The importance of physics to the economies of Europe

Report by Cebr
Centre for Economics and Business Research
for the European Physical Society

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Foreword

Since its establishment in 1968, the European Physical Society (EPS) has held a dual role of learned society and federation of national member societies. After 45 years, the EPS has 41 member societies and represents a very large and varied community of physicists. One of the main objectives of the EPS is to give them a coherent voice despite the existence of many educational, scientific, social and geographic diversities.

Europe has a long lasting tradition of strength in science and technology, and today hosts many of the most important national and international physics research laboratories. Physics is vital to European culture. The new European research program Horizon 2020 is being launched to reinforce the intimate link between basic science and technological applications to favour Europe's progress in research and innovation, a major challenge for the future.

Along this line, key questions arise: how important is physics to the economies of European countries? And how worthwhile is it to maintain and increase investment in physics? To address these issues the EPS has commissioned an independent economic analysis from the Centre for Economics and Business Research (Cebr), using statistics available in the public domain through Eurostat. It is the first time that such a study has been performed on this scale and it covers 29 European countries – the EU27 countries, plus Norway and Switzerland. Under examination is the 4-year period 2007-2010, 2010 being the most recent year for which official data are simultaneously available for all these countries. The Cebr analysis is contained in this detailed report which was completed in December 2012, while the most important results are highlighted in a separate Executive Summary. Please see www.eps.org/physicsandeconomy for further details and downloads.

This 4-year snap-shot of the European economy shows that the physics-based industrial sector generated over 15% of total turnover and over 13% of overall employment within Europe’s business economy. To give some context to these numbers, the turnover per person employed in the physics-based sector substantially outperforms the construction and retail sectors, and physics-based labour productivity (expressed as gross value added per employee) was significantly higher than in many other broad industrial and business sectors, including manufacturing. The European physics-based sector was also highly R&D intensive and despite the effects of the global economic downturn on enterprise birth and failure rates, physics-based industries and enterprises were more resilient in comparison with the wider economy. The thorough analysis of European data, contained in this full Cebr report, can provide us with a deeper understanding of the many achievements and drawbacks within the physics-based sector in the recent past.

Our hope is that the message conveyed by the EPS through the study performed by Cebr will be inspiring for the future, both at the European and national levels, making a convincing case for the support for physics in all of its facets, from education to research, to business and industry.

Luisa Cifarelli
President of the European Physical Society

The importance of physics to the economies of Europe

A study to determine the importance of physics to the EU27 and constituent national economies through the analysis of the economic impact and structure of physics-based industry and output

Report for the European Physical Society

December 2012 – Revised January 2013

Disclaimer

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Authorship and acknowledgements

This is a report by the Centre for Economics and Business Research (Cebr) to provide the European Physical Society with an assessment of the importance of physics to the economies of Europe. Cebr is an independent economics and business research consultancy established in 1992. The study was led by Oliver Hogan, Cebr head of microeconomics with lead modelling and drafting support from Cebr economist, Osman Ismail. Cebr economists Daniel Solomon and Chitraj Channa provided research support. The views expressed herein are those of the authors only and are based upon independent research by them.

The study was commissioned by European Physical Society and is based entirely on data available in the public domain (principally through Eurostat, the EU's statistical service).

The report does not necessarily reflect the views of European Physical Society.

London, January 2013

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1 Introduction and background

The *Importance of physics to the economies of Europe* is a report examining the contribution of physics to the aggregate economy of the 27 EU nations, to its 27 individual national economies and to the economies of two of the four non-EU EFTA countries.[1] We analyse whether the use of physics has changed in the EU between 2007 and 2010. This research highlights the value generated by 'physics based industries' for the economic prosperity of Europe.[2]

This report builds on *The importance of physics to the United Kingdom economy*, a report produced by Cebr for the UK Institute of Physics in February 2007.

The report follows the following structure:

- Section 2 presents the results of our analysis of the jobs, turnover and value added contributions made by the physics-based industries - which, combined, we label the physics-based 'sector'. This is based entirely on data from Eurostat's Structural Business Statistics (SBS) database, which is based on information provided by enterprises in the European 'business economy'.

- Section 3 provides our estimates of the direct economic contributions of physics suggested by the analysis of physics within the 'national' accounting framework. This adapted framework, in which physics-based industries were given an explicit role, provided the basis for our estimates of the indirect and induced multiplier impacts of physics. For this analysis, we used the EU27 SUIOTs (supply-use input-output tables) in conjunction with assumptions developed based on our analysis of the SBS datasets in Section 2.

- Section 4 examines the 'survival' of physics-based enterprises, in terms of birth and death rates.

- Section 5 examines the contributions of physics through international trade, investment and research and development.

- Appendix I provides a short compendium of national-level estimates underlying the aggregate results that are the subject of the main body of the report.

- Appendix II provides the industry-based definition of physics-based activities used for the purposes of our study.

- Appendix III provides more detail on the methodology and data sources used in this study.

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1 The four non-EU European Free Trade Association countries are Iceland, Norway, Lichtenstein and Switzerland. Norway and Switzerland are analysed in this report. Iceland and Lichtenstein were, unfortunately, excluded from the analysis due to the lack of readily available data in a consistent form and the time limit for the study. The estimated national-level impacts of physics are presented in tabular form in Appendix I.

