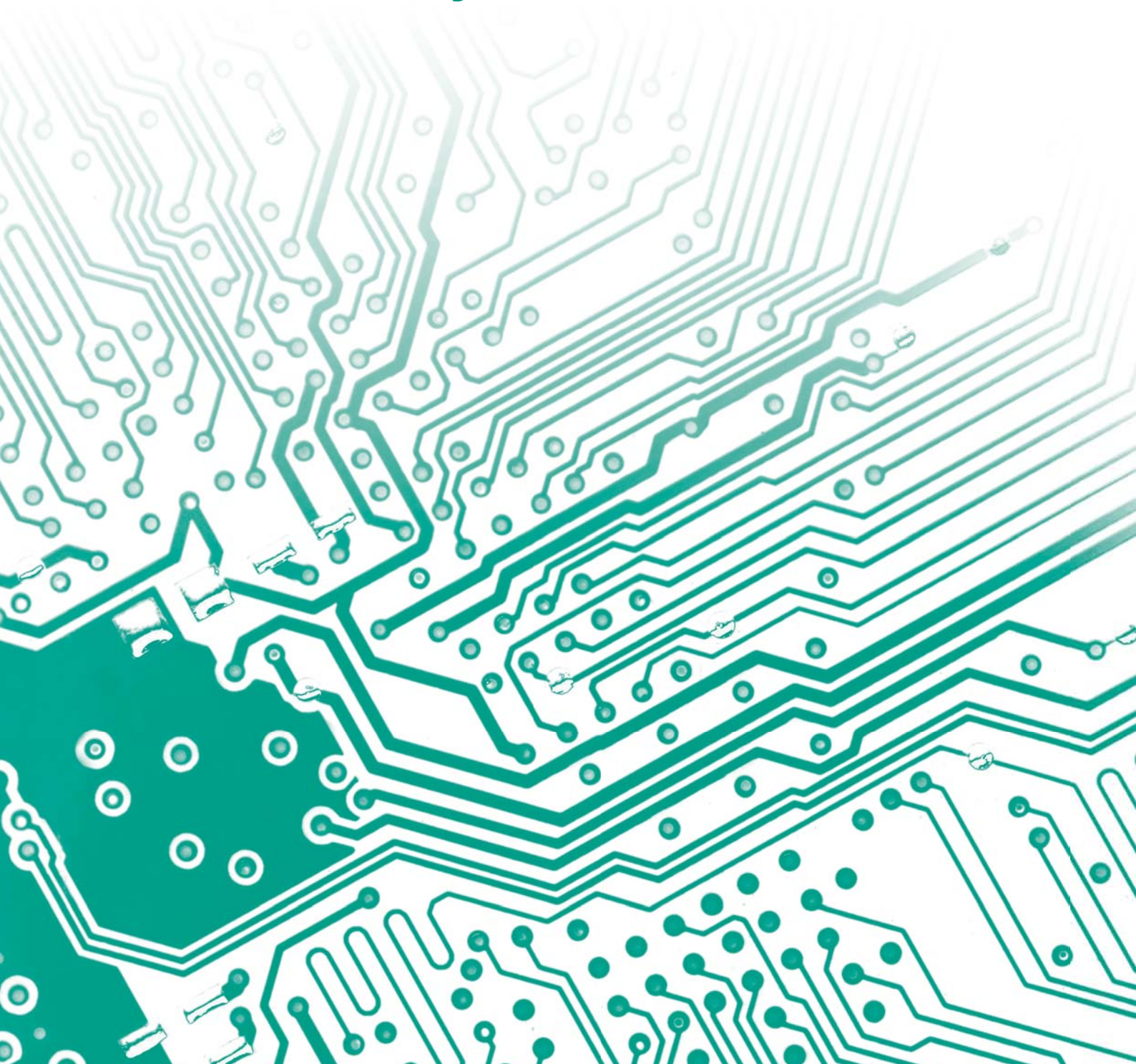


The Importance of Physics to the UK Economy



The Institute of Physics is a leading scientific society. We are a charitable organisation with a worldwide membership of more than 45,000, working together to advance physics education, research and application. We engage with policymakers and the general public to develop awareness and understanding of the value of physics and, through IOP Publishing, we are world leaders in professional scientific communications.

FOREWORD



Physics is central to the economy of the UK. Whether through the application of novel research and technologies, or through the skills and abilities of physics-trained workers, physics drives businesses and innovation.

The new analysis from Deloitte presented in this report demonstrates this conclusively: businesses that are critically dependent on physics contribute more to the national economy than the construction sector, employ more people than the finance sector and have a turnover significantly higher than both. This impact is through sectors ranging from high-technology manufacturing and aerospace to electricity production and satellite communication – sectors that depend on new physics knowledge to survive. These physics-based businesses contribute 8.5% of the UK's economic output and employ more than one million people. If indirect effects such as supply chains for these businesses are taken into account, that number rises to 3.9 million jobs contributing £220 bn to the UK economy. Exports from physics-based business amounted to more than £100 bn in 2009; physics-based business in the UK account for more exports as a share of the total than those in France.

However, the picture painted is not completely rosy. The recent economic downturn affected physics-based sectors as much as the broader economy; there has been a long-term decline in the strength of physics-based manufacturing in the UK. But the signs are there that physics can lead the recovery. As manufacturing has faltered, areas such as telecommunications have increased their share of physics-based output and employment. Physics-based sectors have increased their investment in research and development in the years following the crash.

But they can't do it alone. For the UK economy to be rebalanced in favour of high-technology, knowledge-intensive industries, there must be more and more focused support for physics-based businesses through innovative public procurement strategies and more ready access to the capital essential for growth. This, combined with sustained and stable funding of physics research and a ready supply of physics-trained workers, will allow physics, and the economy, to thrive.

Professor Sir Peter Knight
President, Institute of Physics

CONTENTS

1. EXECUTIVE SUMMARY	8
2. JOBS, TURNOVER AND GROSS VALUE ADDED	12
2.1. Direct jobs	12
2.2. Turnover	16
2.3. Gross value added	18
2.4. Productivity	21
2.5. Conclusion	21
3. PHYSICS-BASED BUSINESSES AND THEIR SURVIVAL	22
3.1. New businesses	22
3.2. Business failure	22
3.3. Conclusion	23
4. INDIRECT AND INDUCED EFFECTS	24
4.1. Incremental effects	24
4.2. Conclusion	24
5. INTERNATIONAL TRADE, INVESTMENT, AND RESEARCH AND DEVELOPMENT	25
5.1. International trade in physics-based sectors	25
5.2. Foreign direct investment in the UK	27
5.3. R&D in physics-based sectors	28
5.4. Conclusion	29
6. ANNEX 1: IMPACT OF PHYSICS IN ENGLAND	30
6.1. Direct jobs	30
6.2. Gross value added	31
6.3. Indirect and induced impacts	31
7. ANNEX 2: METHODOLOGY	34
7.1. Measuring the impact of physics in the economy	34
7.2. Our approach	35
GLOSSARY OF KEY TERMS	38

THE IMPORTANCE OF PHY



1 million

Physics-based businesses employ more than one million people in the UK – 4% of the total workforce, more than the construction industry.



£100 bn

Physics-based businesses export £100 bn of goods and services.



£77 bn

Physics-based businesses directly contribute 8.5% of the UK's economic output, more than £77 bn per year.



£220 bn

Including indirect spending, the total impact of physics-based businesses on the UK economy is more than £220 bn.

“Without physics, and its related fields, we would be unable to have our products meet the efficiency and cost targets that are critical for our business to achieve profitability” **BBOX Ltd**

4% of the UK workforce is employed in physics-based sectors,

PHYSICS TO THE UK ECONOMY



3.9 m

In addition to the one million people employed directly, physics-based businesses support an extra 2.75 million jobs in the wider economy.



x2

The gross value added per worker in physics-based businesses is twice the national average.



£2.6 bn

Physics-based R&D constitutes 16% (£2.6 bn) of the total R&D spend in the UK in 2010.



17%

The source of GVA from physics-based industries is diversifying with 31% from manufacturing and 17% from telecommunications.



"100% of our revenue is dependent on the physics discipline" **Oxford Instruments**

contributing **8.5%** of the total UK economic output.

EXECUTIVE SUMMARY

¹ Physics-based sectors are defined as those sectors of the UK economy where the use of physics – in terms of technologies and expertise – is critical to their existence, i.e. if there was no physics, these sectors would not exist. See Section 7 for a full list of sectors.

² Hereafter referred to as the 2003 report and 2007 report respectively. The 2007 report can be found on the IOP website at www.iop.org/publications/iop/2007/page_42716.html. The report updates earlier assessments of the contribution of physics, namely *The Importance of Physics to the UK Economy 2003* and *Physics and the UK Economy 2007*.

³ Given changes to the UK economy and changes in the way data are collected and defined, in some instances, we have not sought to make direct comparisons between the information presented in this report and earlier reports.

⁴ This report considers jobs or employees in physics-based sectors rather than employment. This means our definition does not include the self-employed. However, our analysis suggests the numbers of self-employed in physics-based sectors is minimal. Across the economy the difference between employees and those in employment is around 5%, although for physics-based sectors, due to their nature, this variation is much lower.

⁵ i.e. those jobs with businesses operating within physics-based sectors.

⁶ See HMT/BIS Plan for Growth. Latest update is available at http://cdn.hm-treasury.gov.uk/growth_implementation_update.pdf.

⁷ The total number of UK jobs in 2010, as estimated by the Business Register and Employment Survey, was 27.8 million.

This report examines the contribution of physics to the UK economy between the years 2005 and 2010 (the latest year of available data), highlighting how physics-based sectors¹ can play an important part in generating economic growth and prosperity.

The focus of this report is the UK with separate analysis for England being placed in the Annex. Deloitte has also produced equivalent reports for the economies of Wales, Scotland, Northern Ireland and the Republic of Ireland and these are available to download from the IOP website at www.iop.org. This report incorporates changes in statistical definitions that have taken place since the last report to reflect the changing structure of the UK economy.^{2,3}

Drawing on Office of National Statistics (ONS) datasets and our own bespoke modelling analysis, the contribution physics-based sectors make to the UK economy between 2005 and 2010 can be summarised as follows.

Physics-based sectors continue to play a significant role in the UK economy, generating jobs and value

Jobs in physics-based sectors⁴

When considering direct jobs⁵ in physics-based sectors, this analysis shows that while the number of jobs is lower than its peak in 2008, the 2010 figure is still in excess of 1 million jobs. Over the period 2005–2010, direct jobs in physics-based sectors averaged more than 4% of all UK jobs, exceeding the share of direct jobs in the finance, banking and insurance, and construction sectors.⁶

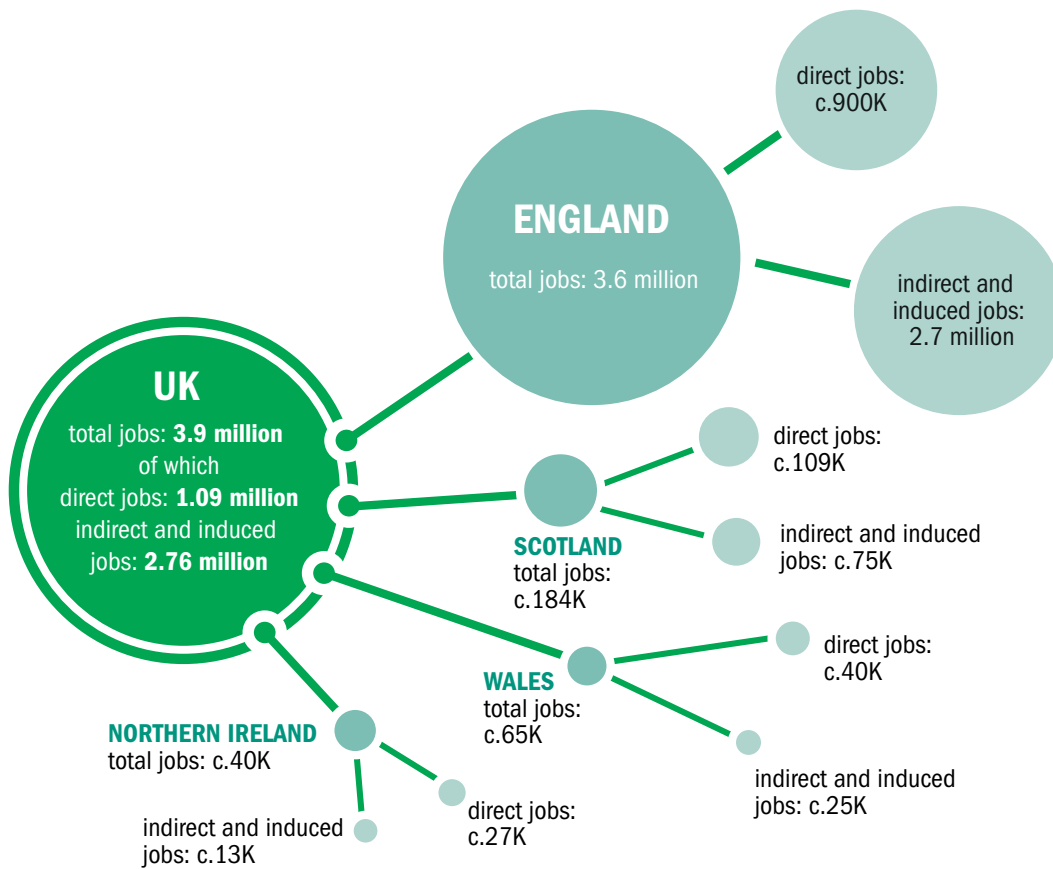
The fact that the number of direct jobs has fallen since 2008 is unsurprising and is reflective of wider falls in employment levels caused by the financial crisis. The fall in direct jobs in physics-based sectors between 2008 and 2010 was larger than the UK average reflecting the composition of these sectors including large shares of manufacturing, which have been particularly exposed to the economic downturn. However, while more than 50% of direct jobs in physics-based sectors can be found in manufacturing-related activities, the share

of other activities including architectural and engineering services, research and development (R&D), transport, electricity production and distribution, and defence activities is increasing. A number of these sectors have been identified by the government as playing a key role in promoting the economic recovery.

The activities of physics-based sectors will also support jobs and growth across the wider economy. For example, a “ripple” or “multiplier” effect can be created by a business in a physics-based business sourcing supplies from the wider economy or through an employee spending their wages in other sectors. Thus, the wider economic footprint of physics includes jobs involved in supplying physics-based sectors (indirect jobs) and jobs supported by the spending of employees in physics-based sectors. This analysis reveals the incremental jobs (indirect plus induced jobs) associated with physics-based sectors to be more than 2.7 million in 2010. This suggests that, in aggregate, the contribution of physics to UK jobs in 2010 was nearly 4 million jobs.⁷ **Figure 1.1** summarises how this figure is broken down across England, Scotland, Wales and Northern Ireland.

Figure 1.1: Total jobs attributable to physics-based sectors in the UK in 2010

Source: Deloitte analysis



Integrated Radiological Services: picturing the future of healthcare

Integrated Radiological Services (IRS) is an SME specialising in radiation protection services, for the implementation of safe medical procedures for X-ray and ultrasound imaging. Its products are used in hospitals, dental surgeries and veterinary practices across Liverpool and the North West of England. Of the 21 employees, 11 are physics trained to first-degree level and six of these graduates to masters level in medical physics, with a further two staff members currently undergoing such training. Physics graduates and their physics training are vital to IRS's business, providing it with the knowledge and expertise to offer the necessary scientific and technical support to its customers.

IRS not only operates within a physics-based industrial sector, but the scientific methods and skills developed from physics also form the core philosophy of the business. Being able to understand, strategically follow and adjust to technological changes in medical imaging requires a detailed understanding of physics. Without this knowledge, IRS says that it would have been impossible to keep up to date with the ongoing technological developments that have occurred over the past 40 years within the company and in the field of medical imaging. Recently, IRS has been able to employ more physics-trained staff, demonstrating a significant improvement in not only the service

delivery, but the introduction of new work practises based on research and development (R&D) programmes. Following this expansion of the company, IRS's turnover is now in excess of £1 m. Looking to the future, IRS aims to develop new ways of providing rapid communication of medical imaging results to clinicians and patients, including transfer of electronic radiological examination records. This may be achieved by developing quality assurance programmes and process controls of medical imaging, which physics R&D could facilitate through improvement of image quality and research into cloud-computing applications.

⁸ Gross value added (GVA) is a measure of the economic contribution of physics-based sectors analogous to gross domestic product (GDP).

Turnover and GVA in physics-based sectors

Direct turnover from businesses in physics-based sectors has begun to recover from falls in 2008 and 2009, with our analysis showing turnover from these sectors reaching £227 bn in 2010. This accounts for around 7% of total UK turnover and, on average, exceeds the contribution of other sectors such as construction, and finance, banking and insurance.

