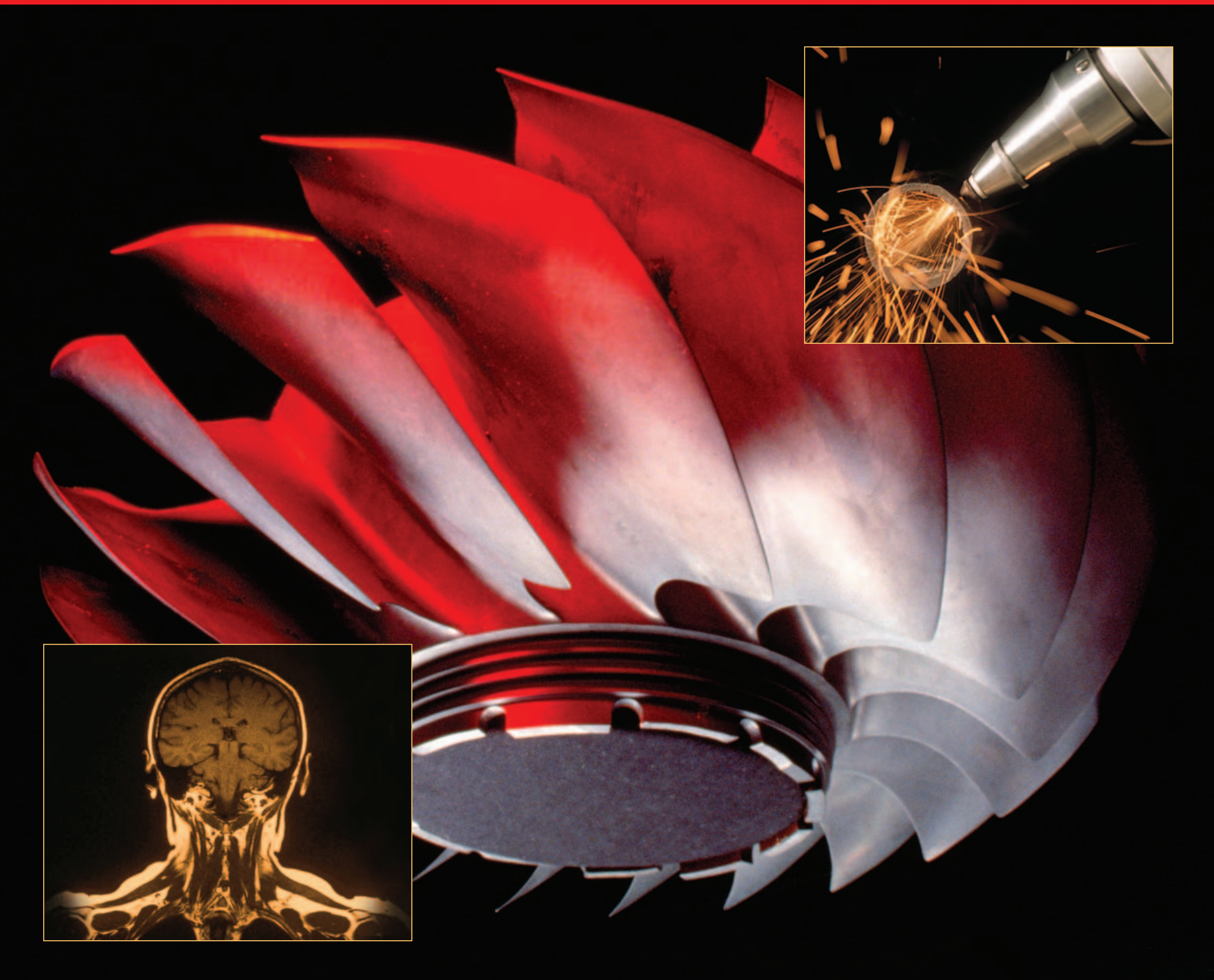
Institute of Physics Report

Physics and the UK Economy

A report prepared for the Institute of Physics by the Centre for Economics and Business Research Ltd

September 2007



IOP Institute of Physics

This is a report by the Centre for Economics and Business Research (cebr) to provide the Institute of Physics with an assessment of the importance of physics to the UK economy. It has been produced by cebr, an independent economics and business research consultancy established in 1993, which provides forecasts and advice to City institutions, government departments, local authorities and numerous blue-chip companies throughout Europe.
London, September 2007

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1: Introduction and summary

This report examines the contribution of physics to the UK and how the use of physics in the UK economy between 2000 and 2005 has changed. This research highlights the value generated by physics-based sectors[1] for the economic prosperity of the UK.

It updates and extends *The Importance of Physics to the UK Economy 2003*. The definition of physics-based sectors has been extended to include a wider range of sectors involved in physics-based activities in the UK economy – and not just within the manufacturing sector – to take account of the rapidly changing structure of business. For example, this would include companies ranging from consultancies to engineering sectors.

Physics-based sectors currently play a large role in the UK economy

In 2005 there were just over a million employee jobs in sectors where the use of physics-based technologies or expertise was critical to the existence of the sector. This is equivalent to the total number of employees in the construction sector and to about 5% of all jobs in the UK. In 2005, employment in physics-based sectors was concentrated in approximately 32 000 businesses where the use of physics-based expertise or technologies was critical to the existence of the sector. This is equivalent to approximately 2% of all registered businesses in the UK.

Physics-based sectors are highly productive

This report shows that physics-based sectors are typically more productive relative to the UK average. The economic activity of physics-based sectors, measured in terms of gross value added (GVA), stood at £70 billion in 2005 – making up 6.4% of the total UK economic activity. This is almost as high as the economic output produced by companies in finance, banking and insurance.

The rise in GVA in physics-based sectors over the last four years reflects the falling cost of raw materials, as well as technological advances and growing demand for high-value products.

Productivity in physics-based sectors is also higher than the national average. In 2005, GVA per employee in physics-based sectors was approximately £69 000 – about 70% higher than in the UK as a whole.

Physics-based sectors also support the wider economy

The activity in physics-based sectors also helps to support jobs and growth in the wider economy. For example, an indirect or multiplier effect is created by the physics-based sectors as they support activity in upstream markets. In 2005, physics-based sectors supported an additional 3.7 million jobs upstream and £53.4 billion of GVA – equivalent to 5% of the UK's economic activity.

Turnover is not rising as fast as in the UK and employment is falling

Although physics-based sectors make a significant contribution to the economy, the sector is in decline. Turnover in physics-based sectors rose by just 4% between 2000 and 2005 – significantly less than the 25% growth in the UK as a whole. Although physics-based sectors are becoming more productive, they are generating less in turnover relative to the rest of the UK. The turnover generated by the physics sectors in 2005 amounted to £180 billion – 9% of the economy's total turnover.

The UK has seen fast growth in employment – particularly from finance and business services, and the public sector. Physics-based sectors, however, have seen a significant decline in employment in recent years. In 2000–2005, employment in physics-based sectors declined by about 16%.

Export performance of physics-based sectors is weaker than other exporting countries

In 2005, physics-based sectors exported £92.9 billion and imported £109.8 billion worth of goods and services. This accounted for 29% of the total value of UK exports and 30% of imports. However, the UK has a significantly lower share of exports in physics-based sectors compared with other major international players.

Research and development (R&D) will help physics-based sectors to continue producing high-value output and to increase their ability to compete internationally. However, since 2001 the amount of investment has fallen each year. The spending on R&D in physics-based sectors amounted to £3.3 billion in 2004 – almost a quarter (24%) of total R&D expenditure in the UK.

1. Physics-based sectors are defined as sectors where the use of physics – in terms of technologies or expertise – is critical to its existence. A fuller outline of this definition is available in appendix 1.

2: Jobs, turnover and value added

This chapter assesses the importance of physics-based sectors to the UK economy in terms of employment, turnover and GVA. To capture this importance the direct contribution made to the economy by sectors where the use of physics is critical for their existence is identified. This is measured in terms of employment, turnover and GVA.

Employment

In this section employment in physics-based sectors is explored. In particular, the range of physics-based sectors in the UK economy and how many people are employed in them are addressed. The trends in employment in the physics-based sectors are analysed and compared to other sectors in the UK.

More than a million employee jobs in physics-based sectors

This report estimates that in 2005 there were just over a million employee jobs in sectors where the use of physics-based technologies or expertise was critical to the existence of the sector. This is roughly equivalent to the total number of people employed in construction and equates to about 5.4% of all jobs in the UK (figure 1).

To measure this, employee jobs data from ONS *Annual Business Inquiry* are used (box 1). The relevant sectors are analysed at a four-digit class classification to develop a definition of physics-based sectors. Given the fine granularity of data at this level, for most cases it is assumed that a sector is, or is not, physics based. Using this method means that the figures presented here will be sensitive to sectors where there are a large number of employees who may not be involved in activities relating to physics. For example, although physics teachers work in the education sector, there are also many other teachers and administrative staff. As a result, adjustments have been made for specific sectors, where appropriate. If all employees in these sectors were included, the number of employees in physics-based sectors would amount to 1.5 million — an increase of 500 000 people.

Our calculations are different from those provided by the Department of Trade and Industry (DTI) in its scoreboard. Businesses that appear in the scoreboard that would be categorised in physics-based sectors have been identified and the scoreboard figures show that employment in sectors where the use of physics is critical, amounted to around 1.3 million in 2005. There is a difference between these calculations for employment using the *Annual Business Inquiry* data presented here and the DTI's figures. The *Annual Business Inquiry* excludes overseas operations of subsidiaries, while the DTI's includes these by taking the group accounts. For example, employment figures for BP plc includes employment in its subsidiaries in other European countries. Additionally, the *Annual Business Inquiry* includes all businesses in the UK, while the DTI's scoreboard only includes the largest 800 companies in the UK.

Box 1: What is included in the estimates of employment in physics-based sectors?

