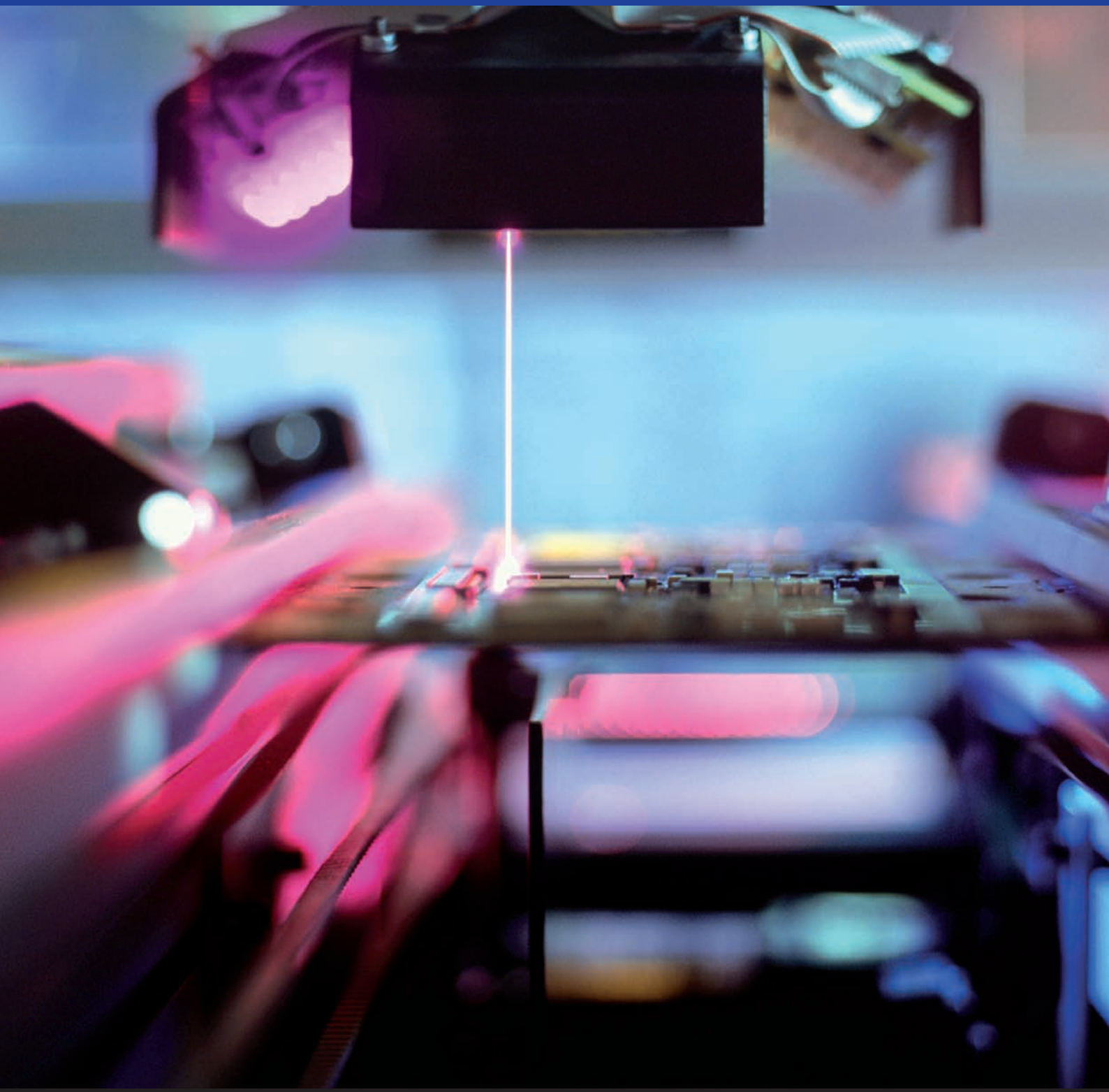
A report produced for the Institute of Physics by the Centre for Economics and Business Research | **January 2017**

The role of physics in supporting economic growth and national productivity in Ireland



IOP Institute of Physics

The Institute of Physics is a leading scientific membership society working to advance physics for the benefit of all.

We have a worldwide membership of more than 50,000, from enthusiastic amateurs to those at the top of their fields in academia, business, education and government.

Our purpose is to gather, inspire, guide, represent and celebrate all who share a passion for physics. And, in our role as a charity, we're here to ensure that physics delivers on its exceptional potential to benefit society.

Alongside professional support for our members, we engage with policymakers and the public to increase awareness and understanding of the value that physics holds for all of us.

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Foreword

Ireland is a strong physics nation, home to international researchers and part of world-leading collaborations.

It is also a nation of businesses that have built significant success on physics knowledge and technologies.

The work presented here from the Centre for Economic and Business Research is the most comprehensive analysis of the role of physics in growth and productivity in Ireland ever undertaken. And it shows something that we always suspected: physics is not just the source of inventions and ideas, but also the means by which Ireland's economic future can be secured.

The data shows that physics-based industries – by which we mean those that are critically dependent on physics knowledge and expertise – have huge impact, lots of jobs and frankly startling productivity.

This shows that the decisions made to protect science spending are paying dividends.

But we cannot pretend that it is all good news. The economic prosperity that physics brings does not happen without the continued support of the education, research and skills systems. The strength of physics-based business in Ireland is built on past investment in cutting-edge physics. Physics in Ireland has suffered cuts over the past 10 years and this can be seen in the recent changes in economic returns from physics-based business.