When considering the direct gross value added (GVA)⁸ contribution of physics-based sectors, the analysis reveals that this has also begun to recover, although it remains below 2007 levels at £77 bn. In contrast to turnover, the total share of UK GVA of physics-based sectors is below that of finance, banking and insurance. Physics-based sectors' share of total UK GVA is around 8%, which is slightly lower than the comparable figure in 2005 (9%). Taking account of indirect and induced effects, the total GVA contribution of physics-based sectors' GVA contribution rises to more than £220 bn in 2010. **Figure 1.2** summarises how this figure is

broken down across England, Scotland, Wales and Northern Ireland.

Physics-based sectors are highly productive

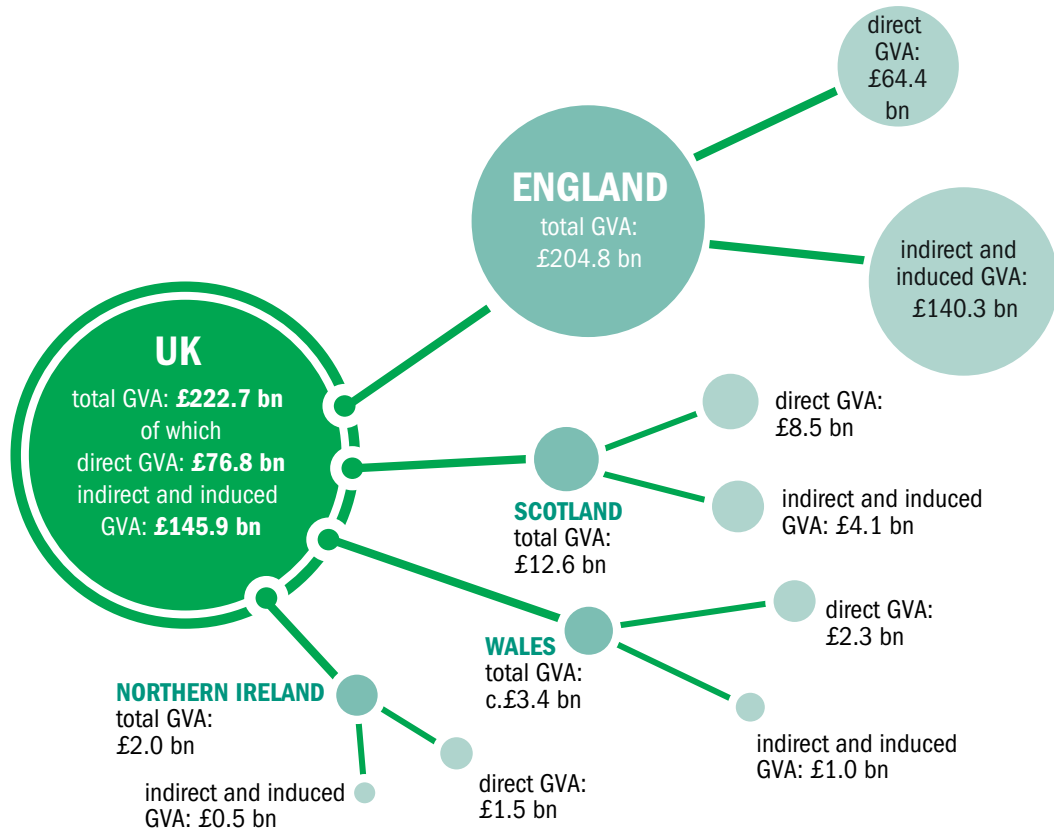
Using a measure of GVA per worker, productivity of employees in physics-based sectors has remained fairly stable over the period 2005–2010, at around £70,000. This compares favourably to the UK average GVA per worker of approximately £36,000 in 2010, but less so compared with finance, banking and insurance, which reported GVA per worker of nearly £110,000 in 2010 (although this figure represents a fall of nearly 20% from 2009 levels).

Businesses in physics-based sectors continue to contribute to innovation and economic growth

New start-ups and business failures

While the recession has seen an increase in the number of business failures across the economy

Figure 1.2: Total GVA attributable to physics-based sectors in the UK in 2010



Source: Deloitte analysis

generally, our analysis reveals that the number of registered businesses⁹ in physics-based sectors actually rose since 2005 – by more than 30% (or 5% since 2008) – and the number of business failures in physics-based sectors declined by around a quarter from a peak in 2009. This suggests that physics has an important role in emerging sectors of the economy that are well positioned to take advantage of recent technological developments and drive economic recovery.

Research and development (R&D) expenditure

Indeed, the evidence shows that physics-based sectors are well placed to contribute to innovation and increased competitiveness. The size of research and development spend in physics-based sectors remains healthy at more than £2.6 bn (2010) and has increased as a proportion of total UK research development spend in recent years from 13% in 2008 to 16% in 2010. The research and development spend per employee in physics-based sectors during the period 2005–2010 averaged in excess of £2000 compared with a UK average of £550.

Inward investment

Since 2008, the extent of foreign direct investment into all UK businesses has fallen – from nearly £50 bn in 2008 to just over £30 bn in 2010. However, it should be noted that the current investment is heavily concentrated in manufacturing, transport and communications – sectors where physics has a significant role to play.

Imports and exports

Physics-based sectors in the UK exported around £100 bn worth of goods and services in 2009 compared with imports of £125 bn. While the wider UK balance of trade between exports and imports deteriorated significantly over the period 2004–2009 with the deficit widening from £32 bn to more than £115 bn, the change in physics-based sectors' balance of trade was less pronounced at £26 bn. This reflects the finding that when compared with the rest of the UK economy, businesses in physics-based sectors earn a greater share of turnover from exports than businesses in the rest of the economy.

The data further show that UK businesses in physics-based sectors export less (as a proportion of turnover) than their counterparts in Germany, Japan and the US, but more than France. In contrast, UK businesses import more than all of the other countries in our sample, except Japan.

⁹This figure is based on VAT registrations, which may miss businesses below the VAT threshold.

BBOXX: powering the future

BBOXX provides solar equipment and services dedicated to the electrification markets in 12 developing countries across Africa and Asia. Based in Macclesfield, it has sites in China, Hong Kong and Uganda. The company is relatively small: it has eight employees in sales, 45 in production facility and 50 in independent franchises across the globe, but its turnover this year to date is approximately £920,000.

BBOXX aims to combine local knowledge with its global research and logistical base and the experience gained



from previous successful electrification projects to make a significant difference in the developing world.

Physics plays a leading role in developing the electronic components of the solar equipment that is fundamental to BBOXX's products. Ongoing

physics-based R&D has led to an increase in the performance of its solar panels. BBOXX endeavours to increase its annual turnover further by developing its solar panels and batteries, for energy generation and storage, respectively. This would lead to an increase in the overall module efficiency and provide cheaper energy for the consumers. Physics R&D could accelerate the implementation of more cost-effective materials and produce more efficient electronic components to further reduce the cost of the products.

“Without physics, and its related fields, we would be unable to have our products meet the efficiency and cost targets that are critical for our business to achieve profitability”

Chris Baker-Brian,
BBOXX

JOBS, TURNOVER AND GROSS VALUE ADDED

¹⁰ As explained in more detail in the methodology annex, not all numbers are directly comparable with the 2007 study due to changes in the definition of physics-based sectors. Further, as is discussed later, it should be noted that not all jobs in physics-based sectors are held by trained physicists.

This chapter assesses the importance of physics-based sectors to the UK economy in terms of jobs, turnover and GVA. The focus of this chapter is the direct impact of physics-based sectors. Chapter 4 contains further details of indirect and induced impacts – those occurring through the upstream supply chain and through consumer spending. Our methodology for estimating these numbers and any adjustments made to the data can be found in the Annex.

2.1. Direct jobs

There are more than one million direct jobs in physics-based sectors

In this section the number of direct jobs in physics-based sectors is explored.¹⁰ In particular, the range of physics-based sectors in the UK economy and how many people are employed in them. The trends in jobs in the physics-based sectors are analysed and compared across other sectors in the UK.

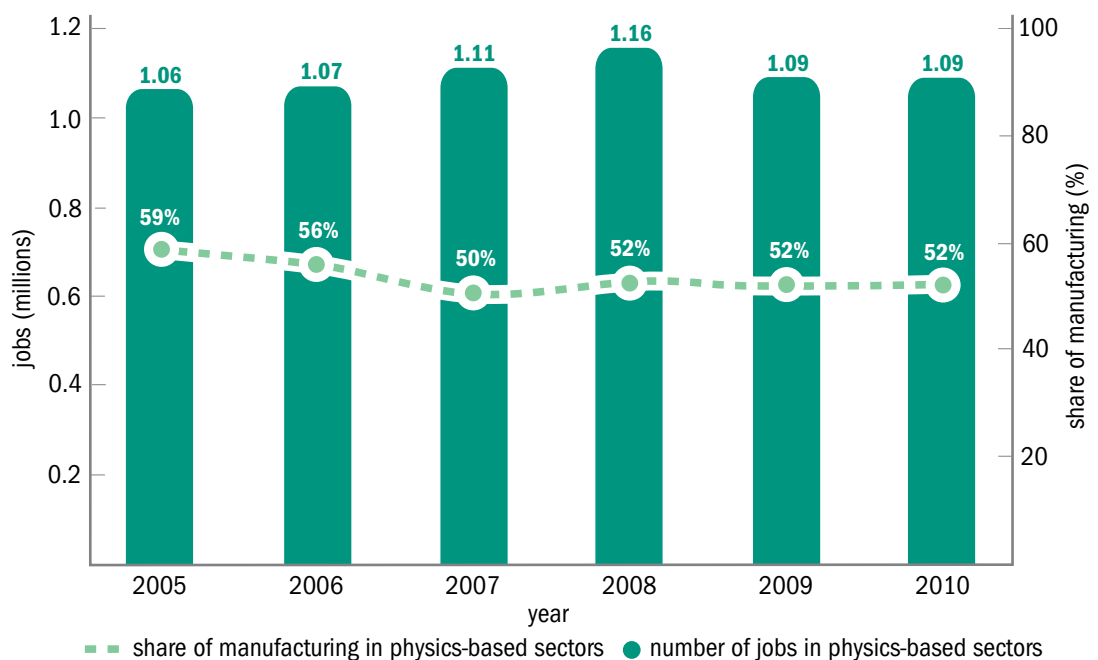
Our analysis estimates that there were 1.1 million direct jobs in 2010. This is down from a peak of 1.2 million jobs in 2008 and is likely to be reflective

Box 2.1: What is included in the estimates of employment in physics-based sectors

Our estimates of jobs (direct, indirect and induced) include:

- Employee jobs from the Office of National Statistics (ONS) Annual Business Survey and Business Register Employment Survey (both used to get a more detailed breakdown of physics-based sectors). This more detailed breakdown of jobs by sector does not include the self-employed, unpaid family workers and those on government-supported training and employment programmes.
- Adjustments to certain physics-based sectors to reflect the fact that there may be a significant number of jobs that do not involve or depend on physics. This adjustment is based on 2001 census data and the Standard Occupational Code (SOC) framework. More details of our approach are provided in the Annex.

Figure 2.1: Direct jobs in physics-based sectors, 2005–2010



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

of the wider economic downturn following the financial crisis.

Across all sectors, our analysis suggests that there was a fall of more than 3% in the total number of jobs in the UK between 2008 and 2010 from 27.7 million in 2008 to 26.8 million in 2010, however, in physics-based sectors the equivalent fall was nearly 6%. This larger than average fall may be explained by the composition of industries that make up physics-based sectors, which includes large shares of manufacturing industries that have been particularly affected by

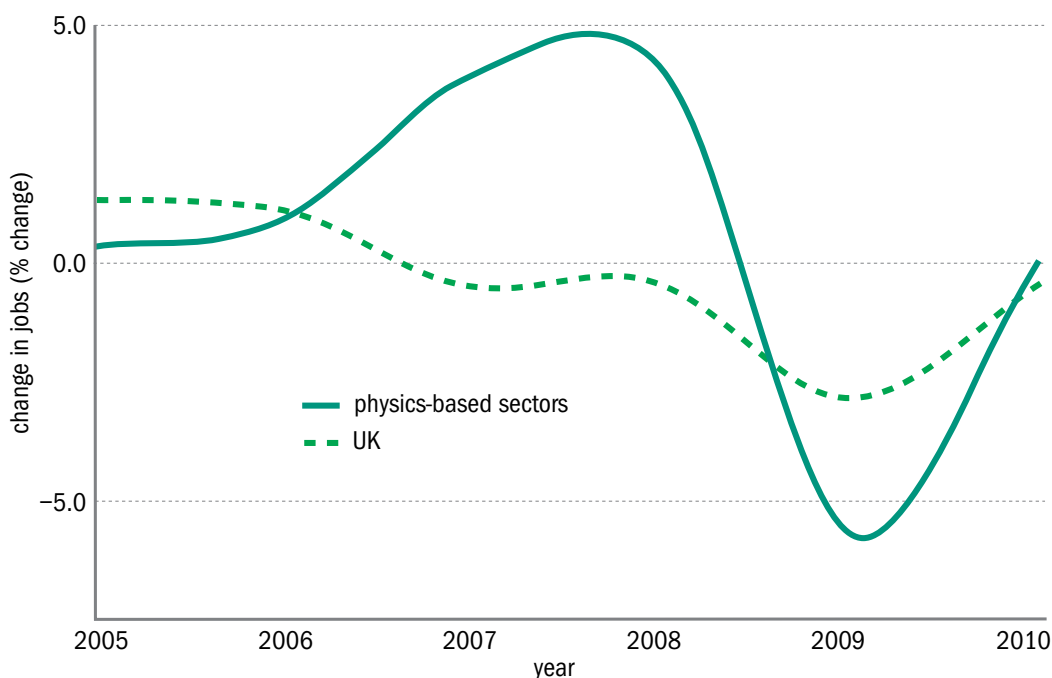
the economic downturn¹¹ and have also historically seen employee numbers falling as the focus of the economy has shifted towards finance, business services and retail. The difference between job growth in all sectors and in physics-based sectors only over this period is shown in **figure 2.2**.

Prior to 2008, physics-based sectors exhibited stronger growth in job numbers compared with the rest of the economy. However, following the financial crisis, this trend was reversed, with a large fall in the number of jobs in physics-based sectors.¹²

¹¹ The Markit/CPI UK Purchasing Managers' Index (PMIs) showed a substantial reduction in new order inflows in UK manufacturing in 2008–2009, with the subsequent recovery faltering from 2010. See www.markiteconomics.com/MarkitFiles/Pages/ViewPressRelease.aspx?ID=8738.

¹² The divergence in trends between physics-based sectors and the rest of the economy may be explained by other non-manufacturing sectors suffering a time lag before the full effects of the financial crisis were felt. Given the nature of just-in-time manufacturing, physics-based sectors may be more sensitive to fluctuations in macroeconomic conditions. It is also worth noting that some degree of volatility might be due to sample-size considerations, with a proportionately larger sample for all sectors seeing some form of balancing effect.

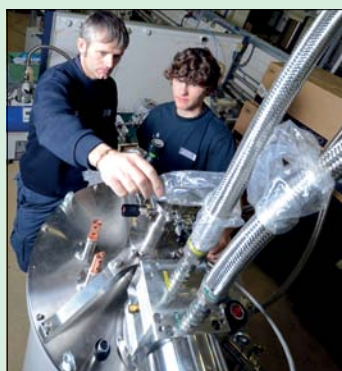
Figure 2.2: Growth/decline in jobs in physics-based sectors versus UK average, 2005–2010



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Oxford Instruments: innovating research and development

Oxford Instruments is a leading provider of high-technology tools and systems to academic, research and industrial markets. A FTSE250 company, its £337 m annual turnover is completely reliant on physics. A global business with 33 sites around the world and more than 1900 employees, Oxford Instruments' core skills lie in



science, technology, engineering and mathematics (STEM) subjects. Its products are used to address the key challenges of the 21st century and range from fundamental physics research into quantum processing and new materials like graphene, to compliance testing for hazardous substances and metals analysis.

“100% of our revenue is dependent on the physics discipline”

Jonathan Flint,
Oxford Instruments

¹³ The 2007 report further noted that the share of jobs in physics-based manufacturing fell by 7% between 1998 and 2005.

¹⁴ This is a matrix that breaks down the number of jobs by occupation (as defined by SOC 2000) by each sector of the economy (as measured by SIC four-digit level).

¹⁵ The SOC framework does not separate out physicists as an individual occupation. However, we believe that this provides a good indication of the types of sectors that physicists are employed in.

¹⁶ Quoted in *The Career Paths of Physics Graduates: a longitudinal study 2006–2010*, available at www.iop.org/publications/iop/2012/file_55924.pdf.

