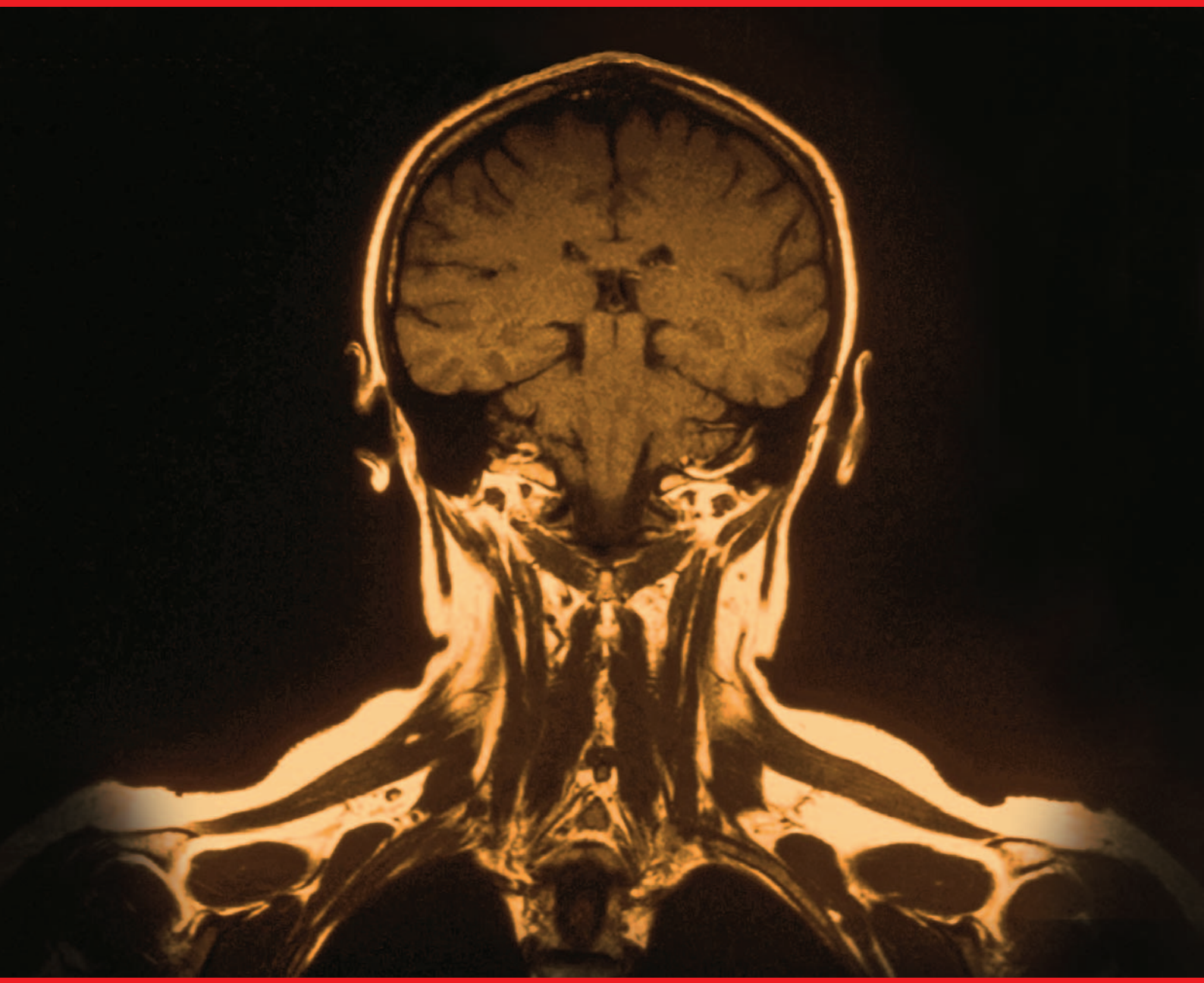
Institute of Physics Report

Physics and the Irish Economy

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

October 2007



IOP Institute of Physics

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

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1: Introduction and summary

This report examines the contribution of physics to the economic prosperity of the Republic of Ireland (ROI). The role of physics-based sectors[1] in the ROI is evaluated in terms of how they developed between 2000 and 2005.

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

In 2005 there were more than 85 500 jobs in physics-based sectors in the ROI. This compared with 82 000 jobs in the banking, finance and insurance sector and was equivalent to 5.3% of all jobs in the economy.

Physics-based sectors are highly productive

In terms of gross value added (GVA), this study shows that physics-based sectors contributed ¤15 billion to the ROI economy in 2005 – 10.5% of total GVA generated in the economy. This was slightly more than the 10.1% share of total national GVA accounted for by the ROI's banking, finance and insurance sector in the same year.

Productivity in physics-based sectors is also relatively high. On average between 2000 and 2005, the GVA per employee in physics-based sectors was around ¤150 200 per annum – approximately 88% higher than the national average.

Physics-based sectors also support activity in the wider economy

Aside from the direct impacts described above, physics-based sectors help to support activity in the wider economy. The spending of physics-based sectors on intermediate goods and services in the ROI in 2005 helped to support 69 100 jobs and ¤6.1 billion worth of GVA in supplier sectors.

The spend of employees from physics-based sectors on goods and services in the wider economy amounted to ¤3.1 billion in 2005. This helped to support 16 700 jobs and more than ¤1.5 billion worth of GVA in the wider economy.

Physics-based sectors also play a vital role in the economy by supplying intermediate goods and services to many other industries. In 2005 these industries spent a total of ¤18.2 billion on intermediate goods and services from physics-based sectors. This is equivalent to 128 400 jobs and more than ¤9.6 billion of the GVA generated in these non-physics-based sectors.

But turnover is not rising as fast as the national average and employment is falling

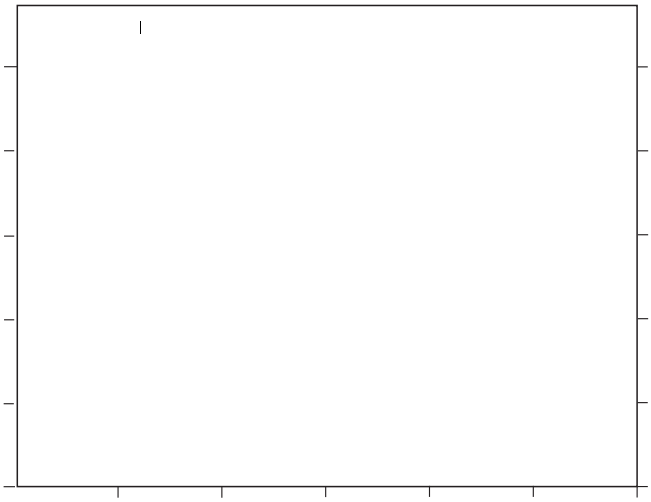
Physics-based sectors generated a turnover of ¤29 billion in 2005 – 8.9% of the ROI's total turnover. Although this represents a large contribution to the economy, it has been deteriorating in recent years. Turnover in physics-based sectors rose by just 19% between 2000 and 2005 – significantly less than the 53% increase in total turnover in the ROI. Although physics-based sectors may be becoming more productive as a whole, they are less competitive relative to the rest of the economy.

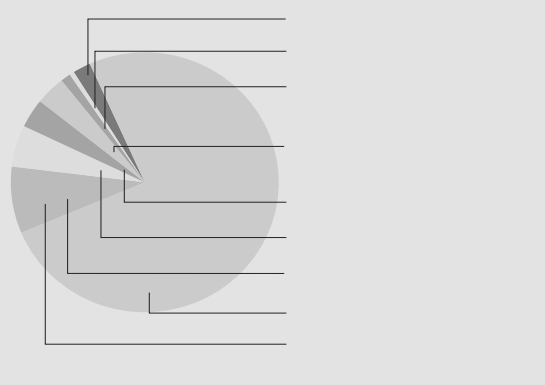
With the shift towards services, the ROI has seen fast growth in employment, boosted by finance and business services as well as in the public sector. However, this report finds that employment in physics-based sectors has not seen a similar performance. Employment declined by 11% between 2000 and 2005. While the decline in manufacturing in part explains the falling number of jobs in physics-based sectors in recent years, the share of manufacturing jobs has also been falling.

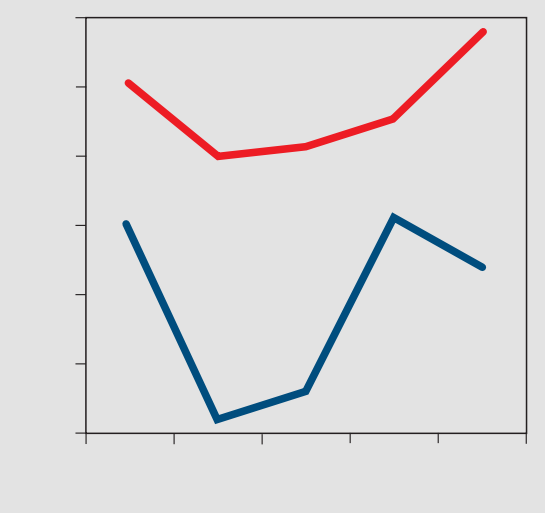
Physics-based sectors in the ROI export less than their counterparts in other countries

Physics-based sectors in the ROI exported ¤29.9 billion and imported ¤39.6 billion worth of goods and services in 2005, accounting for 28% and 44% of the total value of exports and imports in the economy. The ROI has a significantly lower share of exports in physics-based sectors relative to other major international players.

1. A physics-based sector is defined as one in which the use of physics expertise and/or physics technologies is deemed to be critical to its existence. Appendix 1 provides the methodology that has been used to identify physics-based sectors. In chapter 5 a broader assessment is offered, looking at sectors that are considered to be dependent on the use of physics expertise or technology to some extent, not just those in which the use of physics is critical.







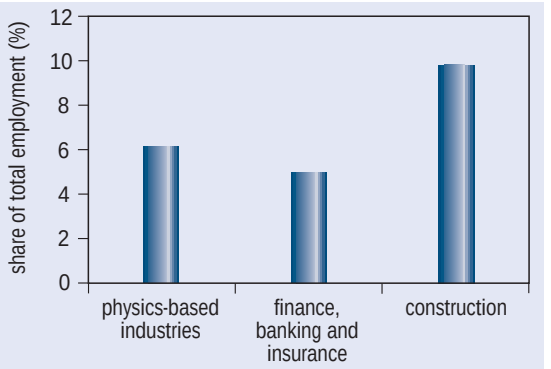


Figure 4: Share of total ROI employment, average over 2000–2005. Source: ONS *Annual Business Inquiry 2004*, Eurostat *Labour Force Survey*, CSOI *2003 Republic of Ireland Census* and cebr analysis.