2 'Physics-based industries' are defined as industries where the use of physics – in terms of technologies or expertise – is critical to its existence. A fuller outline of this definition is available in Appendix II – Measuring physics in the economy.

2 Jobs, turnover and value added

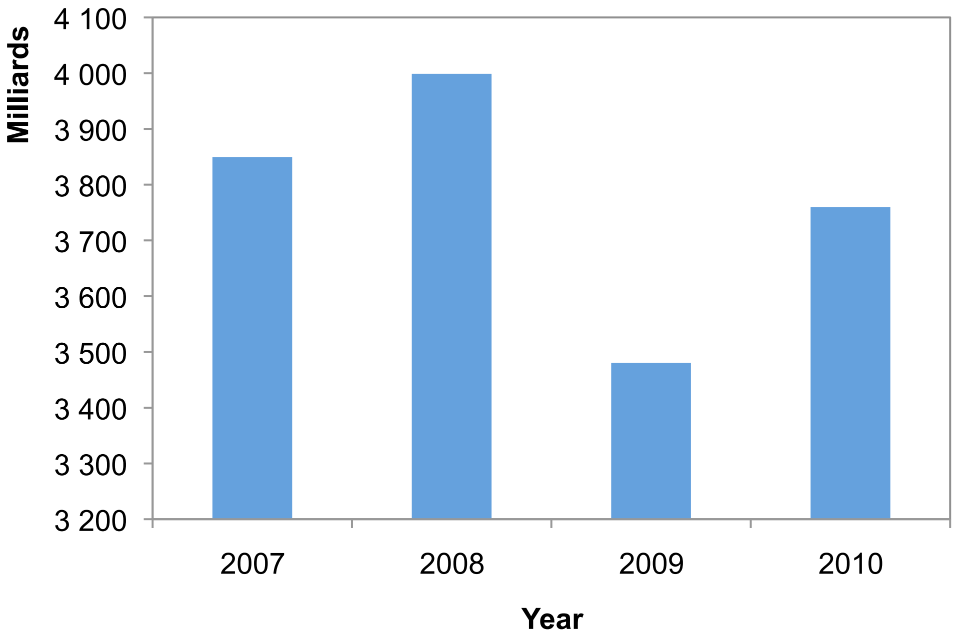
This section provides an assessment of the importance of physics-based industries to the European 'business economy' in terms of employment, turnover and gross value added over the period 2007-2010.[3] The Europe-wide assessment is supported by the national-level estimates in Appendix I for the most important indicators used in this section.

2.1 Turnover

This section examines the contribution of the physics-based industries to the European economy in terms of turnover generated by those industries.

Figure 1 shows that **the European economy's physics-based economic activities generated over €3.85 trillion in turnover during 2007**, rising by 3.9% in the subsequent year to around €4.00 trillion. But, in the recent economic downturn, **total turnover generated by physics-based activities decreased by 13.0%, reaching €3.48 trillion in 2009**. The latest year for which data were available **2010 saw a healthy bounce-back in total turnover, rising by 8.0% to €3.76 trillion**. However, we can see that turnover remains markedly below its 2008 peak by the end of our period of analysis.