Estimated figures in this part of the report include:

- employee jobs from the ONS *Annual Business Inquiry* and not workforce jobs (as estimated in the *Labour Force Survey*); this method allowed a more detailed breakdown of employment by sector and, as a result, the figures do not include the self-employed, unpaid family workers and those who are on government-supported training and employment programmes;
- adjustments for the large number of employees in three of the sectors: defence activities; architectural and engineering activities, and related technical consultancy; and telecommunications.

Source: ONS 2006.

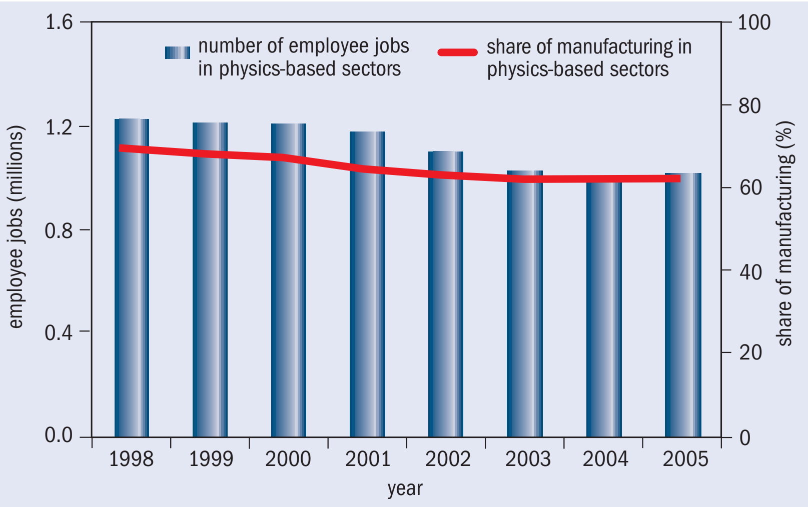


Figure 1: Employment in physics-based sectors. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

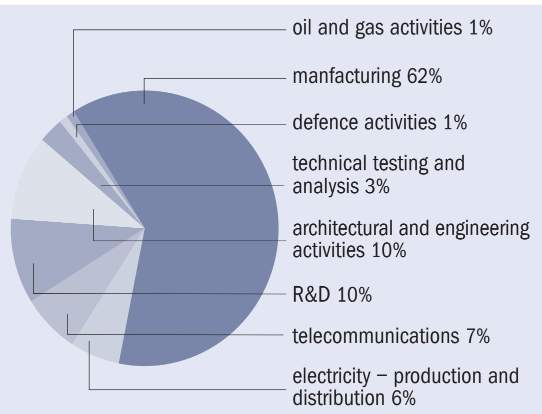


Figure 2: Share of UK employment in physics-based sectors by broad sector (%). Source: cebr analysis of ONS *Annual Business Inquiry 2004*.

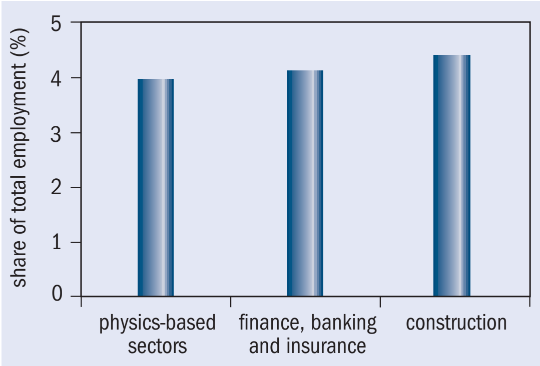


Figure 3: Share of total UK employment – the 2000–2005 average. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

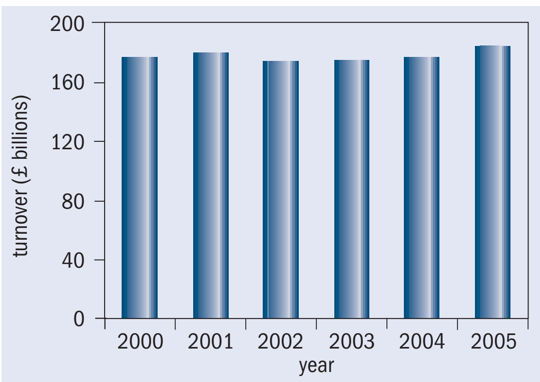


Figure 4: Turnover in physics-based sectors (at current prices). Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

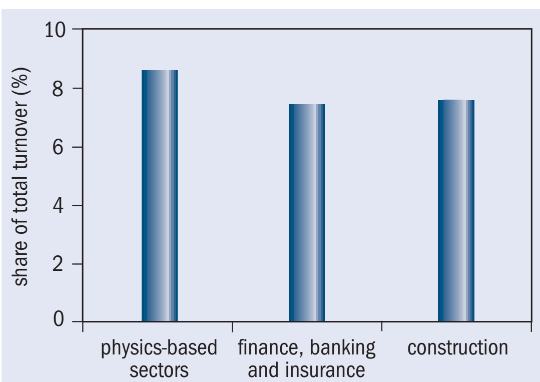


Figure 5: Share of total UK turnover – the 2000–2005 average. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

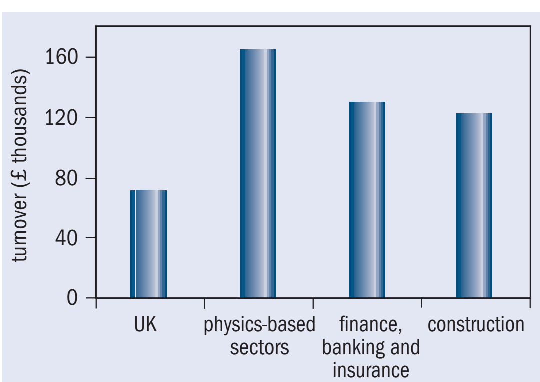


Figure 6: Turnover per employee, 2000–2005 average (at current prices). Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

Manufacturing plays a large role in physics-based sectors
Overall, employment in the UK increased by about 8% between 1998 and 2005. With the shift towards services, this growth has been boosted by higher employment levels from finance and business services as well as in the public sector. However, employment in physics-based sectors has not seen a similar performance. This is reflected in the 27% decline in jobs in the manufacturing and production industries in the UK over the same period. Although this assessment looks beyond the manufacturing sector, manufacturing in 2005 still accounted for 62% of employee jobs in sectors where the use of physics-based technologies or expertise were critical to the existence of the sector. This, in part, explains the decline in employment in physics-based sectors, as illustrated in figure 1.

However, the share of employment in physics-based sectors in manufacturing has also declined – falling by 7% between 1998 and 2005. This highlights how the use of physics is becoming more widespread in the economy and less confined to the manufacturing industries. Indeed, out of the 9658 physicists, geologists and meteorologists[2] in the 2001 census, 94% were recorded as not being employed in manufacturing businesses.

The data presented here show that the largest employers of physicists are in architectural and engineering firms, and related technical consultancy, with approximately 3700 physicists, geologists and meteorologists. The definition of physics-based sectors is narrow and there are many other sectors that may regularly use physics in some way that this report does not capture.

Employment in physics-based sectors is similar to that in financial services
In figure 3 the share of the total national employment in physics-based sectors is compared with that in other sectors between 2000 and 2005. This analysis reveals that physics-based sectors accounted for an average of 3.9% of the total UK employment between 2000 and 2005. This compares to a 4.1% share in the finance, banking and insurance sector, and 4.4% in the construction sector in the UK.

Turnover
Here the focus is on the contribution of physics-based sectors to the UK economy in terms of the turnover that they generated. Figure 4 shows that the turnover of physics-based sectors was about £180 billion – making up 8.6% of all turnover from businesses in the UK.

While employment in physics-based sectors has declined, its turnover has increased – albeit at a relatively slow rate. The 4% rise in turnover between 2000 and 2005 is significantly less than the 25% increase in total turnover in the UK, highlighting the weakening competitiveness of physics-based sectors.

Although the contribution of physics-based sectors in the UK has declined, figure 5 shows that, between 2000 and 2005, it still accounted for 8.6% of the national total. This contribution was greater than that of the construction sector and the banking finance and insurance sectors, which accounted for 7.6% and 7.4% of total turnover in the UK respectively.

The relatively higher level of turnover generated in physics-based sectors is reflected in higher levels of

2. The *Census 2001* does not separate physicists from the four-digit standard occupational classification "2113: physicists, meteorologists and geologists", but a level of detail does provide a good indication of the types of sectors that physicists are employed in.

Box 2: What is value added?

The measure used to evaluate the economic contribution of physics-based sectors is gross value added (GVA). This is the difference between output and intermediate consumption – the difference between the value of goods and services produced and the cost of inputs used in production. It is estimated by summing the gross profits and gross wages and salaries generated by the physics-based sectors. Gross profits represent the value of the goods and services produced; gross wages and salaries represent the cost of the inputs.

The GVA analysis is based on the latest input/output tables from the ONS, which are available for 123 industries across the UK economy. To conduct the analysis at a more detailed sector breakdown, the most disaggregated GVA data by sector available from the *Annual Business Inquiry* were used to disaggregate the data from the input/output tables. However, the *Annual Business Inquiry* does not cover all sectors of the economy. In these instances the share of employment to estimate size of industry output is taken.

Source: ONS 2006.

turnover per employee. Figure 6 shows that the turnover per employee between 2000 and 2005 in physics-based sectors was around £165 000 per annum – this is £93 000 more than the national average, where turnover per employee equates to around £72 000. It is also much greater than that of banking, finance and insurance, as well as construction.

Our calculations are different from those provided by the DTI in its scoreboard. Businesses that appear in the scoreboard that would be categorised in physics-based sectors have been identified and the figures show that turnover, where the use of physics is critical, amounted to around £677 billion in 2005.

Value added

Here the focus is on the economic value of physics-based sectors to the UK economy. Box 2 outlines how the economic contribution or GVA of physics-based sectors is measured.