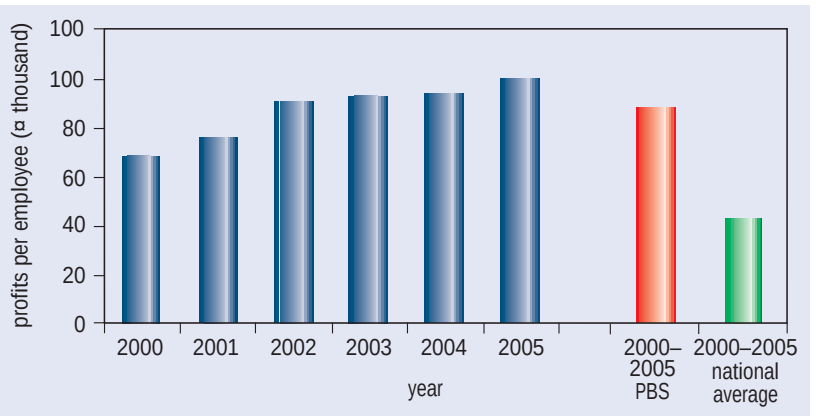


Figure 5 (above): Profits per employee in physics-based sectors, current prices. Source: ONS, CSOI and cebr analysis.

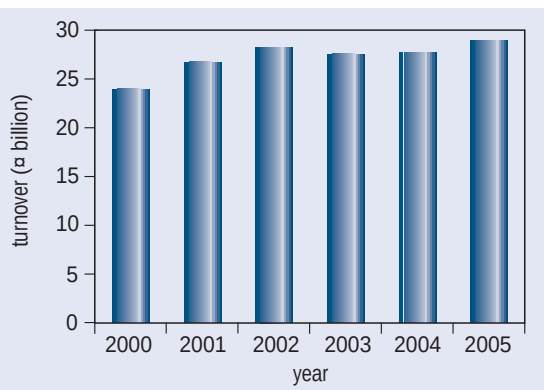


Figure 6: Turnover in physics-based sectors, current prices. Source: ONS, CSOI and cebr analysis.

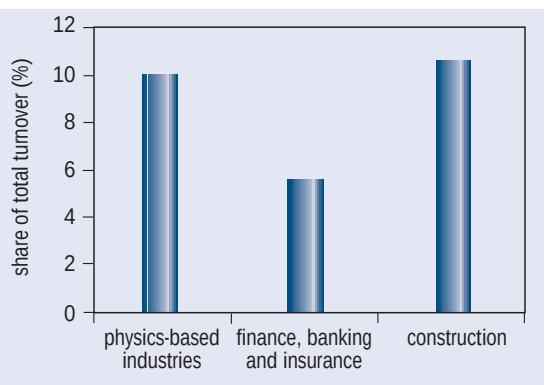


Figure 7: Share of total ROI turnover, average over 2000–2005. Source: ONS, CSOI and cebr analysis.

Where the use of physics is critical, manufacturing still has a large role

The total number of jobs in physics-based sectors in the ROI fell by 11% between 2000 and 2005, compared with a decline of 16% in the UK. Overall jobs growth in the ROI has increased by approximately 18% over the same period. The simultaneous decline in employment in physics-based sectors and rise in overall employment represent a structural shift in the economy to a greater concentration of services, with growing levels of employment in sectors such as finance and business services.

The share of employment in manufacturing in all physics-based sectors in the ROI declined by 5% between 2000 and 2005, as shown in figure 1. However, as can be seen from figure 3, manufacturing still accounted for 75% of jobs in sectors where the use of physics-based technologies or expertise was critical in 2005. This compares with 62% in the UK.

The ROI's aerospace industry employs approximately 5500 people, of whom 4000 are employed in maintenance, repair and overhaul, 900 in manufacturing, 500 in services and 100 in space activities.

Source: Shannon Ireland 2006, www.shannonireland.com/ShannonIrelandSectors/Aerospace/.

Figure 2 shows that employment in physics-based sectors declined almost every year between 2000 and 2005. This is in stark contrast with total employment in the ROI, which rose every year – and at an increasing rate between 2002 and 2005.

Figure 4 compares the share of total ROI employment in physics-based sectors to that accounted for by other large sectors on average between 2000 and 2005. This analysis reveals that physics-based sectors accounted for an average of 6.1% of total national employment over the period, compared with only a 4.9% share in the finance, banking and insurance sector.

Profits (measured as gross operating surplus) per employee in physics-based sectors are relatively high when compared with those of the average sector in the ROI. Figure 5 illustrates that, on average, between 2000 and 2005, profits per employee in physics-based sectors were more than double those of the national average.

Turnover

In this section the focus is on the financial contribution of physics-based sectors to the ROI economy in terms of the turnover that they collectively generate.

Figure 6 shows that the turnover of physics-based sectors increased by 19% between 2000 and 2005 to just less than ¤29 billion, making up 8.9% of all turnover from busi-

nesses in the ROI (compared with 8.7% for the UK). To put this contribution into context, in 2004, turnover in the physics-based sectors was more than twice the ¤12 billion turnover generated by the construction industry.[2]

While employment in physics-based sectors in the ROI declined, between 2000 and 2005 the turnover increased by 19%, compared with only 4% in the UK. However, this 19% rise is substantially lower than the 53% increase in total ROI turnover for the same period, highlighting the weakening competitiveness of physics-based sectors.

cebr estimates show that the hotels and restaurants sector in the ROI generated a turnover of ¤8.8 billion in 2005 – less than a third of the turnover created by physics-based sectors in the same year.

Source: ONS, CSOI and cebr analysis.

Figure 7 shows that, between 2000 and 2005, the turnover generated by physics-based sectors accounted for 10.1% of the ROI total. This contribution was almost equivalent to that of the construction industry, which accounted for 10.6% of total turnover, and it represents almost double the share of total turnover generated by the finance, banking and insurance sector.

Importantly, the rise in gross turnover generated in physics-based sectors has been accompanied by a rise in the turnover per employee. Figure 8 shows that the turnover per employee increased by 34% between 2000 and 2005 in physics-based sectors. On average, the turnover per employee stood at more than ¤300 000 between 2000 and 2005 – 68% higher than the national average.

Gross value added

This section examines how much economic value physics-based sectors add to the ROI economy. The measure used to evaluate the economic contribution of physics-based sectors is GVA. The GVA of a sector is the difference between output and intermediate consumption in the sector. This is the difference between the value of goods and services produced and the cost of inputs that are used in production. It includes taxes on production (e.g. business rates) and net subsidies but excludes subsidies and taxes on products (e.g. value added tax and excise duty).

In this report the GVA is estimated by calculating the sum of the gross operating surplus, and gross wages and salaries generated. The gross operating surplus represents the value of the goods and services produced, while gross wages and salaries represent the cost of inputs.[3]

The GVA analysis presented here is based on the 2000 input/output table for the ROI sourced from the CSOI. This is broken down into 52 industries across the economy, and in this analysis the data are forecast to 2005 using aggregate GVA data for the ROI. To conduct this analysis at a more detailed sector breakdown the most disaggregate GVA data by sector available from the CSOI are used. Estimates were made for sectors for which there are no raw data. These estimates are based on UK productivity rates,

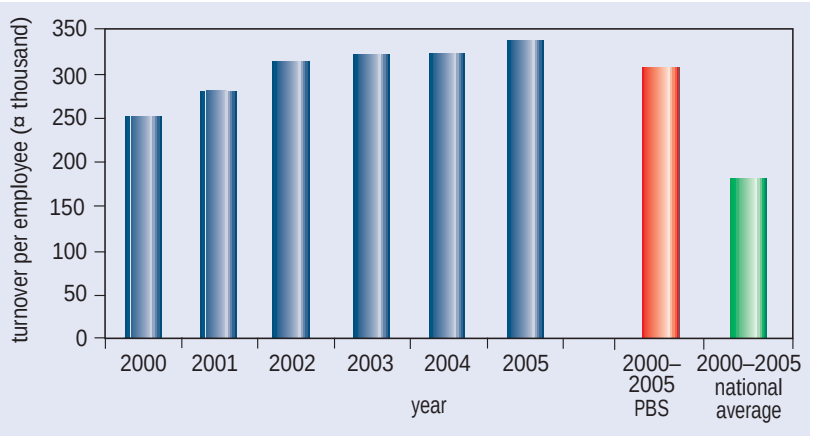


Figure 8: Turnover per employee in physics-based sectors, current prices. Source: ONS, CSOI and cebr analysis.

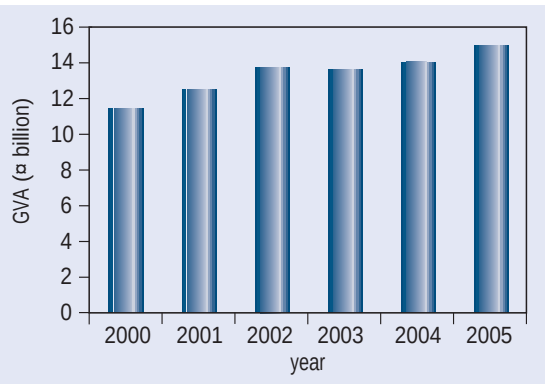


Figure 9: GVA in physics-based sectors, current prices. Source: ONS, CSOI and cebr analysis.

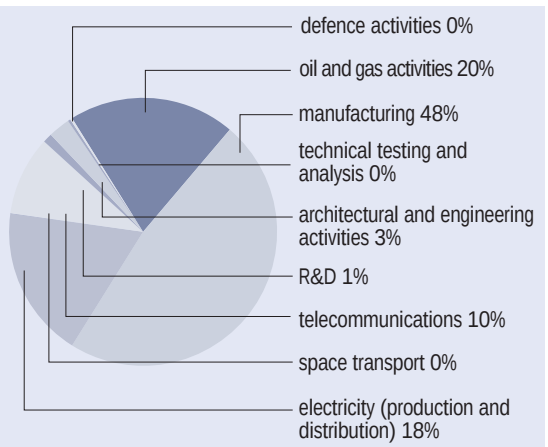


Figure 10: Share of GVA in physics-based sectors in the ROI by broad sector. Source: ONS *Annual Business Inquiry 2004*, Eurostat Labour Force Survey, CSOI 2003 Republic of Ireland Census and cebr analysis.