Figure 1: Turnover in physics-based industries, € current prices

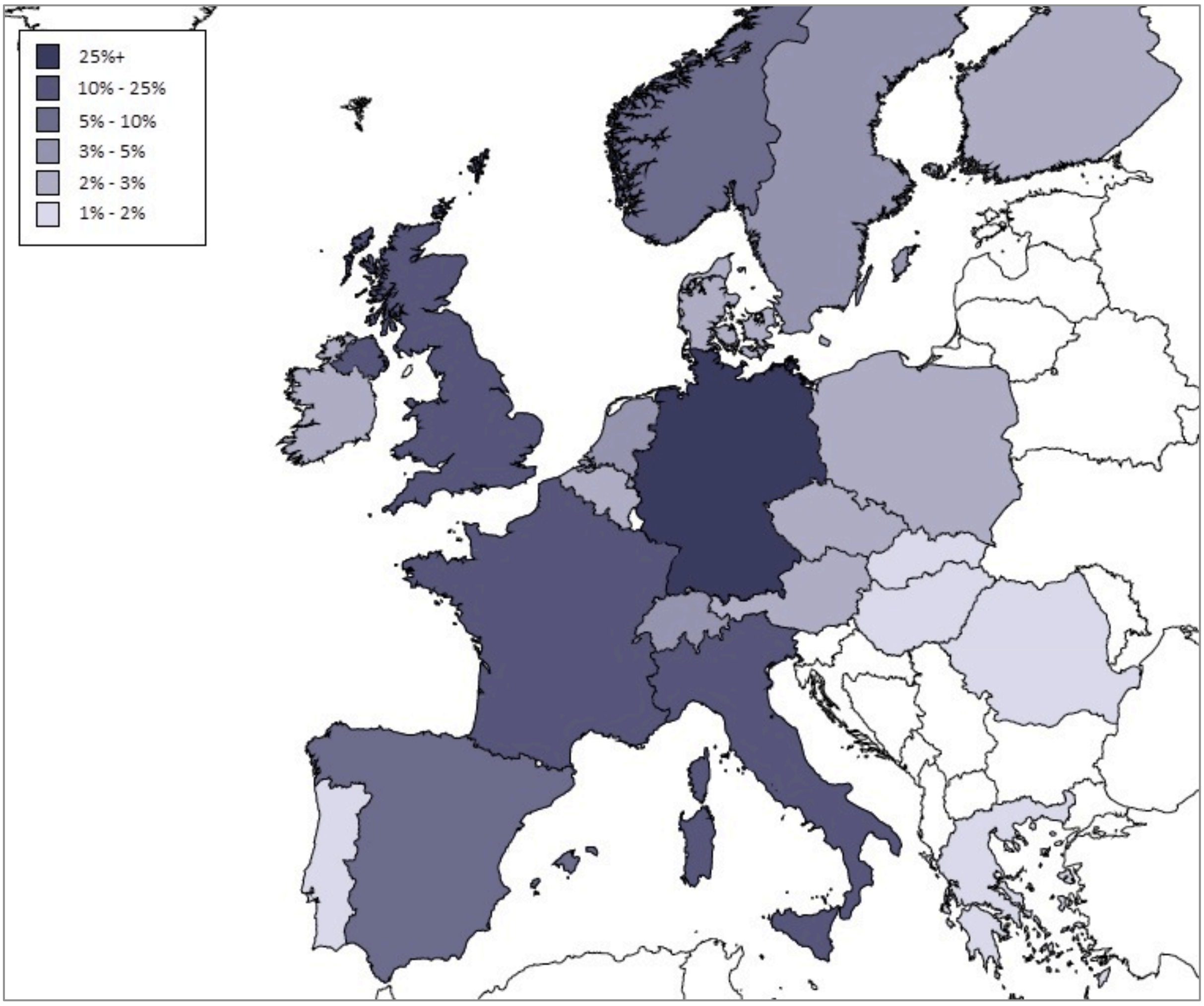


Source: Eurostat Structural Business Statistics (SBS), Cebr analysis

[3] The 'business economy' includes industry, construction and distributive trades and services and defines the scope covered by the SBS database. Financial services do not feature because of their specific nature and the limited availability of most types of standard business statistics in this area. Neither does SBS cover agriculture, forestry and fishing or public administration and (largely) non-market services like education and health.

Figure 2 below illustrates each country's share of the European physics-based sector's turnover.

Figure 2: Map illustrating country shares of total physics-based turnover in Europe; average 2007-10

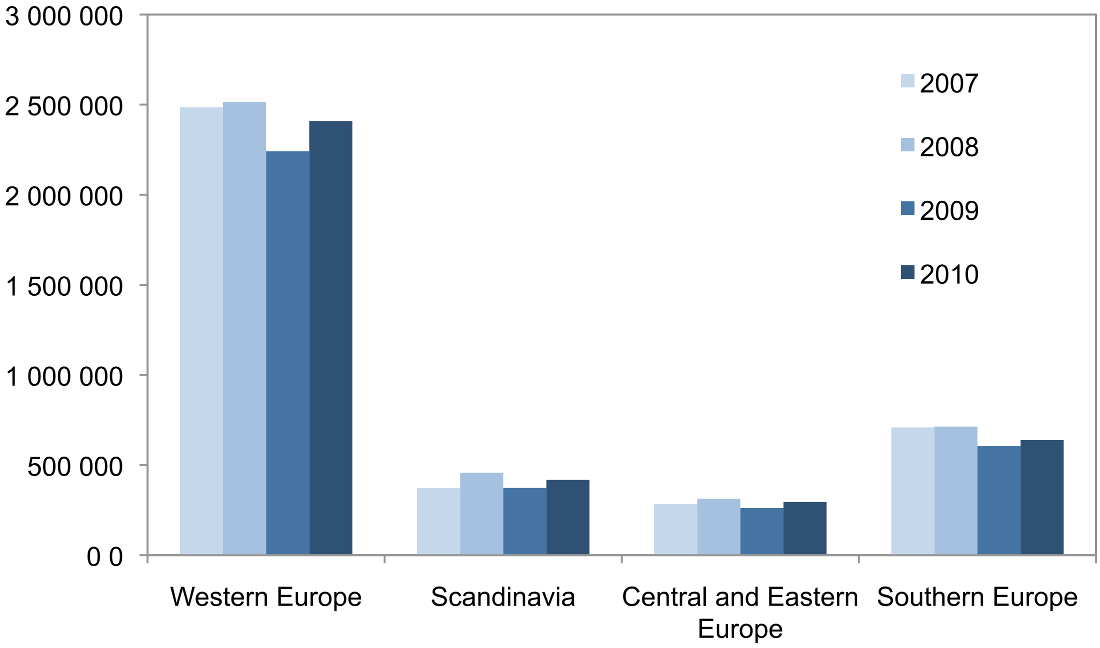


Source: Eurostat SBS, Cebr analysis

Figure 3 shows an alternative visualisation of the size of physics-based industries across Europe by turnover, and how they have fared over the years 2007-10.