We know that it is often the basic, curiosity-driven research that inspires and underpins the applications and technologies of tomorrow.

If Ireland wants to have a high technology, high productivity, high prosperity economy for the future then it must continue to invest in physics today – in schools, research, higher and further education and in the businesses that take the fruits of physics.

The Institute of Physics is working with the community to ensure that the benefits of physics are maintained and the investments necessary for this are made.

Over the next two years we will strive to demonstrate the value of physics to those that hold the purse strings, encouraging them to strengthen physics and secure a bright future for us all.

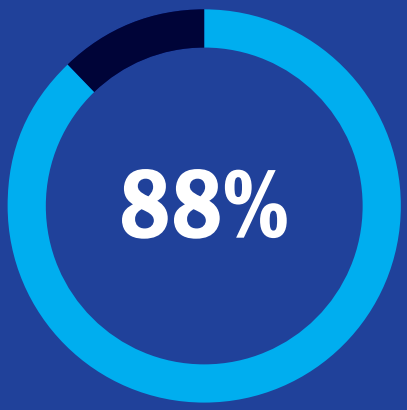
The analysis we present here will inform that push.

Dr Mark Lang
Chair, IOP Ireland

Physics in the Irish economy

€37 bn

Around €37 bn of physics-based goods and services were exported from Ireland in 2013



Physics-based manufacturing accounted for 88% of that total

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€138,273

A person employed in Irish physics-based industries contributed an average of €138,273 a year in value added

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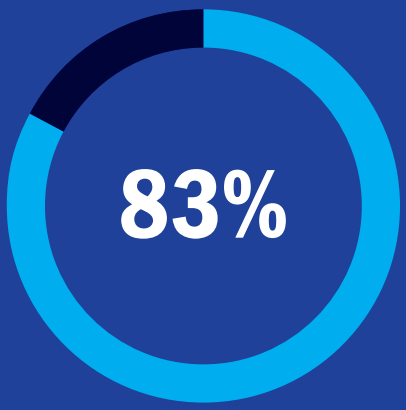
€2.3 bn

Ireland's physics-based industries invested just under €2.3 bn in R&D in 2013



That's 83% of all R&D investment and around 1.3% of Ireland's GDP in that year

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€23.3 bn

Ireland's physics-based sectors contributed €23.3 bn in gross value added (GVA)

26%

Which is a 26% share of total GVA in Ireland's business economy

Add in indirect effects

€23.3 bn	+ €14.9 bn

and overall GVA rises to

€38.2 bn

GO TO PAGE 12

160,000

160,000 people were employed in physics-based industries in Ireland

8.6%

That's 8.6% of the total workforce

Add in indirect effects

160,000	+ 127,600

and overall jobs rises to

287,600

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€48.7 bn

Physics-based industries generated turnover worth €48.7 bn

14%

That's 14% of overall turnover in Ireland's business economy

Add in indirect effects

€48.7 bn	+ €24.3 bn

and overall turnover rises to

€73.0 bn

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Introduction

This report examines the contribution and importance of physics to Ireland's economy, through the lens of the industries that rely on physics for their existence, and how these industries play an important role in enhancing productivity, boosting economic growth and increasing prosperity. Our examination spans the period 2011–14.

When using absolute indicators, we compare the contributions of Ireland's physics-based industries with those in the smaller UK nations of Wales, Scotland and Northern Ireland. We also compare Ireland with the UK, France and Germany when considering relative indicators.

Physics-based industries can be defined as the industries in which the use of physics – in terms of technologies and expertise – is critical to their existence. This means that the industries considered are those in which workers with some training in physics would be expected to be employed, and in which the industrial activities themselves rely heavily on the theories and results of physics to achieve their commercial goals.

This research provides a thorough and comprehensive examination of the role of physics-based industries in Ireland's economy. The report presents a range of analyses demonstrating different aspects of the value they bring. One of the main goals of the research was to demonstrate how physics-based industries contribute to national productivity, economic growth and the broader prosperity agenda. This, alongside the ongoing contributions made by these industries as measured by contributions to annual GDP and employment, is designed to demonstrate the impact of physics on the real economy.

The purpose of the research was also to provide a range of comparisons, including:

- How the economic indicators vary across different categories or groupings of physics-based industries.
- How the economic indicators for the physics-based industries vary between Ireland and the smaller nations of the UK in absolute terms and with the UK, France and Germany in relative terms.
- How the indicators for the physics-based industries compare with other important sectors of the Irish economy.

The appendix provides a full list of physics-based industries for the purposes of this report.

Centre for Economics and Business Research, London 2017

Productivity, economic growth and prosperity

Future prosperity requires growth in the economy. This, in turn, depends on the quantities of the factors of production employed (specifically, labour and capital) and the efficiency with which those quantities are utilised. Growth can be sustained by increasing the amounts of labour and/or capital that are used. But, as additional units of these factors are added, the amount of additional output as a result tends to diminish so only increases in the level of technological progress can offset this decline in growth that occurs as economies mature and diminishing returns to labour and capital set in.

We examine how physics-based industries contribute to productivity and economic growth through the lens of average levels of labour productivity, investment in R&D, and international trade.