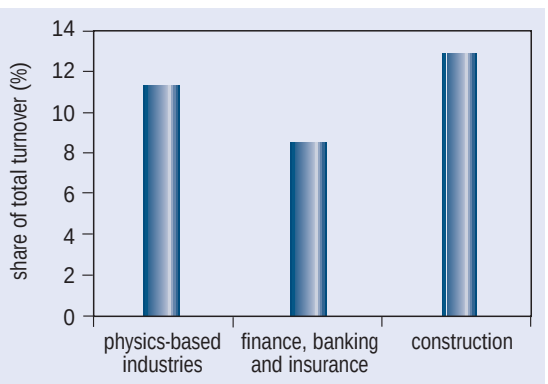


Figure 11: Share of total ROI GVA, average over 2000–2005. Source: ONS, CSOI and cebr analysis.

2. Source: Central Statistics Office, Republic of Ireland.
3. Source: Office of National Statistics.
4. A similar methodology was used to derive the figures for turnover.

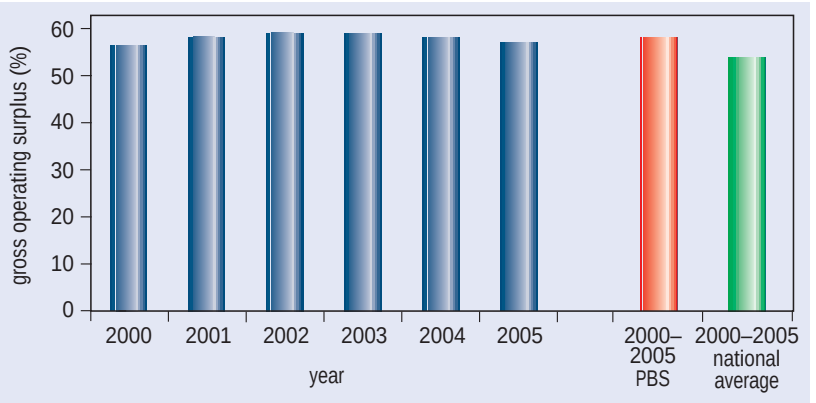


Figure 12: Gross operating surplus as a share of GVA in physics-based sectors. Source for figures 12–15: ONS, CSOI and cebr analysis.

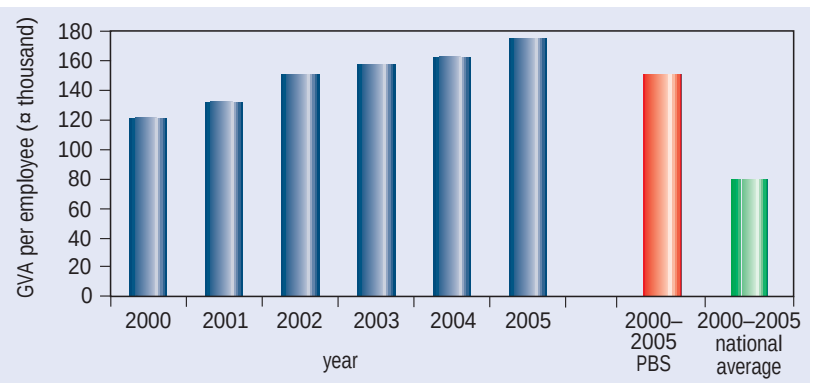


Figure 13: GVA per employee in physics-based sectors, current prices.

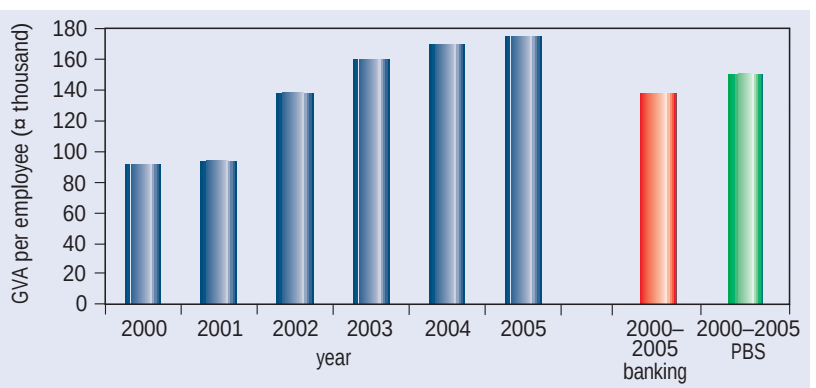


Figure 14: GVA per employee in banking, finance and insurance, current prices.

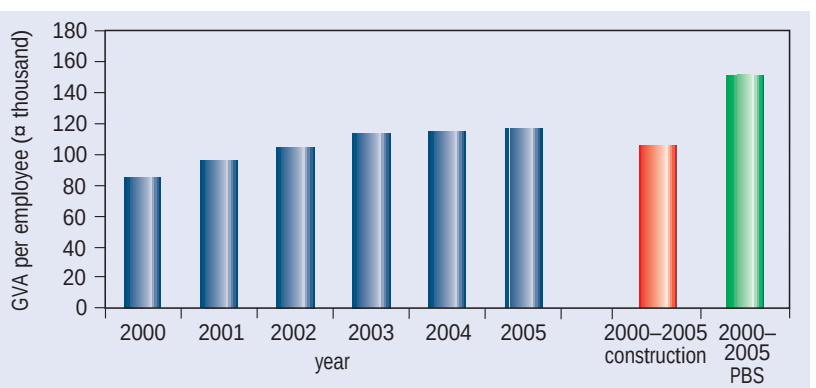


Figure 15: GVA per employee in construction, current prices.

applying these to the total GVA figures for the ROI. To verify these data, comparisons were made with the presented employment figures to check the viability of implied ROI productivity rates per sector.[4]

Physics-based sectors generate ¤15 billion

Figure 9 shows that the GVA of physics-based sectors has risen rapidly in the last four years, growing by 29% to stand at just less than ¤15 billion in 2005 – making up 10.5% of the ROI's total GVA, compared with an equivalent figure of only 6.4% in the UK. This rapid rise reflects the falling cost of raw materials used as inputs. Technological advances have helped physics-based sectors to keep the cost of inputs down in terms of the price of machinery and equipment as well as lower wage costs through the use of a more capital-intensive approach. This is evident in the rise in GVA per employee (figure 13).

Almost half of physics-based GVA is from manufacturing businesses

Figure 10 shows how this GVA is split between different areas of the ROI economy. The manufacturing sector accounts for 48% of GVA generated by physics-based sectors (compared with an equivalent figure of 43% in the UK). Businesses involved in the extraction of crude petroleum and natural gas account for 20% while 10% comes from telecommunications (compared with equivalent shares of 13% and 10% in the UK respectively).

According to figures based on the *Census for Industrial Production* (CSOI 2003), the optical and electrical equipment industry in the ROI generated a GVA of more than ¤8.2 billion in 2003.

Source: Nanotechnology background paper, NanoIreland 2005.

Figure 11 shows that, between 2000 and 2005, physics-based industries in the ROI accounted for 11.3% of total GVA on average. This share is comparable to that of the construction sector, which produced 13% of total GVA, and is substantially higher than the 8.6% share generated in the finance, banking and insurance sector.

Figure 12 reveals that the proportion of GVA accounted for by gross operating surplus is marginally higher in the physics-based sector than across the economy on average. Over the period 2000–2005, gross operating surplus accounted for 58% of GVA generated in physics-based sectors, while the equivalent figure stood at 54% across the whole ROI economy.

Productivity

Figure 13 shows that productivity levels in physics-based sectors in the ROI were almost double the national average between 2000 and 2005. This partly represents the fact that the majority of physics-based sectors are in the manufacturing sector. As manufacturing is more capital-intensive than many other sectors in the economy, the level of GVA generated per employee is substantially higher.

Figure 14 shows that productivity levels in the ROI's banking, finance and insurance sector rose rapidly between 2000 and 2005, with GVA per employee standing at just less than ¤175 000 in 2005. Over this period GVA per employee in the banking, finance and insurance sector grew at a compound annual growth rate of 13.9%, compared with 7.7% in physics-based sectors. Despite this higher growth rate in productivity in the banking, finance and insurance sector, the level of productivity in physics-based sectors was still 8.8% higher in 2005.

Figure 15 shows that productivity levels in the ROI's construction sector have risen at a more gradual pace, with GVA per employee approaching ¤117 000 in 2005. The compound annual growth rate of productivity in the construction sector was 6.9% between 2000 and 2005 – 0.8% lower than that of physics-based sectors.

Higher-than-average productivity rates in physics-based sectors are reflected in the relative wages and salaries of their employees compared with the national mean.

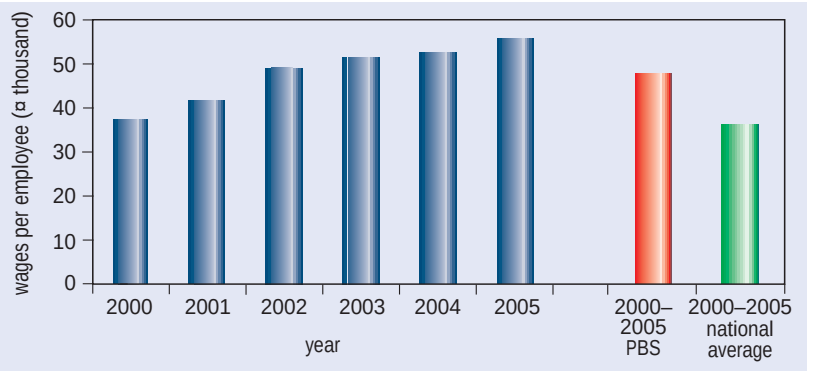


Figure 16: Wages and salaries per employee in physics-based sectors, current prices. Source: ONS, CSOI and cebr analysis.

Figure 16 shows that, on average, between 2000 and 2005 the wages and salaries paid to employees in the physics-based sector were 33.4% higher than the national mean.