Physics-based sectors generate £70 billion of GVA

Figure 7 shows that the GVA of the physics-based sectors currently stands at £70 billion — making up 6.4% of the total UK economic output.[3] It has grown over the last four years, reflecting the falling cost of raw materials used as inputs. Technological advances will have helped physics-based sectors to keep the cost of inputs down in terms of the price of machinery and equipment as well as lower wage costs through a more capital-intensive approach. This is evident in the rise in GVA per head.

Almost half of physics-based GVA is from manufacturing businesses

Figure 8 shows the sources of the GVA that is generated

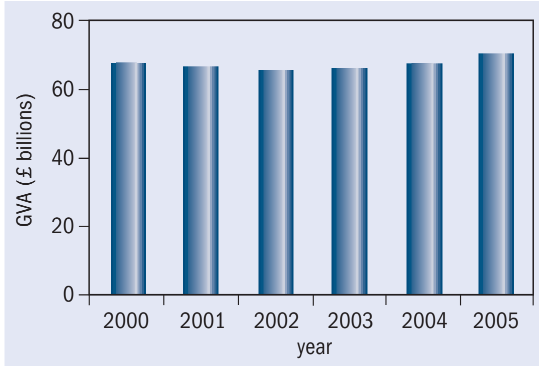


Figure 7: GVA in physics-based sectors. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

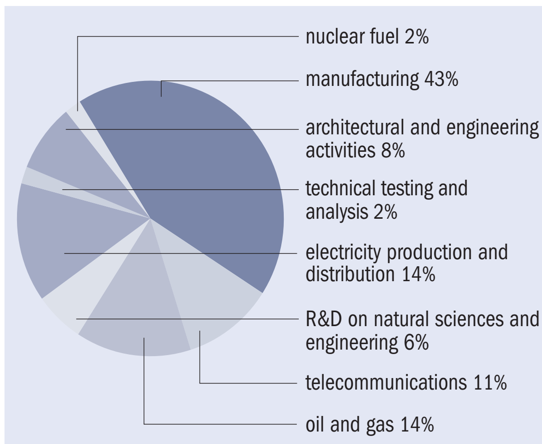


Figure 8: Share of GVA in physics-based sectors. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

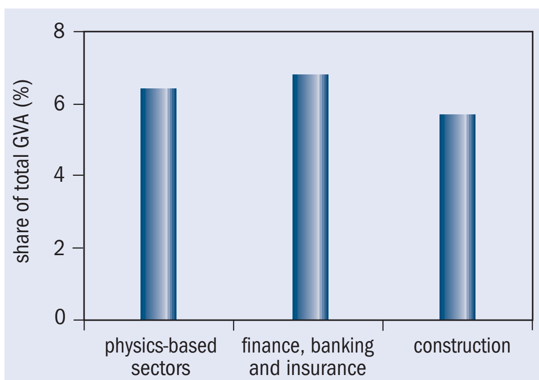


Figure 9: Share of total GVA in the UK – the 2000–2005 average. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

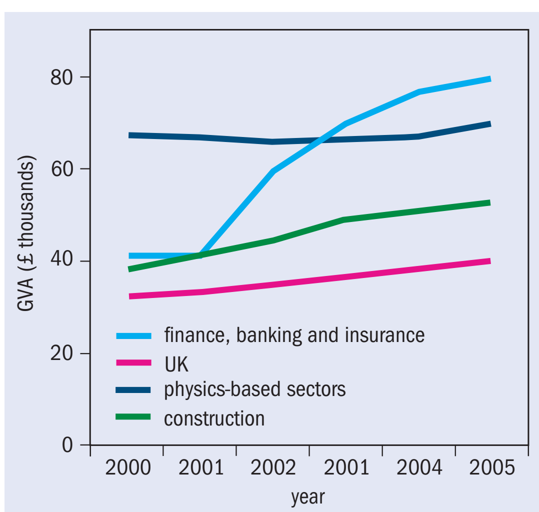


Figure 10: Productivity (GVA per head) in physics-based sectors. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

3. A comparison with the 2003 study is shown in appendix 3.

by physics-based sectors in the UK. The manufacturing sector makes up almost half (43%) – 13% comes from businesses involved in the extraction of crude petroleum and natural gas, while a tenth (10.8%) comes from telecommunications.

Figure 9 shows that, between 2000 and 2005, physics-based sectors accounted for 6.4% of the total GVA on average. This share is comparable to that of the construction sector and finance, banking and insurance, which produced 5.7% and 6.8% of the total GVA respectively.

Figure 10 shows that productivity levels in physics-based sectors in 2005 were almost twice as high as the UK average. This, in part, reflects that many physics-based sectors are manufacturing based. Manufacturing is more technology-intensive than many other sectors in the economy, and as a result the level of GVA generated per employee is higher. Productivity in physics-based sectors is higher than that of the construction sector, but in recent years it has been lower than that of the finance, banking and insurance sector.

Again, the calculations presented here are different from those provided by the DTI in its scoreboard. Businesses that appear in the scoreboard that would be categorised in physics-based sectors are identified and the figures show that GVA where the use of physics is critical amounted to around £143.2 billion in 2005.

3: Businesses and their survival

In this chapter the trends in the number of businesses in physics-based sectors and their survival rates are assessed.

New businesses

The number of business start-ups in physics-based sectors is estimated using data from the DTI's small business service analysis of value added tax (VAT) registrations and business deregistrations. Box 3 provides a summary of the data and the method used to estimate the number of businesses in physics-based sectors.

5% fall in businesses in physics-based sectors in the last five years

The total number of businesses in the UK increased by 5% between 2000 and 2005. Over the same period the number of businesses in physics-based sectors fell by 5%, with a net decline in businesses each year from 2001. This is shown in figure 11.[4]

In 2005 there were about 32 000 businesses in physics-based sectors where the use of physics-based expertise or

Box 3: Notes on the data used to estimate businesses in physics-based sectors

Data on business registrations and deregistrations from the DTI are used in this report. However, the Small Business Services estimates that only 1.8 million of the estimated 4.3 million businesses in the UK are registered for VAT and, as a result, the figures are likely to be underestimates of the actual number of UK businesses. The data cover businesses in all parts of the economy, other than some very small businesses (including the self-employed and those without employees, and with low turnover) and some non-profit-making organisations. It is available at a three-digit standard industrial classification level. The number of businesses in physics-based sectors is estimated by taking the share of employment in physics-based sectors at a four digit class level within employment in physics-based sectors at the three digit class level.

Source: ONS 2006.

4. A comparison with estimates from the 2003 study are outlined in appendix 3.

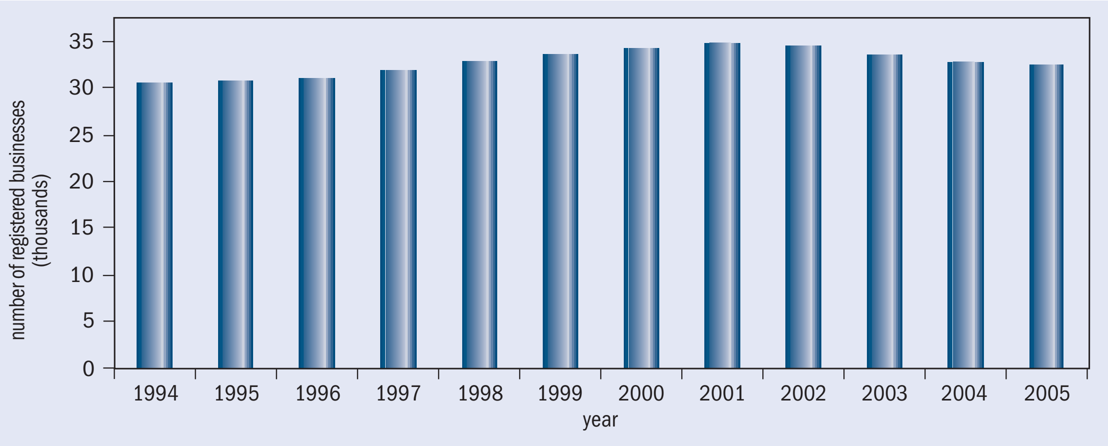


Figure 11: Number of registered businesses in physics-based sectors in the UK at the start of the year. Source: Small Business Service and cebr analysis.

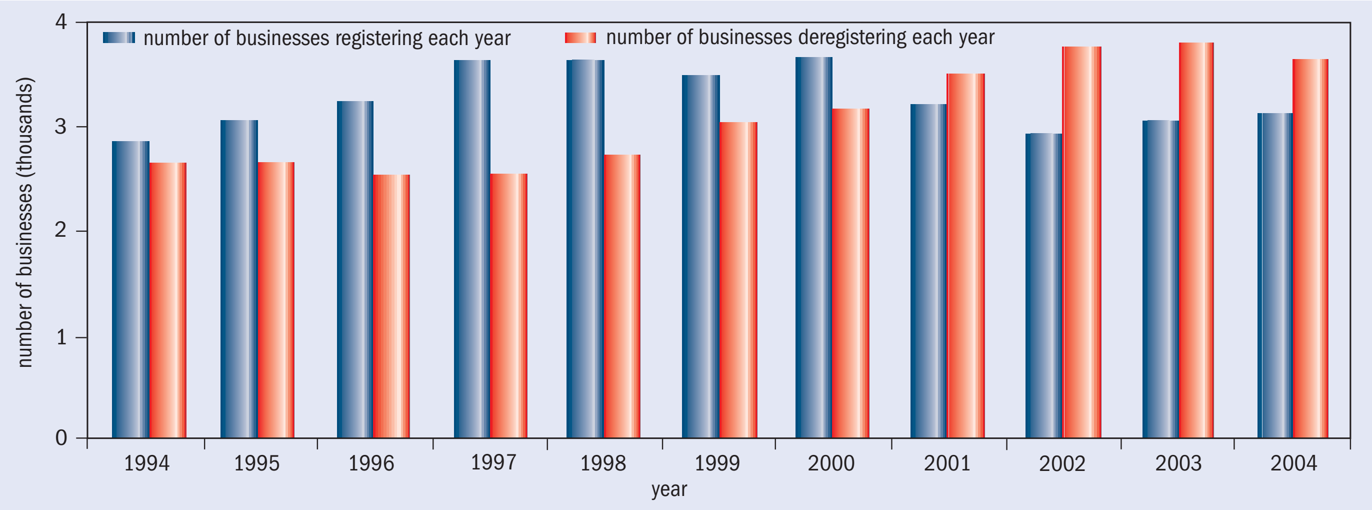


Figure 12: Number of business registrations and deregistrations in the UK . Source: Small Business Service and cebr analysis.

