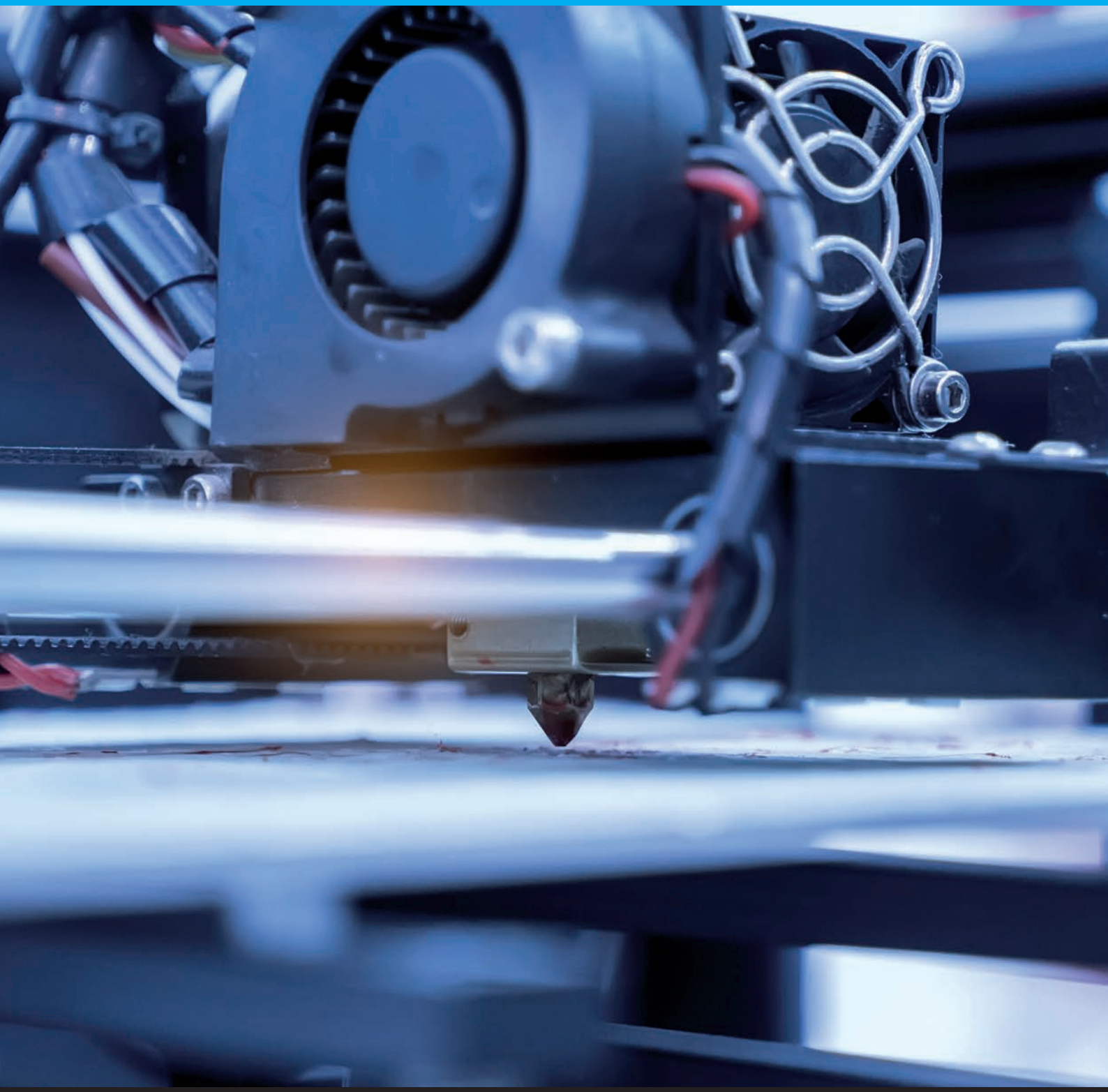
A report produced for the Institute of Physics by the Centre for Economics and Business Research | **January 2017**

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



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

In an uncertain economic climate, it is more important than ever for Scotland to focus efforts on areas that can be relied upon to deliver results.