Most direct physics-based jobs are in the manufacturing sector, however, the share of the total jobs in physics-based sectors continues to adapt to changes in the economic climate with an increase in the number of jobs in other sectors

Looking at the composition of physics-based sectors, one can see that the share of manufacturing has continued to decline (down from 62% in 2005),¹³ although manufacturing still remains the largest component of the physics-based job sector.

As **figure 2.3** shows, physics has an impact across a large number of economic sectors, not just manufacturing. Focusing specifically on physicists (rather than direct jobs in physics-based sectors), analysis of the standard industrial code – standard operation code (SIC-SOC) matrix,¹⁴ highlights the spread of physicists working outside manufacturing. Out of more than 26,000 physicists, geologists and meteorologists,¹⁵ large numbers could be found working in engineering and related technical consultancy services, oil and gas activities, other technical activities and in tertiary education (including universities). Indeed, less than 5% of physicists, geologists and meteorologists were reported as directly

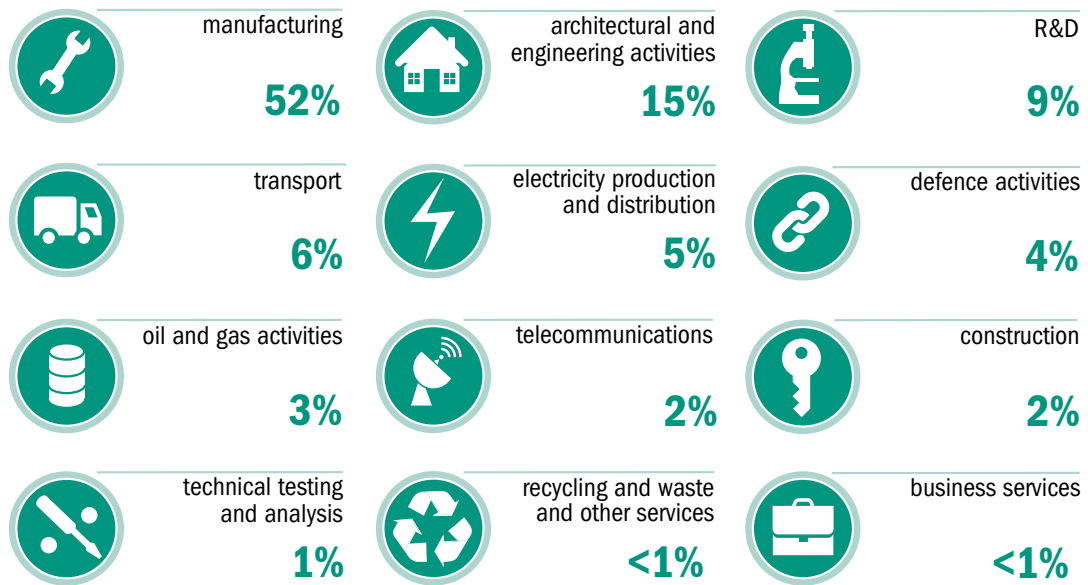
employed in manufacturing sectors. The data contained in the SIC-SOC matrix suggest that the largest employers of physicists are in the tertiary education, engineering, related technical consultancy services and other technical activities. This is consistent with IOP research that revealed physics graduates working in a wide range of jobs one year from graduation including in education, finance, or scientific and technical industries.¹⁶

The share of jobs in physics-based sectors as a proportion of all UK jobs is comparable to other well defined sectors

Figure 2.4 compares the share of jobs in physics-based sectors against two other sectors between 2005 and 2010. The analysis reveals that jobs in physics-based sectors accounted for just over 4% of all UK jobs over the period, more than both the finance, banking and insurance, and construction sectors.

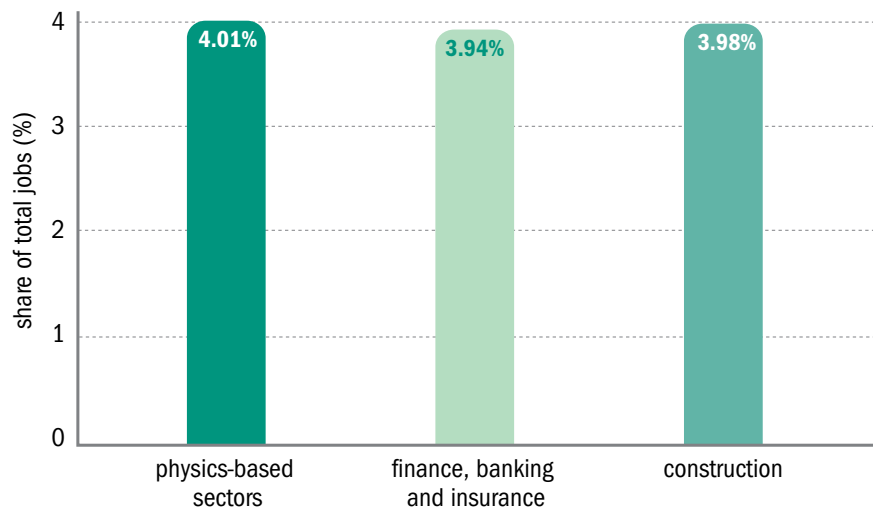
Figure 2.5 charts the respective share of each of the three sectors of all UK jobs over the period 2005–2010. As can be seen the share of jobs in physics-based sectors has moved from the lowest of the three sectors to the highest.

Figure 2.3: Share of UK jobs in physics-based sectors by broad sector, 2010



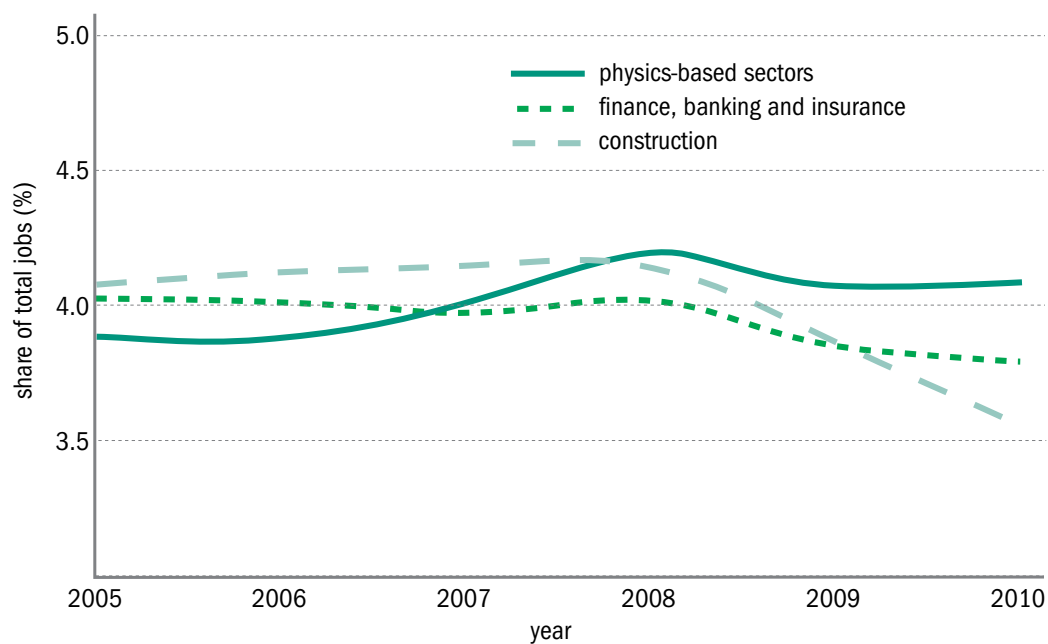
Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Figure 2.4: Share of total UK employment, average 2005–2010



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Figure 2.5: Share of total UK employment, longitudinal analysis, 2005–2010



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

¹⁷ For a comparison with turnover and GVA changes in different countries in the UK please see separate reports and/or the England annex to this report.

2.2. Turnover¹⁷

Turnover in physics-based sectors has recovered following the 2008 financial crisis

Here the contribution of physics-based sectors to the UK economy in terms of the turnover (gross output) they generated is considered.

Figure 2.6 shows that in 2010, turnover in physics-based sectors reached in excess of £225 bn. The analysis shows that, on current prices, turnover in 2010 actually exceeded turnover in 2007 (the year before the financial crisis). This is in contrast to the trend observed for jobs in physics-based sectors, implying an increase in turnover per worker, which in turn has positive productivity implications. Indeed, as **figure 2.7** and **figure 2.8** show, physics-based sectors have performed

strongly as a proportion of total UK turnover. Over the period from 2005 to 2010, physics-based sectors contributed, on average, to more than 7% of the total UK turnover, a greater contribution to the economy than from finance, banking and insurance, and construction sectors. However, while physics-based sectors contributed more than finance, banking and insurance on average over the period 2005–2010, since 2008, turnover has been greater in finance, banking and insurance than physics-based sectors.

The relatively high level of turnover generated in physics-based sectors is reflected in higher levels of turnover per employee compared with the UK average over the same period, as shown in **figure 2.9**. This shows that average turnover per employee in physics-based sectors over the

Figure sources: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Figure 2.6: Turnover in physics-based sectors (current prices), 2005–2010

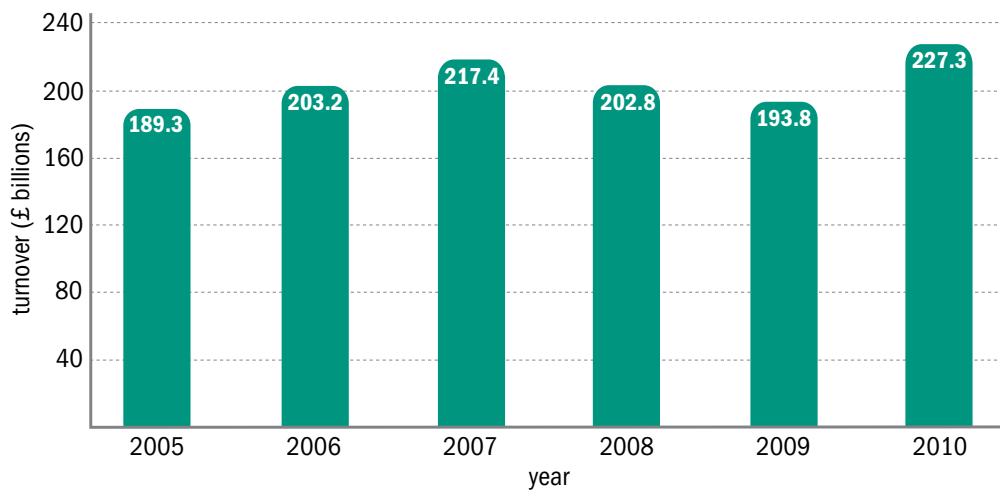


Figure 2.7: Share of total UK turnover, average 2005–2010

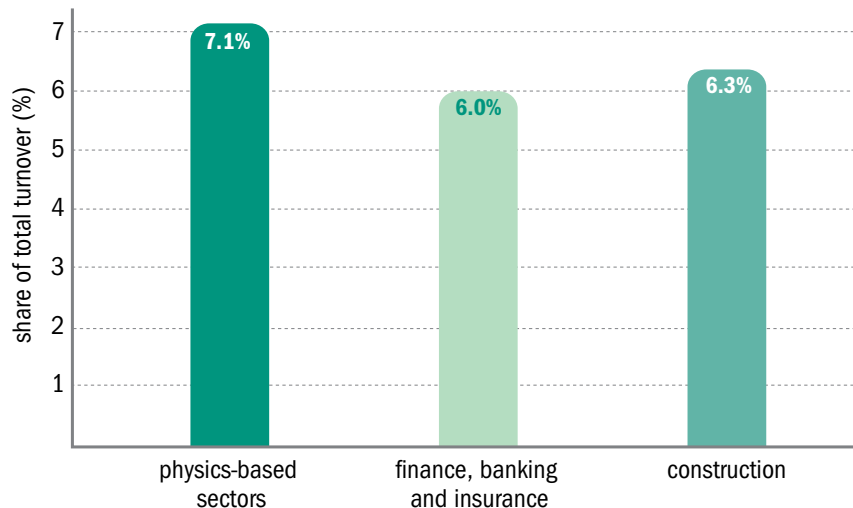
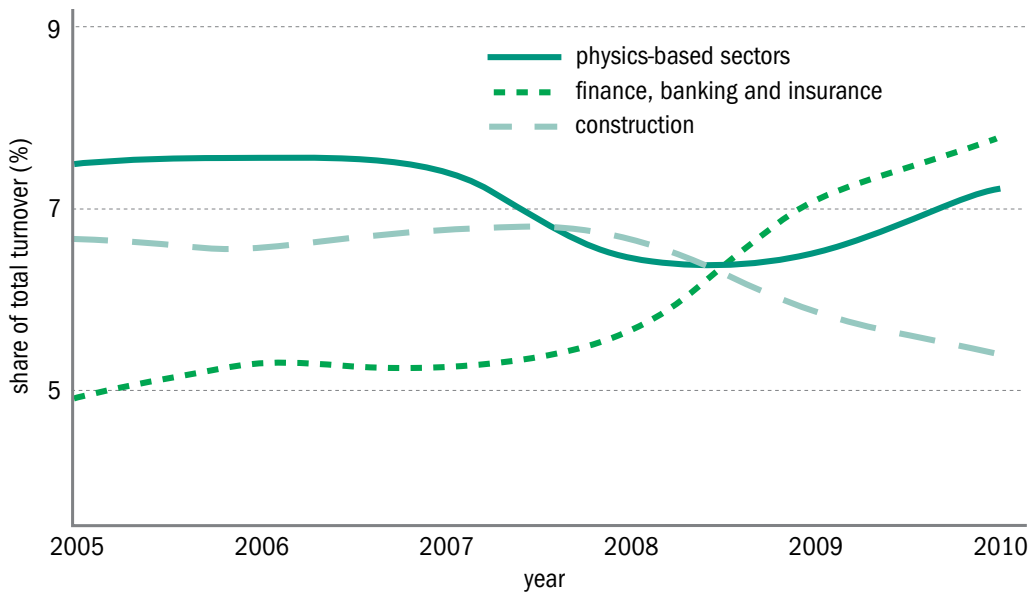
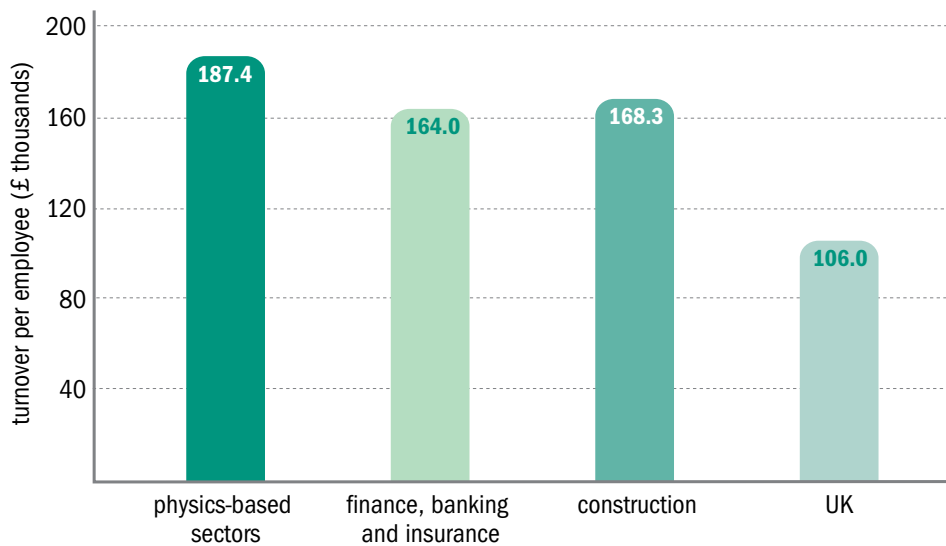


Figure 2.8: Share of total UK turnover, longitudinal analysis, 2005–2010



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Figure 2.9: Turnover per employee, 2005–2010 average (current prices)

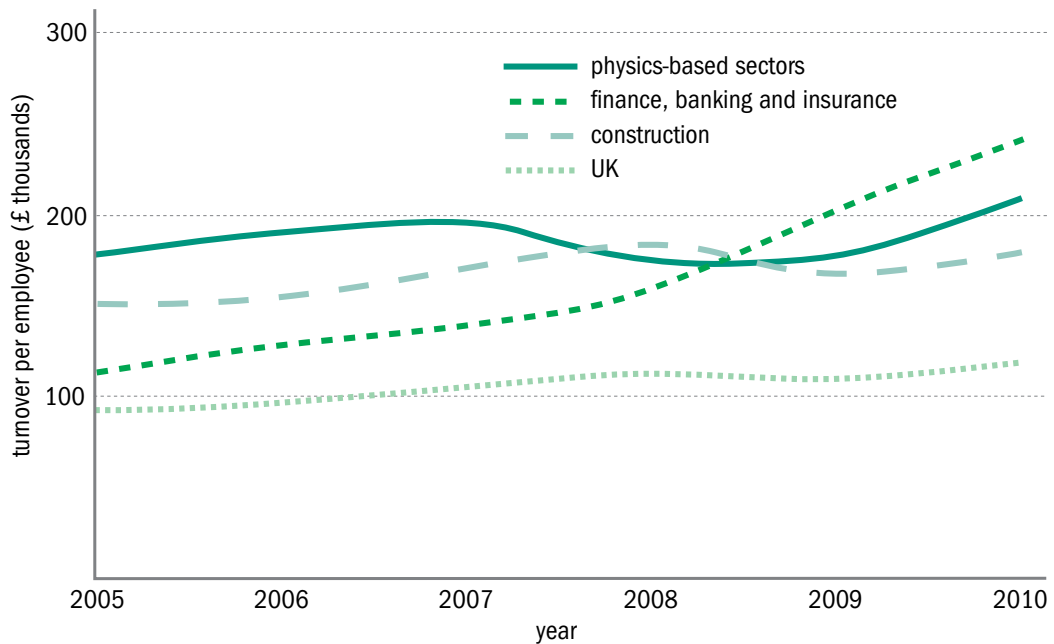


Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

period 2005–2010 was nearly £190,000 – in considerable excess of the UK average and above that of other sectors including finance, banking and insurance, and construction.