€138,273

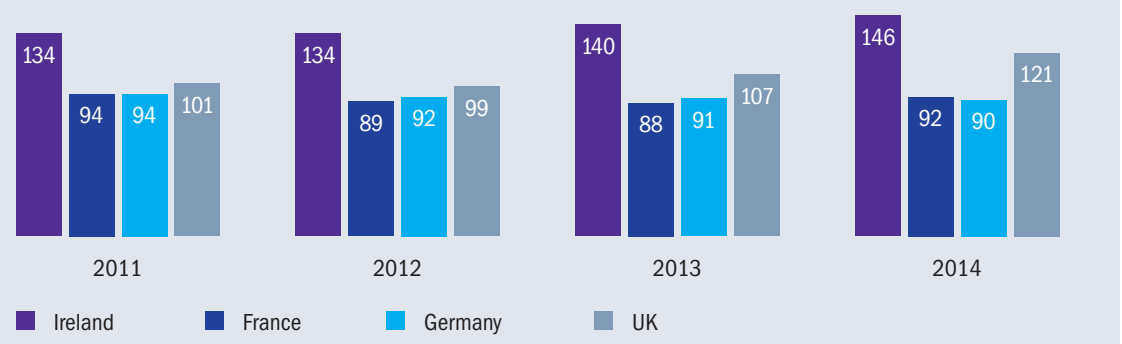
A person employed in Irish physics-based industries contributed an average of €138,273 a year in value added

Productivity per employee

Throughout the period of the study, 2011–14, a person employed in physics-based industries contributed an average of €138,273 a year in gross value added. This is significantly higher than that of the construction sector at €47,146 and is more than three times the equivalent figure of €28,610 in the retail industry. However, physics-based industries are just outperformed on this measure by financial services, which generated an average of €144,403 of GVA per person. They are significantly outperformed by the broader manufacturing sector, which recorded an average GVA per person in employment of €201,329 over the period.

However, physics-based manufacturing industries generate more value added per person employed (on average €278,275 in the years 2011–14) than broader manufacturing. This suggests that those production technologies and processes that draw more heavily upon physics sustain greater levels of GVA per worker relative to the average for manufacturing as a whole.

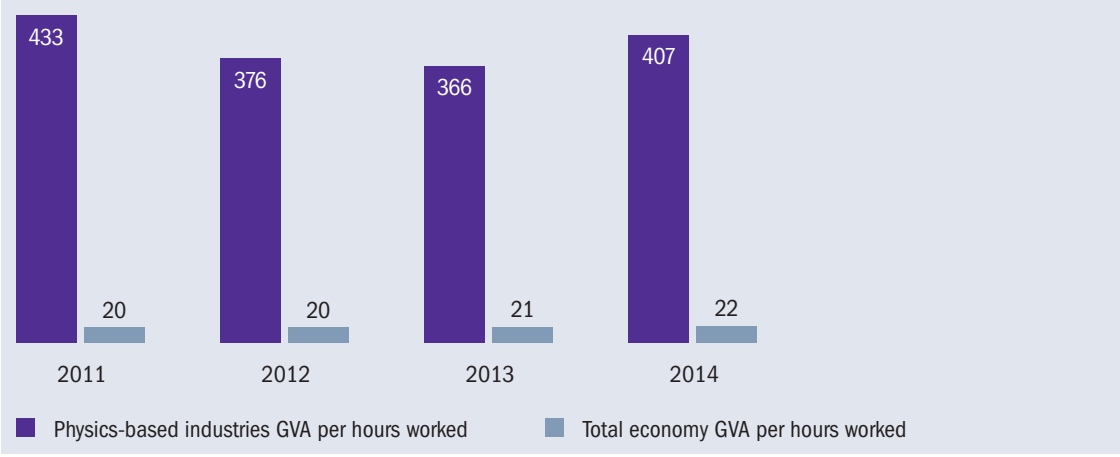
Comparison of country-level physics-based productivity (€'000 per person per year)



In real terms, GVA per person employed in physics-based industries shows an increase of 4.6% over the 2011–14 period and average annual growth of 1.6%, despite a 3.5% decline between 2011 and 2012. At the economy-wide level, growth was weaker, averaging -1.9% over the period, with a less significant decline of 1.6% in 2014.

Real GVA per person employed in the physics-based industries and Ireland's economy (€'000)

Real GVA per hour worked in the physics-based industries and Ireland-wide economy (€)