Physics is just such one of those areas.

Scotland has long punched above its weight when it comes to physics: it is home to many internationally leading researchers and plays key roles in a number of major international collaborations.

And it serves as a base for numerous 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 yet undertaken of the role of physics in growth and productivity in Scotland. It demonstrates something that we always suspected: physics is not just the source of inventions and ideas, but also the means by which the country's economic future can be secured.

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

But 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 Scotland is built on past investment in cutting-edge physics, and we know that it is often the basic, curiosity-driven research of today that inspires and underpins the applications and technologies of tomorrow.

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

The Institute of Physics is working with communities across the country to ensure that the benefits of physics are maintained and the investments necessary for this are secured.

We will continue to 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.

Professor Martin Hendry
Chair, IOP Scotland

Physics in the Scottish economy

£15 bn

Aggregate gross value added (GVA) of the physics-based industries was £15 bn in 2013

12.1%

Which is a 12.1% share of GVA generated by the entire Scottish business economy

£31.6 bn

Add in indirect effects and overall GVA rises to £31.6 bn

£15 bn | **+ £16.6 bn**

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£77,725

A person employed in Scottish physics-based industries contributed an average of £77,725 a year in value added

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199,000 → 7.9%

Employment in physics-based industries topped 199,000 in 2015

That's 7.9% of the total workforce

↓

522,020

Add in indirect effects and overall jobs rises to 522,020

199,000 | **+ 323,020**

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£43.5 bn → £94.6 bn

Physics-based industries generated turnover to the value of £43.5 bn

Add in indirect effects and overall turnover rises to £94.6 bn

£43.5 bn | **+ £51.1 bn**

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Introduction

This report examines the contribution and importance of physics to Scotland'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 2011–13 with some additional data from 2014 and 2015.

When using absolute indicators, we compare the contributions of Scotland's physics-based industries with other sectors, such as manufacturing, construction and retail, and also with other UK nations.

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 Scotland'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 Scotland and the other nations of the UK in absolute terms
- How the indicators for the physics-based industries compare with other important sectors of the Scottish economy

The appendix provides a full list of physics-based industries.

Centre for Economics and Business Research, London 2017

Productivity, economic growth and prosperity

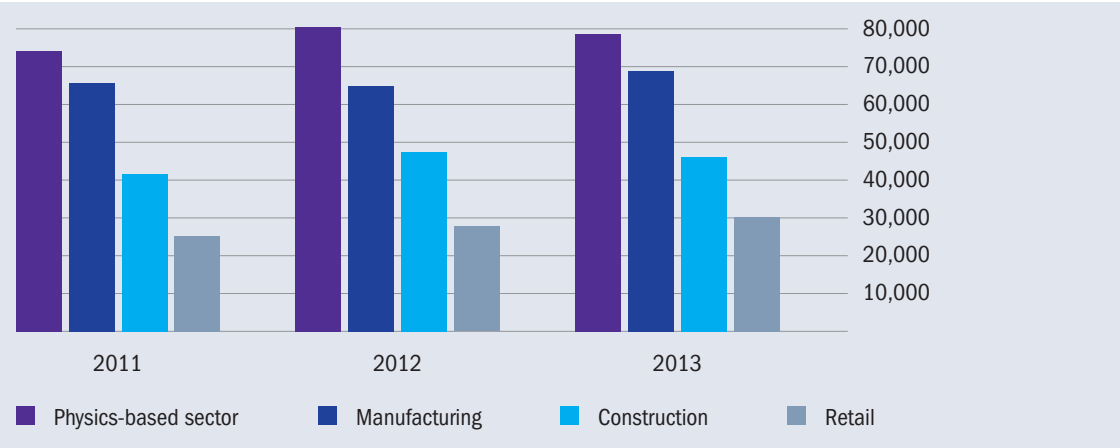
Future prosperity in Scotland requires growth in the economy. This, in turn, depends on the quantities of the factors of production employed (specifically, labour and capital) and the efficiency with which those quantities are utilised. Growth can be sustained by increasing the amounts of labour and/or 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.

