The Importance of Physics to the Irish Economy
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FOREWORD

The fruits of physics research are at the heart of innovation in Ireland, and the physics-based businesses that depend on this research and the trained people that it creates can drive the Irish economy into the future.

Across Ireland, physics, and physics-trained people, underpin a wide range of technologies and sectors, from medical technologies to ICT and web services, and even some areas of finance. The analysis by Deloitte presented in this report describes the impact of sectors that are critically dependent on the supply of new physics research and physics-trained people. These physics-based sectors contribute more than €7 bn to the Irish economy – 5.9% of total economic output – and support more than 86,000 jobs.

Direct employment in physics-based sectors is comparable to that of all of the finance, banking and insurance sectors combined. Including induced and indirect sectors, employment rises to 205,000 and the GVA contribution to €12 bn.

The jobs in physics-based sectors are significantly more productive than the national average and, at €86,000 per worker, twice as productive as jobs in the construction sector. And these sectors have shown resilience in the face of the economic downturn. Physics-based companies such as Intel demonstrate high-value inward investment to the country; physics-based sectors export more than €23 bn of goods and services per year. The decline of the construction sector has devastated some areas of the economy. Clearly physics has a major role to play in building the new Irish economy.

For these physics-based sectors to achieve their potential, and for Ireland to build a sustainable economy of the future, built on high-technology, knowledge-intensive industries, there must be more and more focused support. The source of the strength of physics-based industries is the products of physics research. To be able to develop this research, and create wealth, there must be a ready supply of physics-trained workers. Finally, physics-based businesses must be given the conditions to enable them to thrive. Focused innovative procurement mechanisms have shown great success around the world – Ireland must follow suit.

Dr Kevin McGuigan Chair, Institute of Physics in Ireland
Professor Sir Peter Knight President, Institute of Physics
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The Importance of Physics to the Irish Economy

- **86,000**
  - 4.5% of the Irish workforce are directly employed in physics-based jobs; 86,000 people.

- **€7 bn**
  - Physics-based businesses directly contributed €7 bn to the Irish economy in 2010.

- **45%**
  - As a proportion of turnover, businesses in physics-based sectors in Ireland have consistently exported more than the national average: 45% between 2005 and 2008.

- **€23 bn**
  - Physics-based sectors exported more than €23 bn worth of goods and services in 2009.

4.5% of the Irish workforce are employed in physics-based sectors and contribute 5.9% to the total economic output.
The importance of physics to the Irish economy

- Business expenditure on research and development (R&D) exceeded €1 bn in 2009.
- Turnover in physics-based sectors reached in excess of €27 bn in 2010.
- 4.5% of the Irish workforce are employed in physics-based sectors and contribute 5.9% to the total economic output.
- Turnover per employee in physics-based businesses is €313,000, twice the national average.
- Considering direct and indirect employment, more than 205,000 people are employed in physics-based sectors in Ireland.
- Business expenditure on research and development (R&D) exceeded €1 bn in 2009.

Turnover per employee in physics-based businesses is €313,000, twice the national average.

Considering direct and indirect employment, more than 205,000 people are employed in physics-based sectors in Ireland.

Turnover in physics-based sectors reached in excess of €27 bn in 2010.

Business expenditure on research and development (R&D) exceeded €1 bn in 2009.
This report examines the contribution of physics to the Irish economy between the years 2005 and 2010 (the last year of available data). This research highlights how physics-based sectors can play an important part in generating economic growth and prosperity. The report updates earlier assessments of the contribution of physics, namely *Physics and the Irish Economy 2007*. This report incorporates changes in statistical definitions that have taken place since the last report to reflect the changing structure of the Irish economy.

Drawing on a number of publicly available datasets and our own bespoke modelling analysis, the contribution physics-based sectors made to the Irish economy between 2005 and 2010 has been analysed. Deloitte has also produced equivalent reports for the economies of Wales, Scotland, Northern Ireland and the United Kingdom, and these are available to download from the IOP website at www.iop.org.

EXECUTIVE SUMMARY

Physics-based sectors continue to play a significant role in the Irish economy, generating jobs and GVA.

