

Institute of Physics Report

Physics and the Scottish Economy

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

September 2007



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 Scottish 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.
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1: Introduction

This report provides an assessment of the importance of physics-based sectors to the Scottish economy.

Its key findings are:

- In 2005 there were about 102 000 employee jobs in Scotland in sectors where the use of physics-based technologies or expertise was critical. This is equivalent to 4.3% of all jobs in Scotland and 10% of jobs in physics-based sectors in the UK.
- Between 2001 and 2005 there was a decline in the number of jobs in physics-based sectors in Scotland, mirroring the trend of falling employment in physics-based sectors in the UK.
- In 2005 levels of gross value added (GVA) due to the physics-based sectors were about £8 billion, making up 9.4% of the economic output of Scotland.
- Productivity levels in physics-based sectors in Scotland in 2005 were almost twice as high as the UK average.

2: Jobs and value added

To capture the importance of physics in Scotland, only the direct contribution to the economy made by firms for whom the use of physics is essential for their existence is identified. This is measured in terms of both employment and GVA.

Employment

In this section the levels of employment in physics-based sectors are detailed. In particular, the range of physics-based sectors in the Scottish economy and how many people are employed in them are examined. The trends in employment in the physics-based sectors are analysed and compared with those in other sectors in the UK.

The level of direct employment impact of the physics-based sectors is estimated by measuring the number of jobs in the sectors that rely on physics – where the use of physics is critical to the existence of the businesses.

102 000 employee jobs in physics-based sectors

In 2005 there were about 102 000 employee jobs in Scotland in sectors where the use of physics-based technologies or expertise was critical to the existence of the sector. This equates to about 4.3% of all jobs in Scotland and 10% of jobs in physics-based sectors in the UK (figure 1). Figure 2 shows the breakdown of physics-based employment in Scotland.

The number of people employed in physics-based sectors has declined since 2001, following a similar pattern to the trend in employment in physics-based sectors in the UK. Box 1 gives an explanation of the methods of measuring employment levels used in this report.

Employment in physics-based sectors is higher than in financial services

In figure 3 the share of total employment in physics-based sectors in Scotland is compared with that of the UK, as well as the share of employment in other sectors between 2000 and 2005. This analysis reveals that physics-based sectors in the UK accounted for an average of 3.9% of total national employment during the period 2000–2005. This compares with a 4.1% share in the finance, banking and insurance sector and 4.4% in the construction sector, also in the UK.

Value added

Physics-based sectors generate £8 billion

Figure 4 shows that the GVA of the physics-based sectors currently stands at £8 billion, making up 9.4% of the Scottish economic output. It rose rapidly between 2001 and 2005, reflecting the falling cost of raw materials used as inputs. Technological advances will have helped physics-based sectors to keep the cost of these 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. Box 2 outlines how the economic contribution or GVA of physics-based sectors is measured.

Figure 5 shows that, between 2000 and 2005, physics-based sectors in Scotland accounted for an average of

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

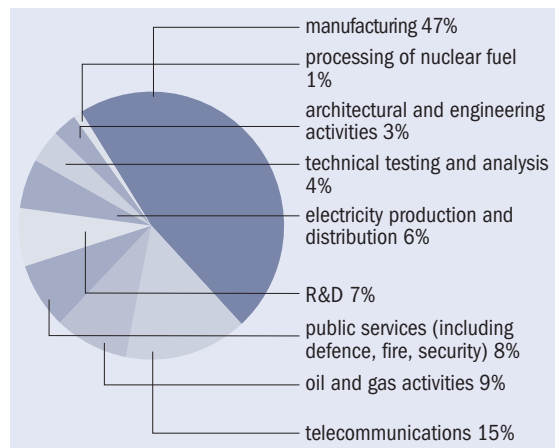


Figure 2 (left): Share of employment in physics-based sectors by broad sector, Scotland. Source: cebr analysis of the ONS Annual Business Inquiry 2004.

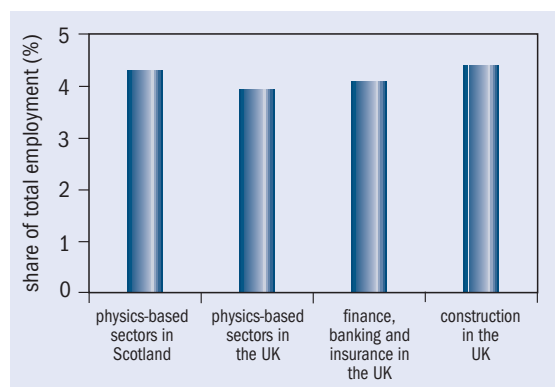


Figure 3: Average share of total employment, 2000–2005. Source: ONS Annual Business Inquiry 2004 and cebr analysis.