This section considers the contribution of physics-based industries to economic growth in Scotland through the levels of labour productivity in those located there. We first consider productivity levels in current price terms before presenting our estimates of productivity growth in real terms.

£77,725

A person employed in Scottish physics-based industries contributed an average of £77,725 a year in value added

Apparent labour productivity (value added per person employed per year) (£)

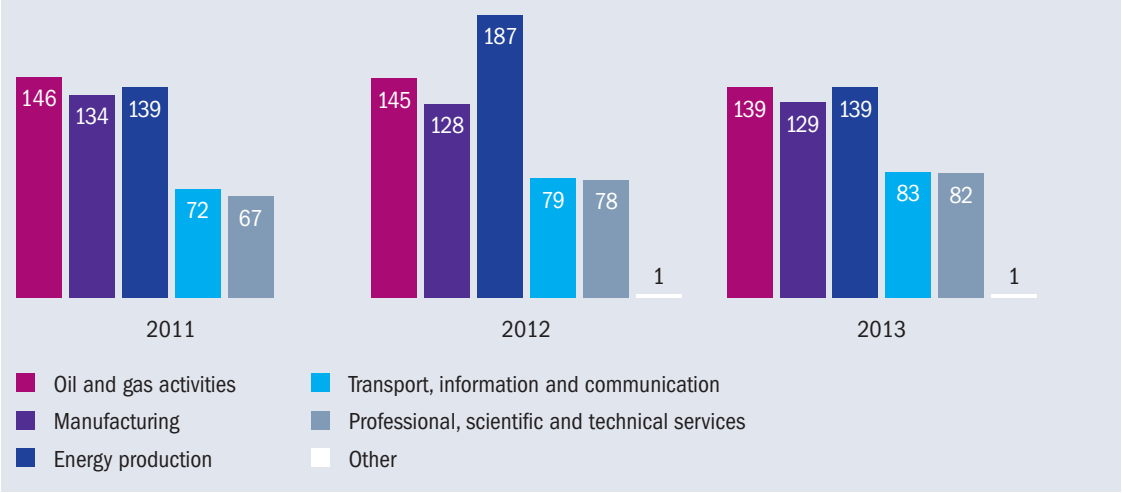


High levels of productivity per employee

The figure compares gross value added (GVA) per person employed in physics-based industries relative to comparator sectors. Throughout the period under consideration (2011–13), a person employed in physics-based industries contributed an average of £77,725 a year in value added. This is markedly above both the manufacturing and construction sectors' average labour productivity levels, which averaged £66,437 and £45,061 respectively. The average across physics-based industries is almost three times the equivalent figure of £27,691 in retail.

A divergence between GVA per person employed in oil and gas and the other physics-based industries is not seen in Scotland. Manufacturing is consistently on a par with oil and gas, while energy production is higher than or equal to oil and gas in two out of the three years. Transport and communications and professional services measure higher in Scotland than in either England or the UK.

Labour productivity within different physics-based sub-sectors (£'000)



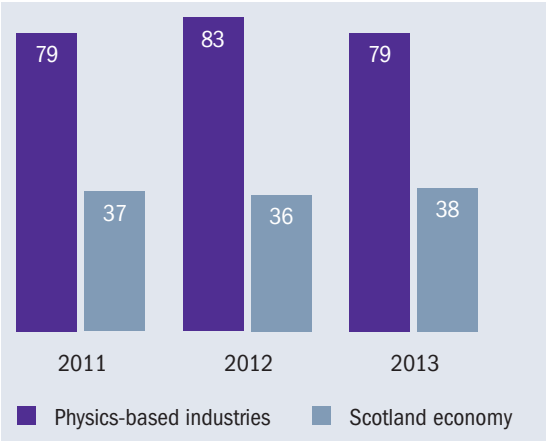
Without oil and gas or energy activities, the physics-based industries' average GVA per person employed over the period would have only been £62,017. While this is higher than construction and retail, it is not as high as for Scottish manufacturing.