**Jobs in physics-based sectors**

When considering direct jobs in physics-based sectors, our analysis shows that the number of jobs was 86,000 in 2010. Over the period 2005–2010, direct jobs in physics-based sectors averaged more than 4.5% of all Irish jobs, slightly exceeding the share of direct jobs in finance, banking and insurance. The comparative figure for the UK was just over 4%, showing the strength of the physics-based jobs market in Ireland.

The number of direct jobs has fallen since 2008; however, this is unsurprising and is reflective of wider falls in employment levels caused by the financial crisis, and compared with the change in total Irish employment levels, physics-based sectors have suffered proportionally fewer job losses. Despite this, with more than 60% of direct jobs in physics-based sectors found in manufacturing-related activities, these jobs remain vulnerable in the economic downturn.

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 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. Our analysis reveals the incremental jobs (indirect plus induced jobs) associated with physics-based sectors to be more than 118,000 in 2010. This suggests that, in aggregate, the contribution of physics to Irish jobs in 2010 was more than 200,000 jobs.

Turnover and GVA in physics-based sectors
Direct turnover from businesses in physics-based sectors remains below 2005 levels, with our analysis showing turnover from these sectors reaching approximately €27 bn in 2010. Nonetheless, over the period 2005–2009, turnover per employee in physics-based sectors averaged €313,000, significantly higher than the Ireland average of €153,000.

When considering the direct GVA contribution of physics-based sectors, the analysis reveals that this also remains below 2005 levels at just over €7 bn. However, the total share of Irish GVA from physics-based sectors (nearly 6%) exceeds that from the construction sector, but is below that of finance, banking and insurance.

Our analysis reveals that incremental GVA attributable to physics-based sectors reached more than €5 bn in 2010. Taking account of these impacts, the total GVA contribution of physics-based sectors rises to more than €12 bn in 2010.

Physics-based sectors are highly productive
Using a measure of GVA per worker, productivity of employees in physics-based sectors has fallen over the period 2005–2010, from more than €100,000 to €86,000. However, a similar fall in productivity can be seen in the construction, and finance, banking and insurance sectors, and GVA per worker in physics-based sectors remained above the Irish national average of €76,000.

Figure 1.2: Total GVA attributable to physics in Ireland

Source: Deloitte analysis
Businesses in physics-based sectors continue to contribute to innovation and economic growth

R&D spend
The evidence shows that physics-based sectors are well placed to contribute to innovation and increased competitiveness. Business expenditure on research and development (R&D) exceeded €1 bn in the manufacturing, information and communications sectors – all sectors where physics can play an important role.

Inward investment
Since 2009, the extent of foreign direct investment (FDI) into all Irish businesses has begun to increase, with net inflows of more than €15 bn.

Imports and exports
Physics-based sectors exported more than €23 bn worth of goods and services in 2009, compared with imports of more than €18 bn. As a proportion of turnover, businesses in physics-based sectors in Ireland have consistently exported more than the national average: 45% in physics-based businesses between 2005 and 2008, compared with the national average of 41%. However, the data further show that Irish businesses in physics-based sectors export less (as a proportion of all exports) than their counterparts in Germany, Japan and the US, but more than France. Moreover, Irish businesses in physics-based sectors import the least as a proportion of all imports in our country comparator group.

“Ireland is Intel’s centre of manufacturing excellence in Europe. Since 1989, Intel has invested US$7.5 bn turning 360 acres of the Collinstown Industrial Park into the most advanced industrial campus in Europe. More than 4500 people work at the Leixlip, Co. Kildare campus and in addition there are more than 200 people employed at Intel Communications Europe located in Shannon, Co. Clare, which is the Ireland product-development arm of the Communications Product Group.

The labs at the Leixlip campus produce 300 mm wafers on multiple process technologies and their combined facilities constitute one of Intel’s most technologically advanced, high-volume manufacturing sites in the world. These facilities produce leading-edge silicon products that power platforms and technology advancements, which are essential to the way we learn, live and work today.

Physicists and physics-trained people are critically important in the design, manufacture and operations of semiconductor equipment. Intel’s innovation roadmap is based on the expansion and extension of Moore’s Law. This challenge is a material science challenge, using novel materials, vacuum and plasma technology, and sophisticated imaging techniques to build smaller and more powerful microchips at the nanometre scale. Physics and physics-trained people, along with material scientists, chemists, and electronic and mechanical engineers, are required to help solve material science and lithography problems using state-of-the-art technology equipment.