Figure 2.10 again shows that on a year-by-year basis, turnover per employee in physics-based sectors has been consistently above £175,000 per employee and has been increasing since 2008.

Figure 2.10: Turnover per employee, longitudinal analysis, 2005–2010 (current prices)



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

¹⁸This section uses GVA to measure the economic contribution of physics-based sectors to the UK economy. GVA is a more accurate measure of the economic contribution than turnover because it does not include intermediate consumption by organisations.

2.3. Gross value added

Direct GVA¹⁸ in physics-based sectors is greater than £76 bn, an 8.5% share of the total UK GVA

Figure 2.11 shows that direct GVA of physics-based sectors reached £76.8 bn in 2010. This is a slight increase on 2009 levels, but still below the

peaks of 2007 and 2008.

In contrast to the figures regarding the share of total UK turnover in **figure 2.7**, the contribution of physics-based sectors to total direct UK GVA is below that of finance, banking and insurance.

An increase in the turnover per employee combined with a decrease in the number of jobs

KP Technology: probing the depths of physics research and development

KP Technology is a global manufacturer of Kelvin probes and other scientific instruments for surface analysis; important for the electronics and semiconductor industries. Although its site in Caithness is small, employing 12 people, the annual turnover is in excess of £1 m. It is a highly skilled team as three of the staff have physics PhDs, three have undergraduate physics degrees, and they work alongside electronic and software

engineers and business administrators. Communication between KP Technology and its customers across the scientific disciplines is vital. In turn, physics R&D is essential to develop and grow a technological company that is able to provide the services demanded by its current and potential customers. KP Technology has a commercial R&D lab where new equipment and patents are developed to meet its customer's needs.

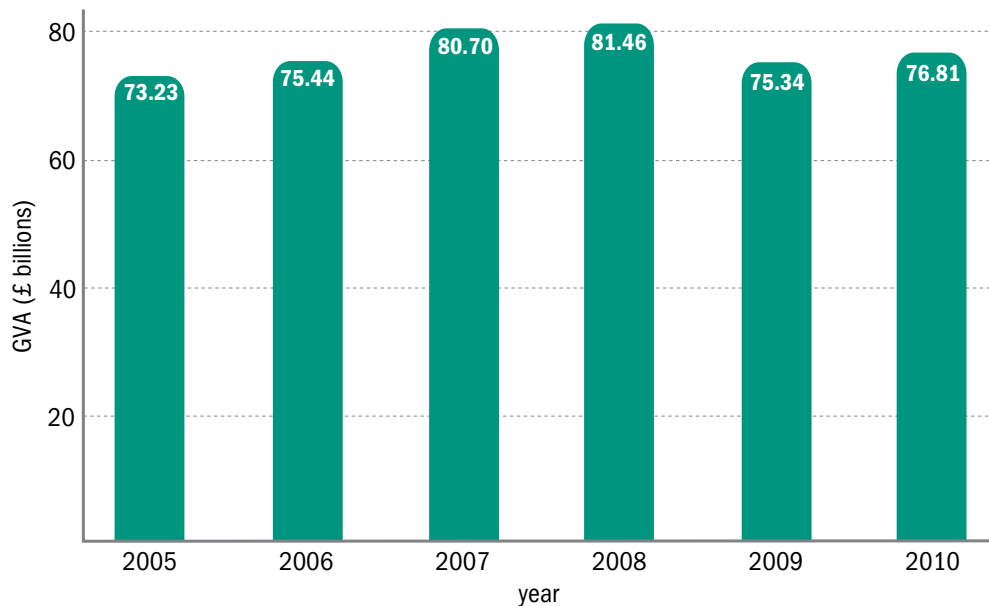
KP Technology says that an increased understanding of the global markets, in particular Asia and other emerging markets, would allow it to increase its sales base and export revenue. It has previously found that international conferences and exhibitions have allowed for discussion with academics and industrialists, leading to the identification of market opportunities for innovative product design and manufacture.

Box 2.2: What is gross value added?

The measure used to evaluate the economic contribution of physics-based sectors is gross value added (GVA). The Organisation for Economic Co-operation and Development (OECD) defines GVA as the value of output less the value of intermediate consumption. It is analogous to gross domestic product.

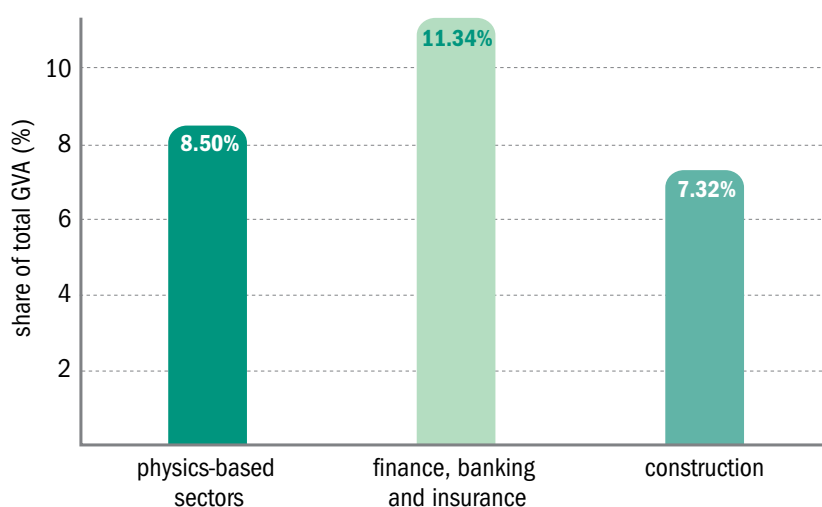
The GVA analysis presented herein is based on domestic use input/output tables from the ONS.

Figure 2.11: Direct GVA of physics-based sectors, 2005–2010 (current prices)



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Figure 2.12: Share of total GVA in the UK, 2005–2010 average



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

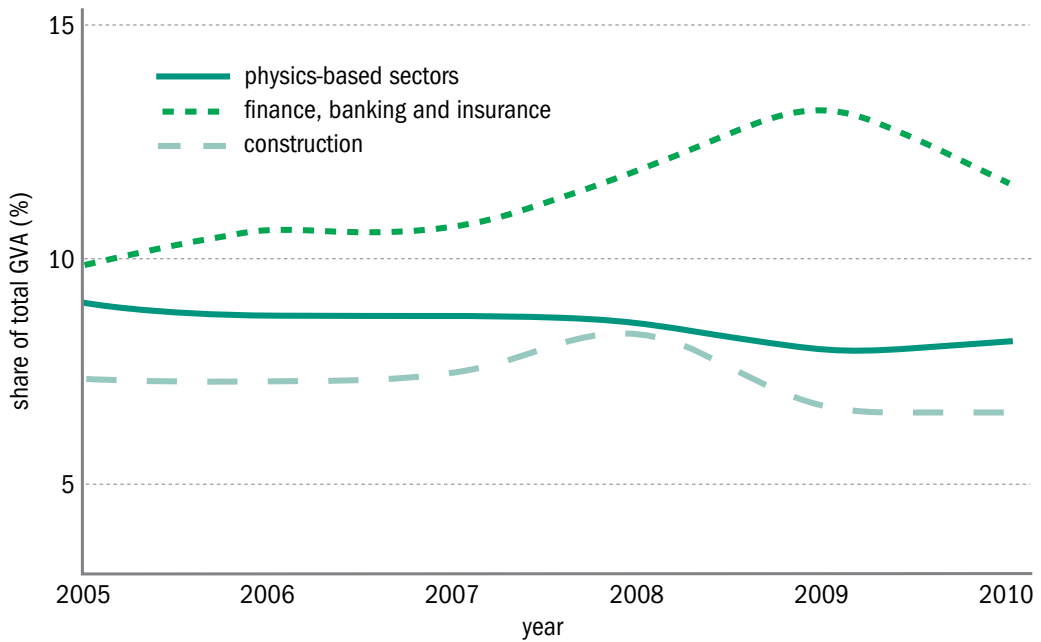
¹⁹ http://cdn.hm-treasury.gov.uk/2011budget_growth.pdf

in physics-based sectors would be expected to yield an increase in the GVA. However, as seen in **figure 2.13** the share of GVA from physics-based sectors remains constant as the UK's economic climate continues to change and diversify. Looking forward, it may be the case that, given the changing composition of physics-based sectors, their GVA contribution will increase as

they advance new technologies and act as engines of growth¹⁹ as identified by the Treasury (HMT) and the Department of Business, Innovation and Skills (BIS) in the Plan for Growth. This point is emphasised when the sources of GVA generated by physics-based sectors is explored, as in **figure 2.14**. There have been significant increases in GVA contribution from architectural

Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Figure 2.13: Share of total GVA, longitudinal analysis, 2005–2010 (current prices)



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Figure 2.14: Share of GVA in physics-based sectors

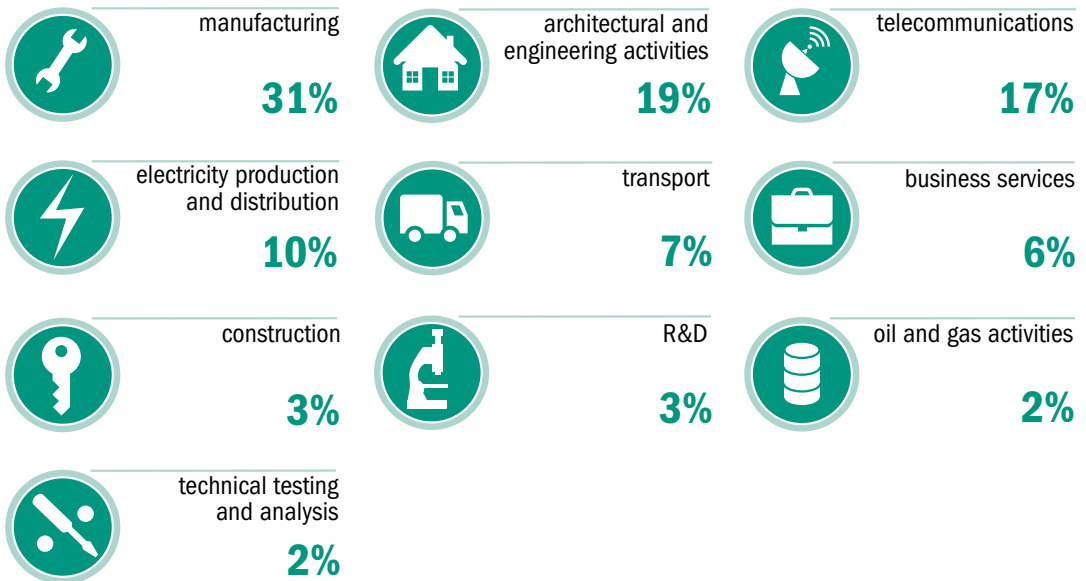
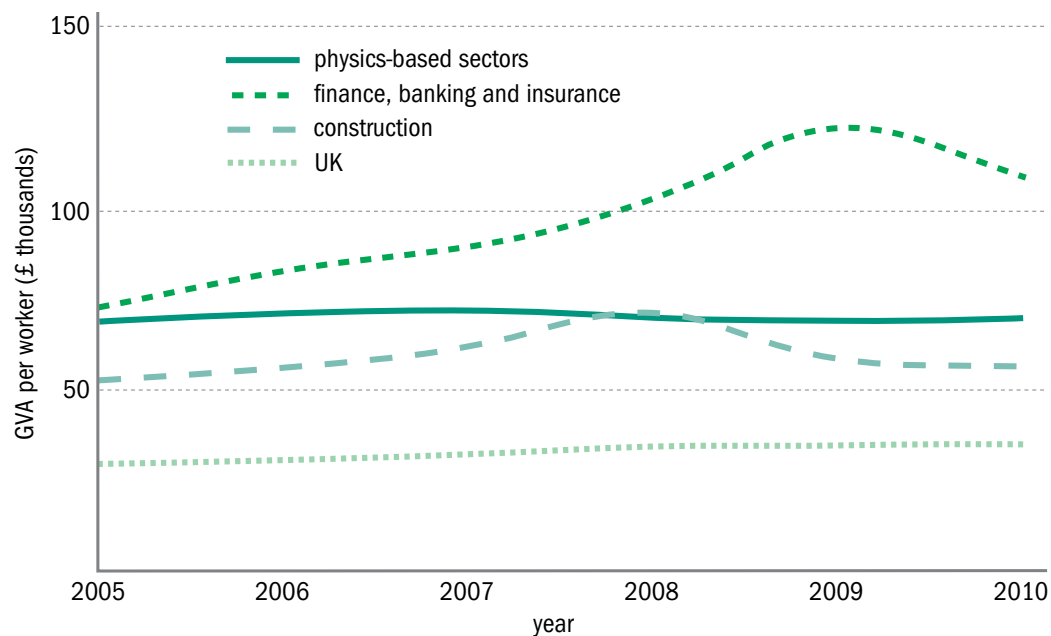


Figure 2.15: Productivity (GVA per worker), longitudinal analysis, 2005–2010 (current prices)



Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

and engineering activities and telecommunications, rising from 8% to 19% and 11% to 17%, respectively. This is in contrast to the decline seen in manufacturing with the GVA share down from 40% in 2005 to 31% in 2010.

2.4. Productivity

Productivity in physics-based sectors has remained stable, but well ahead of the UK average

Figure 2.15 compares productivity (as defined by GVA per worker) in physics-based sectors against other sectors and the UK average. GVA per worker in physics-based sectors was more than £70,000 in 2010, double the UK average of £36,000, below that of finance, banking and insurance (£110,000), but greater than the construction industry.

Between 2005 and 2010, productivity has remained constant in physics-based sectors, with compounded average growth (CAGR) being less than 0.5% – compared with a CAGR of more than 3.5% across all sectors in the UK.

2.5. Conclusion

This chapter has considered the contribution of physics-based sectors to the UK economy in terms of direct jobs and direct GVA generated in 2010. The analysis has resulted in the following key findings.

- There are more than one million direct jobs in physics-based sectors in the UK.
- The majority of these jobs are in the manufacturing sector, but consistent with wider structural changes to the UK, a significant number of jobs can be found in architectural and engineering activities, research and development, transport, electricity, production and construction, and defence activities.
- Turnover from physics-based sectors reached £227 bn in 2010, generating £77 bn in GVA.
- Productivity (as measured by GVA per worker) is significantly higher in physics-based sectors compared with the UK average.
- While GVA generated and productivity per worker in physics-based sectors has declined somewhat in recent years, this might be driven by falling output in manufacturing sectors. As physics-based sectors evolve to include businesses involved in the digital economy and other high-value goods and services, there is the potential for this trend to be reversed and physics to become a much larger contributor to UK GDP.

PHYSICS-BASED BUSINESSES AND THEIR SURVIVAL

²⁰The number of new business registrations has been estimated using the ONS Business Demography release, which uses extracts from the Inter-Departmental Business Register (IDBR). As the ONS explains in its background notes (www.ons.gov.uk/ons/rel/bus-register/business-demography/2010/stb-business-demography-2010.html#tab-background-notes) although the statistics in this release are derived from the IDBR, the total stock of active businesses is greater than the *UK Business: Activity, Size and Location* publication. This is mainly because the definition of an active business is based on activity at any point in the year, whereas *UK Business: Activity, Size and Location* is based on an annual snapshot at a point in time. Further details of adjustments made by ONS to this dataset can be found in the link above.

²¹These figures are based on VAT registrations, which might miss businesses below the VAT threshold.