What is also clear is that the Scottish physics-based manufacturing industries generate more value added per person employed (on average £130,394 in the years 2011–13) than the wider manufacturing sector (which averaged £66,437 over the same period). This suggests that those production processes that draw more heavily upon physics sustain a greater level of labour productivity relative to the average for manufacturing as a whole, as observed throughout the rest of the UK.

Real productivity growth in physics-based industries

The figure opposite provides our estimates of the same measure of labour productivity for the entire economy. Clearly, physics-based industries' average GVA per person employed is significantly greater than that of Scotland's economy as a whole – in fact, more than twice as large. Growth over the period averaged 1.4%, but reached 5.9% growth between 2012 and 2013. This is stronger than that estimated for physics-based industries, but the whole-economy growth estimates are taken from a lower base.

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



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

The figure opposite provides GVA per hour worked for Scottish physics-based industries in comparison to that for Scotland's business economy as a whole. There is a stark difference between physics-based industries and the economy-wide average.

GVA per hour worked grew strongly in 2012, by almost 7%, but declined again slightly in 2013. Once the data are released, it is likely that the same significant decline observed at the UK level in 2014 will also be seen in Scotland. Scotland is onshore home to much of the UK's oil and gas activities and is therefore unlikely to have been immune from the declines in that industry observable at the UK level.

£15 bn

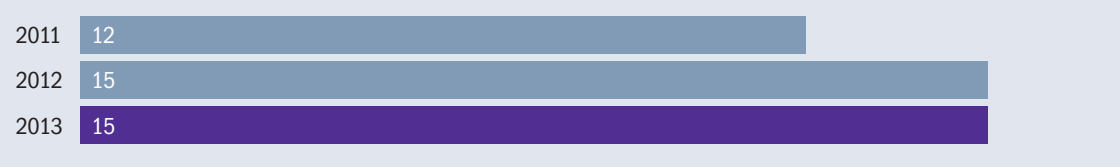
Aggregate GVA of the physics-based industries was £15 bn

Which is a 12.1% share of GVA generated by the entire Scottish business economy

Physics-based industries' GVA contributions to GDP

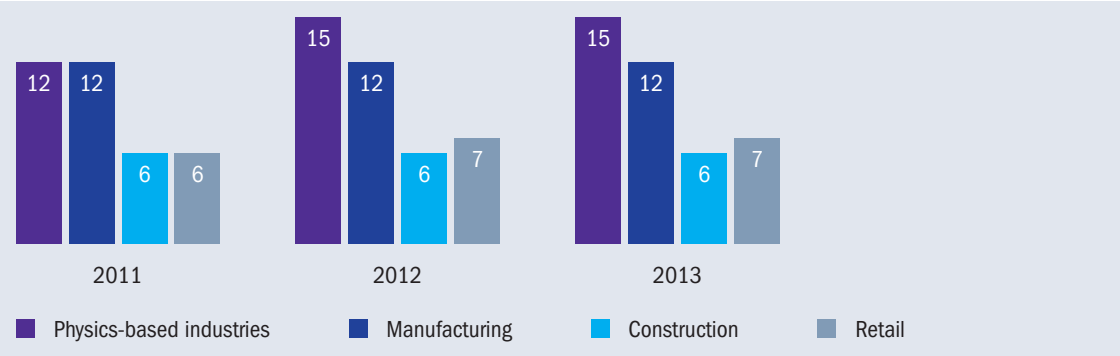
This section considers the contribution of physics-based industries to economic growth in Scotland through the levels of labour productivity in those located there. We first consider productivity levels in current price terms before presenting our estimates of productivity growth in real terms.

GVA in physics-based industries (£ billions)



The latest data suggest a £15 bn GVA contribution in 2013. Annual growth averaged 11.4% between 2011 and 2013, but was strongest in 2012 at 21.3%. This is compared with the same selection of other sectors in the graph below. Physics-based industries' GVA contributions exceed those of the broad manufacturing sector in Scotland, which is not the case in England or Wales. The GVA contributions are more than twice the size (in turnover terms) of the Scottish retail sector and almost three times the size of the construction sector.