Further innovations are required in the future, to an even larger extent as we approach physical limits, and require new disruptive materials systems and manufacturing processes.”
This chapter assesses the importance of physics-based sectors to the Irish economy in terms of jobs, turnover and gross value added (GVA). The focus of this chapter is the direct impact of physics-based sectors. Chapter 3 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 86,000 direct jobs in physics-based sectors

In this section the number of direct jobs in physics-based sectors is explored. In particular, the range of physics-based sectors in the Irish 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 Ireland.

Shown in figure 2.1 our analysis estimates that there were 86,000 direct jobs in physics-based sectors in Ireland in 2010. This is down from a peak of 98,000 jobs in 2005 and is likely to be reflective of the wider economic downturn following the financial crisis.

Across all sectors, our analysis suggests that there was a fall of more than 12% in the total

**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 CSO data. As in the 2007 report, 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 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 in Ireland, 2005–2010**

- Share of manufacturing in physics-based sectors
- Number of jobs in physics-based sectors

Source: Deloitte analysis using CSO data
number of jobs in Ireland between 2008 and 2010, from 2.1 million in 2008 to 1.9 million in 2010, and in physics-based sectors the equivalent fall was a little lower at just over 10%. 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. However, compared with the change in total Irish employment levels, physics-based sectors have suffered proportionally fewer job losses. This difference between job growth/decline in all sectors and in physics-based sectors only in this period is shown in figure 2.2. Prior to 2008, there was actually a fall in the number of physics-based jobs, although the rate of decline was slowing. There was some positive job creation in 2008 before large falls in 2009 and 2010. However, these falls were less than that of all sectors (~6% versus ~8.9% in 2009, and ~3.6% versus ~3.7% in 2010). Media reports and official data in 2012 suggest that unemployment remains significant, with the total employment figures (including self-employed) in June 2011 still below June 2005 levels.

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

![Graph showing growth/decline in jobs](image)

Source: Deloitte analysis using CSO data
Most direct physics-based jobs are in the manufacturing sector, but the share of jobs in other physics-based sectors is increasing.

Exploring the composition of physics-based sectors, one can see that the share of manufacturing has continued to decline (down from 75% in 2004\(^7\)), although it still remains the largest component. **Figure 2.3** shows that physics has an impact across a number of other economic sectors, not just manufacturing. Many of these sectors (such as technical testing and analysis, and R&D) produce high-value products and services and can have wider impact across the economy in terms of innovation and competitiveness.

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

- **manufacturing**: 64%
- **technical testing and analysis**: 8%
- **electricity production and distribution**: 7%
- **transport**: 7%
- **architectural and engineering activities**: 6%
- **R&D**: 2%
- **defence activities**: 2%
- **telecommunications**: 2%
- **oil and gas activities**: 1%
- **construction**: <1%
- **recycling and waste and other services**: <1%

Source: Deloitte analysis using CSO data
The share of jobs in physics-based sectors as a proportion of all Irish jobs has remained steady. Figure 2.4 shows how the proportion of construction jobs in the Irish economy has fallen significantly since the financial crisis. In contrast, jobs in physics-based sectors, as a proportion of all jobs, have remained relatively constant and are comparable with jobs in finance, banking and insurance. The consistency in the number of physics-based jobs reflects the trends in job growth and decline shown earlier in figure 2.2.

In fact they have marginally increased their share from 4.51% in 2008 to 4.65% in 2010.

Figure 2.4: Share of total Irish employment, 2005–2010

Source: Deloitte analysis using CSO data
2.2. Turnover

Turnover in physics-based sectors reached in excess of €27 bn in 2010

Here the focus is on the contribution of physics-based sectors to the Irish economy in terms of the turnover (gross output) they generated. Figure 2.5 shows that in 2010, turnover in physics-based sectors reached in excess of €27 bn. The analysis shows that, on current prices, turnover in 2010 remains lower than 2005 levels. However, the fall in turnover was less, as a proportion, than for jobs. The compounded annual growth rate (CAGR) in turnover over this period was −0.2%, compared with a CAGR of −2.54% for jobs.