€2.3 bn

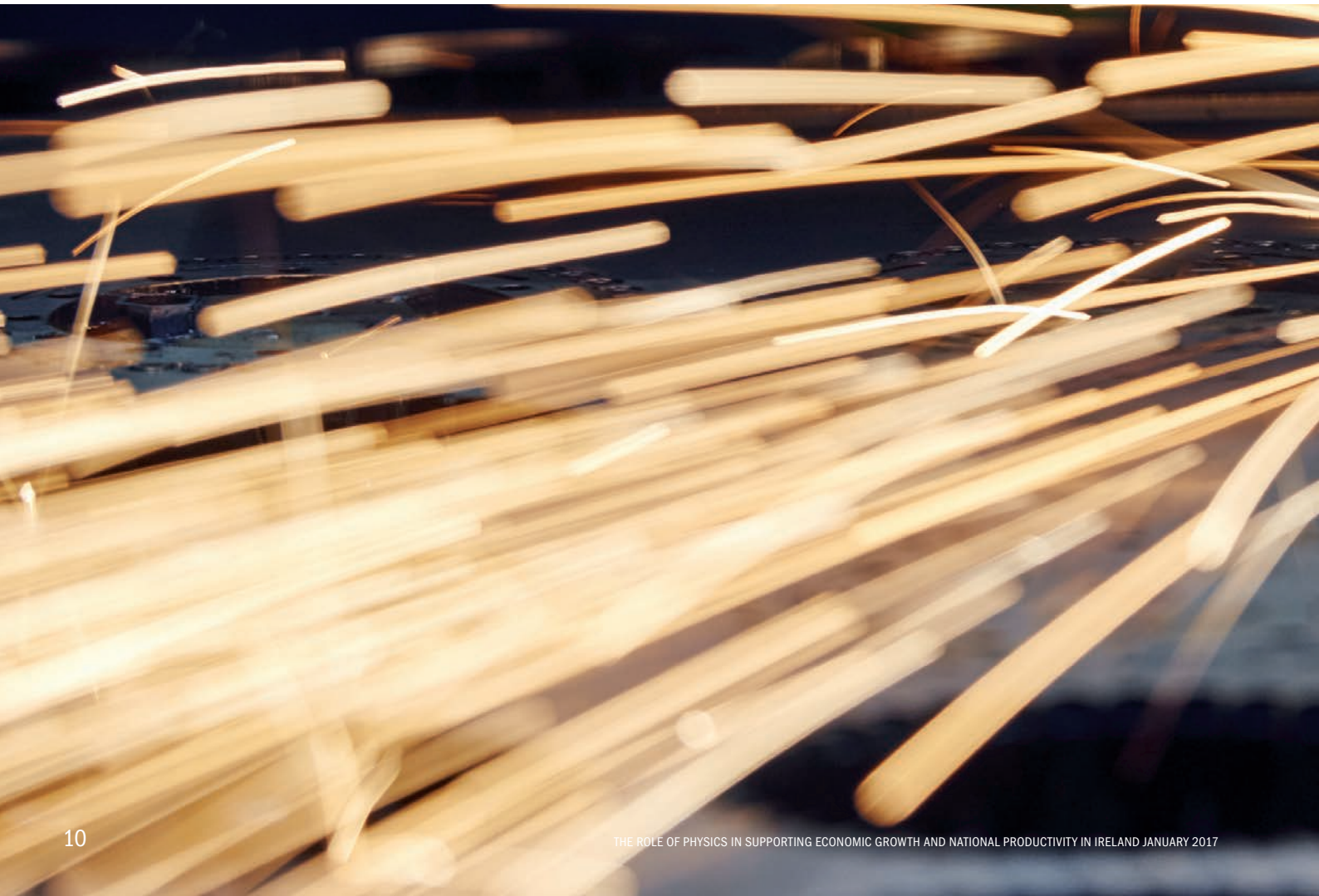
Ireland's physics-based industries invested just under €2.3 bn in R&D in 2013

That's just under 83% of all R&D investment and around 1.3% of Ireland's GDP in that year

Productivity through R&D

Physics-based knowledge is likely to be an important driver of technological progress in physics-based industries and in the economy as a whole through spillover impacts. Technological advances drive total factor productivity – the efficiency with which the factors of production are combined to produce output – and a principal source of technological advance is investment in R&D.

At just under an estimated €2.3 bn in 2013, external R&D expenditures by physics-based industries represented just under 83% of all external R&D spend in that year. We estimate that this could be associated with a long run boost to GDP of up to €14.4 bn. This means that Ireland's GDP could be up to 4.9% higher in the long run than it could have been without R&D investment by physics-based industries.



Productivity through exporting

Trade is associated with significant productivity benefits. It increases the potential for business to exploit economies of scale by opening up new markets. This, by reducing unit costs of production, helps them to maintain or improve competitiveness on global markets. We estimate that €37 bn of physics-based goods and services were exported from Ireland in 2013. As a ratio of Irish GDP, this is more than 50%, which is a quite staggering figure for physics-based industries.

Consumers also benefit from imports in the form of lower prices and greater choice, and because domestic firms must improve efficiency to remain competitive. These effects can, in turn, lead to higher real incomes, greater discretionary spending and higher GDP than would otherwise have been the case. We estimate that €27 bn of physics-based goods and services were imported into Ireland in 2013. Physics-based manufacturing is responsible for 69% of the total, with professional, scientific and technical services accounting for 25%.

Combining the export and import estimates suggests that Ireland had a trade surplus in physics-based goods and services of nearly €11 bn in 2013. This element of Ireland's balance of trade alone can be equated with more than 15% of Irish GDP.

Assuming that most or all of Ireland's physics-based exports are produced by the Irish physics-based industries and comparing these export numbers (€37 bn in 2013) with the value of imported intermediate inputs consumed by physics-based industries as part of their production processes provides another perspective on the contribution of physics to the trade balance.

Our estimates suggest that physics-based industries imported goods and services worth €31 bn in 2013. This is high and is consistent with the low multiplier impacts of physics-based industries in Ireland relative to France, Germany and the UK. Subtracting this from the estimate of exports leaves a surplus of €6 bn. This provides a more accurate picture of the contributions of physics-based industries themselves to the trade balance.