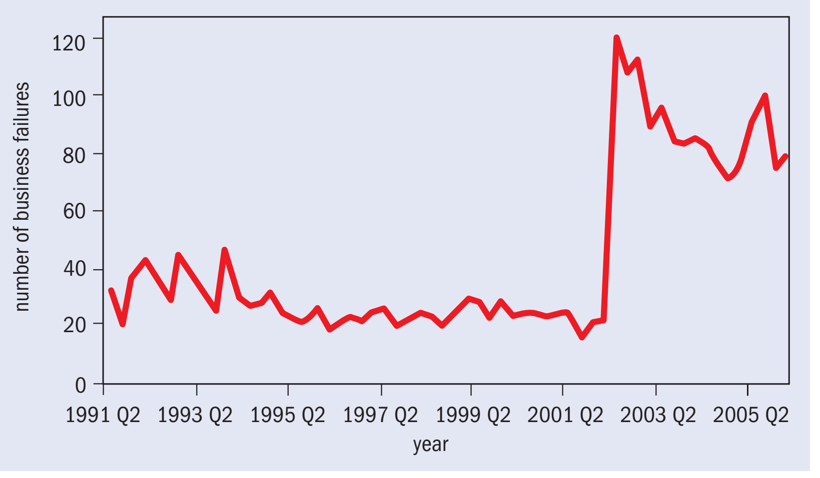


Figure 13: Number of business failures in physics-based sectors in the UK. Source: The Insolvency Service and cebr analysis.

technologies was critical to the existence of the sector. This is equivalent to around 2% of all registered UK businesses.

With the structure of the UK shifting more towards the service sector, the number of business deregistrations in physics-based sectors — which have a high share of manufacturing-based sectors — has risen by 15% (figure 12).

As discussed earlier, the output per head in physics-based sectors has been increasing over the past five years, which suggests that it is the more efficient and productive firms that remain. This may have contributed to the falling number of businesses registrations in physics-based sectors as new businesses find it increasingly hard to compete with the bigger players in the sector. Business registrations in physics-based sectors declined by 15% between 2001 and 2004, and only about 3000 were registered in 2004.

Businesses failures

The number of business failures in physics-based sectors is estimated using data from the DTI's insolvency service. Figure 13 illustrates the trend in the number of business failures in physics-based sectors in recent years. Business failures in physics-based sectors have accounted for just 20% of all failures in the UK since 1992.

The sharp rise in the number of businesses failing in 2002 was a result of the dot.com crash, which led to many physics-based sectors in the service sector becoming insolvent. This is reflected in the VAT registration data with 807 more deregistrations than registrations in 2002. This followed positive net registrations (registrations minus deregistrations) between 1994 and 1999, and 280 more deregistrations in 2001.

4: Indirect impacts

In addition to the direct impacts of physics-based sectors measured, such as jobs and economic activity generated, there are a number of other ways that these sectors contribute to the prosperity of the UK economy. The indirect (or multiplier) impacts of these sectors on the economy is estimated here. This chapter looks at the following impacts:

- **Upstream** Jobs and economic activity supported in sectors that supply goods to the physics-based sectors.
- **Employee spending** Jobs and economic activity supported in the economy by spending of employees in physics-based sectors.
- **Downstream** Jobs and economic activity supported in sectors that use products from physics-based sectors.

Upstream impacts

Physics-based sectors support up to 840 000 jobs upstream

The upstream impact captures the contribution of physics-based sectors to jobs and economic activity in sectors from which they purchase goods and services. This report estimates that physics-based sectors spent £93.9 billion on intermediate goods and services across the UK economy in 2005. This supported £50.1 billion worth of GVA in the UK economy. This was made up of £27.4 billion in earnings and £22.8 billion in gross operating surplus. In addition, 1.2 million jobs were supported in upstream sectors across the UK economy in 2005.

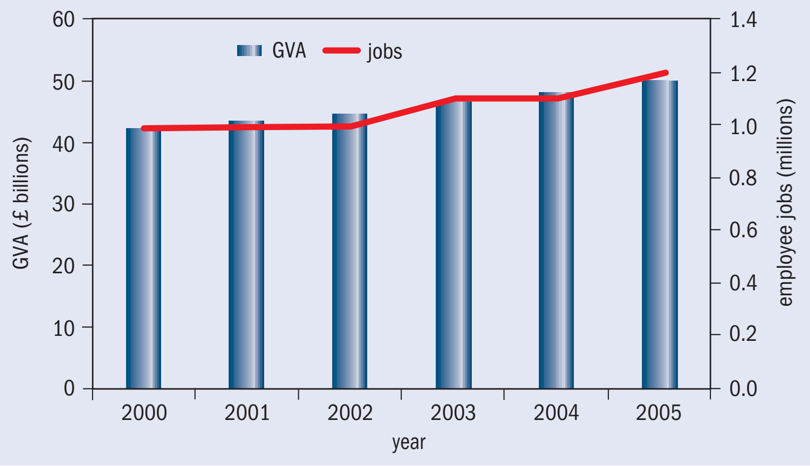


Figure 14: GVA and jobs supported in upstream sectors by physics-based sectors. Source: ONS and cebr analysis.

Spending on goods and services by employees and the multiplier

The second indirect effect comes from the spending on goods and services by employees in the physics-based sectors. This report estimates that employees who work in physics-based sectors spent £25.4 billion on goods and services across the UK economy in 2005. This supported £17.3 billion of GVA generated in the UK economy. This was made up of £7.8 billion in earnings and £9.4 billion in gross operating surplus. Further to this, 400 000 jobs were supported by the spending of employees in physics-based sectors across the UK economy in 2005.

Together, the upstream and employee-spending impacts constitute the overall multiplier effect of the physics sectors on the UK economy. This takes account of the proportion of activity in other sectors of the economy that is supported by the intermediate demand of physics-based sectors, as well as the spending of employees in physics-based sectors. Figure 16 shows how this multiplier effect has changed over time.

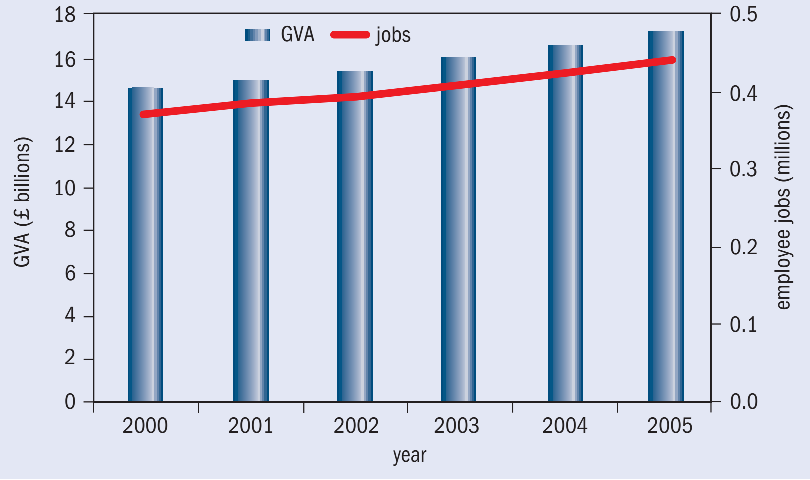


Figure 15: GVA and jobs supported by spending of employees in physics-based sectors. Source: ONS and cebr analysis.

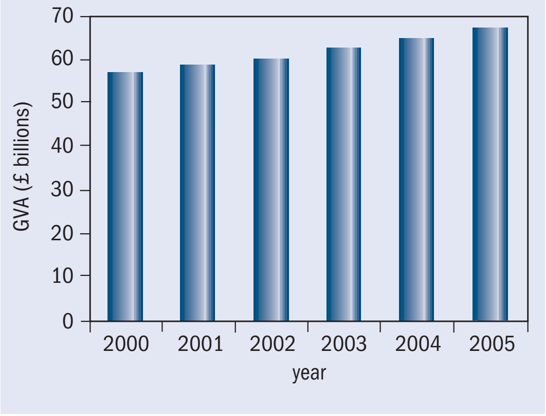


Figure 16: Multiplier effects as a result of activities in physics-based sectors. Source: ONS and cebr analysis.

Downstream impacts

By supplying goods and services to other sectors, physics-based sectors help to support the economic activity that

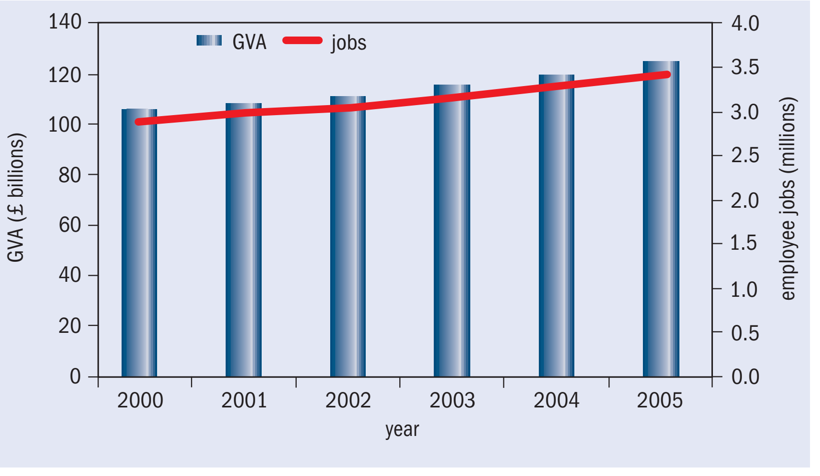


Figure 17: GVA and jobs supported in downstream sectors by physics-based sectors. Source: ONS and cebr analysis.

they carry out.