Figure 2.6 charts the changes in turnover per employee between 2005 and 2009. Over the period 2005–2009, turnover per employee in physics-based sectors averaged €313,000 – significantly higher than the Irish average of €153,000.

Figure 2.5: Turnover in physics-based sectors (current prices), 2005–2010

Figure 2.6: Turnover per employee, 2005–2009 average (current prices)
The following section uses GVA to measure the economic contribution of physics-based sectors to the Irish economy. GVA is an accepted measure of economic contribution, as opposed to turnover that includes intermediate consumption.

2.3. Gross value added

*Direct GVA in physics-based sectors has begun to recover, but remains below 2008 levels*

Figure 2.7 shows that direct GVA of physics-based sectors reached €7.42 bn in 2010. This is a slight increase in 2009 levels, but still below the peaks of 2006 and 2007.

Shown in figure 2.8, the bulk of this direct GVA contribution is attributable to manufacturing, although engineering and architectural activities also make a significant contribution.

The contribution of physics-based sectors to total direct Irish GVA is below that of finance, banking and insurance, but above that of construction, as shown in figure 2.9. Indeed, the analysis suggests that there has been a decline in the relative contribution of physics-based sectors to total Irish GVA since 2005, as shown in figure 2.10.

**Box 2.2: What is 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 defines gross value added as the value of output less the value of intermediate consumption. It is analogous to gross domestic product.

The GVA analysis presented is based on domestic use input/output tables.

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**Figure 2.7: Direct GVA of physics-based sectors, 2005–2010 (current prices)**

<table>
<thead>
<tr>
<th>Year</th>
<th>GVA (€ bn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>10.39</td>
</tr>
<tr>
<td>2006</td>
<td>10.13</td>
</tr>
<tr>
<td>2007</td>
<td>10.10</td>
</tr>
<tr>
<td>2008</td>
<td>8.83</td>
</tr>
<tr>
<td>2009</td>
<td>7.37</td>
</tr>
<tr>
<td>2010</td>
<td>7.42</td>
</tr>
</tbody>
</table>

Source: Deloitte analysis using CSO data
Figure 2.8: Share of GVA in physics-based sectors by broad sector

- Manufacturing: 56%
- Architectural and engineering activities: 21%
- Construction: 4%
- Transport: 4%
- Business services: 4%
- Electricity production and distribution: 3%
- R&D: 3%
- Oil and gas activities: 3%
- Technical testing and analysis: 2%

Source: Deloitte analysis using CSO data

Figure 2.9: Share of total Irish GVA, 2005–2010 average

- Physics-based sectors: 5.92%
- Finance, banking and insurance: 8.52%
- Construction: 5.90%

Source: Deloitte analysis using CSO data

Figure 2.10: Share of GVA, longitudinal analysis, 2005–2010

- Physics-based sectors
- Finance, banking and insurance
- Construction

Source: Deloitte analysis using CSO data
2.4. Productivity

Productivity in physics-based sectors remains ahead of the Irish average

Figure 2.11 compares productivity (as defined by GVA per worker) in physics-based sectors against other sectors in Ireland and the Irish average. Productivity of employees in physics-based sectors has fallen over the period 2005–2010, from more than €100,000 to €86,000. A similar fall in productivity can be seen in the construction, and finance, banking and insurance sectors. GVA per worker in physics-based sectors remained above the Irish national average of €76,000.

![Graph showing productivity of physics-based sectors and other sectors in Ireland and the Irish average from 2005 to 2010.]

Source: Deloitte analysis using CSO data

This chapter has considered the contribution of physics-based sectors to the Irish 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 86,000 direct jobs in physics-based sectors in Ireland.
- The majority of these jobs are in the manufacturing sector.
- Turnover from physics-based sectors exceeded €27 bn in 2009, generating more than €7 bn in GVA.
- Compared with the UK, physics-based sectors in Ireland account for a greater proportion of economic activity as measured by direct jobs (but not GVA over the period 2005–2010).
- Productivity (as measured by GVA per worker) is higher in physics-based sectors compared with the Irish average.