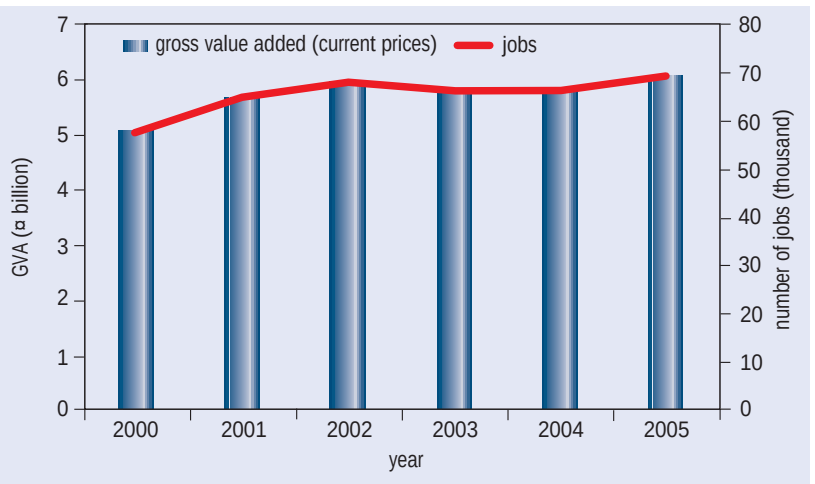
3: Indirect impacts

Figure 17 (top): GVA and jobs supported upstream by physics-based sectors. Source: ONS, Eurostat, CSOI and cebr analysis.

Figure 18: GVA and jobs supported by spending of employees in physics-based sectors. Source: ONS, Eurostat, CSOI and cebr analysis.

This section estimates the impact of physics-based sectors on the wider ROI economy. Aside from the direct activity generated in terms of employment, turnover and GVA, physics-based sectors make a significant contribution to the economy through the following impacts:

- **Upstream** – physics-based sectors indirectly support jobs and economic activity in sectors from which they purchase inputs (i.e. those that supply physics-based sectors with goods and services).
- **Employee spending** – the wages earned by employees in physics-based sectors are spent on goods and services from all types of sectors, helping to support jobs and economic activity across all sectors.
- **Downstream** – physics-based sectors indirectly support jobs and economic activity in sectors to which they supply inputs (i.e. those that demand goods and services from physics-based sectors).



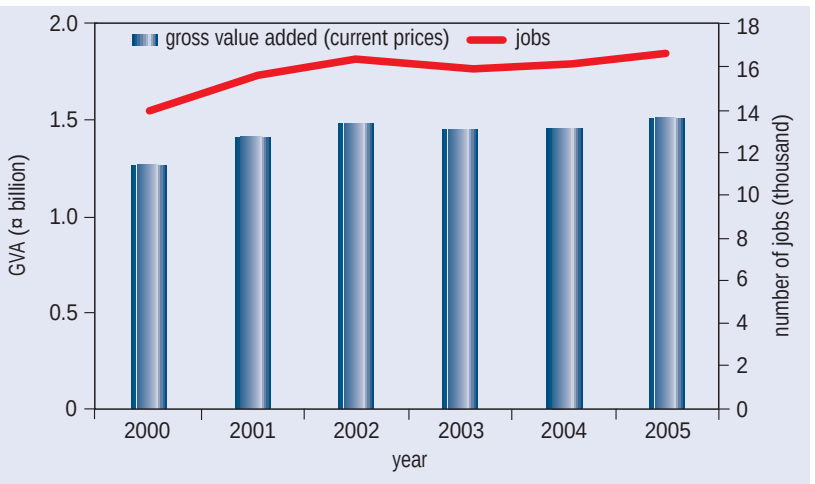


Table 1: Multiplier effect of physics-based sectors on GVA and employment, 2000–2005

	2000	2001	2002	2003	2004	2005
GVA (%)	55	56	54	53	52	51
Jobs (%)	75	84	93	95	95	100

Source: ONS, Eurostat, CSOI and cebr analysis.

Comparing the combined upstream and employee spending impacts with these direct impacts, it is possible to assess the multiplier effect of physics-based sectors. This effect demonstrates, for example, how much GVA is supported indirectly by physics-based sectors for every ¤1 that they directly generate.

Upstream impacts

Physics-based sectors support 69 100 jobs upstream

As described earlier, the upstream impact captures the contribution of physics-based sectors to jobs and economic activity in sectors from which they purchase goods and services. This report estimates that physics-based sectors spent ¤18.5 billion on intermediate goods and services across the ROI economy in 2005.

As shown in figure 17, this spend supported ¤6.1 billion worth of GVA in upstream industries. ¤3.6 billion of this was made up of gross operating surplus while ¤2.5 billion was composed of wages. In addition, the demand from physics-based sectors for intermediate goods and services helped to support 69 100 jobs in their upstream sectors in 2005 – equivalent to 4.3% of all jobs in the ROI economy. In the UK, this share stood at 4.2% in 2005.

Employee spending impacts

The spending of employees in physics-based sectors supports at least ¤1.5 billion of the economy's GVA

The spending of physics-based sector employees on consumer goods in the economy plays a key role in supporting the economic activity of the sectors from which they buy. This report estimates that employees in physics-based sectors spent ¤3.1 billion on goods and services in the ROI economy in 2005. This supported ¤1.5 billion worth of GVA, composed of ¤0.94 billion worth of gross operating surplus and ¤0.57 billion of wages in the economy. It also helped to support more than 16 700 jobs across the ROI economy in 2005 (figure 18).

Together, the upstream and employee spending impacts constitute the overall multiplier effect of physics-based sectors on the ROI economy. This takes account of the proportion of activity in other sectors of the economy that is supported by the intermediate demand of physics-based sectors as well as the spending of their employees.

Table 1 shows how this multiplier effect has changed over time. In 2005 the spending of physics-based sectors

on goods and services from upstream industries, combined with the spending of their employees in the wider economy, supported a GVA equivalent to 51% of the GVA directly generated by physics-based sectors. That is to say, for each ¤1 of GVA directly generated by the physics industries, a further ¤0.51 of GVA was supported in the wider economy. In terms of jobs, this multiplier effect stood at 100% in 2005, rising from 75% in 2000. In the UK the multiplier effects for GVA and employment stood at 96% and 157% respectively in 2005. The lower multiplier effects for the ROI are driven by the fact that the ROI is a much more export-dependent economy than that of the UK.

Downstream impacts

Physics-based sectors support at least ¤9.6 billion of GVA in sectors to which they supply goods and services

By supplying goods and services to other sectors, physics-based sectors help to support the economic activity that they carry out. This report estimates that ¤18.2 billion was spent on goods and services from the physics-based sector in 2005. This spend is equivalent to ¤9.6 billion of GVA, composed of ¤6.0 billion worth of gross operating surplus and ¤3.6 billion worth of wages in downstream industries.

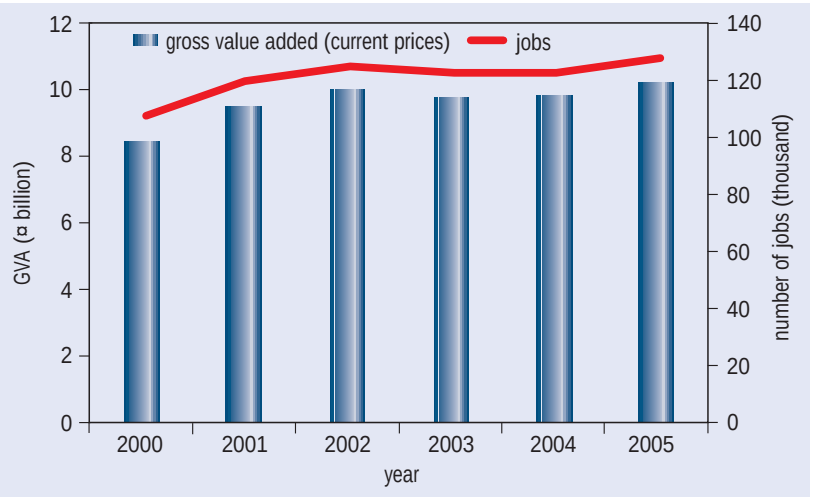


Figure 19: GVA and jobs supported downstream by physics-based sectors. Source: ONS, Eurostat, CSOI and cebr analysis.

As shown in figure 19, this spend also helped to support almost 128 400 jobs across the physics-based sectors' downstream industries in 2005 – 7.9% of all jobs in the ROI economy. In the UK, this share stood at 12.6% in 2005. Further details of these indirect impacts are tabulated in appendix 3.

4: International trade, foreign direct investment, and research and development

This section analyses the contribution of physics-based sectors to ROI trade. It also compares foreign direct investment and research and development (R&D) in the ROI and the UK to provide some indication of the role that physics

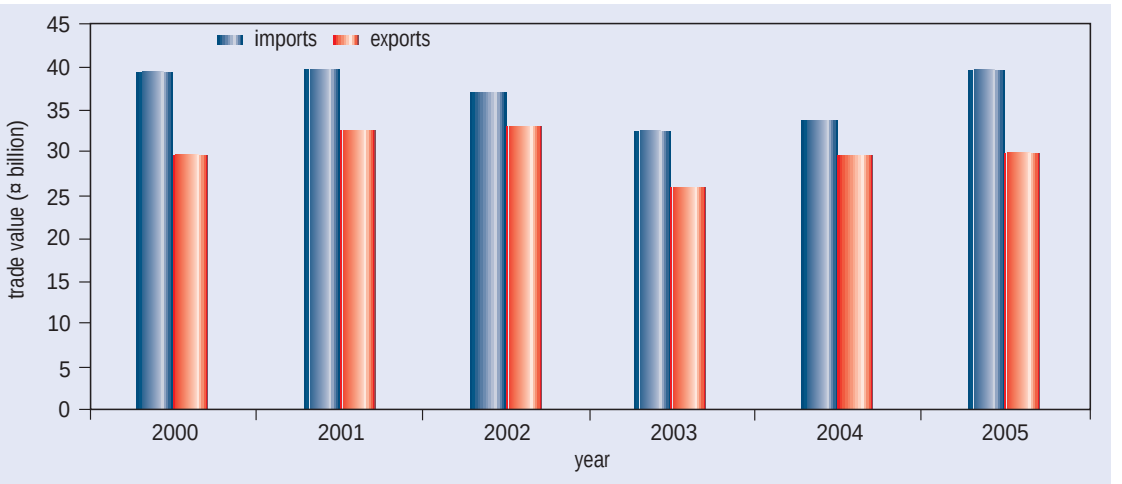


Figure 20: Trade in physics-based sectors in the ROI, current prices. Source: CSOI and cebr analysis.