This chapter examines trends in the number of businesses in physics-based sectors and their survival rates.²⁰

3.1. New businesses²¹

The number of registered businesses in physics-based sectors has increased since 2008

As **figure 3.1** shows, the number of registered businesses in physics-based sectors rose from approximately 81,000 in 2005 to approximately 106,000 in 2010. While it is unlikely that all of the increase in business registrations can solely be attributed to new start-ups (due to re-registrations, divestments, etc), the above analysis suggests that the application of physics to commercial activities can potentially play an important role in creating new businesses and being an engine of enterprise.

Across the UK the data reports an increase in the number of business failures and a fall in new

business start-ups since 2008. This is perhaps unsurprising given the wider macroeconomic climate following the financial crisis.

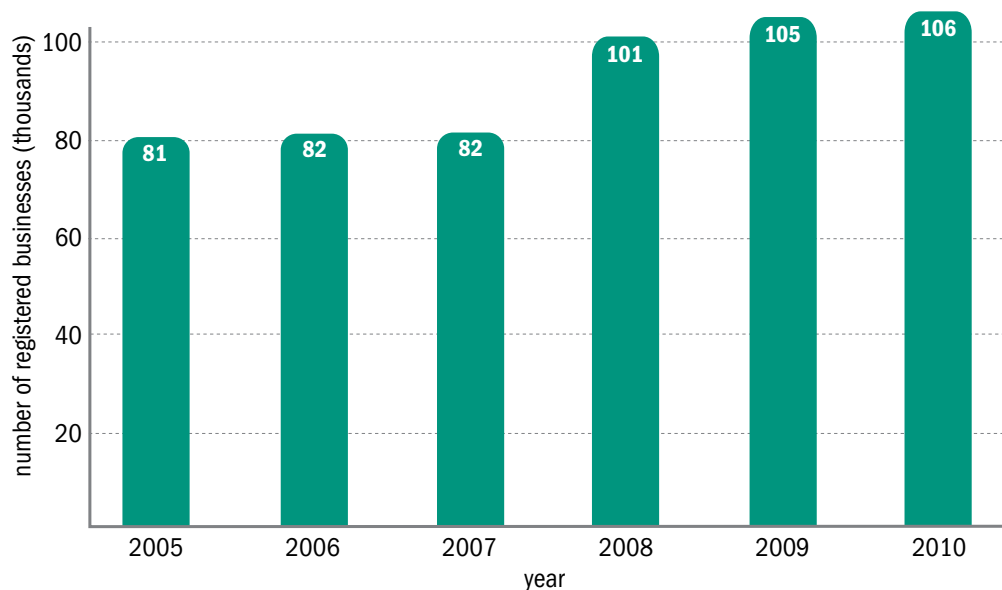
3.2. Business failure

Consistent with wider trends, the number of business failures in physics-based sectors has risen since 2005

The number of business failures in physics-based sectors is estimated using data from the Insolvency Service. As seen in **figure 3.2**, the number of business failures across the economy spiked in 2009 and a similar picture emerges for physics-based sectors, as can be seen between 2005 and 2010.

However, it is instructive to note that the number of business failures per quarter has fallen in physics-based sectors since a peak in mid-2009, although these still remain significantly above 2005 levels.

Figure 3.1: Number of registered businesses in physics-based sectors in the UK at the start of the year, (thousands) 2005–2010



Source: Deloitte analysis using ONS Business Demography

Figure 3.2: Number of business start-ups and failures in the UK, 2005–2010

Source: Deloitte analysis using ONS Business Demography

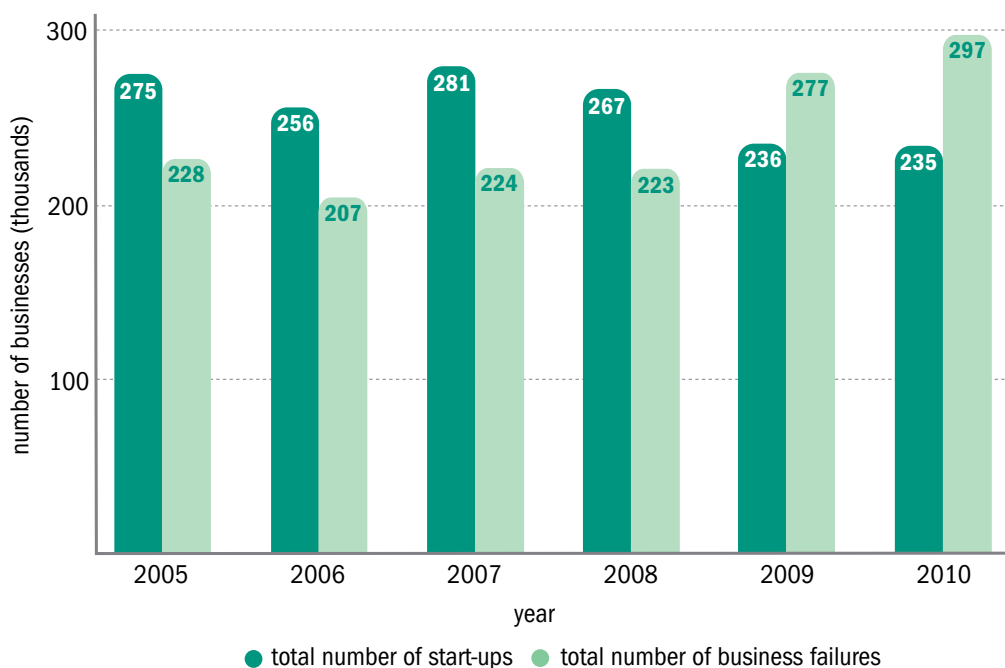
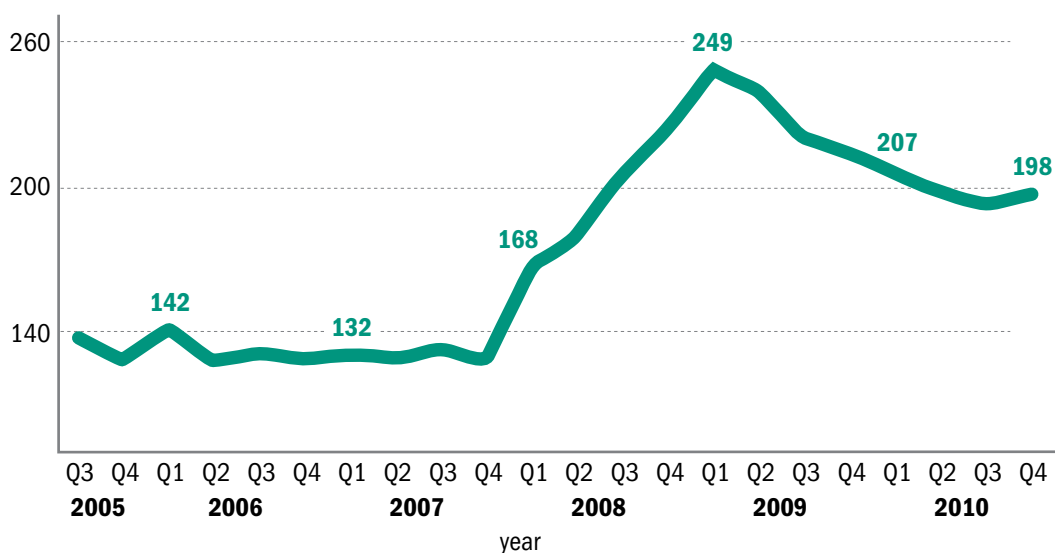


Figure 3.3: Number of business failures in physics-based sectors in the UK, longitudinal analysis, 2005–2010

Source: Deloitte analysis using data from Insolvency Service



3.3. Conclusion

This chapter has considered trends in the number of businesses in physics-based sectors. The analysis has resulted in the following key findings:

- The number of business registrations in physics-based sectors has risen since 2005 –

by more than 30% (or 5% since 2008).

- While the number of business failures in physics-based sectors rose, in line with the rest of the economy following the financial crisis, the number of business failures has subsequently declined in 2010.

INDIRECT AND INDUCED EFFECTS

This chapter presents the indirect and induced impacts of physics-based sectors in the UK (collectively referred to as incremental effects). The methodology for calculation is outlined in the Annex.

4.1. Incremental effects

The economic footprint of physics-based sectors expands considerably when one considers their wider impacts across the supply chain and on consumer spending

In addition to the direct impacts in terms of jobs and GVA described in Chapter 2, there are a number of other ways that these sectors contribute to the UK economy. For example, a “ripple” or “multiplier” effect can be created by a business in a physics-based business sourcing supplies from the wider economy or through an employee spending their wages in other sectors. Accordingly, we consider:

- The indirect impact of physics-based sectors on the UK economy – changes in employment, productivity and income in associated industries

that supply inputs to physics-based sectors.

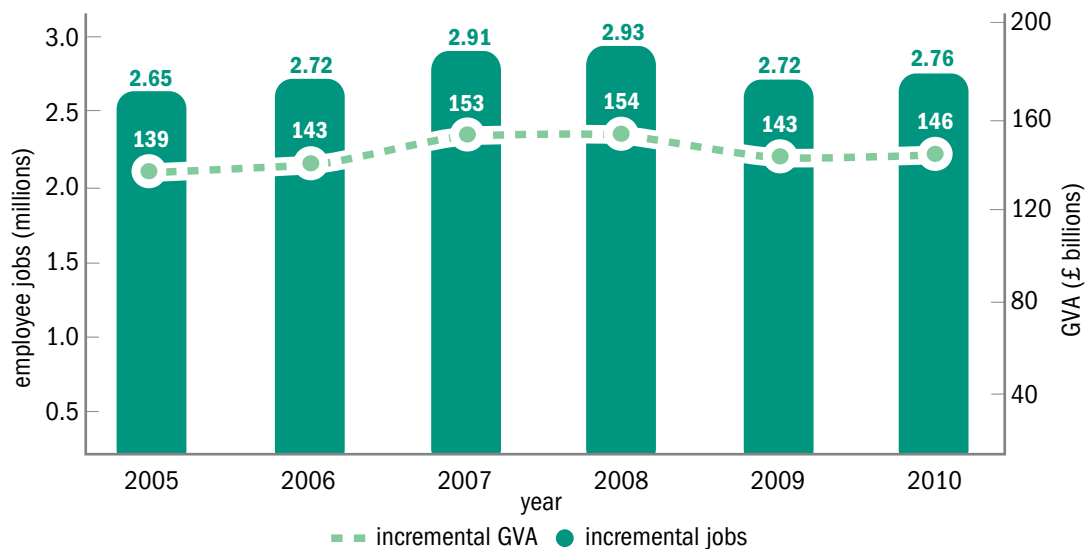
- The induced impact of physics-based sectors – spending by households in the overall economy as a result of direct and indirect effects from the generated economic activity of physics-based sectors and associated sectors.

Together, indirect and induced impacts are known as incremental impacts. These impacts constitute the overall multiplier effect of the physics-based sectors on the UK economy. This takes account of the proportion of activity in other sectors of the economy that are supported by the intermediate demand of physics-based sectors, as well as the spending of employees in physics-based sectors.

Figure 4.1 summarises these impacts in terms of jobs and GVA between 2005 and 2010. The incremental jobs attributable to physics-based sectors follow the trend observed for direct jobs, i.e. a fall in 2008 following the financial crisis, with a small recovery in 2010 and a similar pattern emerges for GVA.

Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

Figure 4.1: Indirect and induced effects on GVA and jobs, longitudinal analysis, 2005–2010



4.2. Conclusion

Combining incremental and direct impacts gives a total contribution of physics-based sectors as 3.9 million jobs and £222.7 bn in GVA generated in 2010. Of this figure:

- 35% of total GVA attributable to physics-based sectors was direct GVA, 65% was indirect and induced (incremental) GVA.

- 28% of total jobs attributable to physics-based sectors was directly in physics sectors, 72% was in the wider economy.
- The share of indirect and induced jobs is higher than GVA as these jobs are associated with a lower productivity per worker than physics-based sectors.

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 a selection of other countries. The investment benefits from physics-based sectors in the UK economy are also analysed – for both foreign and domestic investors.

5.1. International trade in physics-based sectors

Businesses in physics-based sectors perform better than the UK average in terms of exports, but still lag behind their international competitors

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.

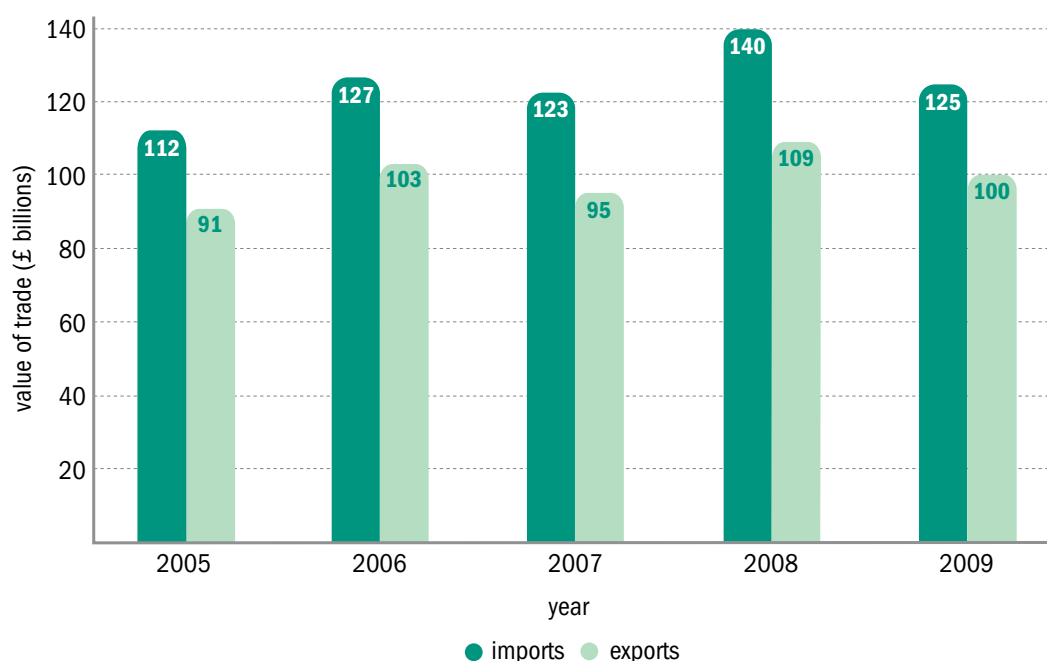
Figure 5.1 shows that the value of exports from

physics-based sectors reached £100 bn in 2009, an increase of nearly £10 bn since 2005. The value of imports also increased, from £112 bn in 2005 to £125 bn in 2010. Both imports and exports are lower in value in 2009 than the previous year, reflecting the effects of the financial crisis.

Compared with the rest of the UK, businesses in physics-based sectors report higher figures when considering exports as a share of turnover – nearly double the UK average between 2005 and 2009. **Figure 5.2** provides further details.

The share of exports and imports that are in physics-based sectors in each input/output category in the UK are then taken and compared with equivalent data for Germany, Japan, France and the USA. As **figure 5.3** shows, the share of exports in physics-based sectors in the UK is exceeded by all countries except France. This is perhaps unsurprising given the even larger share

Figure 5.1: Value of trade in physics-based sectors in the UK, longitudinal analysis, 2005–2009



Source: Deloitte analysis using UKTrade Data and ONS

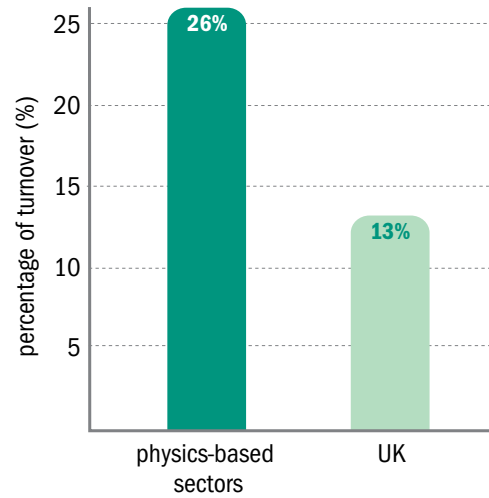
Box 5.1: How is international trade in physics-based sectors measured?

The same definitions of physics-based sectors are used, but applied to Standard Industrial Trade Classification (SITC) data from UKTrade. A correspondence between SIC and SITC is applied. The SITC data are only available for the manufacturing data. To estimate the figures for the services sector, data from input/output tables were used.

of manufacturing in the economic activities of countries such as Germany and Japan. The UK physics-based sectors are also found to import more than all countries except Japan.