€37 bn

Around €37 bn of physics-based goods and services were exported from Ireland in 2013

Physics-based manufacturing accounted for 88% of that total

€23.3 bn

Ireland's physics-based sectors contributed €23.3 bn in GVA

Which is a 26% share of total GVA in Ireland's business economy

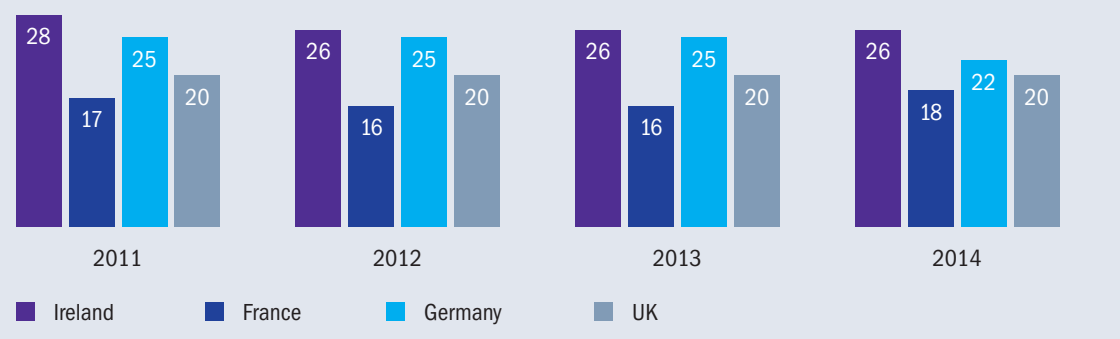
Physics-based industries' GVA contributions to GDP

Physics-based industries made a €23.3 bn GVA contribution to GDP in 2014. This is a 26% share of the GVA of the entire Irish business economy, a 13.6% share of economy-wide GVA and a 12% share of Irish GDP. An annual average decline of 2.2% in the 2011–14 period was driven largely by an 8.6% drop in 2012. But positive growth of 1.25% was achieved in 2014. In comparison to turnover, GVA contributions appear to have held their own, even in pharmaceuticals.

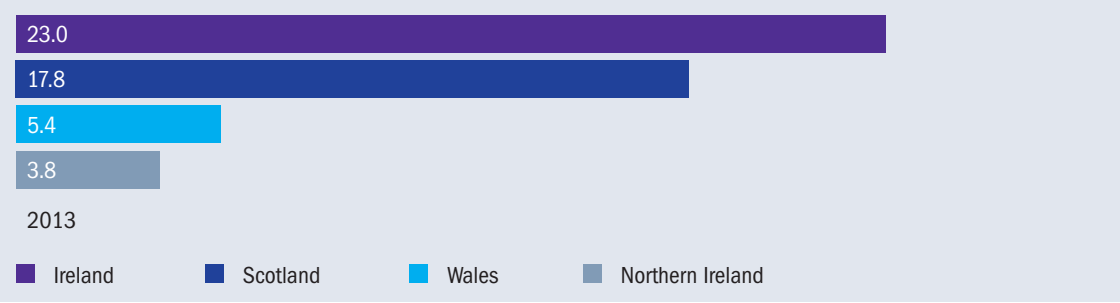
As with employment and turnover, physics-based manufacturing is dominant, maintaining a 72% share through 2013 and 2014, despite the drop in turnover. Transport and communications also make a sizeable contribution of, on average, 16%.

Physics-based industries surpass the other comparator sectors of retail, construction and financial services in the Irish economy. The exception is wider manufacturing, but the gap between the two is significantly smaller in GVA than in turnover terms. What is also notable is that, despite the retail sector almost overtaking physics-based industries in turnover terms, the GVA contribution of the latter is quite significantly greater than that of the retail sector.

Physics-based industries share of GVA in the business economy across countries (%)



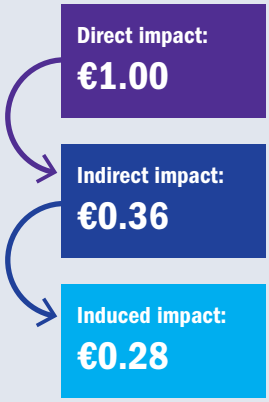
GVA in physics-based industries in selected countries (€ billions)



Ireland's physics-based industries generated substantially higher levels of GVA than in Wales or Northern Ireland. The notable feature is that, despite Scotland overtaking Ireland in turnover terms in 2014, Irish physics-based industries have consistently achieved higher GVA contributions than those in Scotland. Despite the decline in Irish physics-based industries' GVA contribution in the period 2011–13, which is in contrast to more robust growth in the UK nations, this trend improved slightly in 2014.

Comparing physics-based industries' share of the Irish business economy in GVA terms with the UK, France and Germany, they account for a significantly larger share of the business economy on this measure (26%) than when that share is measured in turnover terms (14%). This 26% GVA share is on a par with the share of the German economy accounted for by German physics-based industries (25%) and significantly greater than in France (16–18%) or the UK (20%).

Physics-based industries' GVA multiplier (= 1.64)



Expenditure on the physics-based sector triggers the physics industry's supply response. In providing its services, the physics industry generates additional value added. Assume sufficient expenditure to generate €1 of GVA. This €1 of GVA is the direct GVA impact of the relevant increment in expenditure on physics-based industry.

To increase its supply, the physics-based industry must increase its demands on its suppliers, who increase demands on their suppliers and so on down the supply chain. This generates the indirect impact, an increase in GVA throughout the supply chain of €0.36 for every additional €1 of GVA in the physics-based industry.

The combined direct and indirect impacts have an impact on household income throughout the economy, through increased employment, profits etc. A proportion of this income will be respent on final goods and services, producing a supply response by the producers of these goods/services and further impacts through their supply chains. This produces the induced impact of €0.28 for every additional €1 of GVA in the physics-based industry.