While GVA generated and productivity per worker in physics-based sectors has declined somewhat in recent years, this may 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 Irish GVA.
INDIRECT AND INDUCED EFFECTS

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

3.1. Incremental effects
The economic footprint of Irish 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 Irish economy. For example, a “ripple” or “multiplier” effect can be created by a business in a physics-based sector 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 Irish 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 Irish 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 3.1 summarises these impacts in terms of jobs and GVA between 2005 and 2010 in Ireland. The number of incremental jobs attributable to physics-based sectors in Ireland in 2010 is estimated to be nearly 120,000, with an incremental GVA of around €5.3 bn. The trends in both incremental GVA and jobs follow that of direct GVA and jobs, i.e. a fall in 2008 following the financial crisis.

### Figure 3.1: Indirect and induced, longitudinal analysis, 2005–2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Jobs (thousands)</th>
<th>Incremental GVA (€ bn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>130.4</td>
<td>7.28</td>
</tr>
<tr>
<td>2006</td>
<td>127.7</td>
<td>7.16</td>
</tr>
<tr>
<td>2007</td>
<td>129.3</td>
<td>7.24</td>
</tr>
<tr>
<td>2008</td>
<td>129.9</td>
<td>6.25</td>
</tr>
<tr>
<td>2009</td>
<td>124.3</td>
<td>5.34</td>
</tr>
<tr>
<td>2010</td>
<td>118.9</td>
<td>5.30</td>
</tr>
</tbody>
</table>

3.2. Conclusion
Combining incremental and direct impacts gives a total contribution of physics-based sectors as more than 200,000 jobs and nearly €13 bn in GVA generated. Of this figure:

- 58% of total GVA attributable to physics-based sectors was direct GVA and 42% was indirect and induced (incremental) GVA.
- 42% of physics-based sector jobs were directly in physics-based sectors and 58% in the wider economy.

Source: Deloitte analysis using CSO data
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 Irish economy are also analysed – for both foreign and domestic investors.

**4.1. International trade in physics-based sectors**

*Businesses in physics-based sectors perform better than the Irish 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 Ireland with other countries across the globe.

**Figure 4.1** shows that the value of exports from physics-based sectors reached €23 bn in 2008 and the value of imports reached nearly €18 bn.\(^10\) **Figure 4.2** shows that as a proportion of turnover, businesses in physics-based sectors in Ireland have consistently exported more than the national average: 45% over 2005–2008.

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**Box 4.1: 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 the Organisation of Economic Co-operation and Development (OECD) and other sources. 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.

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**Figure 4.1: Value of trade in physics-based sectors in Ireland, longitudinal analysis, 2005–2008**

![Graph showing value of trade in physics-based sectors in Ireland from 2005 to 2008](chart.png)

Source: Deloitte analysis using CSO data

\(^{10}\) At the time of writing, CSO had not released post-2008 data.
compared with the national average of 41%.

**Figure 4.3** compares the balance of trade in physics-based sectors with that of Ireland’s total over 2005–2008. It shows that throughout this period, physics-based sectors have maintained a positive balance of trade. However, while the balance of trade for physics-based sectors in Ireland is positive, the share of exports as a proportion of all exports is lower than that of Germany, Japan and the USA, and the same as in the UK (**figure 4.4**). Similarly, Irish businesses in physics-based sectors import the least as a proportion of all imports in our country comparator group (**figure 4.5**).

**Figure 4.2:** Exports as a share of turnover in physics-based sectors, 2005–2008

**Figure 4.3:** Balance of trade in physics-based sectors and balance of trade in Ireland

Source: Deloitte analysis using CSO data
Figure 4.4: Exports in physics-based sectors as a share of all exports

Source: Deloitte analysis using OECD data

Figure 4.5: Imports in physics-based sectors as a share of all imports

Source: Deloitte analysis using OECD data
4.2. Foreign direct investment in Ireland

Since 2009, the extent of foreign direct investment into all Irish businesses has begun to recover – with net inflows of more than €15 bn.

Figure 4.6 shows the extent of the changes in inward FDI into Ireland (investment made by non-Irish firms in Ireland). According to the available data, there was a withdrawal of FDI between 2005 and 2006 as foreign investors withdrew money from the Irish economy. In later years, there have been positive inflows, with sustained inward investment in Ireland from foreign investors from 2009. Outward FDI (Irish firms making investments overseas) has remained positive throughout the period.