2: Jobs and value added

Figure 4 (left): GVA in physics-based sectors. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

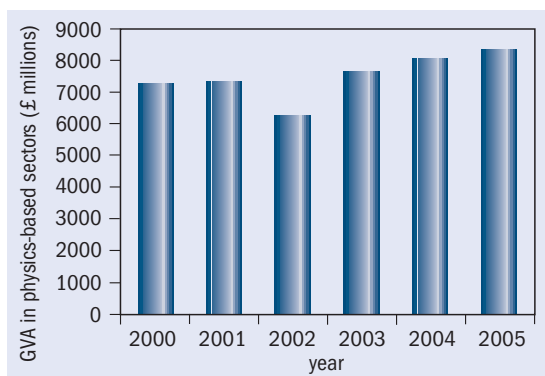
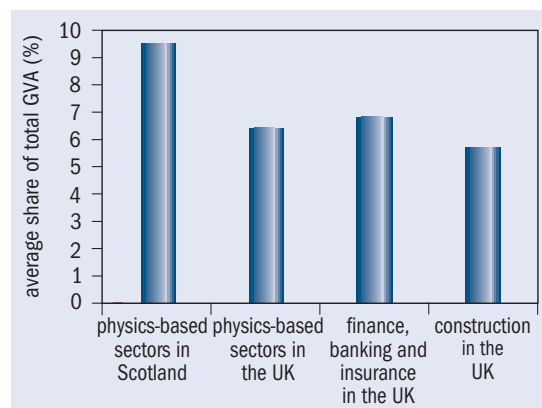


Figure 5 (right): Average share of total GVA into national output levels. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.

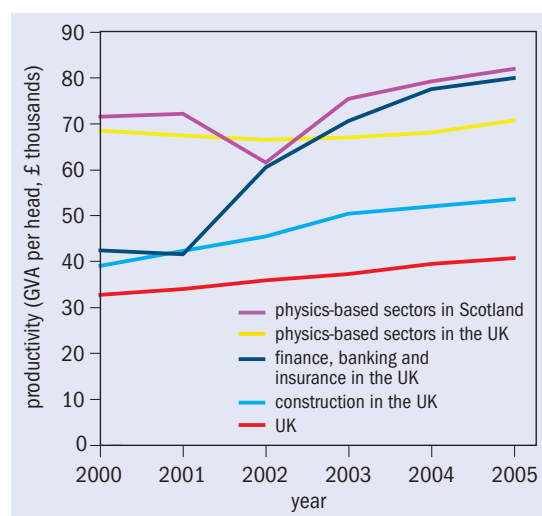


Box 1: What is included in the current estimates of employment in physics-based sectors?

Estimated employment figures in this part of the report include:

- employee jobs from the ONS *Annual Business Inquiry* rather than 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 also telecommunications.

Figure 6: Productivity (GVA per head) in sectors of the economy. Source: ONS *Annual Business Inquiry 2004* and cebr analysis.



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, 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* was 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.

9.5% of national output. This share far exceeds that of physics-based sectors in the UK, that of the UK's construction sector, and of the finance, banking and insurance sectors, which produced 5.7% and 6.8% of the UK's total GVA respectively.

Figure 6 shows that productivity levels in the physics-based sectors in Scotland in 2005 were almost twice as high as those of the UK average. This in part reflects the fact that many physics-based sectors are manufacturing based. Manufacturing is more technology intensive than many other sectors in the economy, so the level of GVA generated per employee is substantially higher. Relative to other sectors, productivity in physics-based sectors is higher than that in the construction sector but, in recent years, has been lower than that in the finance, banking and insurance sector. Productivity levels in physics-based sectors in Scotland and the UK are currently similar, although Scotland has experienced more variability over the past five years relative to the UK.

3: 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 3** shows broad categories of what can be considered physics.

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.

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.
- **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-based 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

Box 3: 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.

are physics based.

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 may require the use of more advanced applications of physics, while others may use applications that are less sophisticated. There are differences in the applications of physics between, for example, laser technologies compared with 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 may be essential for some businesses to function, while other businesses may make use of physics but 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 business on it?

However, business-level data are sparse. Therefore the use of physics in the economy is grouped using sector data. Sectors are groups of businesses engaged in similar activities; businesses are classified according to the main type of economic activity in which they are engaged. For example, an enterprise such as Ford would be classified as a manufacturer of motor vehicles.

Table 1: An example of the UK SIC (Source: ONS 2006)

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)

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

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.¹

The UK SIC system is used in this report 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). The classes are those where:

- physics is used;
- if it is used, whether 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 the activities of the sector.

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 class 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 sectors 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 (table 2). 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.

Given the fine granularity of data at the four-digit SIC level, for most cases it is assumed that a sector either 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 share of all teachers and administrative staff in the school. Another example is the defence sector. Here both expertise in physics and physics technologies are used, but there are a large number of soldiers who also 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 share 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

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

value	Latest estimate	Our estimate using		Our estimate using	
	in 2003 study	2003 definition		latest definition	
	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 4: Differences between the employment analysis and the 2003 analysis (source: ONS 2006)

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*; this is conducted on an annual basis;
- new definitions of physics-based sectors.

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.

2: Comparison with the 2003 study

In this section the current analysis is compared with the findings of the Institute report entitled *The Importance of Physics in the UK Economy*, produced in 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 4) 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.

1. (Opposite) 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.

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