Figure 5.4 compares the balance of trade in physics-based sectors with that of the UK's total between 2004 and 2009. It shows that while the balance in physics-based sectors was negative with an average gap of £24 bn over this period, this was less than the total UK gap of more than £100 bn. As the figure shows, the gap has continued to widen between the two over this period, highlighting that the UK balance of trade has deteriorated at a significantly faster pace than

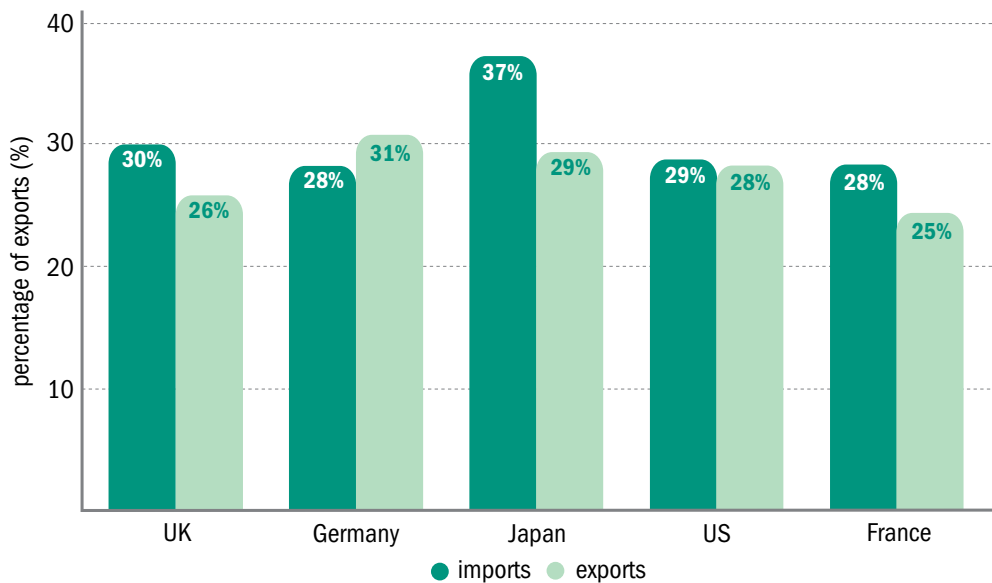
Figure 5.2: Exports as a share of turnover, average 2005–2009



Source: Deloitte analysis using UKTrade Data and ONS

that of physics-based sectors. One might infer that this trend is caused by physics-based sectors remaining globally competitive and specialising in resilient high-value exports. However, as **figure 5.1** confirms, these sectors continue to import more than they export, perhaps reflecting their need for raw materials.

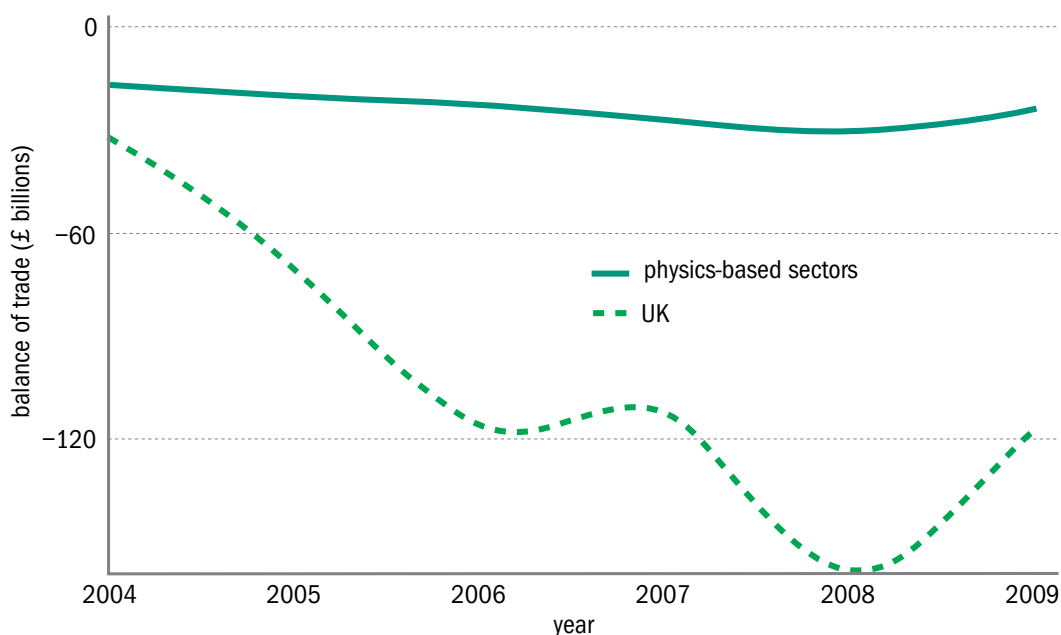
Figure 5.3: Exports and imports in physics-based sectors as a share of all exports, average 2005–2009



Source: Deloitte analysis using UKTrade Data, ONS and OECD

Figure 5.4: Balance of trade in the UK and in physics-based sectors, longitudinal analysis, 2004–2009

Source: Deloitte analysis using UKTrade Data and ONS



5.2. Foreign direct investment in the UK²²

Figure 5.5 shows the extent of the fall inward of FDI into the UK (investment made by non-UK firms in the UK). According to the available data, inward FDI fell from just under £50 bn in 2008 to around £30 bn in 2010. There was also a fall in outward FDI (UK firms making investments overseas), although this fall was more pronounced with outward FDI in

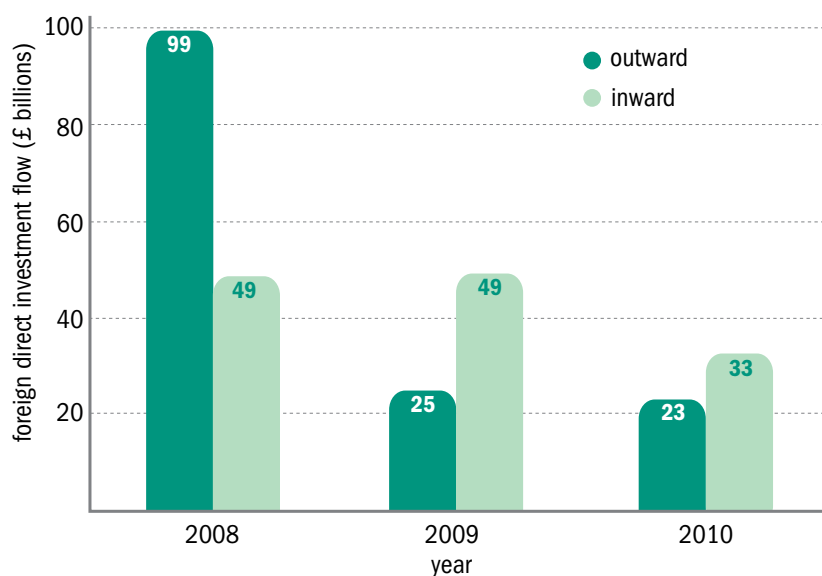
2010 around a quarter of the level of 2008.

Figure 5.6 shows the breakdown of FDI flows into and out of the UK. As can be seen, the manufacturing sector (a significant proportion of which is physics based) receives the most inward FDI, followed by transportation and communication (within which there are also a number of physics-based jobs). This highlights the

²² While we do not have data for physics-based sectors as used in other sections of the report, the extent of foreign direct investment (FDI) has fallen across the UK as a whole over this period, although much of it remains targeted in sectors with large physics components.

Figure 5.5: Foreign direct investment flows in the UK, longitudinal analysis, 2008–2010

Source: Deloitte analysis using UKTrade Data and OECD trade statistics



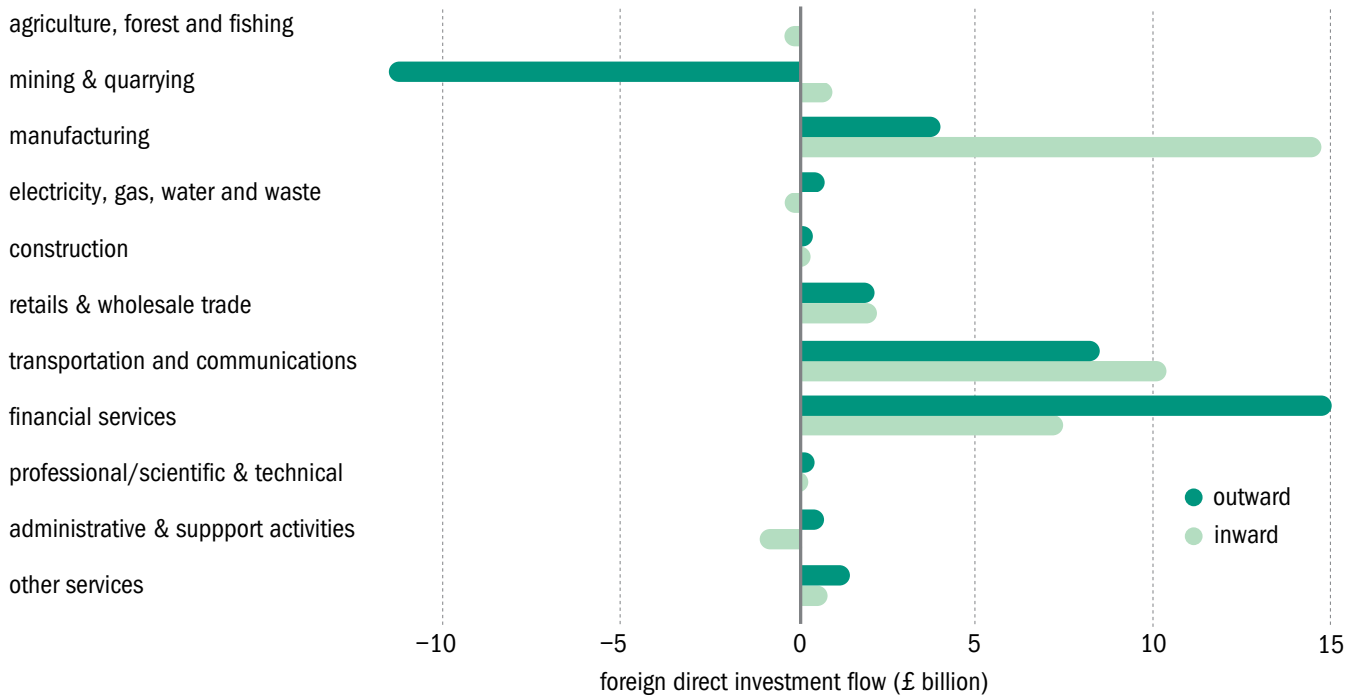
important role that physics-based sectors in the UK play across the globe.

5.3. R&D in physics-based sectors

R&D expenditure in physics-based sectors is significant (more than £2 bn in 2010)

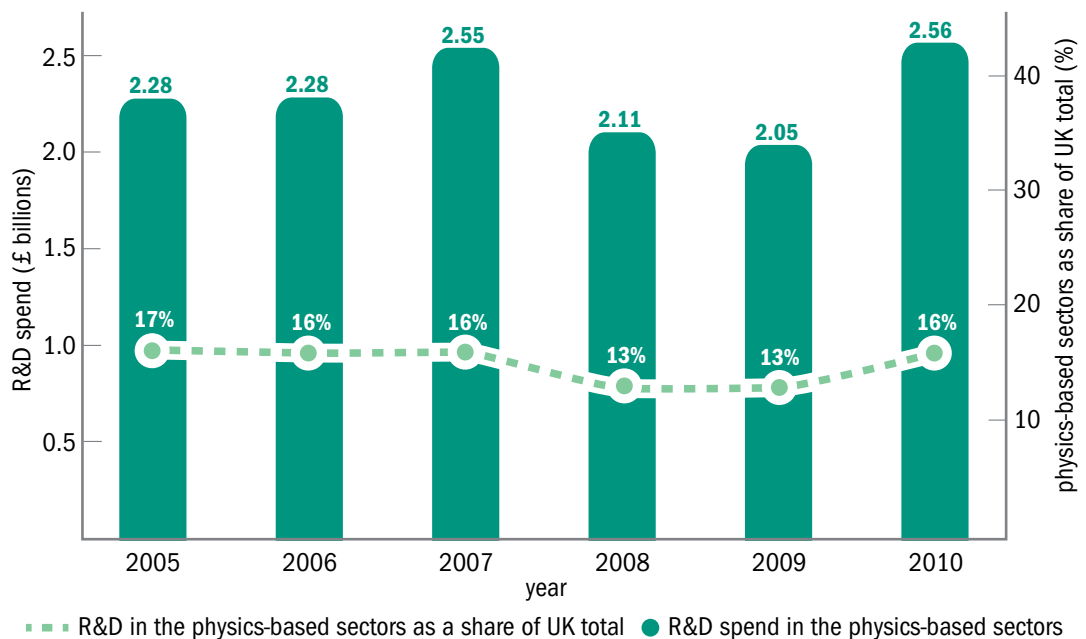
Figure 5.7 shows how much R&D spending takes place in physics-based sectors. According to the available data, in 2010 the spend on R&D in physics-based sectors reached £2.56 bn. The analysis suggests that R&D spending in physics-based sectors constitutes 16% of total R&D spend in the

Figure 5.6: Net foreign direct investment flows in and out of the UK by broad sector, 2010



Source: Deloitte analysis using ONS Business Enterprise Research and Development

Figure 5.7: R&D spending in the physics-based sectors, longitudinal analysis, 2005–2010



UK. Between 2005 and 2010, the average amount of R&D spend per employee exceeded £2000 in physics-based sectors. This figure was nearly four times the UK average.

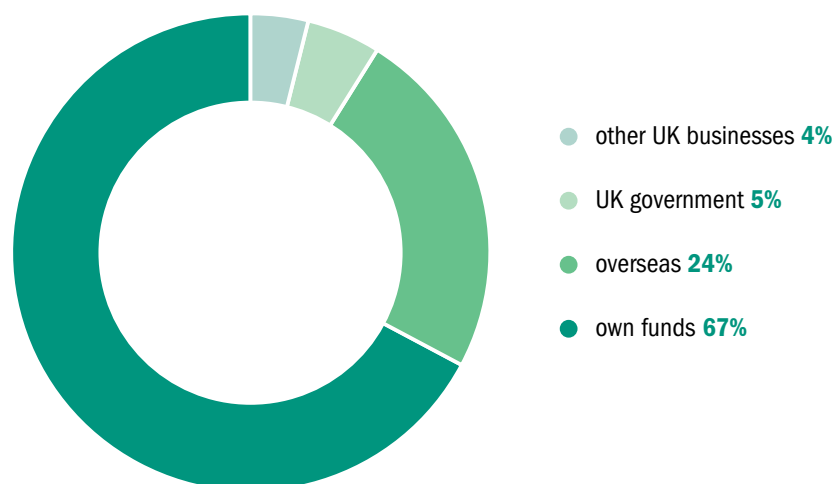
Figure 5.8 illustrates the nature of funding for R&D expenditure in physics-based sectors. The greatest proportion comes from businesses' own funds, with around a quarter coming from inward FDI. Less than 10% of funding is attributable to the UK government or other domestic sources of finance.

5.4. Conclusion

This chapter has considered the international dimension of physics-based sectors and the level of R&D spend. The analysis has resulted in the following key findings:

- Businesses in physics-based sectors perform better than the UK average in terms of exports, but still lag behind their international competitors.
- The extent of FDI has fallen in the UK as a whole over this period, although much of it remains targeted in sectors with large physics components.
- R&D expenditure in physics-based sectors is significant (more than £2 bn in 2010).

Figure 5.8: Source for R&D expenditure for physics-based sectors in 2010



Source: Deloitte analysis using ONS Business Enterprise Research and Development

Shell: greasing the wheels of the economy

Shell Global Solutions is the largest lubricant merchant in the world, with an approximate 13.5% market share of the estimated £30 bn annual global lubricants spend. The company's UK headquarters are based near Chester, employing more than 500 people.

Shell Global Solutions produces fuels and lubricants for the motor industry and industrial machinery. Critical to this is its expertise in understanding

the properties of lubricants and their operating conditions within machinery, which enables it to improve fuel efficiency and increase cost efficiency; financial savings that may then be passed on to the consumer.

Physics, along with other scientific disciplines, such as engineering, chemistry and material science, is an important speciality in the area of tribology; the science of friction, lubrication and wear.

Tribology underpins Shell's lubricants business, which is a large and profitable part of Shell's overall business. Continuing chemical physics research, including lubricant R&D, may lead to the development of less viscous oils, reducing wear in machine elements and increasing machine lifetime. This in turn would enhance the company's profits and overall customer satisfaction.

ANNEX 1: IMPACT OF PHYSICS IN ENGLAND

This Annex presents some supplementary analysis on the impact of physics in England only.

6.1. Direct jobs

As **figure 6.1** shows, a large proportion of direct jobs in UK physics-based sectors are located in England – around 85%. A similar trend in job numbers occurs in England as in the UK.