Western Europe (consisting of Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands and United Kingdom) clearly dominates, accounting for almost two-thirds (64.0%) of the European physics-based sector's turnover over the four years. Southern Europe (defined as Cyprus, Greece, Italy, Malta, Portugal and Spain) is the next largest region, with an average share of 17.7% of the continent's physics-based turnover. The four countries of Scandinavia (Denmark, Finland, Norway and Sweden) account for a larger proportion of Europe's physics-based sector than the ten Central and Eastern European nations in our sample (Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia) in each year under review.

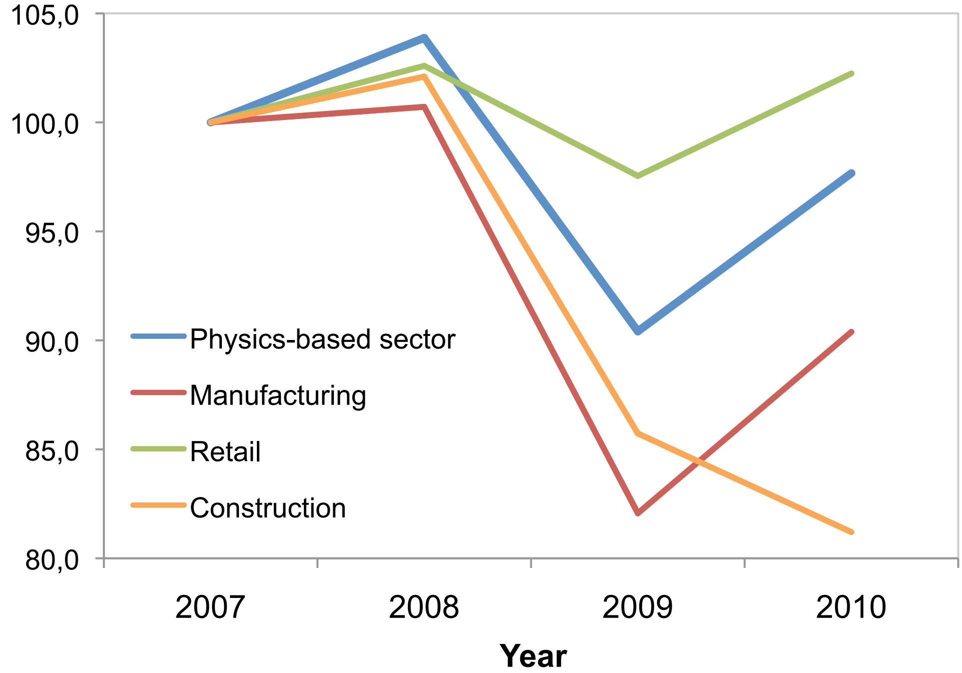
Figure 3: Regional shares of European physics-based turnover, € millions, current prices



Source: Eurostat SBS, Cebr analysis

Figure 4 provides some context for developments in the physics-based sector's overall turnover, comparing trends in the years 2007-10 for selected broad sectors (categories of industries). By 2010, turnover in the physics-based sector was higher (relative to its 2007 level) than in either of the manufacturing or construction sectors. Therefore, in turnover terms, the EU's physics-based sector has recovered more strongly from the 2009 impact of the global recession than either of these sectors. Only the retail sector outperformed the physics-based sector, with retail turnover dropping just 4.9% year-on-year during 2009 and recovering to very close to its 2008 peak in 2010.

Figure 4: Turnover in selected EU sectors, 2007-10, index (2007=100)



Source: Eurostat SBS, Cebr analysis

Section 3 examines physics-based 'output' as defined under the national accounting framework[4] and presents our finding that the physics-based sector generated about 14% of EU-27 output, which is more than the combined output of the construction and retail sectors. This is also approximately half the share of EU-27 output contributed by the entire manufacturing sector (which includes many of the physics-based industries presented in Appendix II).

The relatively high level of turnover generated by the physics-based sector is further reflected in turnover per person in employment in the sector. On this measure, the sector out-performs the broader manufacturing sector.