Selected sectors' GVA contributions to Scottish GVA at basic prices (£ billions)

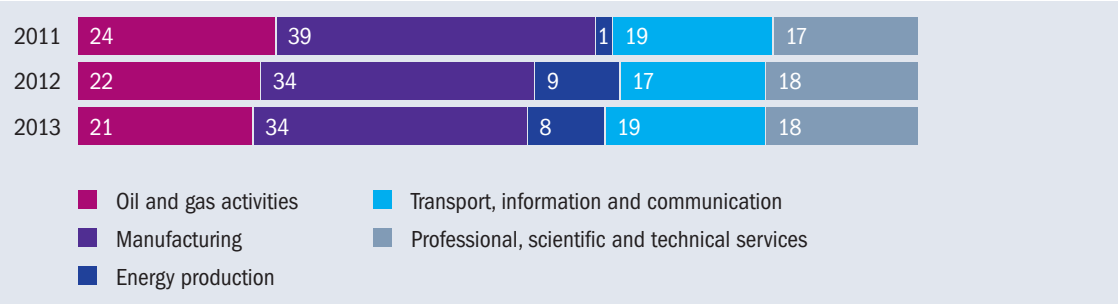


These figures do not include the substantial GVA contributions of oil and gas activities in the the North Sea. In the regional accounts, this is categorised as "ex regio" – that is, values that cannot be assigned to regions. If these values were assigned to Scotland, physics-based industries' GVA then contribution would be a lot higher, at close to £40 bn.

The graph below provides a category breakdown for the GVA estimates. Oil and gas is a more significant contributor to Scotland's physics-based industries, even in the absence of the ex-regio data, but the lion's share belongs to physics-based manufacturing. The next largest contributors are transport and communications and professional services, but these are commensurately reduced given the prominence of oil and gas relative to England or Wales.

With a lower share of Scotland's employment, the physics-based industries generate a greater GVA contribution to GDP than the retail sector.

GVA composition in physics-based industries (%)



Physics-based industries' GVA multiplier (= 2.22)

Direct impact:
£1.00

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.

Indirect impact:
£0.67

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 £0.67 for every additional £1 of GVA in the physics-based industry.

Induced impact:
£0.55

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 £0.55 for every additional £1 of GVA in the physics-based industry.

GVA (at basic prices) of physics-based industries was estimated to be £15 bn in 2013, making up a 12.1% share of the GVA generated by the entire Scottish business economy.

The estimate of the Scottish GVA multiplier is 2.22. This is lower than the UK and England estimates, but is higher than that for Wales.

There is some leakage of the GVA impacts of Scotland's physics-based industries as a result of indirect supply chain and induced spending impacts from Scotland to the rest of the UK. Combining the multiplier with the direct impact of £15 bn results in an estimated aggregate impact of £31.6 bn.