Figure 4.6: Net foreign direct investment flows in and out of Ireland by broad sector, 2010

Figure 4.7: Business expenditure on R&D in Ireland, by broad sector, 2009

Source: Deloitte analysis using Forfas data

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[11] This figure can be negative if foreign firms are withdrawing funds from Ireland.
4.3. R&D in physics-based sectors

*Business expenditure on R&D exceeded €1 bn in the manufacturing, information and communications sectors – all sectors where physics plays an important role.*

Although data on R&D in Ireland are not available in a suitably detailed sectoral breakdown to isolate the contribution of physics, we present some broad-level data that look at the relative contribution of a number of sectors. In 2009, the total business expenditure on R&D is given as more than €1.8 bn. *Figure 4.7* reveals the composition of this expenditure where the bulk of it is spent on manufacturing activities. Given that the share of manufacturing in physics-based sectors stood at nearly two-thirds in 2009, the data suggest that sectors that rely on the use of physics contribute heavily to R&D in Ireland. *Figure 4.8* illustrates the nature of funding for R&D expenditure in physics-based sectors. The greatest proportion comes from businesses’ own funds. Less than 10% of funding is attributable to the Irish government or other domestic sources of finance.

4.4. 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.

- Irish businesses in physics-based sectors maintain a positive balance of trade, but export less than a number of competitors.
- The extent of inward FDI remains strong across Ireland.
- R&D expenditure in physics-based sectors is significant (estimated to be in excess of €1 bn in 2009).

*Figure 4.8: Source for R&D expenditure for physics-based sectors in 2009*

- all other sources 3.2%
- public funding 4.4%
- own company/internal funds 92.4%

Source: Deloitte analysis using Forfas data
5.1. Measuring the impact of physics in the economy

As was recognised in the 2007 report, the pervasiveness of physics makes it hard to reach a single conclusive definition.\(^\text{12}\) For the purposes of this report, we have agreed the following broad categories for what can be considered physics. Following the 2007 report, physics is seen as having an impact on the Irish 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 added\(^\text{13}\) (GVA), as well as the number of new businesses, export performance, R&D expenditure and FDI. There might also be broader social impacts of physics – these are not considered in this report. The impact chain of physics is

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**Box 5.1: 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

**Figure 5.1: Physics logic chain**

Source: Deloitte

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\(^\text{12}\) 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).

\(^\text{13}\) This is analogous to GDP, except that it only includes relevant value added at each stage of production.
The key metrics used to measure the impact of physics on the Irish 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.

5.2. Our approach
To measure the impact of physics on the Irish 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 Irish economy and component nations to quantify the economic impact of physics.
- Policy analysis and reporting – drawing out key insights and trends since the 2007 report.

In figure 5.1 we briefly set 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 because 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 Irish economy. Established in 1948, the SIC classifies businesses and other statistical units by the type of economic activity in which they are engaged. The SIC is a hierarchical five-digit system, with the latest revision occurring in 2007. The SIC first divides the economy into broad sections, with these sections then

Table 5.1: Example SIC(2007) classification

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section C</td>
<td>Manufacturing (comprising divisions 10 to 33)</td>
</tr>
<tr>
<td>Division 13</td>
<td>Manufacture of textiles</td>
</tr>
<tr>
<td>Group 13.9</td>
<td>Manufacture of other textiles</td>
</tr>
<tr>
<td>Class 13.93</td>
<td>Manufacture of carpets and rugs</td>
</tr>
<tr>
<td>Subclass 13.93/1</td>
<td>Manufacture of woven or tufted carpets and rugs</td>
</tr>
</tbody>
</table>

Source: ONS
Table 5.2: List of classes used in the definition of physics-based sectors