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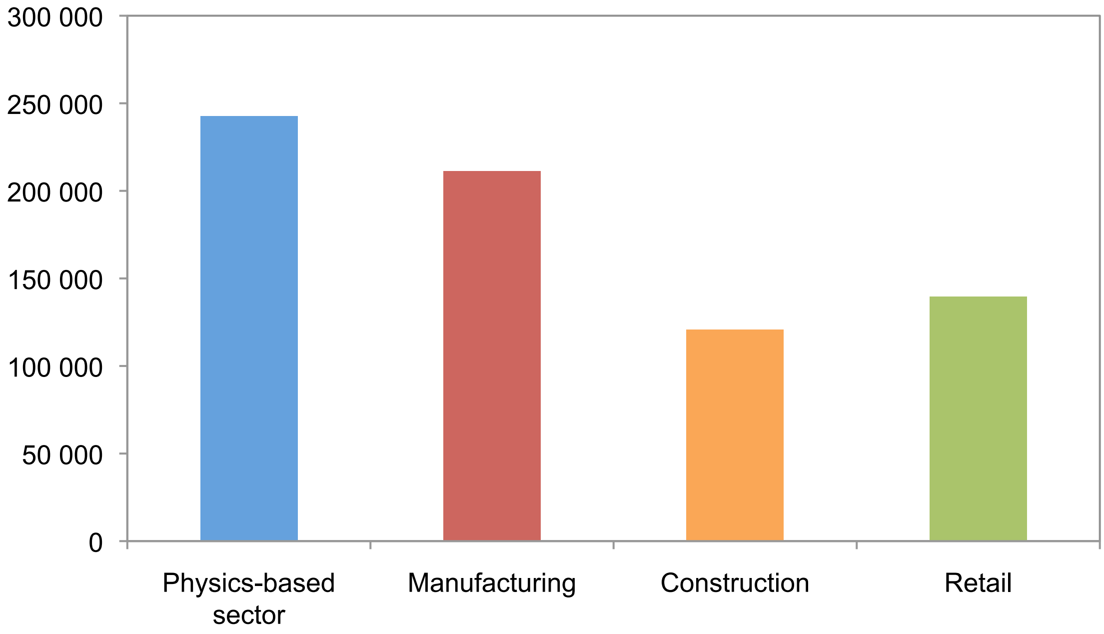
[4] What might be termed 'industrial output' under the national accounting system is valued at basic prices. This is distinct from producers' prices, the basis for turnover in the SBS datasets. See Appendix III.

Figure 5 illustrates that, over the four years 2007-2010, turnover averaged €243 thousand per person employed, over 30 thousand more than the €211 thousand generated in the manufacturing sector. The physics-based sector also substantially out-performs the construction and retail sectors on this measure.

Figure 5: Turnover per person employed in selected European sectors, average over 2007-10, € current prices

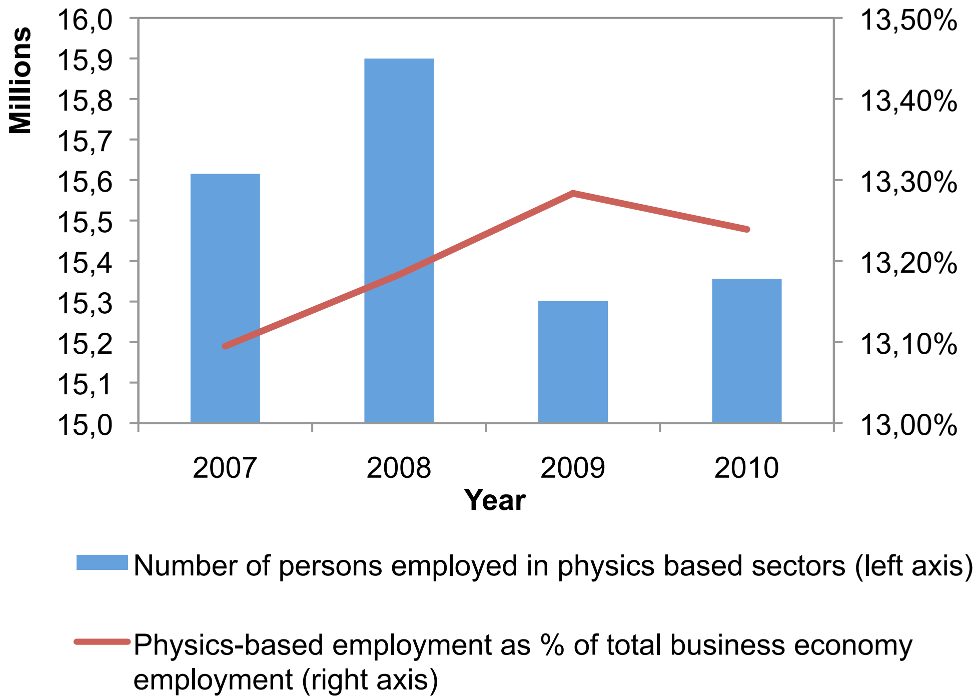


Source: Eurostat SBS, Cebr analysis

2.2 Employment

We estimate that the **'physics-based industries' accounted for the employment of around 15.9 million people in Europe in 2008** but, against a backdrop of sharp economic contraction in 2009[5], this figure had **declined to just under 15.4 million in 2010**. Employment in physics-based industries increased between 2009 and 2010, but overall employment grew more quickly, leading to the share of physics-based employment in the total business economy decreasing marginally.