£16.6 bn

Add in indirect effects and overall GVA rises to

£31.6 bn

199,000

Employment in physics-based industries topped 199,000 in 2015

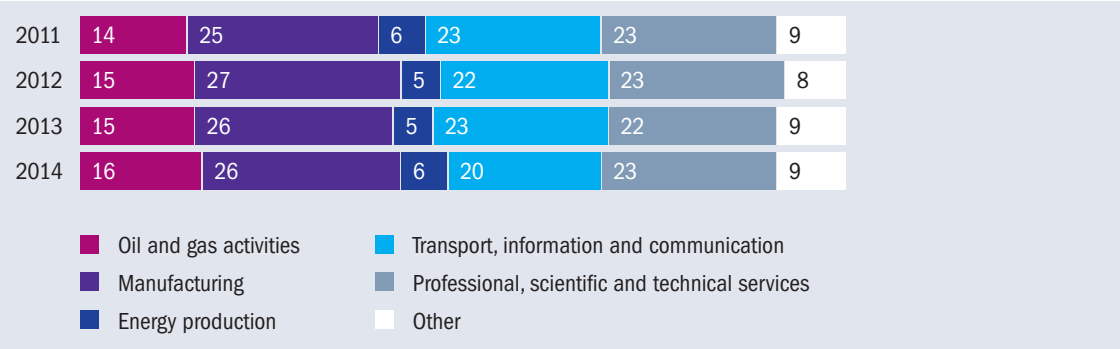
That's 7.9% of the total workforce

Employment

Cebr's estimates suggest that employment in physics-based industries topped 199,000 in 2015. This represents a 1.5% decline from 2014 levels, but 2014 had seen strong growth of 7.5% from the 2013 level. Growth was also strong in 2013 at 4.0%. Employment in physics-based industries amounted to a 7.9% share of total employment in Scotland in 2015.

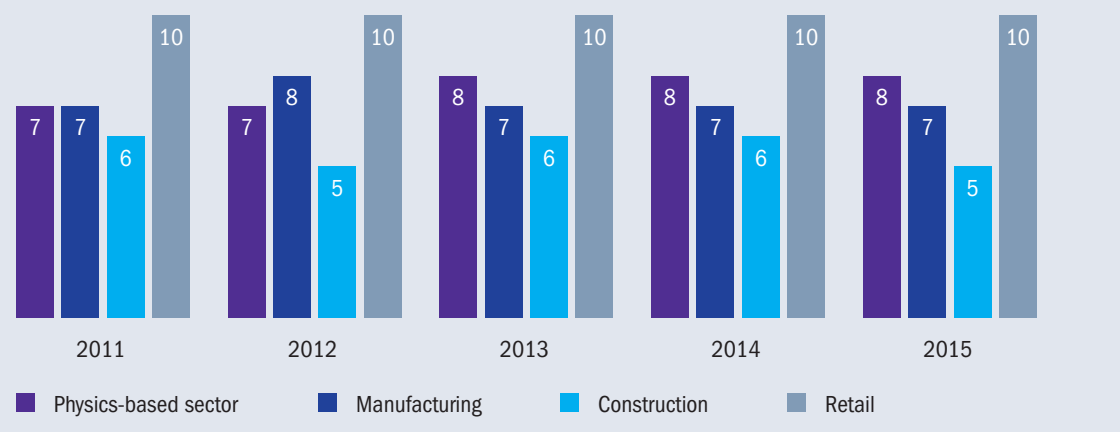
Physics-based industries' activities also support jobs in the wider economy. This multiplier effect is created when they purchase intermediate inputs from other sectors of the economy, with the activity thus supporting indirect jobs in their supply chain, and when the direct and indirect employees of 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.

Employment composition in Scotland's physics-based industries (%)



Large shares of employment in physics-based industries are accounted for by manufacturing activities (26% on average), but transport and communications and physics-based professional services are also significant (with shares of 23% and 20% in 2015, respectively, and with the latter overtaking the former in the same year).

Selected sectors' shares of Scotland's employment (%)



Oil and gas (with 16% share of total employment in the Scottish physics-based industries) is the other broad sector of note. Despite low shares of employment, this sector contributes more significant shares of physics-based industries' GVA contributions to GDP, with oil and gas accounting for 21% (but also accounting for higher shares in the past of 22–24%). The same pattern is observed for the UK as a whole.

This share of total employment is compared with the other sectors of the Scottish economy. While retail contributes a greater share of Scotland's employment, this provides further evidence of physics-based industries' advantage in labour productivity. Despite having a smaller share of Scotland's employment than the retail industry, physics-based industries generate a greater GVA contribution to GDP than retail. The same trend is observed for Wales and for the UK as a whole.

The data for 2015 suggest that physics-based industries accounted for slightly fewer than 200,000 jobs in Scotland, which represents a 7.9% share of total employment in Scotland. The estimate of the Scottish employment multiplier is 2.61.

If this is combined with the direct impact of 199,000 people in employment in Scottish physics-based industries, the aggregate contribution is 522,020.

Physics-based employment multiplier (= 2.61)

Direct impact: **1.00** job

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.