How much other sectors rely on the goods and services provided by physics-based sectors is also analysed. This report estimates that £117.1 billion was spent on goods and services from the physics-based sector in 2005. This was equivalent to £125.0 billion of GVA. This also helped to support more than 3.4 million jobs across in the physics-based sector's downstream sectors in 2005.

Figure 17 shows that the amount of GVA supported in the downstream sectors by the physics-based sector grew by 18% between 2000 and 2005, while the number of jobs supported was relatively unchanged over the same period.

Further details of the indirect impacts are tabulated in appendix 4.

5: International trade, investment, and research and development

This chapter analyses the international role that physics-based sectors play in terms of trade flows, and it compares this against other competitive countries. The investment benefits from physics-based sectors in the UK economy are also analysed – for both foreign and domestic investors.

International trade in physics-based sectors

This section analyses the value of trade from physics-based sectors. Data from a number of sources are used to compare the value of exports and imports in physics-based sectors in the UK with other countries across the globe.

Figure 18 shows that the UK's physics-based sectors accounted for more than £92.9 billion of exports of goods and services, and £109.8 billion of imports, in 2005 – accounting for 29% and 30% respectively of the total value of exports and imports in the same year. Figure 19 highlights the importance of exports in goods and services to physics-based sectors in the UK. Exports in these sectors account for almost a third (32%) of the turnover that they generate. This compares with the UK average of just 12%.

Box 4: How is international trade in physics-based sectors measured?

The same definitions of physics-based sectors but applied these to Standard Industrial Trade Classification (SITC) data from UKTrade are used in this report. An official correspondence between the SITC and SIC is used to apply the current definitions of physics-based industries. The SITC data (the most disaggregate data available) are only available for the manufacturing sector. To estimate the figures for the services sector, data from the input/output tables (which are based on a broader division of categories) are used.

Source: ONS 2006.

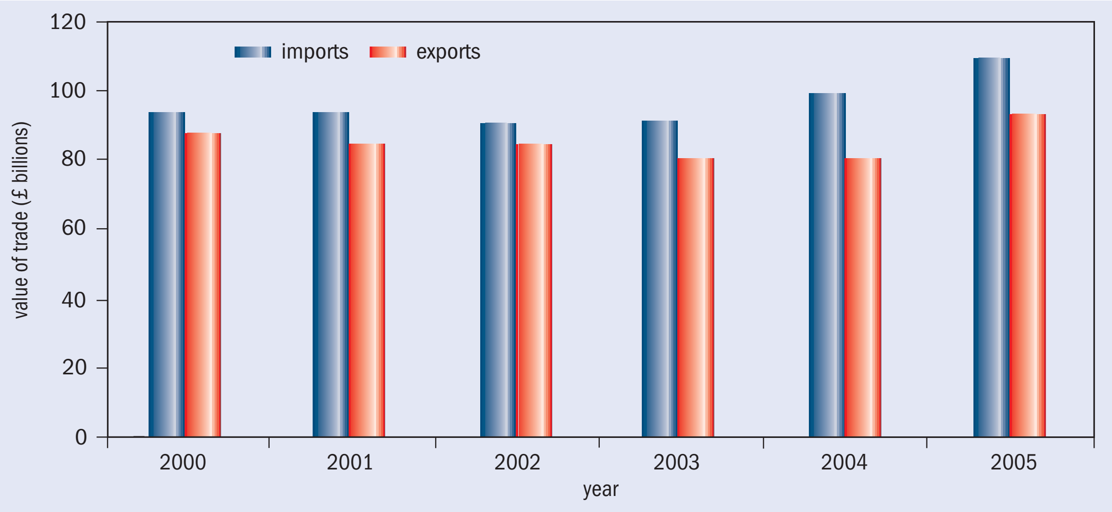
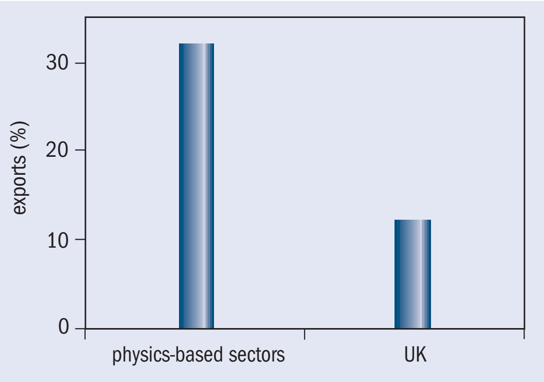


Figure 18: Value of trade in physics-based sectors in the UK. Source: UKTrade data, ONS and cebr analysis.



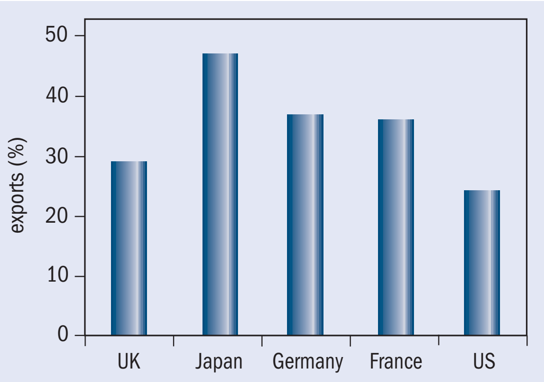


Figure 19 (left): Exports as a share of turnover – the 2000–2005 average. Source: UKTrade data, ONS and cebr analysis.

Figure 20 (right): Exports in physics-based sectors as a share of all exports. Source: UKTrade, OECD and other statistical offices, and cebr analysis.

Figure 21: Imports in physics-based sectors as a share of all imports. Source: UKTrade and cebr analysis.

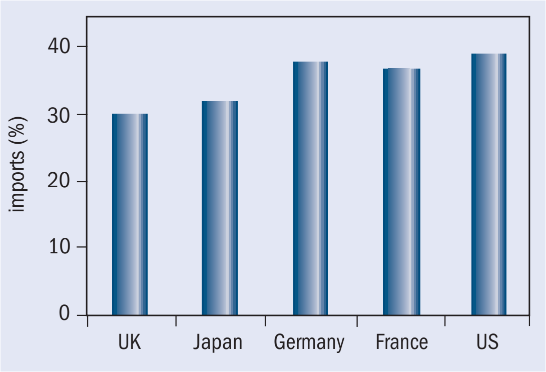


Figure 22: Balance of trade. Source: ONS and cebr analysis.

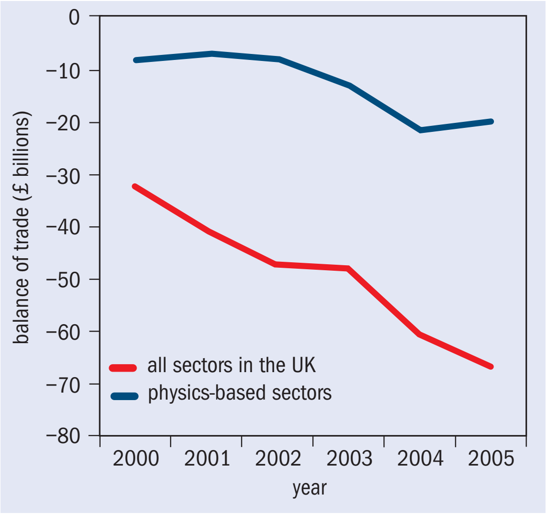
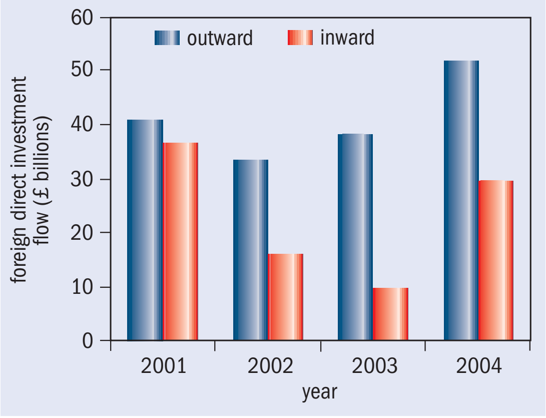


Figure 23: Foreign direct investment flows in the UK. Source: ONS.



How do the estimates presented here compare with other official research?

According to recent research by the DTI, the UK aerospace industry is the second largest in the world. This industry has a strong portfolio of products and is one of the few manufacturing sectors in the UK with a consistent trade surplus since 1980: the trade surplus in 2001 was £2.8 billion. UK manufacturers' successful performance in the world market depends critically on their competitive technology. The aerospace industry produces nearly 8% of manufactured exports in the UK.

Source: *Aerospace & Defence Technology Report 2002/2003*, DTI.

Figure 20 shows exports in physics-based sectors as a share of all exports in the UK and these are compared with those of other countries across the globe. The share of exports that are in physics-based sectors in each input/output category in the UK is taken and applied to input/output table data from other countries. Japan and Germany have the highest share of exports in physics-based sectors relative to all exports in their country.

In figure 21, imports in physics-based sectors as a share of all imports in the UK are compared with other countries. The share of imports that are physics-based in each input/output category in the UK are taken and applied to input/output table data from the other countries. The US and Germany have the highest share of imports in physics-based sectors relative to all imports in their country.

Figure 22 compares the balance of trade in physics-based sectors to that of the UK's total between 2000 and 2005. It shows that the balance of trade was negative in physics-based sectors over this period, with an average of £13 billion more in imports compared with exports between 2000 and 2005. Over the same period the UK trade deficit was significantly larger at around £50 billion. The gap between the two has widened over this period, highlighting that the UK balance of trade has deteriorated more than that of physics-based sectors.

Foreign direct investment in the UK

Figure 23 shows that the UK carries out a higher value of foreign direct investment than it receives from companies abroad. In 2003 the value of outward foreign direct investment was almost four times as large as the value of direct investment made into the UK from overseas companies.