Figure 6: Physics-based employment in Europe, 2007-10

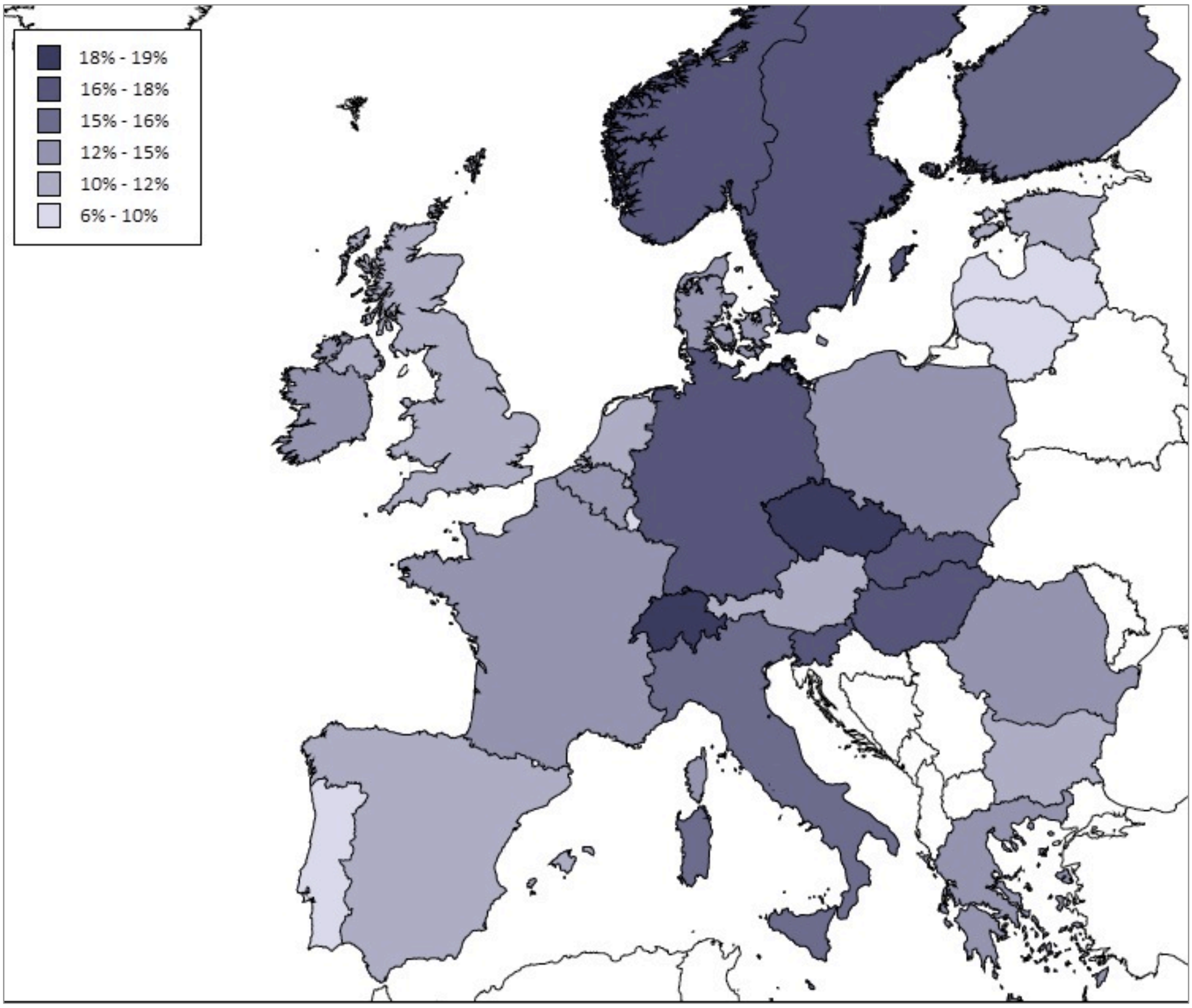


Source: Eurostat SBS, Cebr analysis

[5] The EU27 suffered a 4.3 per cent real decline in the bloc's GDP in 2009.

Figure 7 illustrates the variation in the proportions of employment accounted for by the physics-based industries in each country under analysis.

Figure 7: Physics employment density: percentage of business economy employment accounted for by physics-based sectors; 2010