Indirect impact: **0.86** jobs

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 0.86 jobs for every additional job in the physics-based sector.

Induced impact: **0.75** jobs

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 0.75 jobs for every additional job in the physics-based sector.

323,020

Add in indirect effects and overall jobs rises to

522,020

£43.5 bn

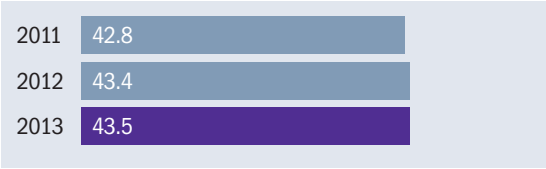
Physics-based industries generated turnover to the value of £43.5 bn

Turnover

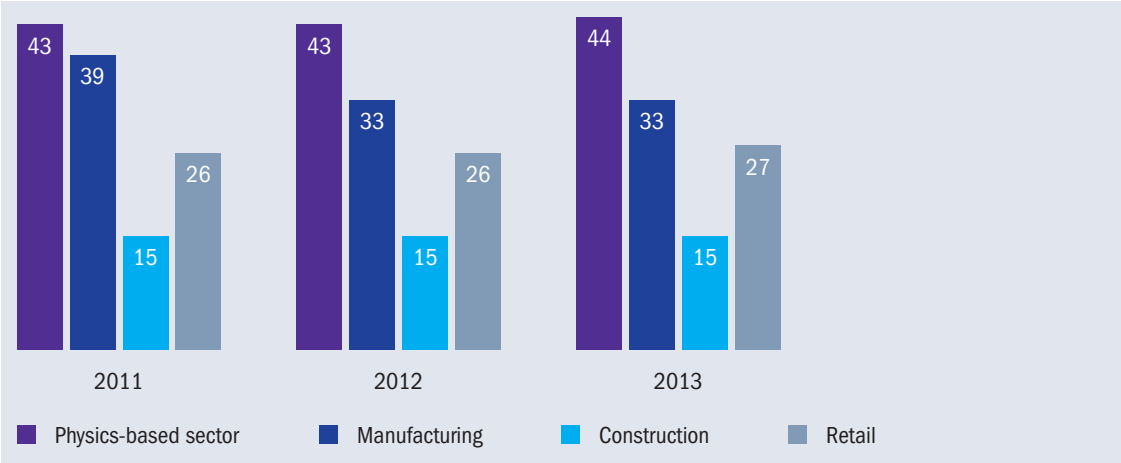
Physics-based industries generated turnover to the value of £43.5 bn in 2013. This represents marginal growth of 0.3% on the 2012 estimate of £43.4 bn.