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>06.10</td>
<td>Extraction of crude petroleum</td>
<td>30.20</td>
<td>Manufacture of railway locomotives and rolling stock</td>
</tr>
<tr>
<td>06.20</td>
<td>Extraction of natural gas</td>
<td>30.30</td>
<td>Manufacture of air and spacecraft and related machinery</td>
</tr>
<tr>
<td>09.10</td>
<td>Support activities for petroleum and natural gas extraction</td>
<td>30.40</td>
<td>Manufacture of military fighting vehicles</td>
</tr>
<tr>
<td>20.13</td>
<td>Manufacture of inorganic basic chemicals</td>
<td>30.91</td>
<td>Manufacture of motorcycles</td>
</tr>
<tr>
<td>21.20</td>
<td>Manufacture of pharmaceutical preparations</td>
<td>32.50</td>
<td>Manufacture of medical and dental instruments and supplies</td>
</tr>
<tr>
<td>23.44</td>
<td>Manufacture of other technical ceramic products</td>
<td>33.11</td>
<td>Repair of fabricated metal products</td>
</tr>
<tr>
<td>24.46</td>
<td>Processing of nuclear fuel</td>
<td>33.12</td>
<td>Repair of machinery</td>
</tr>
<tr>
<td>25.40</td>
<td>Manufacture of weapons and ammunition</td>
<td>33.13</td>
<td>Repair of electronic and optical equipment</td>
</tr>
<tr>
<td>25.99</td>
<td>Manufacture of other fabricated metal products n.e.c.</td>
<td>33.14</td>
<td>Repair of electrical equipment</td>
</tr>
<tr>
<td>26.11</td>
<td>Manufacture of electronic components</td>
<td>33.15</td>
<td>Repair and maintenance of ships and boats</td>
</tr>
<tr>
<td>26.12</td>
<td>Manufacture of loaded electronic boards</td>
<td>33.17</td>
<td>Repair and maintenance of transport equipment n.e.c.</td>
</tr>
<tr>
<td>26.20</td>
<td>Manufacture of computers and peripheral equipment</td>
<td>33.20</td>
<td>Installation of industrial machinery and equipment</td>
</tr>
<tr>
<td>26.30</td>
<td>Manufacture of communication equipment</td>
<td>35.11</td>
<td>Production of electricity</td>
</tr>
<tr>
<td>26.40</td>
<td>Manufacture of consumer electronics</td>
<td>35.12</td>
<td>Transmission of electricity</td>
</tr>
<tr>
<td>26.51</td>
<td>Manufacture of instruments and appliances for measuring, testing and navigation</td>
<td>35.13</td>
<td>Distribution of electricity</td>
</tr>
<tr>
<td>26.60</td>
<td>Manufacture of irradiation, electromedical and electrotherapeutic equipment</td>
<td>38.12</td>
<td>Collection of hazardous waste</td>
</tr>
<tr>
<td>26.70</td>
<td>Manufacture of optical instruments and photographic equipment</td>
<td>38.22</td>
<td>Treatment and disposal of hazardous waste</td>
</tr>
<tr>
<td>26.80</td>
<td>Manufacture of magnetic and optical media</td>
<td>43.22</td>
<td>Plumbing, heat and air-conditioning installation</td>
</tr>
<tr>
<td>27.11</td>
<td>Manufacture of electric motors, generators and transformers</td>
<td>51.22</td>
<td>Space transport</td>
</tr>
<tr>
<td>27.12</td>
<td>Manufacture of electricity distribution and control apparatus</td>
<td>52.21</td>
<td>Service activities incidental to land transportation</td>
</tr>
<tr>
<td>27.20</td>
<td>Manufacture of batteries and accumulators</td>
<td>52.22</td>
<td>Service activities incidental to water transportation</td>
</tr>
<tr>
<td>27.31</td>
<td>Manufacture of fibre-optic cables</td>
<td>52.23</td>
<td>Service activities incidental to air transportation</td>
</tr>
<tr>
<td>27.32</td>
<td>Manufacture of other electronic and electric wires and cables</td>
<td>60.10</td>
<td>Radio broadcasting</td>
</tr>
<tr>
<td>27.33</td>
<td>Manufacture of wiring devices</td>
<td>61.10</td>
<td>Wired telecommunications activities</td>
</tr>
<tr>
<td>27.40</td>
<td>Manufacture of electric lighting equipment</td>
<td>61.20</td>
<td>Wireless telecommunications activities</td>
</tr>
<tr>
<td>27.51</td>
<td>Manufacture of electric domestic appliances</td>
<td>61.30</td>
<td>Satellite telecommunications activities</td>
</tr>
<tr>
<td>27.90</td>
<td>Manufacture of other electrical equipment</td>
<td>61.90</td>
<td>Other telecommunications activities</td>
</tr>
<tr>
<td>28.11</td>
<td>Manufacture of engines and turbines, except aircraft, vehicle and cycle engines</td>
<td>62.09</td>
<td>Other information technology and computer service activities</td>
</tr>
<tr>
<td>28.21</td>
<td>Manufacture of ovens, furnaces and furnace burners</td>
<td>71.11</td>
<td>Architectural activities</td>
</tr>
<tr>
<td>28.23</td>
<td>Manufacture of office machinery and equipment (except computers and peripheral equipment)</td>
<td>71.12</td>
<td>Engineering activities and related technical consultancy</td>
</tr>
<tr>
<td>28.25</td>
<td>Manufacture of non-domestic cooling and ventilation equipment</td>
<td>71.20</td>
<td>Technical testing and analysis</td>
</tr>
<tr>
<td>28.29</td>
<td>Manufacture of other general-purpose machinery n.e.c.</td>
<td>72.11</td>
<td>Research and experimental development on biotechnology</td>
</tr>
<tr>
<td>28.49</td>
<td>Manufacture of other machine tools</td>
<td>72.19</td>
<td>Other research and experimental development on natural sciences and engineering</td>
</tr>
<tr>
<td>28.99</td>
<td>Manufacture of other special-purpose machinery n.e.c.</td>
<td>74.20</td>
<td>Photographic activities</td>
</tr>
<tr>
<td>29.10</td>
<td>Manufacture of motor vehicles</td>
<td>74.90</td>
<td>Other professional, scientific and technical activities n.e.c.</td>
</tr>
<tr>
<td>29.31</td>
<td>Manufacture of electrical and electronic equipment for motor vehicles</td>
<td>84.22</td>
<td>Defence activities</td>
</tr>
<tr>
<td>30.11</td>
<td>Building of ships and floating structures</td>
<td>95.12</td>
<td>Repair of communication equipment</td>
</tr>
</tbody>
</table>
Broadly speaking, the domestic impact of €1.8 m. This adjustment is made on the basis of 2001 census data and Standard Occupational Code (SOC) data for 2010–2005. Data is 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.