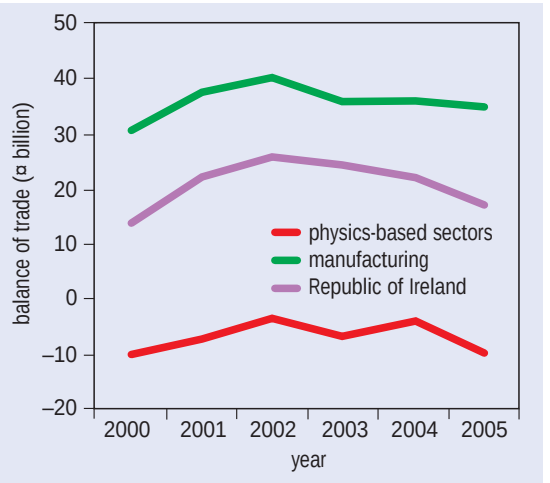


Figure 21 (left): Balance of trade in physics-based sectors in the ROI, current prices. Source: CSOI and cebr analysis.

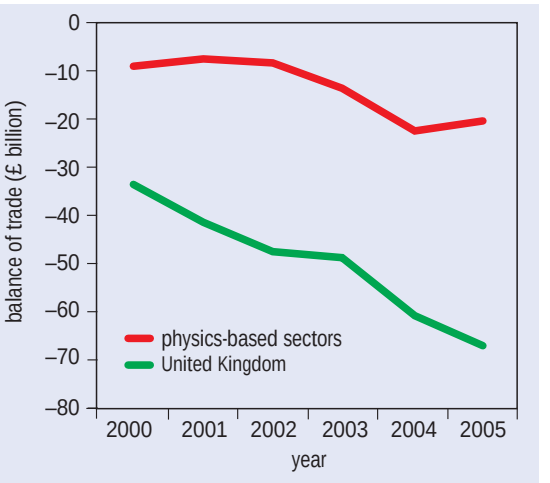


Figure 22 (right): Balance of trade in physics-based sectors in the UK, current prices. Source: ONS and cebr analysis.

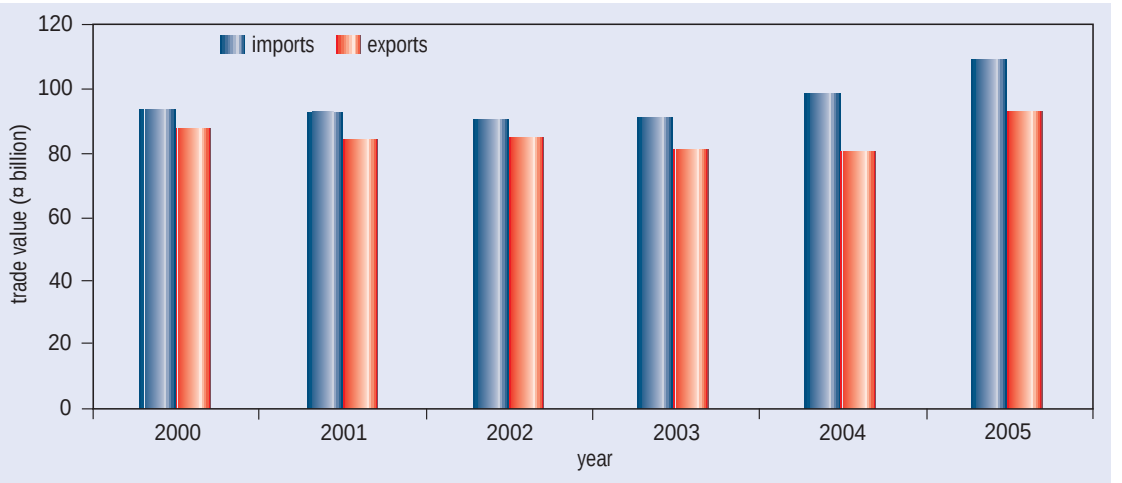


Figure 23: Trade in physics-based sectors in the UK, current prices. Source: UKTrade data, ONS and cebr analysis.

may play in supporting and generating this investment. The estimates presented in this study for trade in physics-based sectors in the ROI are compared with other international estimates.

Trade in physics-based sectors – an international comparison

This section analyses the value of trade from physics-based sectors between 2000 and 2005. This report uses data from a number of sources to compare the value of exports and imports in physics-based sectors in the ROI with other countries across the globe.

The analysis is based on Standard Industrial Trade Classification (SITC) data from the CSOI. An official correspondence between the SITC and the Standard Industrial Classification (SIC) is used to apply the definitions of physics-based industries (appendix 2). The SITC data only cover trade in the manufacturing sector. To estimate the value of trade in the services sector, data from the input/output tables are used.

Figure 20 shows that physics-based sectors in the ROI traded more than ¤29.9 billion worth of exports and ¤39.6 billion worth of imports in 2005 – accounting for 28% and 44% respectively of the total value of exports and imports in the same year. Of the ¤29.9 billion value of exports, 85% was from the manufacturing sector while 15% was from the service sector. Of the total ¤39.6 billion value of imports, 61% was from the manufacturing sector while 39% came from services.

In the UK, physics-based sectors accounted for 30% of total imports and 29% of total exports in 2005 (figure 23).

Figure 21 compares the balance of trade in physics-based sectors with that of the manufacturing sector and the ROI total between 2000 and 2005. The graph shows that the balance of trade was consistently negative in physics-based sectors over this period, with imports outstripping exports by an annual average of ¤6.9 billion between 2000 and 2005. This is in contrast with the total national balance of trade, which stood at ¤20.7 billion on average between 2000 and 2005, and manufacturing, in which the average balance of trade over the same period

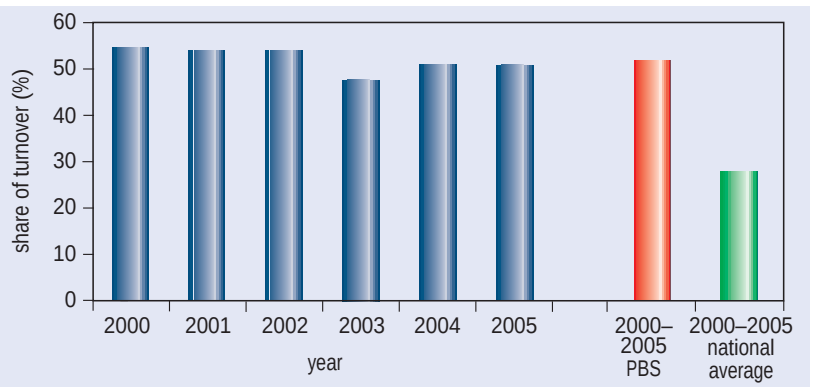
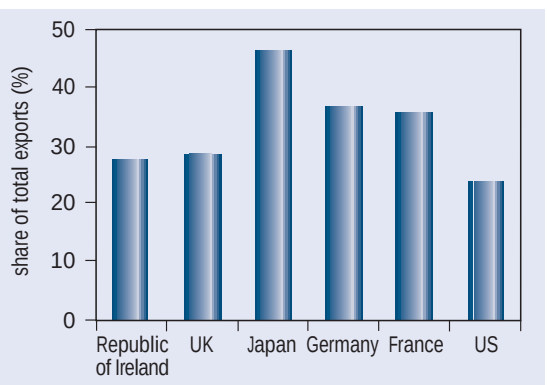


Figure 24: Exports as a share of turnover in physics-based sectors, 2000–2005. Source: CSOI and cebr analysis.



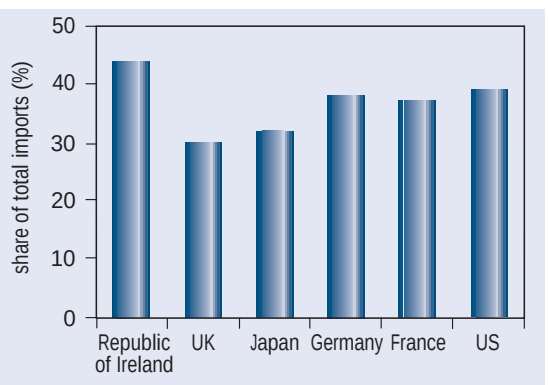


Figure 25 (left): Exports in physics-based sectors as a share of all exports. Source: CSOI, UKTrade and cebr analysis.

Figure 26 (right): Imports in physics-based sectors as a share of all imports. Source: CSOI, UKTrade and cebr analysis.

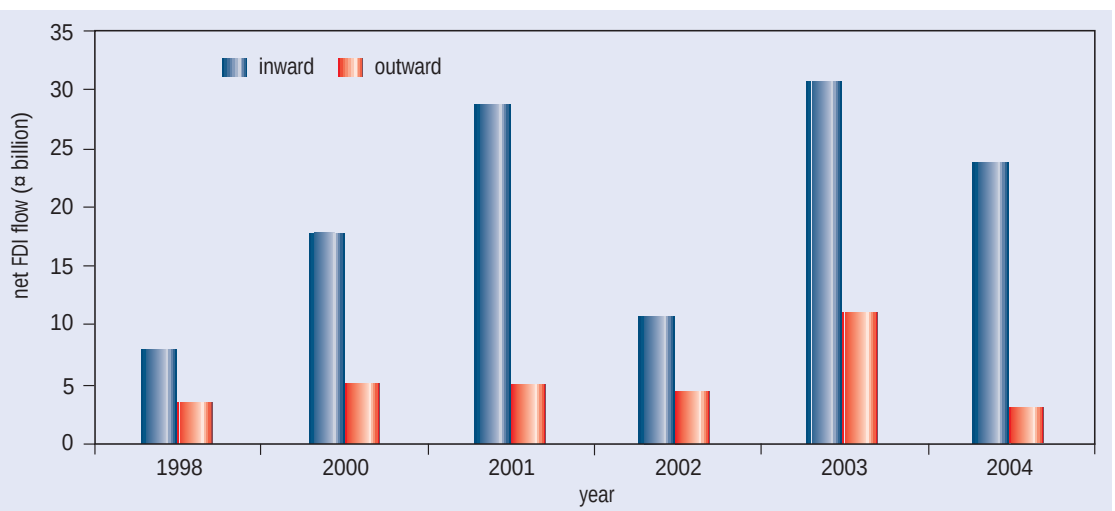


Figure 27: Net foreign direct investment flows in and out of the ROI in 2004, current prices. Source: OECD *International Direct Investment Statistics 2005*.

