard that aerospace and defence sector R&D is highly concentrated with the two largest R&D spenders (BAE Systems and Rolls-Royce) accounting for over 70% of R&D spending. There is no reason to think that the defence industry alone is any less concentrated.

role in defence innovation and that we are seeing a shift from a closed to a more open defence innovation system.<sup>28</sup>

## 6.2 Policy options

If the MOD has reaped what it has sown then what, if any, options are open to policy makers concerned to increase the level of own funded R&D in the UK defence industry?

Should policy makers seek to change industry structure? This returns us to our starting point in industrial organisation economics theory. The U-shape relationship between structure and innovation suggests that policies aimed at increasing competition may stimulate an increase in industry innovation, *in some circumstances*. An increase in competition in the armoured fighting vehicle or submarine sectors might well stimulate an increase in industry own funded R&D as would-be new entrants sought to establish themselves and established companies sought to defend their incumbent positions. In other sub-sectors (such as C4ISTAR) increased competition might actually have the effect of reducing industry innovation. At the moment, increasing competition may simply reinforce incumbents in their belief that the UK is an unattractive market and cause them to redouble their efforts to shift the focus of their investments from the UK to the US.<sup>29</sup>

If increased competition may stimulate innovation in some circumstances then what regulatory tools could policy makers use to increase competition? MOD has already made the UK defence market contestable by threatening or actually opening up its national markets to competition from foreign firms. However, there is some evidence to suggest that foreign (and especially US firms) are becoming concerned that they are used as stalking horses to generate competition without having a realistic chance of winning those competitions.<sup>30</sup> Sustaining contestability is important. Equally, MOD might enhance competition through procurement reforms that make it easier for non-defence

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<sup>28</sup> James, AD (ed) (2008). *The Dynamics of Innovation in the Defence Sector: Economics, Technology and the New Security Environment*. Cheltenham: Edward Elgar.

<sup>29</sup> Harrison, M (2007). "Cobham urges more defence R&D spending". *The Independent*. 16 March 2007.

<sup>30</sup> Codner, M, Willett, L and Heywood, L (2007). *The Defence Industrial Strategy -- An Analysis of Industrial Responses*. London: Royal United Services Institute.

suppliers to act as prime contractors. We admit that the latter is an old chestnut that has been the aspiration of procurement authorities on both sides of the Atlantic for two decades or more without leading to any discernible change.

Should policy makers seek to change the balance between risk and return on procurement contracts? The importance of profit in generating or attracting funds for innovation is a core element of industrial organisation economics theory and it has been the source of considerable tension between industry and government in the UK. Prior to the publication of the MOD's Defence Industrial Strategy, BAE Systems had publicly complained about the profitability of its UK contracts and threatened to withdraw from the UK market in favour of the US.<sup>31</sup> More recently, a spokesman for the UK industry association the Society of British Aerospace Companies (SBAC) was quoted as saying:

"The MoD wants to change the balance of investment in defence R&D. But we have not seen a change from the government in the balance of risk and reward. The government needs to create an environment in the UK in which companies feel comfortable to invest".<sup>32</sup>

There is growing interest in the potential for long term fixed price contracts for the delivery of a service rather than an item of equipment ("power by the hour"). Such contracts are used in civilian markets where they can act to incentivise industry to invest in innovation as a means of increasing industry's profit margins within these fixed price contracts.

Should policy makers shift their attention towards the contribution of supporting industries to innovation? Looking at the US, King and Driessnack argue that policy makers may be better served by focusing on innovation within the supply chain rather than seeking to sustain competition amongst prime contractors. In their view, ensuring

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<sup>31</sup> Barrie, D (2005). "British defense industrial strategy secures BAE Systems as U.K. champion, *Aviation Week & Space Technology*, December 17, 2005

<sup>32</sup> Gilbert, N (2007). "Prepared for a fight: battle continues over defence funding". *The Guardian*. March 13, 2007.



that work is delegated to appropriate tiers of the supply chain will help sustain competition and innovation while prime contractors can focus on their core capabilities in systems integration.<sup>33</sup> The same can be said of the UK and the Defence Industrial Strategy and Defence Technology Strategy indicate that there is an increasing recognition amongst policy makers of the importance of the supply chain to defence innovation. The Defence Technology Strategy includes discussion on how to broaden the supplier base, “spin in” technologies and stimulate new entrants to the supply chain. The Defence Industrial Strategy includes a recognition that procurement policies need to ensure that suppliers receive proper returns for innovation and that value flows through to the layers of the supply chain that are innovating rather than being retained by prime contractors.<sup>34</sup>

## **7. CONCLUSION**

We conclude that, in the special case of the defence industry, industrial organisation economics theory is necessary but not sufficient for an understanding of how industry innovation has changed in the UK. We have noted how industry consolidation has been accompanied by a steep decline in industry’s own funded defence R&D and we have argued that this may be explained in part by changes in industry structure. We have also argued that industry competition is not the whole story and that another part of the explanation relates to public policy. The MOD as monopsonist has reaped what it has sown: changes in its level of demand for defence equipment, procurement reforms that have shifted the balance of risk and reward for industry and the changing character of demand have all played a part in reducing both the opportunities and incentives for defence industry innovation. We have also proposed a third explanation, namely that changes in the nature of defence innovation may themselves in part have driven consolidation.

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<sup>33</sup> King, DR and Driessnack, JD (2007). “Analysis of competition in the defense industrial base: an F-22 case study”. *Contemporary Economic Policy*. 25 (1), 57–66.

<sup>34</sup> Ministry of Defence (2005). *Defence Industrial Strategy*. Ministry of Defence: London: p.66.

In this paper, however, the constraints of the available data mean that we have been able to do no more than speculate on many of these issues. For instance, our analysis has been based on an input measure of innovation (defence R&D spending) and it would be desirable to develop suitable output measures. A starting point could be a time-series analysis of patenting data for UK defence companies. Patent data have their critics, of course, and the role of secrecy in the defence sector means that patenting may only provide a partial account of the innovation output of the defence industry. Nevertheless, it would be a start. Equally, an analysis of the profitability of defence companies operating in the UK market would be desirable albeit full of practical difficulties. There is also a need for case studies of defence equipment innovation in the UK as a means of understanding the dynamics of the innovation process and the relative importance of competition, industry R&D, government conducted R&D and linkages with overseas sources of technology.

### **Acknowledgement**

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