Figure 24 shows the sector breakdown of foreign direct investment flows in and out of the UK. The manufacturing sector, which makes up 62% of physics-based sectors in the UK, invests almost eight times as much abroad as it receives from manufacturers abroad. This highlights the important role that physics-based sectors in the UK play across the globe.

R&D in physics-based sectors

Figure 25 shows how much R&D[5] spending takes place in physics-based sectors. According to the latest data available, in 2004 the spend on R&D in physics-based sectors amounted to £3.3 billion – almost a quarter (24%) of total R&D expenditure in the UK.

In 2004 a quarter of the R&D in physics-based sectors was spent on radio, television and communication equipment investment. Machinery and equipment,[6] precision instruments, motor vehicles and parts, and other transport equipment collectively accounted for 43% of R&D in physics-based sectors.

Expenditure on R&D in physics-based sectors has fallen in absolute terms, as well as in relative terms, compared with the UK. The decline in relative terms has been more marked than the absolute relative, as shown in figure 25. This shows that the trend in total R&D spend across the

5.The R&D figures reported relate to investment activity that has taken place in businesses based in the UK.

6. Including office machinery and computers, and electrical machinery and apparatus.

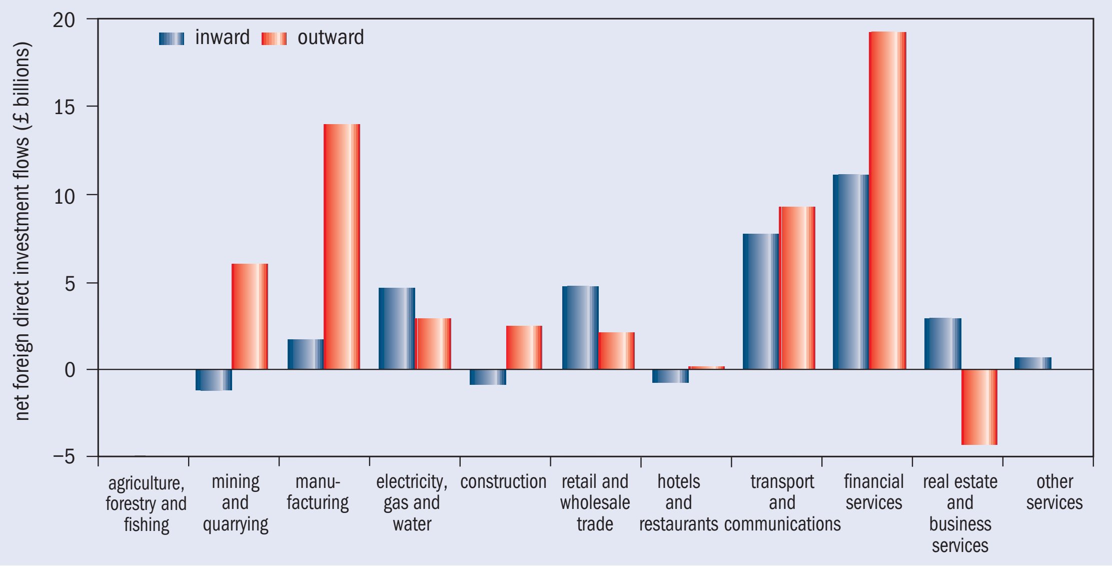


Figure 24: Net foreign direct investment flows in and out of the UK by broad sector during 2004. Source: ONS.

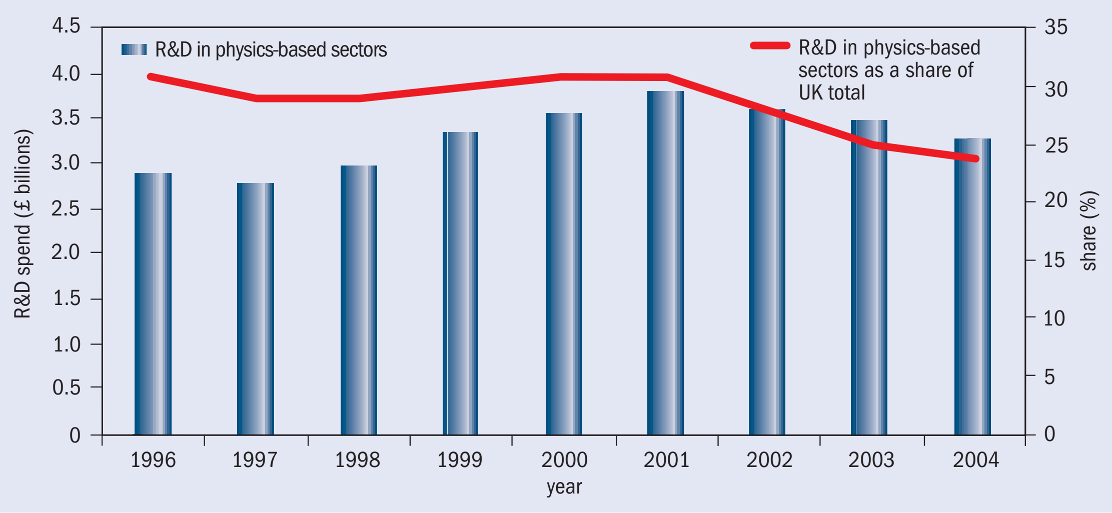
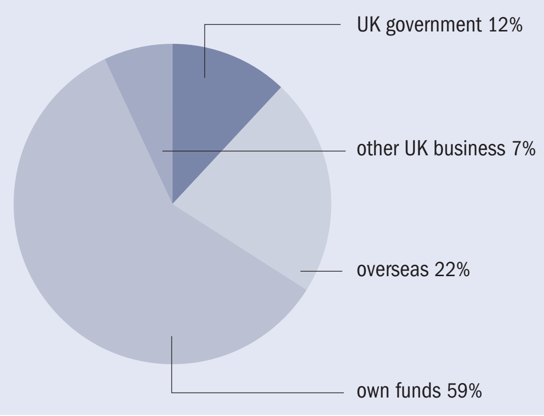


Figure 25: R&D in physics-based sectors. Source: ONS and cebr analysis.



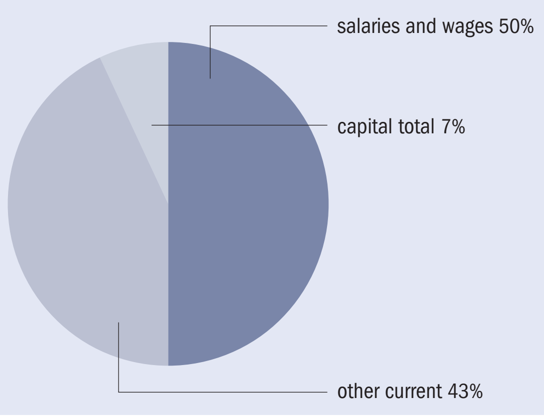


Figure 26 (left): Source of funds for R&D in physics-based sectors in 2004 (%). Source: ONS and cebr analysis.

Figure 27 (right): Current and capital expenditure R&D in physics-based sectors in 2004 (%). Source: ONS and cebr analysis.

whole economy in recent years has been stronger than that in physics-based sectors.

Figure 26 shows how the R&D in the physics-based sectors is funded. Just 12% of all R&D is funded by the domestic government. Over two-thirds (66%) is funded privately by businesses and, of this, 89% comes from businesses' own funds.

Figure 27 illustrates the nature of money allocated to R&D expenditure by physics-based sectors in the UK. 43% of spend on R&D is other current expenditure while 50% of spend on R&D goes towards salaries and wages..

It is widely recognised that investment in technology-based sectors is an essential part of remaining competitive.

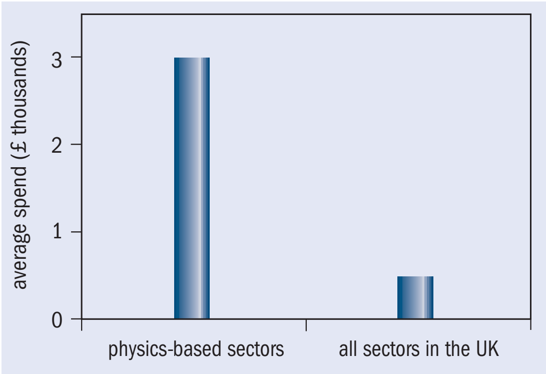


Figure 28: Average spend per employee on R&D in physics-based sectors in the UK between 2000 and 2004. Source: ONS and cebr analysis.

The need to remain competitive through technologies has been highlighted in recent research. To retain high-value economic activities, "science and innovation are at the heart of these transformations".

Source: *Science and innovation investment framework 2004–2014: next steps*, DTI.

Figure 28 shows that the amount of R&D expenditure per employee is much higher in physics-based sectors compared with the UK's average. In physics-based sectors there is £2600 more R&D invested per employee compared with the UK's average.

The calculations presented here are different from those provided by the DTI's scoreboard. Businesses that appear in the scoreboard that would be categorised in physics-based sectors have been identified. The figures show that R&D where the use of physics is critical amounted to around £1.8 billion in 2005.

6: A wider assessment

In this chapter the implications of extending the analysis to look at the economic contribution of physics to a wider range of sectors are assessed – the "broader definition". These are sectors that are considered to be dependent on the use of physics expertise or technology to some extent, not just those in which the use of physics is critical. This classification therefore includes a wider range of sectors than those examined in the previous chapters.

Employment, turnover and value added

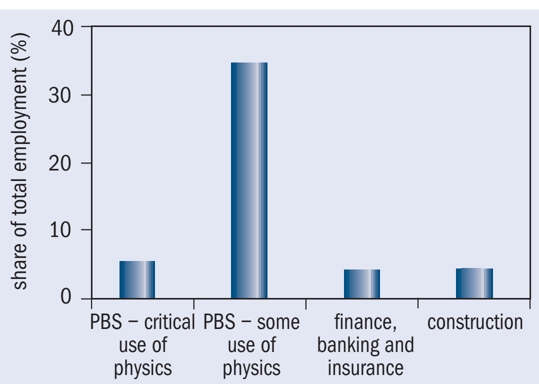
This report estimates that in 2005 there were 9.5 million people in the UK employed in sectors where physics was used to some extent (figure 29). This equates to 35% of all employee jobs in the UK (figure 30), compared to employment in sectors where the use of physics was critical being only 5%.