Compared with the rest of the UK, there is a greater proportion of physics-based sector jobs in England in architectural and engineering activities, telecommunications and business services, as shown in **figure 6.2**. Whereas for the UK as a whole more than half of all physics-based jobs are in manufacturing, in the UK the equivalent figure is around a third. This may be indicative

Box 6.1: How is the impact of physics calculated for England?

It is possible to provide estimates of indirect and induced economic impacts, in terms of GVA and employment at a sub-UK level.

For England, the Deloitte methodology includes the use of mathematical and economic techniques to approximate the English economy in model form from national-level statistics in terms of:

- Who might be expected to buy what from whom (business-to-business purchases).
- Who might be expected to pay whom for their work (compensation of employees).
- Who might be expected to buy what from whom (consumption of goods and services).

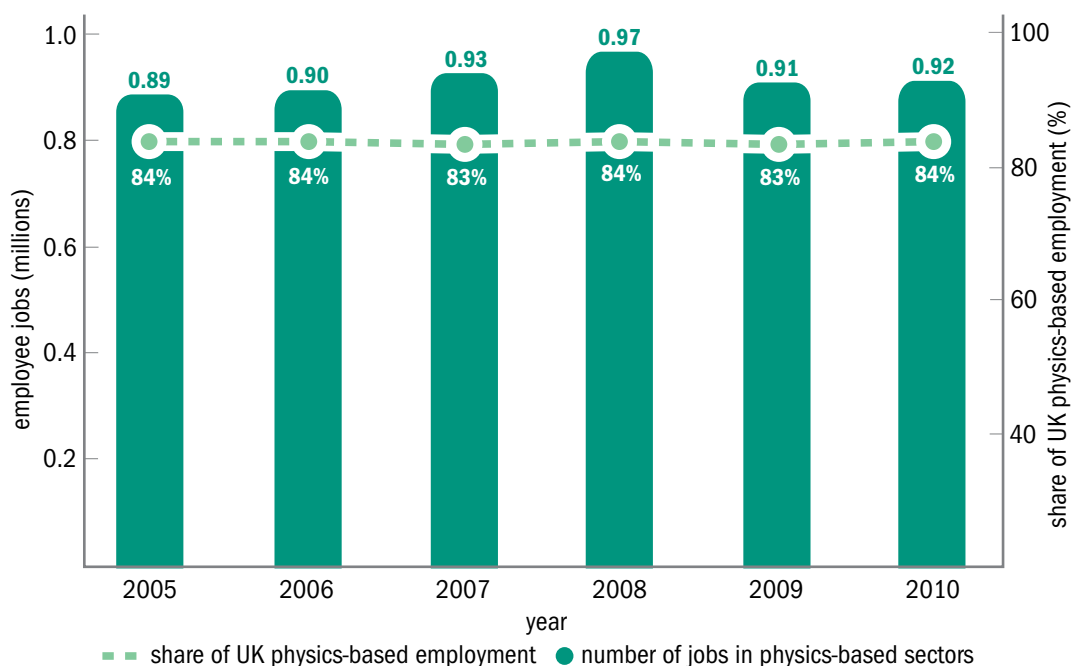
Data to allow this analysis is sourced from official statistics from ONS including the relevant Domestic Use Matrix and BRES data pertaining to industrial structure.

The same methods are used for Wales and Northern Ireland, but the Republic of Ireland and Scotland publish their own national level input-output (I-O) tables, which are used here.

Inevitably, this means that the sum total of indirect and induced effects for countries in the UK from individual elements does not equal those implied by the UK-level model.

Source: Deloitte analysis using ONS Business Enterprise Research and Development

Figure 6.1: Employment in physics-based sectors, England only



of the English economy being more focused on services than manufacturing, compared with the economies of Scotland, Wales and Northern Ireland. The share of employment in physics-based sectors in England is similar to the UK figure, as shown in **figure 6.3**.

6.2. Gross value added

Given the size of the English economy relative to that of Scotland, Wales and Northern Ireland, it is not surprising that the bulk of UK direct GVA is generated in England – around 84%.

6.3. Indirect and induced impacts

A similar picture emerges when considering the incremental impacts (indirect and induced) of physics-based sectors in England and the UK. As seen in **figure 6.5** the majority of these impacts on jobs and GVA are found in England.

Combining direct and incremental impacts gives a total contribution of physics-based sectors of around 3.6 million jobs and nearly £205 bn GVA in 2010. Of this figure:

- 31% of total GVA attributable to physics-based sectors was direct GVA and 69% was indirect

Figure 6.2: Share of physics employment by broad sector in England, 2010

Figure sources: Deloitte analysis using ONS Business Enterprise Research and Development

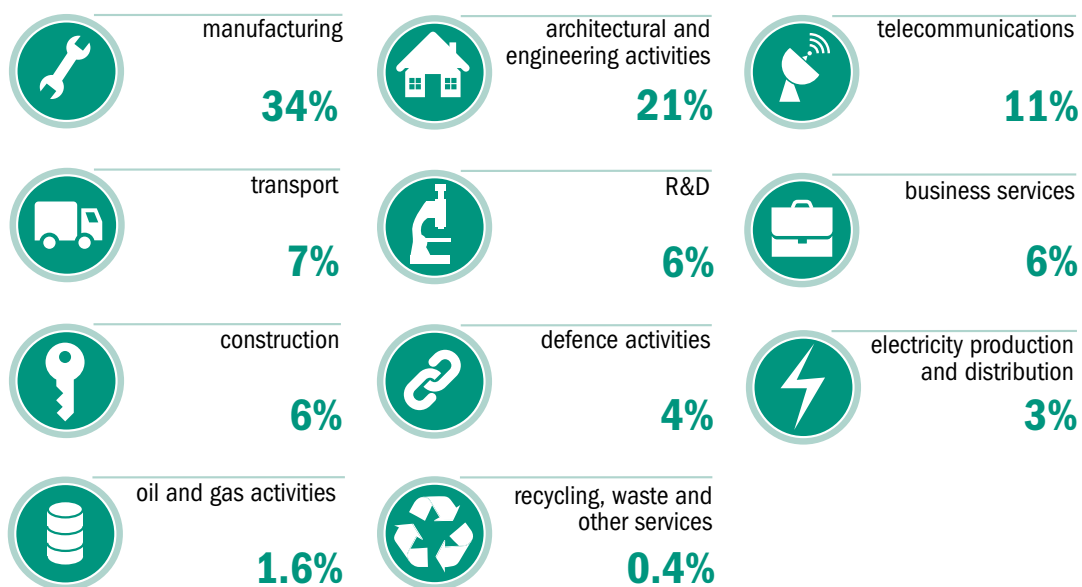


Figure 6.3: Share of employment, England versus UK, 2005–2010 average

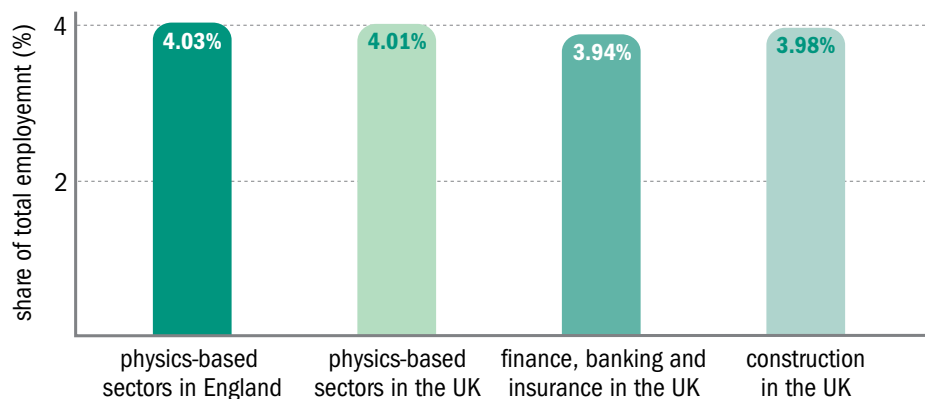


Table 6.1: Physics-based employees in England in 2010 – an analysis

Region	Physics-based employees	Total employees	Physics share of total (%)	Location quotient (100 = England average share)
East	111,000	2,346,000	4.7	115.3
East Midlands	65,000	1,861,000	3.5	85.5
London	143,000	4,090,000	3.5	85.5
North East	43,000	999,000	4.3	106.1
North West	114,000	2,918,000	3.9	95.7
South East	188,000	3,702,000	5.1	123.7
South West	107,000	2,257,000	4.7	116.0
West Midlands	85,000	2,281,000	3.7	91.1
Yorkshire & the Humber	70,000	2,167,000	3.2	78.5
England	926,000	22,621,000	4.1	100.0

Source: Deloitte analysis using Business Register Employment Survey and Annual Business Survey

- and induced (incremental) GVA.
- 26% of total jobs attributable to physics-based sectors were directly in physics-based sectors and 74% were in the wider economy.

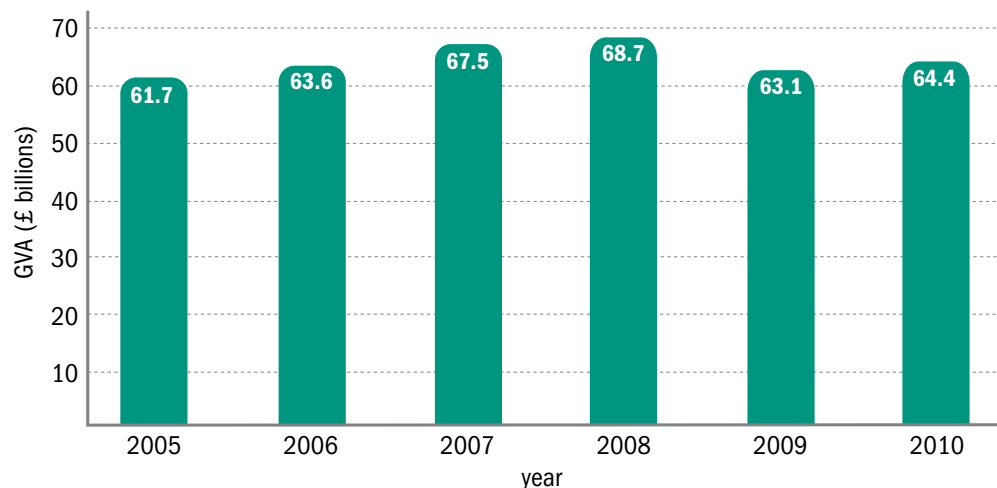
Thus, while there has been a decline in the absolute number of jobs in physics-based sectors since 2008, on average, as a proportion of total jobs, the physics-based sectors now contribute more to the economy than financial, banking and insurance, and construction as these two sectors have been impacted to a greater extent by the financial crisis and ongoing recession than physics-based sectors, at least in employment terms.

One interpretation of this is that the resilience of physics-based sectors has led to a better employment outcome for the UK than would have been the case with a mix of employment skewed more towards financial services and similar sectors.

In England, the regional contribution of physics-based sectors is largest in the greater South East (including London) but physics plays a major role in other regions, including the South West and North East.

Table 6.1 shows that, in absolute terms, the greatest contributions from physics-based sectors come from the South East of England followed by

Source: Deloitte analysis using ONS Business Enterprise Research and Development

Figure 6.4: Direct GVA (£) in physics-based sectors in England, 2005–2010

Greater London. These are the largest economies in England; however, when relativities are taken into account, the regions of the UK with the strongest relative presence in physics-based sectors (measured using location quotients) change.

The South East is still the most significant in relative terms, with a location quotient of 123.7, but London has a below-average quotient of 85.5 – only Yorkshire and the Humber are lower.

Other areas where physics-based sectors make an above-average contribution to the economy (as defined by employment location quotients) are the

East of England, South West and the North East.

As detailed in the rest of this report, a significant, albeit decreasing, proportion of physics-related activity comes from manufacturing. If the above analysis is repeated with manufacturing excluded so that only non-manufacturing physics-based sectors are included, London's location quotient rises significantly from 85.5 to 107.1. This substantial change suggests that London's contribution to the UK economy from physics-based businesses is strongly linked to non-manufacturing sectors.

Figure 6.5: Direct GVA in physics-based sectors in the home nations, 2010

Figure sources: Deloitte analysis using ONS Business Enterprise Research and Development

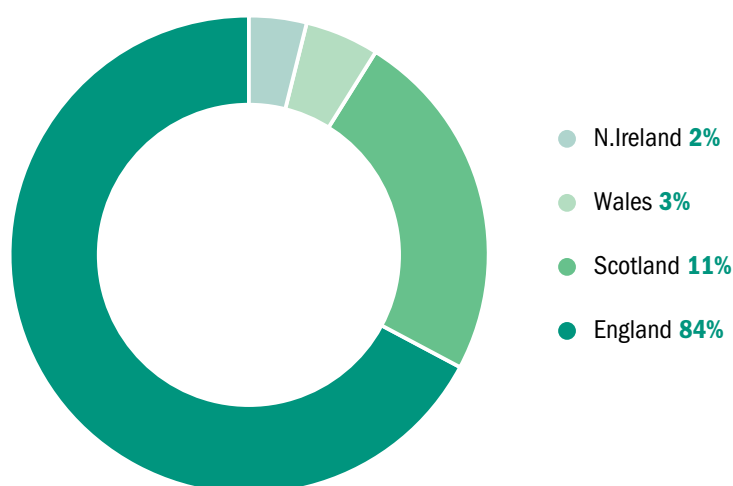
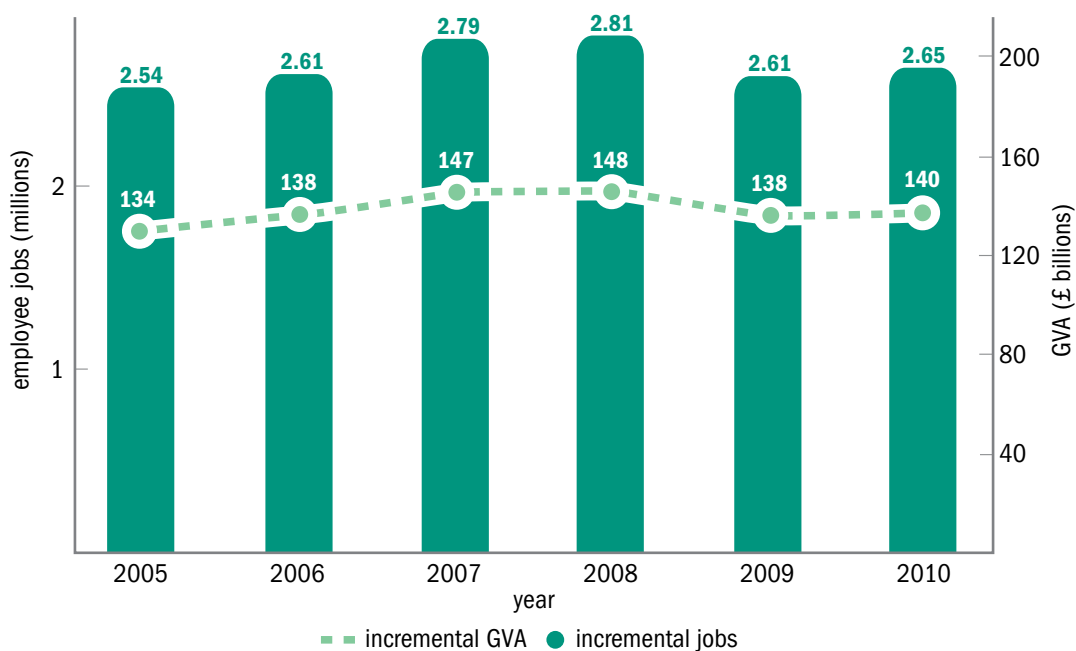


Figure 6.6: GVA in physics-based sectors in England, 2005–2010



ANNEX 2: METHODOLOGY

²³ Dictionary definitions are often along the lines of “the study of matter, energy and the interaction between them”. Such definitions do not adequately capture the role of physics in asking fundamental questions and trying to answer them by observing and experimenting (source www.physics.org).

²⁴ This is analogous to GDP, except that it only includes relevant value added at each stage of production.

7.1. Measuring the impact of physics in the economy

The pervasiveness of physics makes it hard to reach a single conclusive definition.²³ For the purposes of this report, broad categories were agreed with IOP for what can be considered physics.

Physics is seen as having an impact on the UK economy through three main routes:

- As a science – through employees who are in occupations that are engaged in physics as a scientific discipline. This includes teachers, academics and other researchers.
- In a role that uses expertise beyond the science – through businesses that employ staff who use

expertise from physics.

- Through technologies that have been developed based on the science – through employees who use technologies based on an understanding and application of physics.