The GVA multiplier, capturing indirect and induced GVA impacts arising from the productive activities of the physics-based industries, is estimated at 1.64. That is to say, for every €1 of GVA generated by physics-based industries, an additional €0.64 is generated in the wider economy through indirect supply chain impacts and induced employee spending impacts. Combining this with the direct GVA contribution of Irish physics-based industries of €23.3 bn produces an aggregate GVA contribution of €38.2 bn.

The GVA multiplier impacts, like those on turnover and employment, are lower than those of physics-based industries in Wales, Scotland, Northern Ireland, France, Germany or the UK as a whole. This is, we suspect, attributable to two factors:

- The small, open nature of Ireland's economy is such that the value of exports is usually greater than 100% as a ratio of GDP, while imports are a bit less than 100% but still close to it. This is reflected both in physics-based industries' strong export performance (see below) and in the high import content in their supply chains, which would be expected to lead to lower multiplier estimates when measured on a domestic economy only basis
- The skewness of Ireland's physics-based industries towards high-value high-tech manufacturing would mean impacts are more heavily weighted towards direct, rather than indirect and induced. This would again act to suppress physics-based industries' multiplier impacts

Add in indirect effects and overall GVA rises to

€38.2 bn

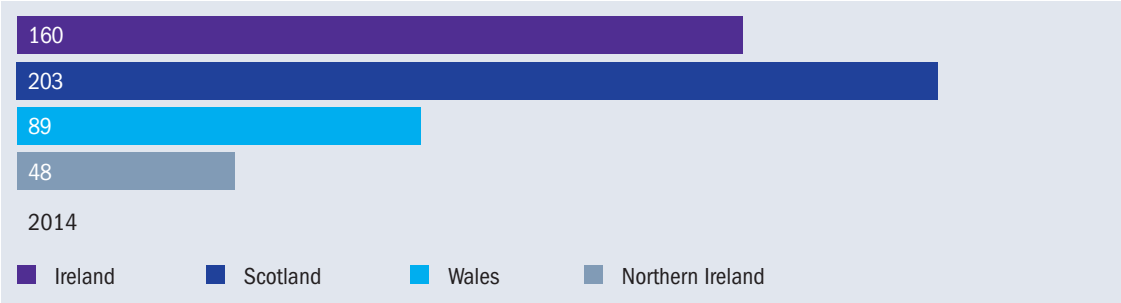
160,000

160,000 people were employed in physics-based industries in Ireland

That's 8.6% of Ireland's total workforce

Employment

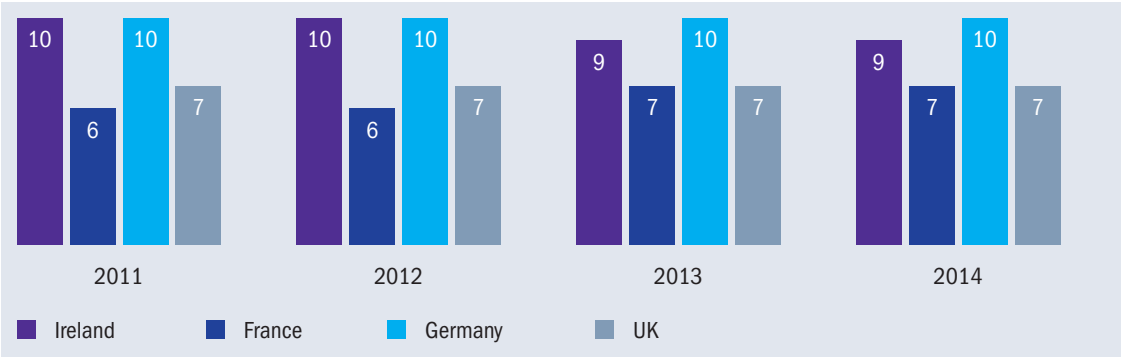
Physics-based employment across countries ('000)



Direct employment in physics-based industries was around 160,000 in 2014, amounting to an 8.6% share of total employment in Ireland. Our analysis suggests that physics-based industries' share of aggregate employment exceeds that of both the construction and financial services sectors, as well as the broader manufacturing sector, except in 2014 when the manufacturing sector appears to have pulled ahead of the physics-based industries.

Physics-based industries' share of employment has been in persistent decline since 2011 when it stood at 10.3%. Growth in employment has, likewise, been trending downward, with an annual average decline of 4.9% over 2011–14.

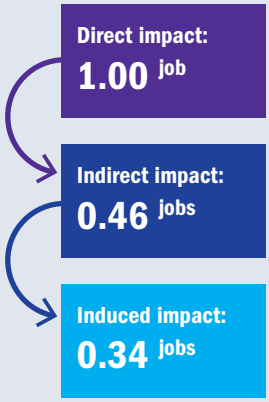
Physics-based industries share of total economy employment across countries (%)



Physics-based manufacturing accounted for 37% of the direct jobs contribution of physics-based industries in 2014. This is a smaller share than observed for turnover and GVA, which is consistent with the lower labour intensities that can be expected in the high-tech manufacturing industries in which Ireland is specialist – namely, ICT and pharmaceuticals. This compares with 37% in the UK also, 44% in France and 63% in Germany.

In 2014, employment by physics-based industries in Ireland was lower than in Scotland (203,000), but higher than in either Wales (89,000) or Northern Ireland (48,000).