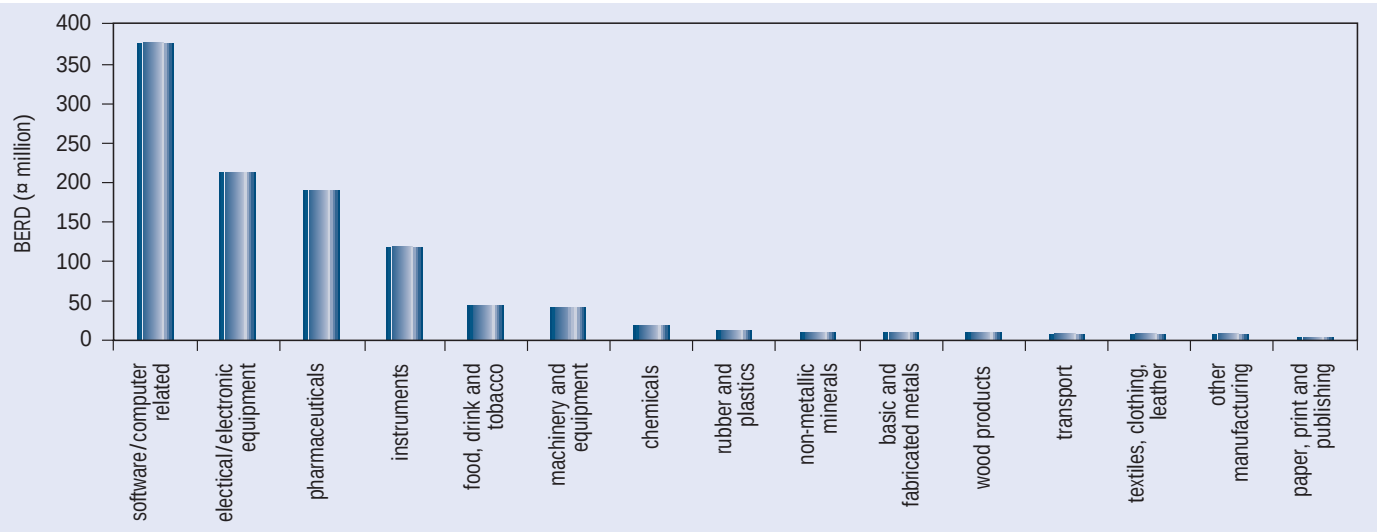
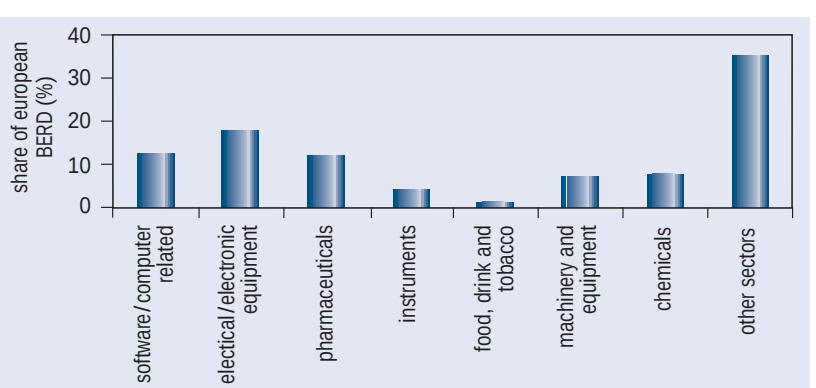


Figure 28: Business expenditure on research and development in the ROI, broad sector, current prices. Source: Forfás *Business Expenditure on Research and Development Ireland 2003/4*.

Figure 29: Business expenditure on research and development in the ROI as a share of total European business expenditure on research and development, broad sector. Source: Forfás *Business Expenditure on Research and Development Ireland 2003/4*.



was ¤35.7 billion.

The two sectors making the most significant contribution to the manufacturing balance over this period were "manufacture of pharmaceutical preparations" and "manufacture of other organic chemicals". Total exports in these two sectors amounted to ¤30.0 billion in 2005, compared with only ¤3.8 billion of imports. These sectors are not classed as physics based and therefore do not contribute to the physics-based sectors' balance of trade.

The trade deficit in physics-based sectors has been driven by high levels of imports in a few particular sectors, including "research and experimental development on natural sciences and engineering", "manufacture of motor vehicles", "extraction of crude petroleum and natural gas" and "manufacture of railway and tramway locomotives and rolling stock". Together, the value of imports in these sectors was ¤17.6 billion higher than exports. Omitting these sectors from the analysis implies that there was a trade surplus in physics-based sectors, which stood at an average of ¤8.9 billion between 2000 and 2005.

Figure 22 shows that there was also a trade deficit in physics-based sectors in the UK between 2000 and 2005, although this was not as extreme as for the UK average.

Figure 24 shows that exports account for a higher than average share of turnover in physics-based sectors in the ROI. In an average sector of the economy, exports account for approximately 28% of turnover – substantially less than the 52% share in physics-based sectors.

In figure 25 a comparison is shown between exports in physics-based sectors as a share of total exports in the ROI, and other countries across the globe. For Japan, Germany, France and the US the share of exports in physics-based sectors in each input/output category in the UK has been applied. Using this measure, Japan and Germany have the highest share of exports in physics-based sectors relative to total exports in their country.

Figure 26 shows the imports in physics-based sectors as a share of total imports in the ROI and other countries. For Japan, Germany, France and the US the share of imports in physics-based sectors in each input/output category in the UK has been applied. Although in comparison to the other countries the ROI has one of the lowest shares of exports in physics-based sectors relative to total exports, the country has the highest share of imports in physics-based sectors relative to total imports.

Foreign direct investment in the ROI

Figure 27 shows that the ROI receives a greater value of foreign direct investment than its companies make abroad. In 2003, for example, the value of inward foreign direct investment was almost eight times as large as the value of direct investment made abroad by ROI companies. This is in stark contrast with the UK, where the total value of outward foreign direct investment in 2004 was almost twice as large as inward foreign direct investment.

Research and development in the ROI

Although data on R&D in the ROI are not available in a suitably detailed sectoral breakdown to isolate the contribution of physics, presented here are some general time series data that look at the relative contribution of a number of sectors.

Total business expenditure on R&D in the ROI[5] rose by 217% between 1993 and 2003.

Figure 28 shows the composition of business expendi-

ture on R&D in the ROI in 2003. The total spend in this year amounted to ¤1.1 billion. More than 35% of this was in the software and computers sector, while manufacturing sectors accounted for a further 57%. The fact that the share of manufacturing in physics-based sectors stood at 77% in 2003 indicates that sectors that rely on the use of physics contribute significantly to R&D in the ROI.

Figure 29 presents ROI business expenditure on R&D as a share of European business expenditure on R&D in 2003 by individual sector. R&D in the ROI accounts for a significant amount of the European total – in electrical and electronic equipment, for example, it accounted for just over 18% of the European total in 2003.

Figure 30 shows that funding for R&D in the ROI is split between different sources. In 2003 just 3% of all R&D was funded by the domestic government. This includes grants from government under the "research, technology and innovation" scheme. Almost nine-tenths (87%) was funded privately by businesses. Some 9% was sourced from abroad – totalling ¤98.7 million in 2003. Of this, ¤3.7 million was direct funding from the EU, while the remaining ¤95.0 million was sourced from other foreign sources.

It is widely recognised that investment in technology-based industries is essential to remain competitive.

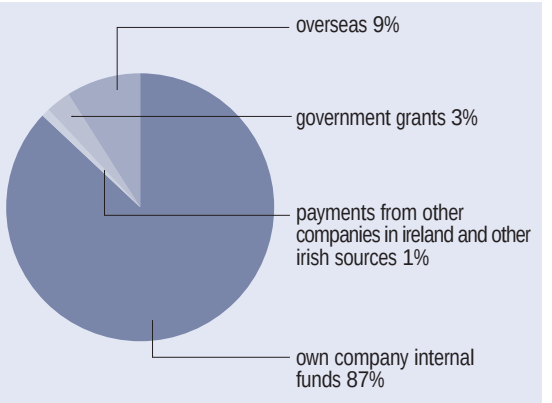


Figure 30: Source of funds for research and development in the ROI, 2003. Source: Forfás *Business Expenditure on Research and Development Ireland 2003/4* and cebr analysis.

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

Source: UK DTI *Science and Innovation Investment Framework 2004–2014: Next Steps*.

5. The research and development figures reported relate to investment activity that has taken place in businesses based in the ROI.

5: A broader assessment

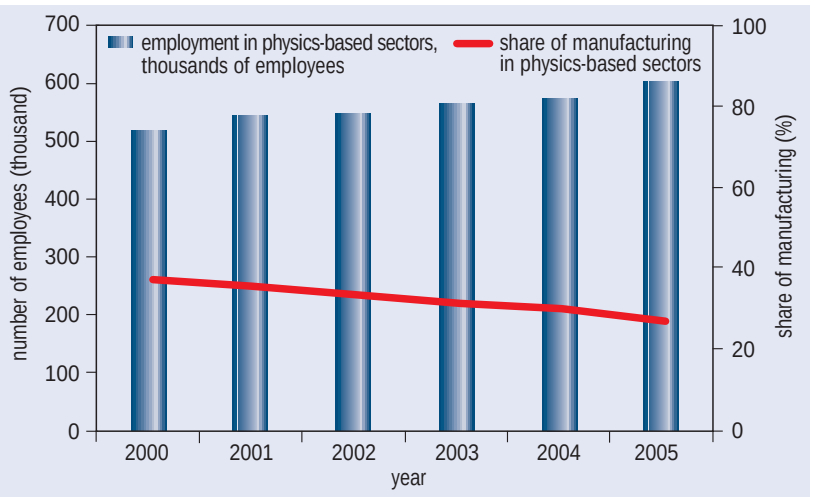


Figure 31 (above): Employment in physics-based sectors (broad definition) in the ROI. Source: ONS *Annual Business Inquiry 2004*, Eurostat *Labour Force Survey*, CSOI *2003 Republic of Ireland Census* and cebr analysis.