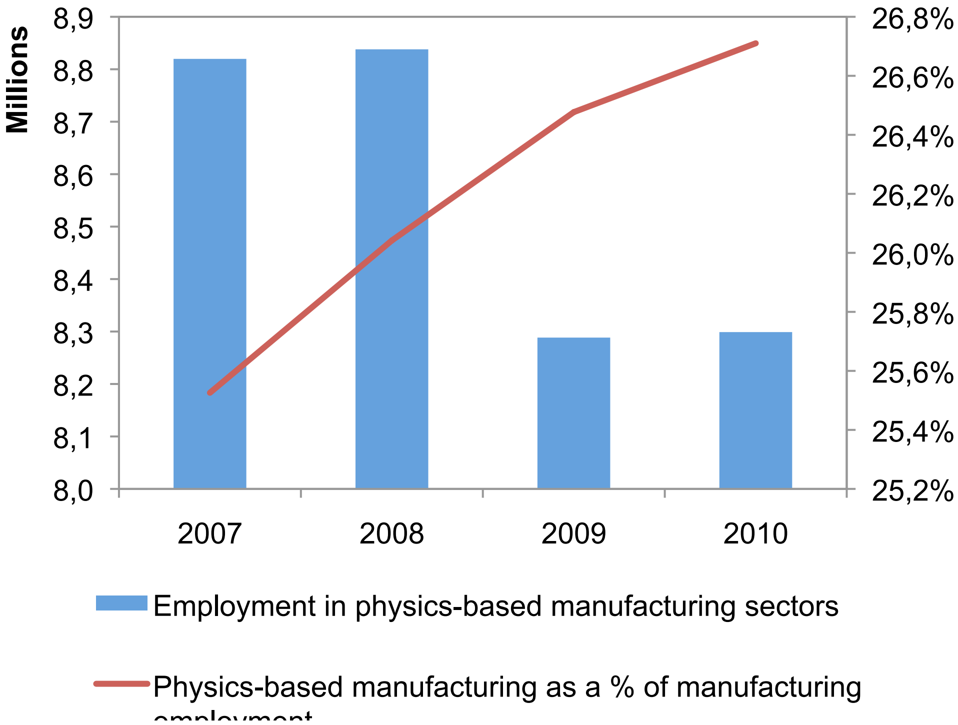


Source: Eurostat SBS, Cebr analysis

Large shares of employment in the physics-based industries are accounted for by manufacturing activities. This means that the performance of the manufacturing sector will have a bearing upon the employment levels and profiles of the physics-based industries. During the years 2007-10, the observed fall in employment within Europe's manufacturing sector was 10.1%. The decline in physics-based manufacturing employment was not as sharp.

Figure 8 illustrates that **employment within physics-based manufacturing industries decreased from 8.8 million in 2007 to around 8.3 million in 2010**, representing a drop of 5.9%. However, the share of physics-based manufacturing employment in overall EU manufacturing employment rose in every year from 2007-10. This suggests that manufacturing activities utilising some degree of physics are becoming more important in the wider manufacturing sector.

Figure 8: Physics-based manufacturing employment in Europe, 2007-10

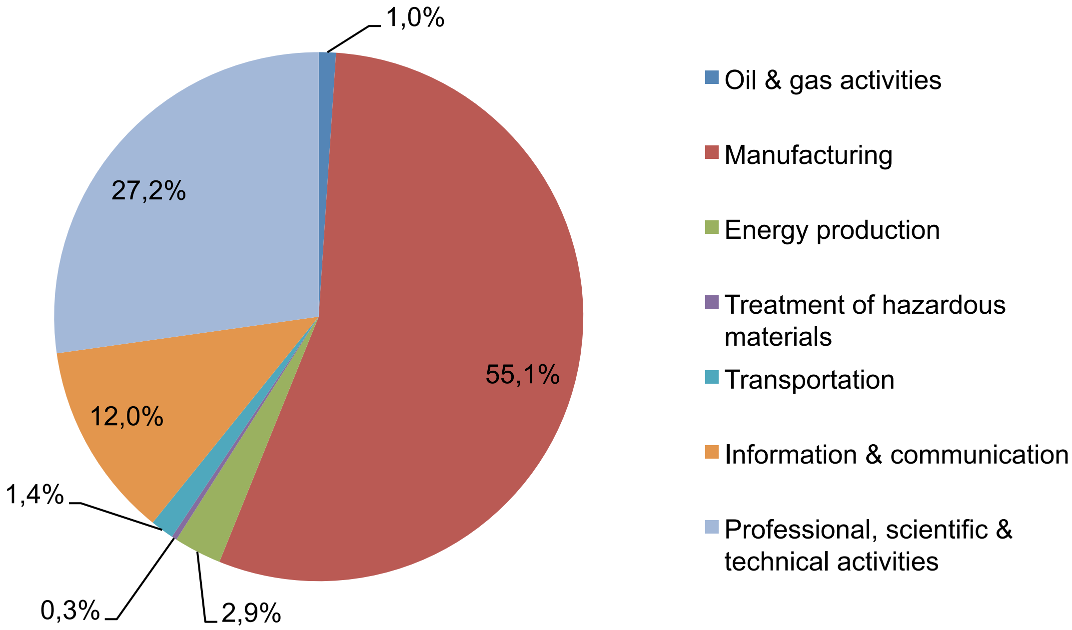


Source: Eurostat SBS, Cebr analysis

While manufacturing accounts for the lions share of physics-based employment,

Figure 9 demonstrates the other broad categories of activities that are dependent on physics. These are not insignificant, with professional, scientific and technical activities in 2010 accounting for **employment totalling 4.3 million in fields where physics is important like architecture, engineering and research and development**. In the same year, the information and communications sector is estimated to have provided **1.8 million jobs through physics-based activities related to telecommunications**.