Figure 29: Employment in sectors where there is some use of physics. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

This assessment includes all employment in sectors that may use physics but in which many employees will not be largely involved with physics. For example, in the education sector there will be employees who teach physics and therefore require physics expertise. However, there will be a number of other staff who will not be involved in the use of physics at all. In addition, in the health-care sector many employees deliver a service that, in part, depends on the use of physics (they work on equipment that use technologies based on physics). However, there are also a number of employees who will not need to use this equipment and will therefore not be involved in the use of physics.

This report estimates that in 2005 the turnover of sectors where there is some use of physics amounted to 904 billion (figure 31) – equivalent to 42% of the total UK turnover seen in figure 32. This compares with 8.6% where the use of physics was critical.

Turnover in sectors where there is some use of physics increased by 19% between 2000 and 2005 – not far below the 25% growth in UK turnover as a whole. However, this



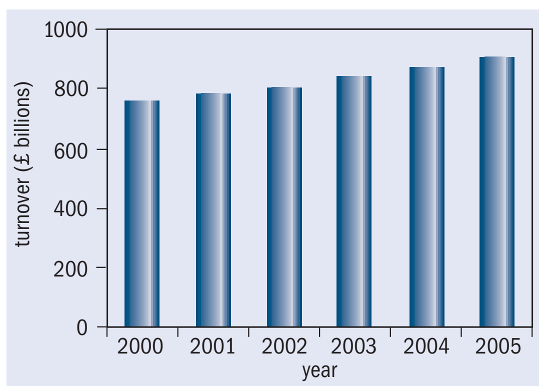
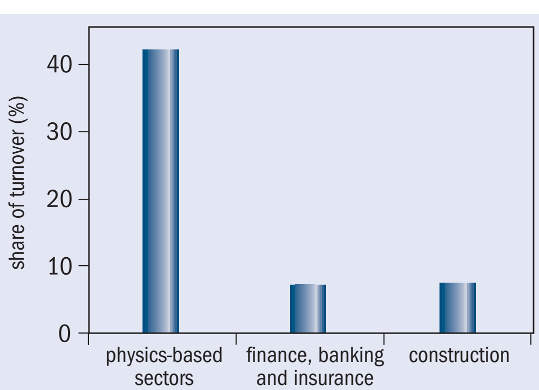


Figure 30 (far left): Share of total employment, a 2000–2005 average. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

Figure 31: Turnover in sectors where there is some use of physics. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.



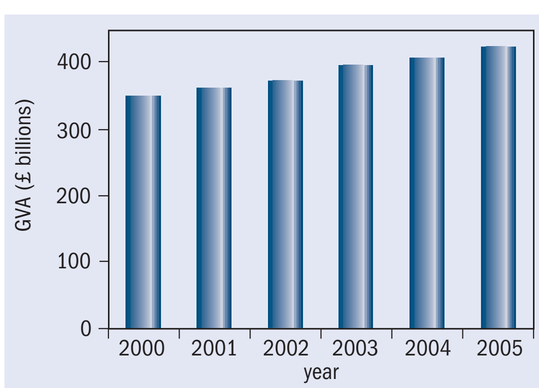
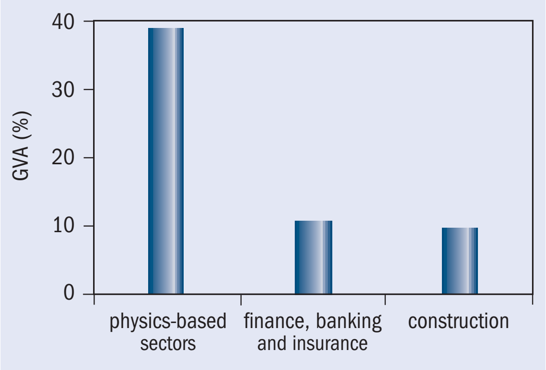


Figure 32 (far left): Share of total turnover, a 2000–2005 average. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

Figure 33: GVA in sectors where there is some use of physics. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.



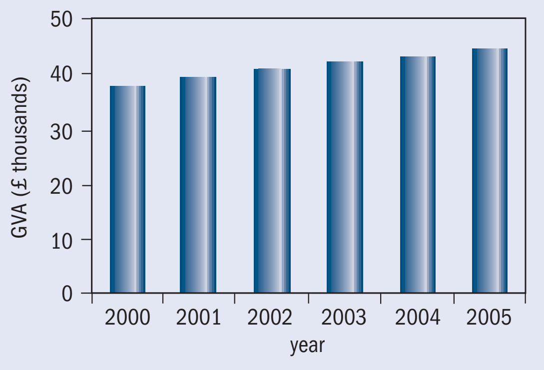


Figure 34 (left): Share of total GVA, a 2000–2005 average. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

Figure 35 (right): GVA per head in sectors where there is some use of physics. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

does highlight the weakening competitiveness of sectors that use physics relative to the UK.

This report estimates that in 2005, the GVA of physics-based sectors amounted to £424 billion (figure 33) – equivalent to 39% of UK turnover (figure 34). It has risen rapidly in the last four years, reflecting the falling cost of raw materials used as inputs. Technological advances have helped physics-based sectors to keep the cost of inputs down in terms of the price of machinery and equipment, as well as lower wage costs through a more capital-intensive approach. This is evident in the rise in GVA per head (figure 35).

Figure 36 shows that the balance of trade in sectors that make some use of physics is much closer to that of the UK's total than in sectors where the use of physics is critical. The graph shows that the trade deficit in physics-based sectors between 2000 and 2005 was a result of an average of £25 billion more in imports compared with exports between 2000 and 2005. Over the same period the UK trade deficit was around £50 billion.

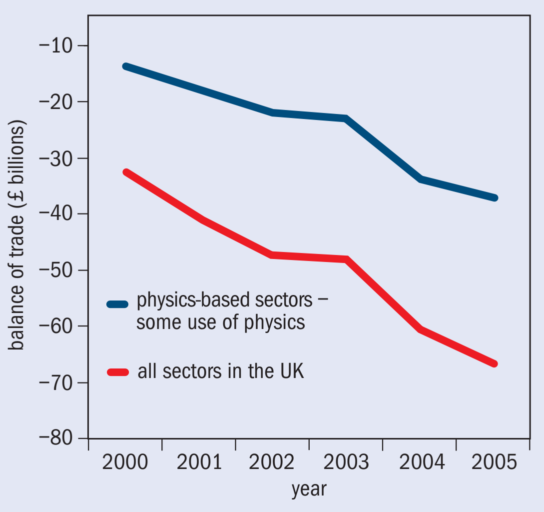


Figure 36: Balance of trade. Source: ONS and cebr analysis.

7: Appendices

1: Measuring physics in the economy

Physics is pervasive, both as an academic subject that covers the splitting of subatomic particles to the formation of galaxies, and as an applied science underpinning manufacturing and high-technology industries. Physics will be found in unexpected places. It is the driving force behind telecommunications and aerospace, but it is also hugely important to the biomedical and pharmacological industries, providing the tools to analyse the molecular structures of tissues and drugs. This pervasiveness means that it is difficult to define physics. For the purposes of this report, box 5 shows broad categories of what can be considered physics.

Through physics-based techniques, such as magnetic resonance imaging and neutron scattering, the molecular structures of biological tissues and novel drugs can be determined. The breadth of industries that are reliant on physics to some degree means that, to determine the contribution of physics to the economy, careful boundaries must be drawn.

As such, the application of physics in businesses can differ widely, highlighting the diverse coverage of concepts and processes in the subject. Below are the different ways in which physics has an impact on sectors of the economy:

- **As a science** There are employees who are engaged in physics as a scientific discipline, such as researchers and teachers.
- **In a role that uses expertise beyond the science** In some businesses there are employees who use expertise from the field of physics. Examples include engineers who perform tests and diagnostics of advanced mechanical and electrical equipment, and information technology systems designers who develop new technologies based on fundamental properties of physics.
- **Through technologies that have been developed based on the science** There are employees who use technologies based on an understanding of physics, using machinery and equipment that work through applications of physics. Without this indirect use of physics they would not be able to perform their job. Examples of this include radiographers using X-ray machines, engineers using advanced mechanical and electrical equipment, and opticians using machines based on laser technology. It is the application of technologies based on physics that is important here, and this is fundamental to many businesses.

To capture the wider impact of physics on the economy, those who indirectly rely on physics-related concepts or processes must be accounted for, as well as those employees who work directly with physics.

The results presented in this report are based on data from the ONS and they are analysed in terms of sectors that are physics based.

Box 5: What is physics?

Physics can be divided into broad categories. Any of these, or any combinations of these, constitute working with physics:

- astronomy and astrophysics
- chemical physics
- materials physics
- nanotechnology
- optics and photonics
- superconductivity
- biophysics
- electricity and magnetism
- mechanics
- nuclear, particle and high-energy physics
- semiconductor physics
- thermodynamics

Source: The Institute of Physics and cebr

How is a physics-based sector defined?

Physics is a constantly evolving discipline and its use varies significantly across different businesses in the UK economy. Some businesses require the use of more advanced applications of physics, while others use less-sophisticated applications. There are differences in the applications of physics between, say, laser technologies and levers and basic mechanics, but both are physics based. Here it is assumed that only more modern and advanced elements of physics can be considered as today's physics.

In addition to the different applications, the dependence that the sector has on the use of physics also needs to be captured. Applications of physics are essential for some businesses to function, while other businesses make use of physics to a lesser extent. In this study only those sectors where the use of physics is critical to survival are considered.