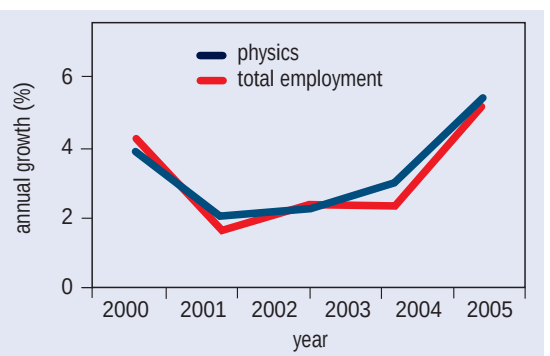


Figure 32 (right): Annual growth in employment in the ROI, 2001–2005. Source: ONS *Annual Business Inquiry 2004*, Eurostat *Labour Force Survey*, CSOI *2003 Republic of Ireland Census* and cebr analysis.

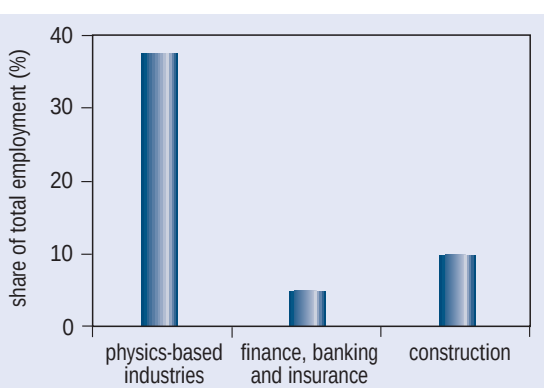


Figure 33: Physics-based share of total ROI employment, average over 2000–2005 added "broad definition". Source: ONS *Annual Business Inquiry 2004*, Eurostat *Labour Force Survey*, CSOI *2003 Republic of Ireland Census* and cebr analysis.

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

Employment, turnover and value added

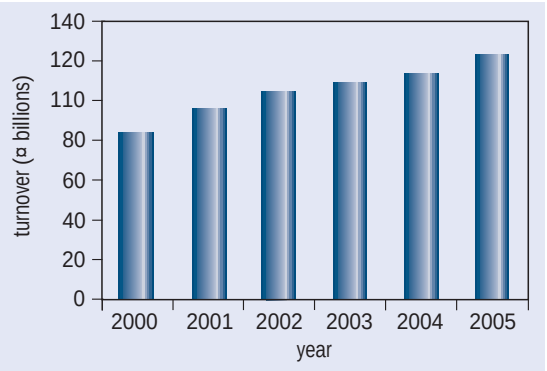
Figure 31 shows that employment in sectors in the ROI that use physics expertise or technologies to some extent actually rose between 2000 and 2005, growing by 17% to stand at more than 604 000 employees. This compares with an 11% decline in employment in sectors where the use of physics is critical. Driving this difference is the fact that the majority of sectors included in the critical definition are based in manufacturing, whereas the wider definition includes a wider range of service sectors – these sectors have been expanding in recent years as the economy has become more service-oriented.

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

Figure 32 shows that the pattern of employment growth in sectors in the ROI that use physics expertise or technologies to some extent has closely mirrored that of total employment, growing by 5.1% in 2005. Figure 33 reveals that physics-related employment accounts for 38% of total employment – almost four times the share of employment accounted for by manufacturing.

Figure 34 shows that turnover in sectors in the ROI using physics expertise or technologies to some extent grew consistently between 2000 and 2005 at a compound annual growth rate of 7.8% – compared with only 3.6% in sectors included under the critical definition. The share of total national turnover accounted for by physics (figure 35) rises to 38.7% using the wider definition – compared with only 5.5% and 10.6% in the finance, banking and insurance sector and the construction sector respectively.

The GVA in sectors in the ROI using physics expertise or technologies to some extent also rose at a compound annual growth rate of 7.8% between 2000 and 2005 (figure 36). This compares with 5.3% using the critical definition. When accounting for this broader use of physics, the share of national GVA generated in physics-based sectors rises to 50.8% (figure 37) – more than five times that of



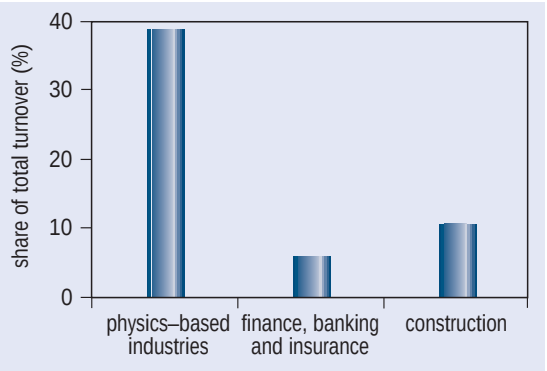
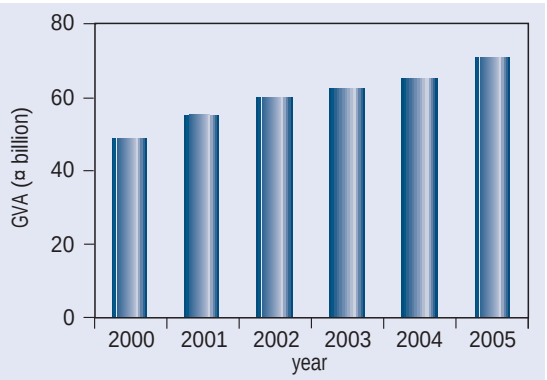


Figure 34 (left): Turnover in physics-based sectors added "broad definition" in the ROI, current prices. Source: ONS, CSOI and cebr analysis.

Figure 35 (right): Share of total turnover, average over 2000–2005. Source: ONS, CSOI and cebr analysis.



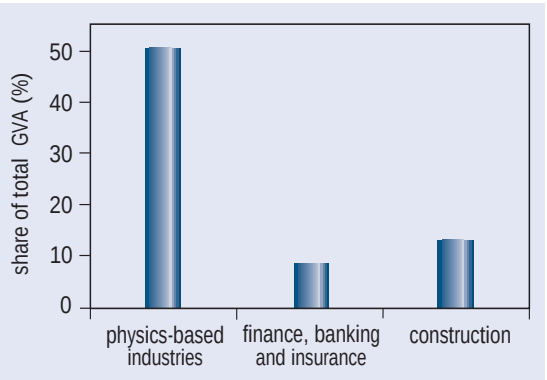


Figure 36 (left): GVA in physics-based sectors added "broad definition", current prices. Source: ONS, CSOI and cebr analysis.

Figure 37 (right): Share of total GVA, average over 2000–2005. Source: ONS, CSOI and cebr analysis.

the finance, banking and insurance sector.

Wider impacts

Under the broad assessment, the contribution of physics to the wider ROI economy is substantially larger than that established using the critical definition of physics-based sectors. On average, 254 600 jobs were supported in upstream industries across the economy between 2000 and 2005 (figure 38) by sectors using physics expertise or technologies to some extent, compared with 65 400 under the critical definition. The spending of employees in physics-based sectors supported an average of 7.3% of national GVA between 2000 and 2005 (figure 39). The equivalent figure under the critical definition is 1.2%.

The activity supported in downstream industries is also significantly higher when accounting for the broader use of physics across the economy. Physics-based sectors supported ¤44.9 billion worth of GVA and 596 300 jobs in downstream industries in 2005 (figure 40). The equivalent figures stood at ¤9.6 billion and 128 400 under the critical definition.

Trade

Figure 41 shows that, under the broader definition, physics-based sectors in the ROI exported a higher value of goods and services than they imported in every year between 2000 and 2005. This resulted in a trade surplus, which closely matched that of the national total over the period.

The movement to a trade surplus under the broader definition reflects the fact that it includes a wider range of sectors, particularly those that are service based and more export intensive, than the primarily manufacturing-based sectors included in the critical definition of physics-based sectors.

Figure 38: GVA and jobs supported upstream by physics-based sectors (added broad definition) in the ROI. Source: ONS, Eurostat, CSOI and cebr analysis.

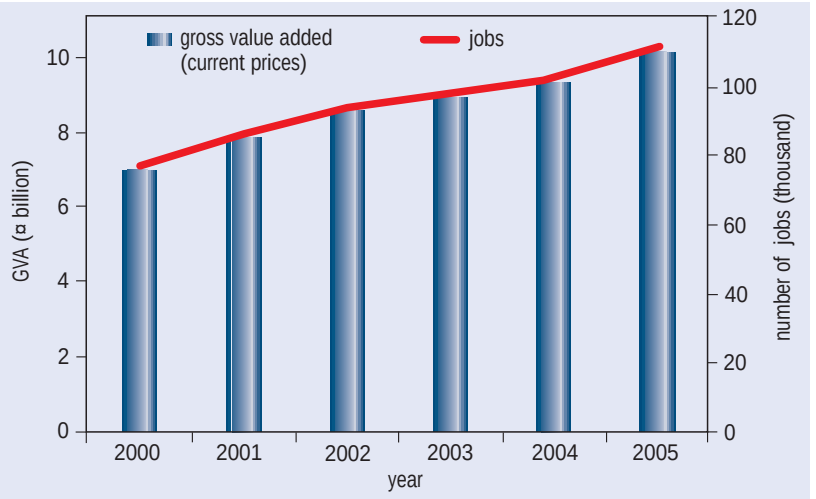


Figure 39: GVA and jobs supported by spending of employees in physics-based sectors (broad definition) in the ROI. Source: ONS, Eurostat, CSOI and cebr analysis.

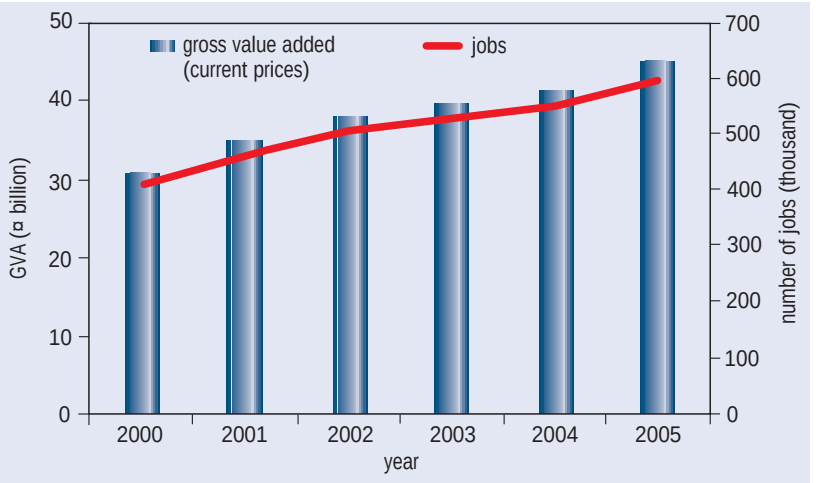


Figure 40: GVA and jobs supported downstream by physics-based sectors (broad definition) in the ROI. Source: ONS, Eurostat, CSOI and cebr analysis.