Physics-based employment multiplier (= 1.80)



Expenditure on the physics-based industries' supply response. In providing its services, the physics-based industry hires additional staff. Assume sufficient expenditure to generate one additional job. This job is the direct employment impact of the relevant increment in expenditure on the physics-based sector.

To increase its supply, the physics-based industry must increase its demands on its suppliers, who increase demands on their suppliers, and so on down the supply chain. This generates the indirect impact, an increase in employment throughout the supply chain of 0.46 jobs for every additional job in the physics-based sector.

The combined direct and indirect impacts have an impact on household income throughout the economy, through increased employment, profits, and so on. A proportion of this will be respent on final goods and services, producing a supply response by the producers of these, and further impacts through their supply chains. This produces the induced impact of 0.34 jobs for every additional job in the physics-based sector.

Physics-based industries' activities also support jobs in the wider economy. This ripple or multiplier effect is created when physics-based industries purchase intermediate inputs from other sectors of the economy, the activity thereby supporting indirect jobs in their supply chain, and when the direct and indirect employees of physics-based industries spend their earnings in the wider economy, thus supporting induced jobs in the sectors that supply final goods and services to households.

The bespoke input–output models produced for this study suggest an employment multiplier of 1.80. This suggests that an additional 127,600 jobs can be attributed to the indirect and induced employment impacts of physics-based industries. This in turn suggests an aggregate contribution to employment in Ireland amounting to 287,600 in 2014.

127,600

Add in indirect effects and overall jobs rises to

287,600

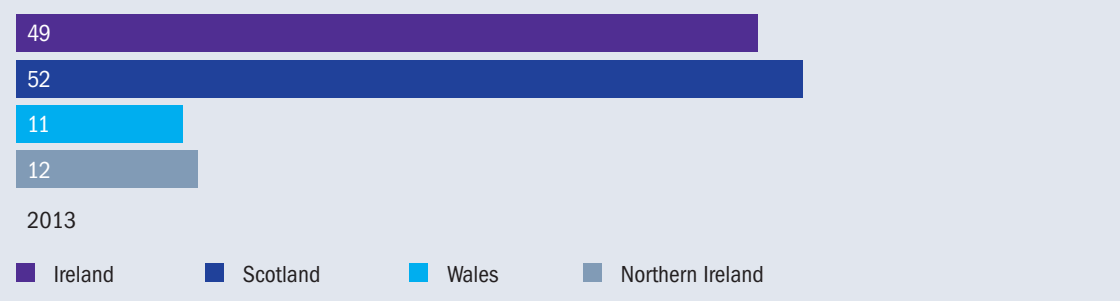
Turnover

€48.7 bn

Physics-based industries generated turnover worth €48.7 bn

That's 14% of overall turnover in Ireland's business economy

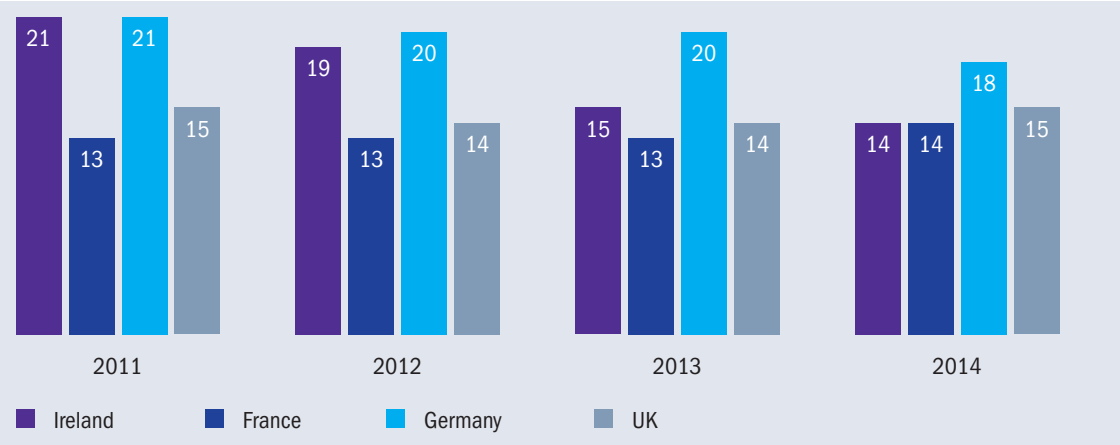
Turnover in physics-based industries in selected countries (€ billions)



Physics-based industries generated turnover to the value of €48.7 bn in 2014 (a 14% share of the entire turnover of Ireland's business economy). Their turnover has been in decline, with an annual average fall of 10% per annum and a decline in 2013 of 21%. The data suggest that this is driven by a 55% drop in 2013 in the turnover of the physics-based industries concerned with the manufacture of basic pharmaceutical products and pharmaceutical preparations. This is most likely a reflection of the patent cliff and of market reforms that have resulted in an increasing prevalence of generic medications in Ireland.

Physics-based manufacturing is dominant in turnover terms, with a 64% share in 2014. But this has been in decline, dropping significantly in 2013 from 75% to 66% and then further in 2014. This is again due to the drop in pharmaceuticals. Transport and communications are the next largest at 22% in 2014. Energy production and professional services account for notable shares, with both increasing over the period.