These routes have an impact on those sectors of the economy that use and generate physics knowledge (physics-based sectors). In turn, the employees in these sectors generate turnover, which has wider spill-over effects that can impact across the entire economy. These spill-over effects can be measured in terms of jobs and gross value added²⁴ (GVA), as well as the number of new businesses, export performance, R&D expenditure

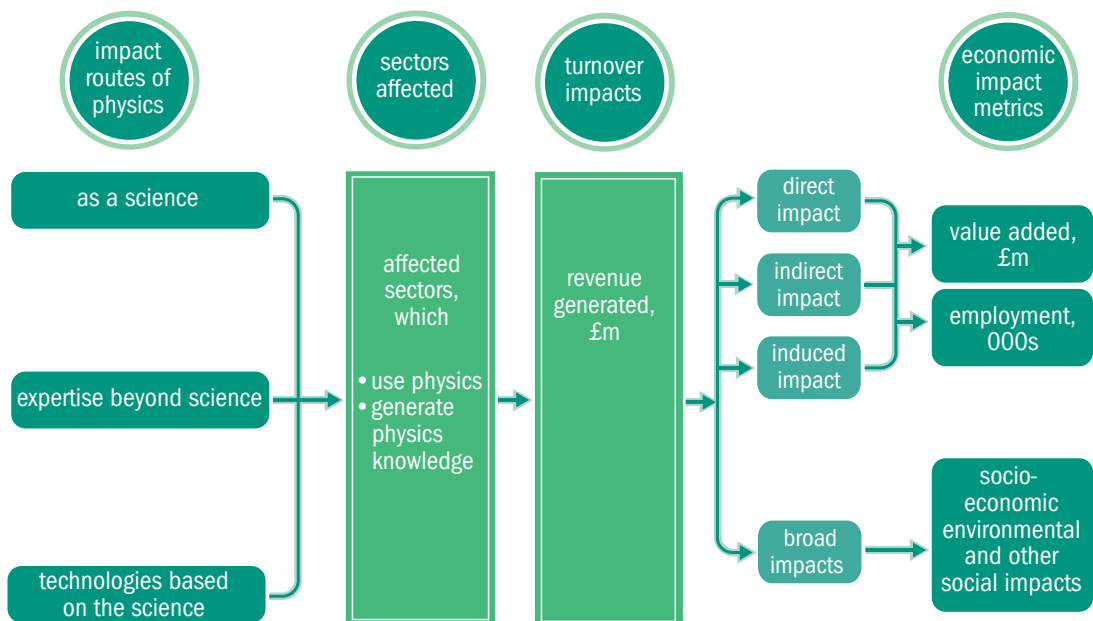
Box 7.1: What is physics?

Broadly speaking, physics can be split into the following categories:

- 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: Deloitte

Figure 7.1: Physics logic chain



and FDI. There might also be broader social impacts of physics – these are not considered in this report.

The impact chain of physics is summarised below.

The key metrics used to measure the impact of physics on the UK economy in this report are:

- Jobs supported by physics in direct, indirect and induced terms.
- GVA due to physics in direct, indirect and induced terms.
- Turnover of physics-based physics in direct, indirect and induced terms.
- Value of exports of physics-based sectors.
- Number of businesses and jobs attributable to physics (directly, indirectly and induced).
- Productivity of physics-based sector employees (£ per employee).
- R&D expenditure of physics-based sectors.
- Business failures and start-ups attributable in physics-based sectors.
- Foreign direct investment in physics-based sectors.

Where appropriate, we also make comparison with other sectors and internationally.

7.2. Our approach

To measure the impact of physics on the UK economy, we have carried out a three-stage approach.

- Confirm definitions and data collection – collecting data from public sources and ensuring it is consistent.
- Economic modelling and data analysis – using a bespoke input-output model of the UK economy and component nations to quantify the economic impact of physics.
- Policy analysis and reporting – drawing out key insights and trends.

Figure 7.1 briefly sets out the steps involved in each stage. Specific assumptions used to calculate individual metrics are not detailed here – they are contained in the relevant footnote when the results are presented.

Definitions

The first step in this stage is to identify which sectors of the economy can be classed as “physics-based” sectors. To recall, these are those sectors of the economy where the use of physics is critical to their existence. In hypothetical terms, the counterfactual scenario of there being no physics would imply these sectors not existing as they are dependent on physics.

It is important to note that the definition of physics-based sectors refers to the use of physics rather than the background of employees. For example, there may be many physics graduates in the professional services sector, but (because they do not make direct use of physics) this sector would not be classed as physics-based. In contrast, an employee involved in the manufacture of fibre-optic cables may not have a physics qualification, but their work directly uses physics knowledge and is hence a physics-based sector.

The criteria used to identify physics-based sectors are the same as in 2007, namely:

- 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?

To isolate physics-based sectors, we have used the Standard Industrial Classification (SIC) in segmenting the UK economy. Established in 1948, the SIC classifies businesses and other statistical units by the type of economic activity in which they are engaged. The UK SIC is a hierarchical five-

Table 7.1: Example SIC(2007) classification

Level	Description
Section C	Manufacturing (comprising divisions 10 to 33)
Division 13	Manufacture of textiles
Group 13.9	Manufacture of other textiles
Class 13.93	Manufacture of carpets and rugs
Subclass 13.93/1	Manufacture of woven or tufted carpets and rugs

Source: ONS

Table 7.2: List of classes used in the definition of physics-based sectors

Class	Description	Class	Description
06.10	Extraction of crude petroleum	30.20	Manufacture of railway locomotives and rolling stock
06.20	Extraction of natural gas	30.30	Manufacture of air and spacecraft and related machinery
09.10	Support activities for petroleum and natural gas extraction	30.40	Manufacture of military fighting vehicles
20.13	Manufacture of inorganic basic chemicals	30.91	Manufacture of motorcycles
21.20	Manufacture of pharmaceutical preparations	32.50	Manufacture of medical and dental instruments and supplies
23.44	Manufacture of other technical ceramic products	33.11	Repair of fabricated metal products
24.46	Processing of nuclear fuel	33.12	Repair of machinery
25.40	Manufacture of weapons and ammunition	33.13	Repair of electronic and optical equipment
25.99	Manufacture of other fabricated metal products n.e.c.	33.14	Repair of electrical equipment
26.11	Manufacture of electronic components	33.15	Repair and maintenance of ships and boats
26.12	Manufacture of loaded electronic boards	33.17	Repair and maintenance of transport equipment n.e.c.
26.20	Manufacture of computers and peripheral equipment	33.20	Installation of industrial machinery and equipment
26.30	Manufacture of communication equipment	35.11	Production of electricity
26.40	Manufacture of consumer electronics	35.12	Transmission of electricity
26.51	Manufacture of instruments and appliances for measuring, testing and navigation	35.13	Distribution of electricity
26.60	Manufacture of irradiation, electromedical and electrotherapeutic equipment	38.12	Collection of hazardous waste
26.70	Manufacture of optical instruments and photographic equipment	38.22	Treatment and disposal of hazardous waste
26.80	Manufacture of magnetic and optical media	43.22	Plumbing, heat and air-conditioning installation
27.11	Manufacture of electric motors, generators and transformers	51.22	Space transport
27.12	Manufacture of electricity distribution and control apparatus	52.21	Service activities incidental to land transportation
27.20	Manufacture of batteries and accumulators	52.22	Service activities incidental to water transportation
27.31	Manufacture of fibre-optic cables	52.23	Service activities incidental to air transportation
27.32	Manufacture of other electronic and electric wires and cables	60.10	Radio broadcasting
27.33	Manufacture of wiring devices	61.10	Wired telecommunications activities
27.40	Manufacture of electric lighting equipment	61.20	Wireless telecommunications activities
27.51	Manufacture of electric domestic appliances	61.30	Satellite telecommunications activities
27.90	Manufacture of other electrical equipment	61.90	Other telecommunications activities
28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	62.09	Other information technology and computer service activities
28.21	Manufacture of ovens, furnaces and furnace burners	71.11	Architectural activities
28.23	Manufacture of office machinery and equipment (except computers and peripheral equipment)	71.12	Engineering activities and related technical consultancy
28.25	Manufacture of non-domestic cooling and ventilation equipment	71.20	Technical testing and analysis
28.29	Manufacture of other general-purpose machinery n.e.c.	72.11	Research and experimental development on biotechnology
28.49	Manufacture of other machine tools	72.19	Other research and experimental development on natural sciences and engineering
28.99	Manufacture of other special-purpose machinery n.e.c.	74.20	Photographic activities
29.10	Manufacture of motor vehicles	74.90	Other professional, scientific and technical activities n.e.c.
29.31	Manufacture of electrical and electronic equipment for motor vehicles	84.22	Defence activities
30.11	Building of ships and floating structures	95.12	Repair of communication equipment

digit system, with the latest revision occurring in 2007. The SIC first divides the economy into broad sections with these sections then disaggregated a further four times to reach a more detailed picture of the economy. **Table 7.1** provides an example.

There are 21 sections, 88 divisions, 272 groups, 615 classes and 191 sub-classes. The UK SIC system is consistent and comparable with the European NACE system and United Nations international standard industrial classification (ISIC) system.

Using the aforementioned criteria, Deloitte has worked with the Institute of Physics to identify which classes (four-digit SIC) can be identified as “physics critical”, i.e. is physics-based. Given the fine granularity of this level of SIC, for most cases it is a binary choice whether a sector is physics critical or not. However, in some larger classes (such as defence activities) an adjustment is necessary to recognise that there will be a proportion of jobs that do not involve physics.²⁵

Table 7.2 sets out the classes chosen to be included in the definition of physics-based sectors.

These classes are not the same as those used in the 2007 report. This is for two reasons. The main reason is that subsequent to the analysis being carried out for the 2007 report, the UK SIC codes were revised (from SIC(2003) to SIC(2007)). The SIC(2007) has consolidated and re-categorised certain sectors on the basis of economic trends and the evolution of the UK economy. Hence, the list of sectors used for this report will differ from the 2007 report. Second, since 2007 the critical use of physics has changed, with some sectors becoming more dependent on physics (due to new discoveries and technologies) and others becoming less dependent. The above classes reflect this change.

Data collection

The data used in this report to construct the impact metrics have predominately come from publicly available sources. These include the:

- ONS Annual Business Survey
- ONS Business Register and Employment Survey
- ONS Business Demography
- Insolvency Service data
- ONS Supply and Use tables
- OECD trade statistics
- ONS Foreign Direct Investment data
- ONS Business Enterprise Research and Development

Where appropriate, adjustments have been made to allow for comparability between surveys and between time periods.

Economic modelling and data analysis

Having collected the data and identified which sectors can be categorised as physics-based, we were able to construct a number of impact metrics, such as R&D expenditure and exports. To calculate the total number of jobs attributable to physics and GVA, we have made use of our established Deloitte UK input-output model to approximate supply-chain linkages.

This UK input-output model allows us to quantify three different categories of input:

- The direct impact of physics – those initial and immediate economic activities (jobs and GVA) generated by physics-based sectors (often referred to as first-round impacts because they coincide with the first round of spending in the economy).
- The indirect effect of physics – changes in employment and income in associated industries that supply inputs to physics-based sectors.
- The induced effect of physics – spending by households in the overall economy as a result of direct and indirect effects from the generated economic activity of physics-based sectors and associated sectors.

The process behind constructing bespoke input-output models for the UK and constituent nations is complex²⁶ and involves creating a “Leontief Inverse” matrix to generate relevant multipliers and differentiating between financial flows and economic outcomes, such that the analysis only represents additional economic activity, compared with the counterfactual case of there being no physics. In this case, a detailed counterfactual case is not necessary given the definition of physics-based sectors implying these sectors not existing in the absence of physics.

Policy analysis and reporting

The final stage of our methodology has involved identifying trends in the results and discussing them with relevant stakeholders to provide further context.

²⁵ This adjustment is made on the basis of 2001 census data and Standard Occupational Code (SOC) data for 2010–2005. Data are used to measure the proportion of the most relevant employees in the industry. As noted, the focus is on the use of physics not necessarily the educational background of employees, i.e. the adjustment considers the occupation of employees and how they apply physics rather than their education background.

²⁶ Broadly speaking, the domestic use matrix (differentiating between domestic purchases and imports) is used to give a matrix of coefficients, detailing the proportion of inputs sourced by an industry from all other industries and labour. The matrix of coefficients is then subtracted from the identity matrix before being inverted to give the Leontief Inverse. This matrix then details Type II multipliers for each country, such that a multiplier of, for example, 1.8 in a physics-based sector means that for a direct impact of £1 m in gross revenue terms, a further £0.8 m would be generated by business-to-business purchases in the supply chain and induced consumer spending for a total expenditure (or gross output) impact of £1.8 m.

GLOSSARY OF KEY TERMS

Broad impacts	Wider impacts caused by the activities of businesses and employees in physics-based sectors. These impacts can sometimes be quantified and assigned a monetary value in GVA and job terms.
Direct impact of physics	Those initial and immediate economic activities (jobs and GVA) generated by physics-based sectors (often referred to as first-round impacts because they coincide with the first round of spending in the economy).
Foreign direct investment (FDI)	Investment by a company in a country different from that in which the company is based.
Gross value added (GVA)	A measure of the value of goods and services produced by a business, industry, sector or region of the economy. The Organisation for Economic Co-operation and Development defines gross value added as the value of output less the value of intermediate consumption. It is analogous to gross domestic product.
Indirect impacts	Changes in the number of jobs and GVA in associated industries that supply inputs to physics-based sectors (sometimes referred to as “supply-chain” impacts).
Induced impacts	The spending by households that results in changes to the number of jobs and GVA due to direct and indirect impacts.
Narrow impacts	The economic impacts caused by the activities of businesses and employees in physics-based sectors. These traditionally cover jobs and GVA generated. These are the sum of direct, indirect and induced effects.
Physics-based sectors	Those sectors of the economy where the use of physics – in terms of technologies or expertise – is critical to their existence. The choice of which sectors constitute physics-based sectors was agreed and reflects previous definitions and changes to nomenclature and SIC. A list of sectors that make up the list of physics-based sectors can be found in the Annex.
Standard Industrial Classification (SIC)	First introduced in the UK in 1948, this is a framework for classifying business establishments and other statistical units by the type of economic activity in which they are engaged. There are a number of levels of the classification, with subsequent levels becoming more detailed.
Standard Occupational Classification (SOC)	A common classification framework of occupational information for the UK on the basis of skill level and skill content.
Standard Industrial Trade Classification (SITC)	The OECD defines this as a statistical classification of the commodities entering external trade. It is designed to provide the commodity aggregates required for purposes of economic analysis and to facilitate the international comparison of trade-by-commodity data.

Disclaimer

This report (the "Report") has been prepared by Deloitte MCS ("Deloitte") for the Institute of Physics in accordance with the contract with them dated 24th February 2012. ("the Contract") and on the basis of the scope and limitations set out below.

The Report has been prepared solely for the purposes of assessing the economic impact of physics on the UK economy, as set out in the Contract. It should not be used for any other purpose or in any other context, and Deloitte accepts no responsibility for its use in either regard including their use by the Institute of Physics for decision making or reporting to third parties.

The Report is provided exclusively for Institute of Physics use under the terms of the Contract. No party other than Institute of Physics is entitled to rely on the Report for any purpose whatsoever and Deloitte accepts no responsibility or liability or duty of care to any party other than Institute of Physics in respect of the Report and/or any of its contents.

As set out in the Contract, the scope of our work has been limited by the time, information and explanations made available to us. The information contained in the Report has been obtained from Institute of Physics and third party sources that are clearly referenced in the appropriate sections of the Report. Deloitte has neither sought to corroborate this information nor to review its overall reasonableness. Further, any results from the analysis contained in the Report are reliant on the information available at the time of writing the Report and should not be relied upon in subsequent periods.

Accordingly, no representation or warranty, express or implied, is given and no responsibility or liability is or will be accepted by or on behalf of Deloitte or by any of its partners, employees or agents or any other person as to the accuracy, completeness or correctness of the information contained in this document or any oral information made available and any such liability is expressly disclaimed.

All copyright and other proprietary rights in the Report remain the property of Deloitte MCS and any rights not expressly granted in these terms or in the Contract are reserved.

This Report and its contents do not constitute financial or other professional advice, and specific advice should be sought about your specific circumstances. In particular, the Report does not constitute a recommendation or endorsement by Deloitte to invest or participate in, exit, or otherwise use any of the markets or companies referred to in it. To the fullest extent possible, both Deloitte and Institute of Physics disclaim any liability arising out of the use (or non-use) of the Report and its contents, including any action or decision taken as a result of such use (or non-use).

For further information contact:

Alex Connor

IOP Institute of Physics

76 Portland Place, London W1B 1NT

Tel +44 (0)20 7470 4800

E-mail alex.connor@iop.org

www.iop.org

Charity registration number 293851

Scottish Charity Register number SC040092

The report is available to download from our website and if you require an alternative format please contact us to discuss your requirements.

The RNIB clear print guidelines have been considered in the production of this document. Clear print is a design approach that considers the requirements of people with visual impairments. For more information, visit www.rnib.org.uk.



This publication was produced by IOP using responsibly sourced materials.