A comparison of our results with those of the 2007 report can be found in the Annex.14 These were referred to as “upstream” effects in the 2007 report.15

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.

Disaggregated a further four times to reach a more detailed picture of the economy. Table 5.1 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 (Nomenclature Générale des Activités Économiques dans les Communautés Européennes) 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.14 Table 5.2 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 NACE codes were revised. The NACE(2008) has consolidated and re-categorised certain sectors on the basis of economic trends. Hence, the list of sectors used for this report will differ from the 2007 report.15

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 CSO
- OECD Trade Statistics
- Various UK ONS publications
- CSO Supply and Use Tables
- Forfas Research and Development Statistics

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 input-output model to approximate supply-chain linkages.

This 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-based sectors 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.16
- 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.17

The process behind constructing bespoke input-output models for Ireland is complex18 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.
# Glossary of Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Broad impacts</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Direct impact of physics</strong></td>
<td>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).</td>
</tr>
<tr>
<td><strong>Foreign direct investment (FDI)</strong></td>
<td>Investment by a company in a country different from that in which the company is based.</td>
</tr>
<tr>
<td><strong>Gross value added (GVA)</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Indirect impacts</strong></td>
<td>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).</td>
</tr>
<tr>
<td><strong>Induced impacts</strong></td>
<td>The spending by households that results in changes to the number of jobs and GVA due to direct and indirect impacts.</td>
</tr>
<tr>
<td><strong>Narrow impacts</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Physics-based sectors</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Standard Industrial Classification (SIC)</strong></td>
<td>First introduced 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.</td>
</tr>
<tr>
<td><strong>Standard Occupational Classification (SOC)</strong></td>
<td>A common classification framework of occupational information for Ireland on the basis of skill level and skill content.</td>
</tr>
<tr>
<td><strong>Standard Industrial Trade Classification (SITC)</strong></td>
<td>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.</td>
</tr>
</tbody>
</table>
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