Physics-based industries share of turnover in the business economy across countries (%)



Physics-based industries' turnover exceeds that of retail, construction and financial services and constitutes about two thirds of the turnover of the overall manufacturing sector. However, since 2013, this ratio has dropped to about a half. There was a significant closing of the gap between retail and physics-based industries, a likely combination of the pharmaceuticals-driven decline in the latter and increasing confidence in the Irish economy since 2013, which looks to have boosted the former.

Ireland's physics-based industries generated substantially higher levels of turnover than those in Wales or Northern Ireland. They were also bigger than Scotland's on this measure, but only until 2012. In 2013, Ireland's physics-based industries appear to have fallen behind their Scottish counterparts in turnover terms. This is again a reflection of the decline in pharmaceuticals.

Physics-based industries gross output (turnover) multiplier (= 1.50)

Direct impact:
€1.00

Expenditure on the physics-based sector triggers the physics-based industry's supply response. In providing its services, the physics-based industry produce additional output. Assume sufficient expenditure to generate €1 of output is the direct output impact of the relevant increment in expenditure on physics.

Indirect impact:
€0.27

To increase its supply, the physics-based industry must increase its demands on their suppliers, who increase demands on their suppliers and so on down the supply chain. This generates the indirect impact, an increase in output throughout the supply chain of €0.27 for every additional €1 of the physics-based industry's output.

Induced impact:
€0.23

The combined direct and indirect impacts have an impact on household income throughout the economy, through increased employment, profits etc. A proportion of this income will be respent on final goods and services, producing a supply response by the producers of these goods/services and further impacts through their supply chains. This produces the induced impact of €0.23 of output for every additional €1 of the physics-based industry's output.

The turnover multiplier estimate of 1.50 means that, for every €1 of turnover produced by Irish physics-based industries, another €0.50 is generated in the wider economy as a result of the indirect and induced impacts of their activities, which are generated through supply chain demands of physics-based industries and the final household demands of their employees spending their earnings. Combining this estimate with their direct contribution implies an aggregate turnover contribution of €73 bn.

€24.3 bn

Add in indirect effects and overall turnover rises to

€73 bn

Appendix

Table of physics-based industries

Definitions of physics-based industries used in this report are given below alongside their code.

Code	Description
06.10	Extraction of crude petroleum
06.20	Extraction of natural gas
09.10	Support activities for petroleum and natural gas extraction
20.13	Manufacture of other inorganic basic chemicals
21.20	Manufacture of pharmaceutical preparations
23.44	Manufacture of other technical ceramic products
24.46	Processing of nuclear fuel
25.40	Manufacture of weapons and ammunition
25.99	Manufacture of other fabricated metal products n.e.c.
26.11	Manufacture of electronic components
26.12	Manufacture of loaded electronic boards
26.20	Manufacture of computers and peripheral equipment
26.30	Manufacture of communication equipment
26.40	Manufacture of consumer electronics
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
26.60	Manufacture of irradiation, electro-medical and electrotherapeutic equipment
26.70	Manufacture of optical instruments and photographic equipment
26.80	Manufacture of magnetic and optical media
27.11	Manufacture of electric motors, generators and transformers
27.12	Manufacture of electricity distribution and control apparatus
27.20	Manufacture of batteries and accumulators
27.31	Manufacture of fibre optic cables
27.32	Manufacture of other electronic and electric wires and cables
27.33	Manufacture of wiring devices
27.40	Manufacture of electric lighting equipment
27.51	Manufacture of electric domestic appliances
27.90	Manufacture of other electrical equipment
28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
28.21	Manufacture of ovens, furnaces and furnace burners
28.23	Manufacture of office machinery and equipment (except computers and peripheral equipment)
28.25	Manufacture of non-domestic cooling and ventilation equipment
28.29	Manufacture of other general-purpose machinery n.e.c.
28.49	Manufacture of other machine tools
28.99	Manufacture of other special-purpose machinery n.e.c.
29.10	Manufacture of motor vehicles
29.31	Manufacture of electrical and electronic equipment for motor vehicles

Code	Description
30.11	Building of ships and floating structures
30.20	Manufacture of railway locomotives and rolling stock
30.30	Manufacture of air and spacecraft and related machinery
30.40	Manufacture of military fighting vehicles
30.91	Manufacture of motorcycles
32.50	Manufacture of medical and dental instruments and supplies
33.11	Repair of fabricated metal products
33.12	Repair of machinery
33.13	Repair of electronic and optical equipment
33.14	Repair of electrical equipment
33.15	Repair and maintenance of ships and boats
33.17	Repair and maintenance of other transport equipment
33.20	Installation of industrial machinery and equipment
35.11	Production of electricity
35.12	Transmission of electricity
35.13	Distribution of electricity
38.12	Collection of hazardous waste
38.22	Treatment and disposal of hazardous waste
43.22	Plumbing, heat and air conditioning installation
51.22	Space transport
52.21	Service activities incidental to land transportation
52.22	Service activities incidental to water transportation
52.23	Service activities incidental to air transportation
60.1	Radio broadcasting
61.1	Wired telecommunications activities
61.2	Wireless telecommunications activities
61.3	Satellite telecommunications activities
61.9	Other telecommunications activities
62.09	Other information technology and computer service activities
71.11	Architectural activities
71.12	Engineering activities and related technical consultancy
71.2	Technical testing and analysis
72.11	Research and experimental development on biotechnology
72.19	Other research and experimental development on natural sciences and engineering
74.2	Photographic activities
74.9	Other professional, scientific and technical activities n.e.c.
84.22	Defence services
95.12	Repair of communication equipment

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