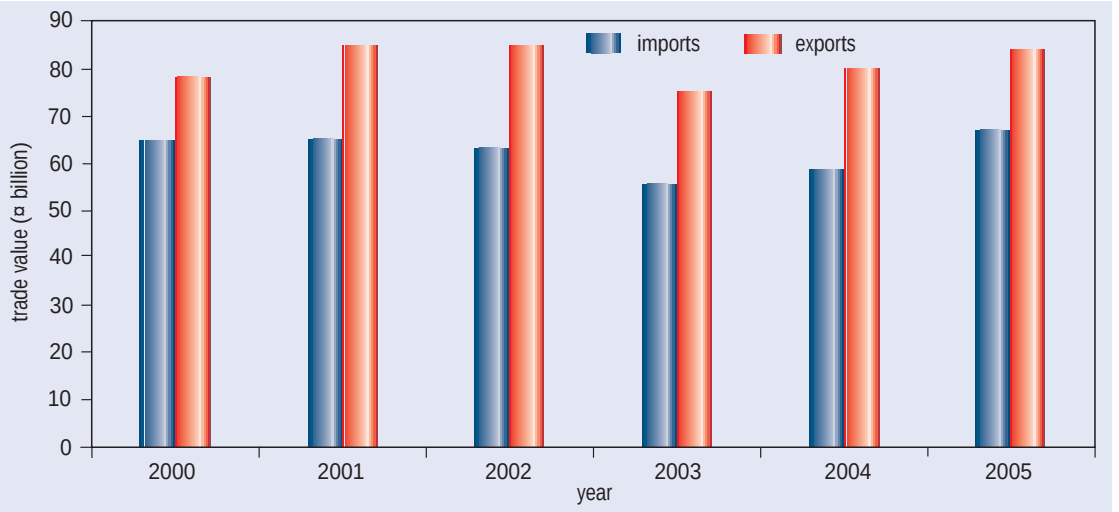


Figure 41: Trade in physics-based sectors added "broad definition" in the ROI, current prices. Source: CSOI and cebr analysis.

6: 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 is 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 means that it is difficult to define physics.

For the purposes of this report, box 1 shows broad categories of what can be considered physics. The breadth of industries that rely 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, machinery and equipment that work through applications of physics. Without this indirect use of physics they would be unable to perform their job. Examples include radiographers using X-ray machines and opticians using machines based on laser technology.

It is the application of technologies based on physics that is important here, and this is fundamental to many businesses. To capture the wider impact of physics on the economy, those who indirectly rely on physics-related concepts or processes must be accounted for, as well as those who work directly with physics. The results presented in this report are based on data from the ONS and are analysed in terms of sectors that 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 economy. Some businesses may require the use of more advanced applications of physics, while others 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. In this report 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 a sector has on the use of physics also needs to be captured. Physics may be essential for some businesses to function, while other businesses 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.

Box 1: What is physics?

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

Measuring physics in economic statistics

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

- Is expertise from the field of physics required?
- Is technology that uses advanced 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.

The NACE Rev 1.1 classification system

The CSOI uses the European Community's statistical classification of economic activities – Nomenclature generale des Activitiés économique dans les Communautes Européennes (NACE) – to describe the various sectors of the ROI economy. This system was prepared by the European Commission in 1970 and in 1990 a regulation

Table 2: An example of the UK SIC

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

Source: ONS 2006.

was passed making it obligatory for all member states to introduce the revised classification system, NACE Rev. 1. In 2002 this was again revised to NACE Rev. 1.1, which has been the official industrial classification in all EU member states since 2003. NACE Rev 1.1 is practically identical to the Standard Industrial Classification (SIC) system used by the UK, therefore permitting a comparison of the ROI results to those of the UK.

To apply the definitions of physics used in this report in a consistent format with that of the UK report, an exact correspondence between the two classification systems was created (appendix 2). This allowed the contribution of physics in the ROI to be assessed under the framework of the SIC.

Table 2 illustrates how the sections of the economy are broken down into varying levels of detail. Sections describe the sector at a broad level. There are 17 sections in the SIC system ranging from "agriculture, hunting and forestry" through "manufacturing" and "financial intermediation" to "education". Subsections, divisions, groups and classes provide more detail about each of the sections.

Although the classifications are exhaustive of sectors in the entire ROI economy, there is an unequal distribution of sectors between services and manufacturing, with manufacturing accounting for 47% of all divisions. This is because the system was constructed at a time when the European economies were heavily concentrated in manufacturing. However, in 2005 manufacturing accounted for only 28% of the ROI GVA.[6]

The SIC classification system is used because it allows consistent comparisons to be made with similar data from other countries across the globe.

The NACE Rev 1.1 and SIC systems also classify the description of the activity by the process or the raw materials used rather than by the product. This allows a better understanding of what the sector does rather than 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 to some extent;
- if it is used, the sector employs physics expertise or technology;
- physics is critical to the activities of the sector.

6. Input/output table for Ireland, CSOI 2000 and cebr analysis.

The results presented in this report describe only those sectors where physics is critical to the activities of the sector (except in chapter 5, which looks at a broader definition of physics-based sectors).

Methodology

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

The definition used here includes 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 3, appendix 2).

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 has 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, this method means that the figures will be sensitive to sectors where there are a large number of employees who are not 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 proportion 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 employees in this field who 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 percentage of the most relevant employees in the industry. The most relevant groups of employees, based on the ONS' standard occupational classifications, used as a benchmark, include:

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

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

Table 3: Sectors currently defined as physics based

SIC class	SIC description	NACE Rev 1.1 class	NACE Rev 1.1 description
11.10	extraction of crude petroleum and natural gas	11.10	extraction of crude petroleum and natural gas
23.30	processing of nuclear fuel	23.30	processing of nuclear fuel
24.65	manufacture of prepared unrecorded media	24.65	manufacture of prepared unrecorded media
28.22	manufacture of central heating radiators and boilers	28.22	manufacture of central heating radiators and boilers
28.30	manufacture of steam generators, except central heating and hot water boilers	28.30	manufacture of steam generators, except central heating and hot water boilers
29.11	manufacture of engines and turbines, except aircraft, vehicle and cycle engines	29.11	manufacture of engines and turbines, except aircraft, vehicle and cycle engines
29.60	manufacture of weapons and ammunition	29.60	manufacture of weapons and ammunition
29.71	manufacture of electric domestic appliances	29.71	manufacture of electric domestic appliances
30.02	manufacture of computers and other information processing equipment	30.02	manufacture of computers and other information processing equipment
31.10	manufacture of electric motors, generators and transformers	31.10	manufacture of electric motors, generators and transformers
31.20	manufacture of electricity distribution and control apparatus	31.20	manufacture of electricity distribution and control apparatus
31.30	manufacture of insulated wire and cable	31.30	manufacture of insulated wire and cable
31.40	manufacture of accumulators, primary cells and primary batteries	31.40	manufacture of accumulators, primary cells and primary batteries
31.50	manufacture of lighting equipment and electric lamps	31.50	manufacture of lighting equipment and electric lamps
31.61	manufacture of electrical equipment for engines and vehicles not elsewhere classified	31.61	manufacture of electrical equipment for engines and vehicles not elsewhere classified
31.62	manufacture of other electrical equipment 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	32.10	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	32.20	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	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	33.10	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	33.20	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	33.30	manufacture of industrial process-control equipment
33.40	manufacture of optical instruments and photographic equipment	33.40	manufacture of optical instruments and photographic equipment
34.10	manufacture of motor vehicles	34.10	manufacture of motor vehicles
35.11	building and repairing of ships	35.11	building and repairing of ships
35.20	manufacture of railway and tramway locomotives and rolling stock	35.20	manufacture of railway and tramway locomotives and rolling stock
35.30	manufacture of aircraft and spacecraft	35.30	manufacture of aircraft and spacecraft
35.41	manufacture of motorcycles	35.41	manufacture of motorcycles
40.10	production and distribution of electricity	40.11	production of electricity
		40.12	transmission of electricity
		40.13	distribution and trade of electricity
62.30	space transport	62.30	space transport
64.20	telecommunications*	64.20	telecommunications*
73.10	research and experimental development on natural sciences and engineering	73.10	research and experimental development on natural sciences and engineering
74.20	architectural and engineering activities, and related technical consultancy*	74.20	architectural and engineering activities, and related technical consultancy*
74.30	technical testing and analysis	74.30	technical testing and analysis
75.22	defence activities*	75.22	defence activities*

* Adjustments have been made for these sectors to allow for the large volume of non-physics-related employment.

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

	2000	2001	2002	2003	2004	2005
upstream	57.9	64.6	67.9	66.4	66.5	69.1
employee spending	14.0	15.6	16.4	16.0	16.1	16.7
downstream	107.5	120.1	126.2	123.3	123.5	128.4
total multiplier (%)	75	84	93	95	95	100

Source: ONS, Eurostat, CSOI and cebr analysis.

Table 5: Indirect impacts on GVA (¤ billions)

	2000	2001	2002	2003	2004	2005
upstream	5.1	5.7	6.0	5.8	5.8	6.1
employee spending	1.3	1.4	1.5	1.5	1.5	1.5
downstream	8.1	9.0	9.5	9.2	9.3	9.6
total multiplier (%)	55	56	54	53	52	51

Source: ONS, Eurostat, CSOI and cebr analysis.

2: Classifications

Table 3 shows the SIC sectors (along with the corresponding NACE Rev 1.1 sectors) that have been included in the definition of physics-based sectors used in this report.

The NACE Rev 1.1 classification of industrial activities used by the European Communities is practically identical to the SIC used in the UK. However, while there are 501 4-digit categories under the SIC, there are 514 4-digit categories under the NACE Rev 1.1 classification.

To apply the present definition of physics-based sectors in the ROI in a consistent format to that of the corresponding *The Importance of Physics to the UK Economy* report, an exact correspondence between the two classification systems was created.

As can be seen from table 3, there is an exact match between the two classification systems in the majority of sectors that are included in the definition of physics. For SIC sector 40.10, however, there are three corresponding NACE Rev 1.1 sectors. As such, any data in this study for SIC sector 40.10 is the sum of the data for the three corresponding NACE Rev 1.1 sectors.

3: Detailed tables

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

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