Measuring physics in economic statistics

To decide whether a business is physics based, the following questions are considered:

- Is expertise from the field of physics required?
- Is technology that uses advanced principles of physics required?
- If the use of physics is required, how dependent is the sector on it?

However, enterprise-level data are sparse. Therefore the use of physics in the economy is grouped using sector data. Sectors are groups of enterprises engaged in similar activities. The main type of economic activity in which they are engaged classifies enterprises or businesses. For example,

Table 1: An example of the UK SIC

Name	Code	Examples
Company		Ford
Class	34.10	manufacture of motor vehicles
Group	34.1	manufacture of motor vehicles
Division	34	manufacture of motor vehicles, trailers and semitrailers
Subsection	DM	manufacture of transport equipment
Section	D	manufacturing (comprising divisions 15–37)

Source: ONS 2006.

Table 2: List of sectors used in the current definition of physics-based sectors

Class	Description
11.10	extraction of crude petroleum and natural gas
23.30	processing of nuclear fuel
24.65	manufacture of prepared unrecorded media
28.22	manufacture of central heating radiators and boilers
28.30	manufacture of steam generators, except central heating hot water boilers
29.11	manufacture of engines and turbines, except aircraft, vehicle and cycle engines
29.60	manufacture of weapons and ammunition
29.71	manufacture of electric domestic appliances
30.02	manufacture of computers and other information processing equipment
31.10	manufacture of electric motors, generators and transformers
31.20	manufacture of electricity distribution and control apparatus
31.30	manufacture of insulated wire and cable
31.40	manufacture of accumulators, primary cells and primary batteries
31.50	manufacture of lighting equipment and electric lamps
31.61	manufacture of electrical equipment for engines and vehicles not elsewhere classified
31.62	manufacture of other electrical equipment not elsewhere classified
32.10	manufacture of electronic valves and tubes and other electronic components
32.20	manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy
32.30	manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods
33.10	manufacture of medical and surgical equipment, and orthopaedic appliances
33.20	manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process-control equipment
33.30	manufacture of industrial process-control equipment
33.40	manufacture of optical instruments and photographic equipment
34.10	manufacture of motor vehicles
35.11	building and repairing of ships
35.20	manufacture of railway and tramway locomotives and rolling stock
35.30	manufacture of aircraft and spacecraft
35.41	manufacture of motorcycles
40.10	production and distribution of electricity
62.30	space transport
64.20	telecommunications
73.10	research and experimental development on natural sciences and engineering
74.20	architectural and engineering activities, and related technical consultancy
74.30	technical testing and analysis
75.22	defence activities

an enterprise such as Ford would be classified as a manufacturer of motor vehicles.

The standard industrial classification system

The ONS uses a standard industrial classification (SIC) to describe sectors in the UK economy. This was first used in the UK in 1948 for classifying business establishments and other statistical units by the type of economic activity in which they were engaged. In this report, SIC codes are used to identify physics-based sectors.

Table 1 illustrates how the sections of the economy are broken down into varying levels of detail. They describe the sector at a broad level. There are 17 sections in the SIC system. These range from "agriculture, hunting and forestry" through to "manufacturing" and "financial intermediation". Subsections, divisions, groups and classes provide more detail about each of the sections.

Although the classifications are exhaustive for the entire UK economy, there is an unequal distribution of sectors between services and manufacturing. Out of the 502 class divisions at the four-digit class level, there are 241 manufacturing sectors, which make up almost half of all divisions. This is because the system was designed at a time when the UK economy was heavily concentrated in manufacturing. However, in 2005, manufacturing accounted for just 15% of UK GVA.[7]

The UK SIC system is used because it allows consistent comparisons to be made with similar data from other countries across the globe. It is almost identical to the European EUROSTAT System NACE at the four-digit class level and the United Nations system ISIC at the two-digit divisional level. This enables the analysis to be comparable to official economics and trade statistics.

The UK SIC (1992) also classifies the description of the activity by the process or the raw materials used, rather than by the product. This allows for a better understanding of what the sector does rather than of the final product that it produces.

To interpret the importance of physics to the different sectors, the relevant classes were selected from the SIC at an appropriate level of disaggregation (three- or four-digit SIC). To do this it is determined whether:

- physics is used;
- if it is used, the sector employs physics expertise or technology;
- physics is critical to the activities of the sector.

The results presented in this report describe those sectors where physics is critical to their activities.

Methodology

In this section the methodology of defining the use of physics across the economy is outlined.

In previous studies, applications of physics-based expertise (using physics) were distinguished from physics-based technologies (activities based on physics). In this report, physics-based sectors are analysed.

The relevant sectors were analysed at a four-digit classification to develop a definition of physics-based sectors in addition to the definition used in the 2003 study. The definition is expanded to include more than manufacturing sectors, but it has been narrowed to include only sectors where the use of physics is essential. Therefore, physics-based sectors are defined in this report as those where there is a critical use of physics in terms of either technologies or expertise that require the application of physics.

There are 35 four-digit industrial classification class groups included in this definition of physics-based sectors. In the 2003 report the definition of physics-based industries (which covered the manufacturing sector only) accounted for 64 SIC class groups. The definition used in this analysis therefore covers a smaller section of the UK economy compared with the 2003 report. The list of sectors that have been used in both definitions – classified by the SIC system – is given in appendix 2.

Given the fine granularity of data at the four-digit SIC level, for most cases it is assumed that a sector is or is not physics based. Each physics-based sector will have employees whose jobs do not involve physics at all (e.g. administrative staff), but these will be included in this analysis because the aim is to capture the size of sectors that are in some way physics based, as opposed to the size of the physics-based components of sectors.

However, using this method means that these figures will be sensitive to sectors where there are a large number of employees who would not be involved in activities relating to physics. For example, although education should be included because there are physics teachers who require knowledge about physics or an expertise in physics to perform their job, they will only be a small part of all teachers and administrative staff in the school. Another example is the defence sector. Here both expertise in physics and physics technologies are crucial, but there are a large number of soldiers who work in this field and do not use advanced physics.

To take account of this, adjustments are made where appropriate. Detailed data from the 2001 census are used to measure the proportion of the most relevant employees in the industry. The most relevant groups of employees, based on the ONS standard occupational classifications, used as a benchmark, include:

- science and technology professionals;
- science and technology associate professionals;
- skilled trades.

It is also important to note that the definition of physics-based sector applied here looks at the use of physics rather than the educational background or training of a sector's employees. For example, there may be physics graduates who work in a particular industry but who do not make direct use of their degree subject. Sectors such as these will not be included in the current definition of physics-based sector unless the work carried out involves some use of physics expertise or physics-based technologies.

Table 3: Reconciliation with 2003 study of direct impacts (overall UK numbers)

	Latest estimate in 2003 study	Our estimate using 2003 definition		Our estimate using latest definition	
value	in 2000	in 2000	in 2005	in 2000	in 2005
employment	1.8 m	1.6 m	1.3 m	1.2 m	1.0 m
turnover (£)	196.3 bn	164.8 bn	166.3 bn	177.4 bn	184.3 bn
GVA (£)	63.0 bn	59.6 bn	56.7 bn	67.7 bn	70.0 bn
GVA/head (£)	35 200	37 300	44 000	56 300	69 100

Box 6: Differences between the employment analysis and the 2003 analysis

The employment analysis is based on the latest official data from the *Annual Business Inquiry*. As a result there are some differences to note between the current estimates and the estimates in the 2003 study. These include:

- revisions to official data that involved benchmarking historic time series data about employee jobs to the estimates of employee jobs from the latest *Annual Business Inquiry* (conducted on an annual basis);
- new definitions of physics-based sectors.

Source: ONS 2006.

2: Sectors analysed

Table 2 shows the sectors that have been included in the current definition of physics-based sectors. The first column shows the standard industrial division group class of the sector, while the second provides a description of the main activities in the sector.

3: Comparison with the 2003 study

In this section the current analysis is compared with the findings of the Institute report *The Importance of Physics*

7. (Opposite page) GVA at basic prices, using 2003 weights. Taken from the UK output, income and expenditure third-quarter 2006 press release, the ONS. The GVA of a sector is the difference between output and intermediate consumption in the sector.

Table 4: Indirect impacts on the number of jobs in the UK (thousands)

	2000	2001	2002	2003	2004	2005
upstream	1.0	1.0	1.0	1.1	1.1	1.1
employee spending	0.4	0.4	0.4	0.4	0.4	0.4
downstream	2.8	2.9	3.0	3.1	3.2	3.4
total multiplier (%)	112	119	130	145	152	157

Table 5: Indirect impacts on GVA in the UK (billions)

	2000	2001	2002	2003	2004	2005
upstream (£)	41.6	42.9	44.0	45.8	47.4	49.3
employee spending (£)	14.3	14.7	15.1	15.7	16.3	16.9
downstream (£)	102.8	105.9	108.5	113.1	117.1	121.8
total multiplier (%)	84	88	91	94	96	96

in the UK Economy 2003. A reconciliation of the latest estimates with the 2003 study for the direct economic impacts of physics-based sectors is shown in table 3.

The estimates for the direct impacts based on the 2003 definition differ due to revisions to data (box 6) that have been made since the previous research was completed. This has led to slightly lower estimates of employment compared with those previously made, but higher turnover and GVA.

The revisions will also have affected the comparability of the estimates in this report, using the latest definition of the results in the previous study. In addition the new definition of physics-based sectors covers the whole economy and not just the manufacturing industries, but it is only used for sectors where the use of physics is critical.

4: Spillover and indirect effects

Tables 4 and 5 present the impact of physics-based sectors on the wider economy (in terms of jobs and GVA) between 2000 and 2005. The results are broken down by the type of indirect impact, including the upstream impact; employee spending impact; and the downstream impact. The tables also presents the “total multiplier effect” — this shows the proportion of jobs or GVA supported upstream and as a result of the spending of employees from physics-based sectors, for every job or unit of GVA that they directly generate.

Institute of Physics Report

Physics and the UK Economy

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