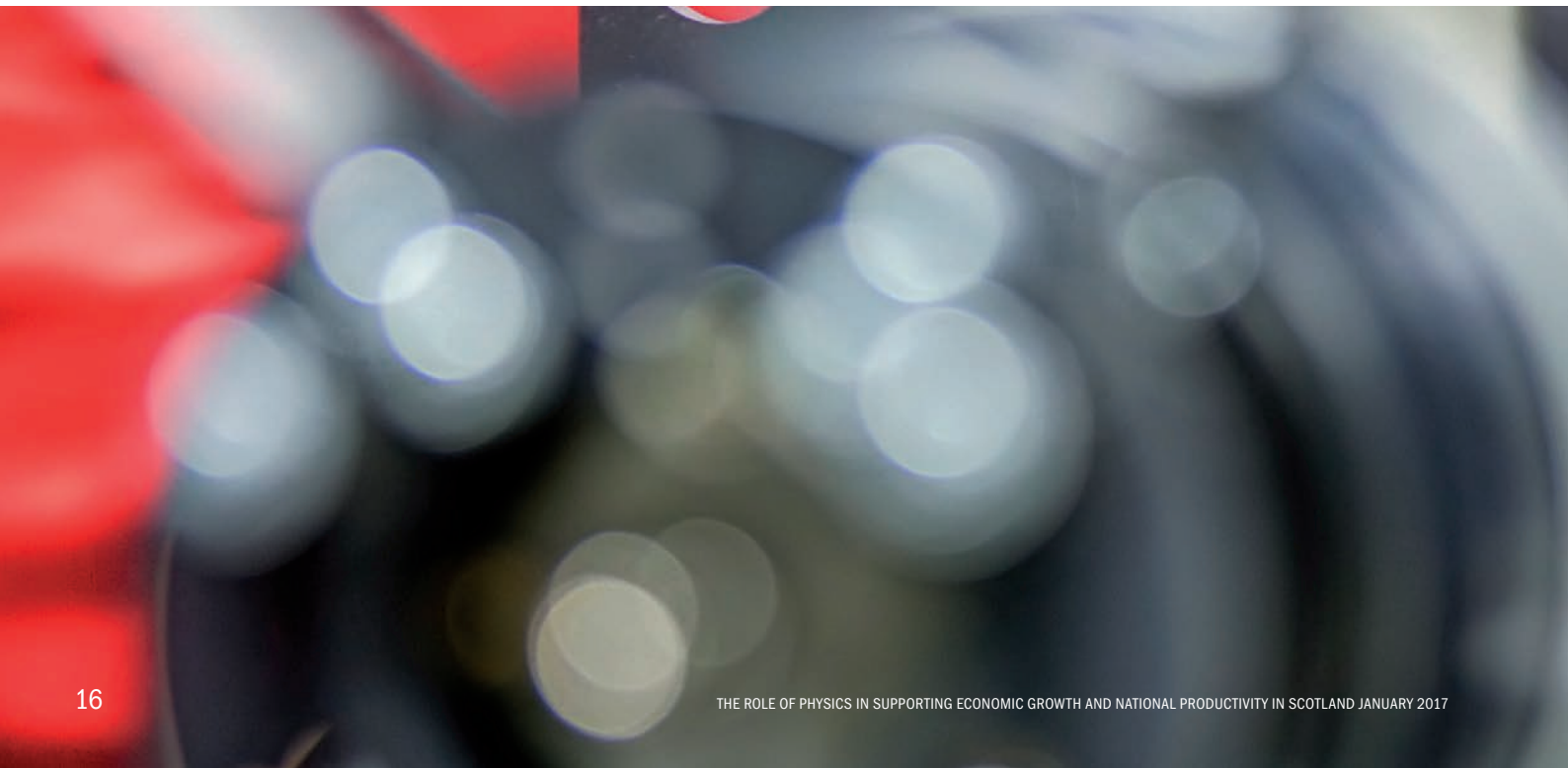
Oil and gas activities and manufacturing are clearly the dominant physics-based industries in Scotland. The contributions of energy production, transport and communications and professional services, although at levels one might expect given Scotland's size, are dwarfed by the dominant oil and gas and manufacturing sectors.

Turnover (£ billions)



Turnover in selected Scotland sectors (£ billions)





The multiplier represents estimates of the indirect and induced gross output multiplier impacts associated with the productive activities of the physics-based industries in Scotland.

Combining this with the direct turnover contribution of £43.5 bn produces an aggregate turnover contribution of £94.6 bn.

This analysis points to the important role of physics-based industries in driving productivity levels and growth in the Scottish economy.

£51.1 bn

Add in indirect effects and overall turnover rises to

£94.6 bn

Physics-based industries gross output (turnover) multiplier (= 2.17)

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. This £1 of output is the direct output impact of the relevant increment in expenditure on physics.

Indirect impact:
£0.64

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 output throughout the supply chain of £0.64 for every additional £1 of the physics-based industry's output.

Induced impact:
£0.53

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 £0.53 of output for every additional £1 of the physics-based industry's output.

Appendix

Table of physics-based industries

Definitions of physics-based industries used in this report are given below alongside their standard industrial classification (SIC) 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

Authorship and acknowledgements
This report has been produced by the Centre for Economics and Business Research, an independent economics and business research consultancy established in 1992. The views expressed herein are those of the authors only and are based upon independent research by them. The report does not necessarily reflect the views of the Institute of Physics

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