Figure 9: Physics-based employment by broad sector, average over 2007-10



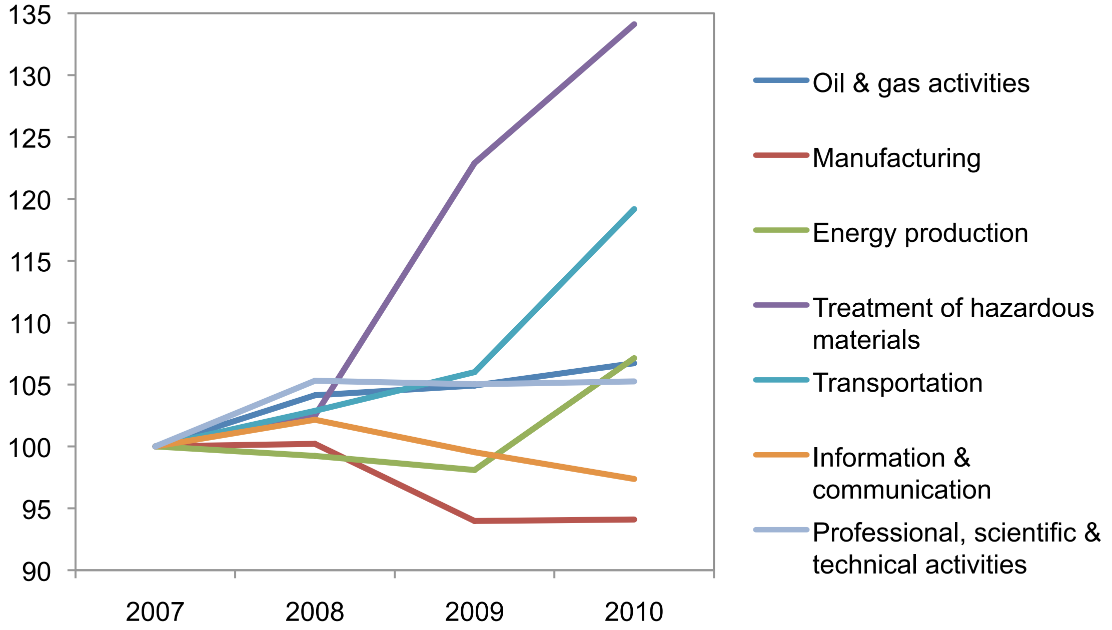
Source: Eurostat SBS, Cebr analysis

The proportions illustrated in

Figure 9 are not static across all years of the analysis. Some sectors have experienced growth in physics-based employment while others have experienced declines.

Figure 10 indicates the development of different sectors' levels of physics-based employment relative to their levels in 2010.

Figure 10: Physics-based employment by broad sector, index (2007=100)



Source: Eurostat SBS, Cebr analysis

The starkest increase over the period is observed in the treatment of hazardous materials sector, referring to the re-processing and/or disposal of hazardous industrial or radioactive waste. But this sector is a relatively small contributor to overall physics-based employment, and the increase of 34.1% represents a rise in employment of approximately 15,000 people. The manufacturing sector and information and communications sectors were the only ones seeing declines in the number of physics-dependent jobs over the period 2007-10.

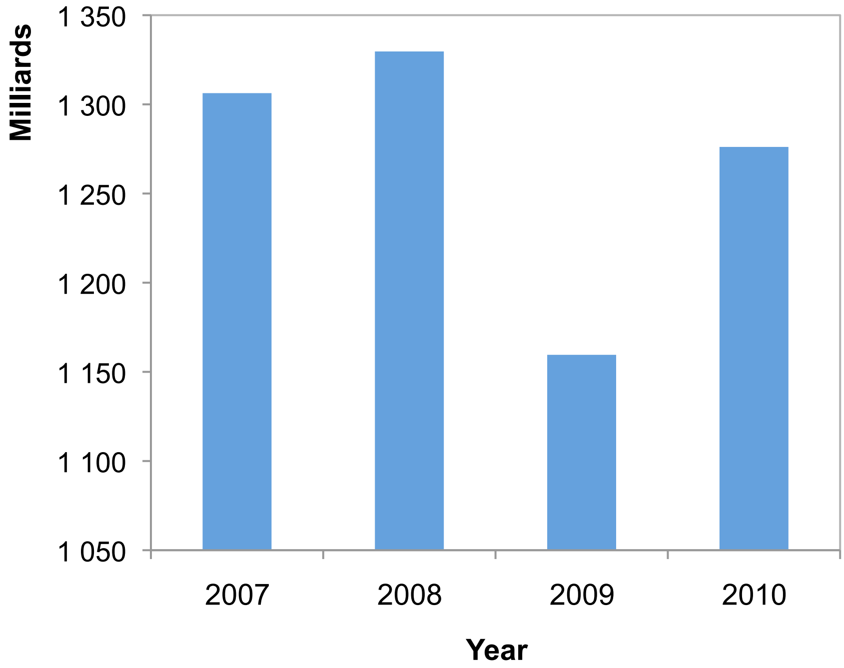
The broad sectors experiencing growth in physics-based employment were estimated to include the oil and gas extraction, transportation, energy production and professional and technical services sectors. The latter, representing physics-based engineering, technical consultancy and research and development, was the area of strongest employment growth during the years 2007-2010 in terms of absolute numbers, with the number of persons employed rising by around 213 thousand, an increase of 5.3%. The European economy saw a drop in employment of approximately 1.0% over the years under review, so the performance of physics-based industries in terms of retaining and adding jobs can be considered resilient during a period of considerable upheaval in the European labour market and wider economy.

2.3 Value added

We now focus on the economic contribution of the physics-based industries (or sector) to the European economy in terms of their value added. Value added is a measure of the total output of a sector, industry or economy; after subtracting the inputs of goods and services that were required to generate this output.[6]

Figure 11 illustrates that the **GVA contribution of the European physics-based sector stood at €1.31 trillion in 2007**, rising by 1.8% to €1.33 trillion in 2008. **The economic downturn of 2009 saw a 12.8% contraction to just under €1.16 trillion**. This was followed in 2010 by an increase of around €116 billion, a rise of 10.1%, leaving the physics-based sector's GVA contribution at **just under €1.28 trillion at the end of our period of analysis**. This is suggestive of a robust rebound from the recession.

Figure 11: Gross value added in physics based sectors, €, current prices

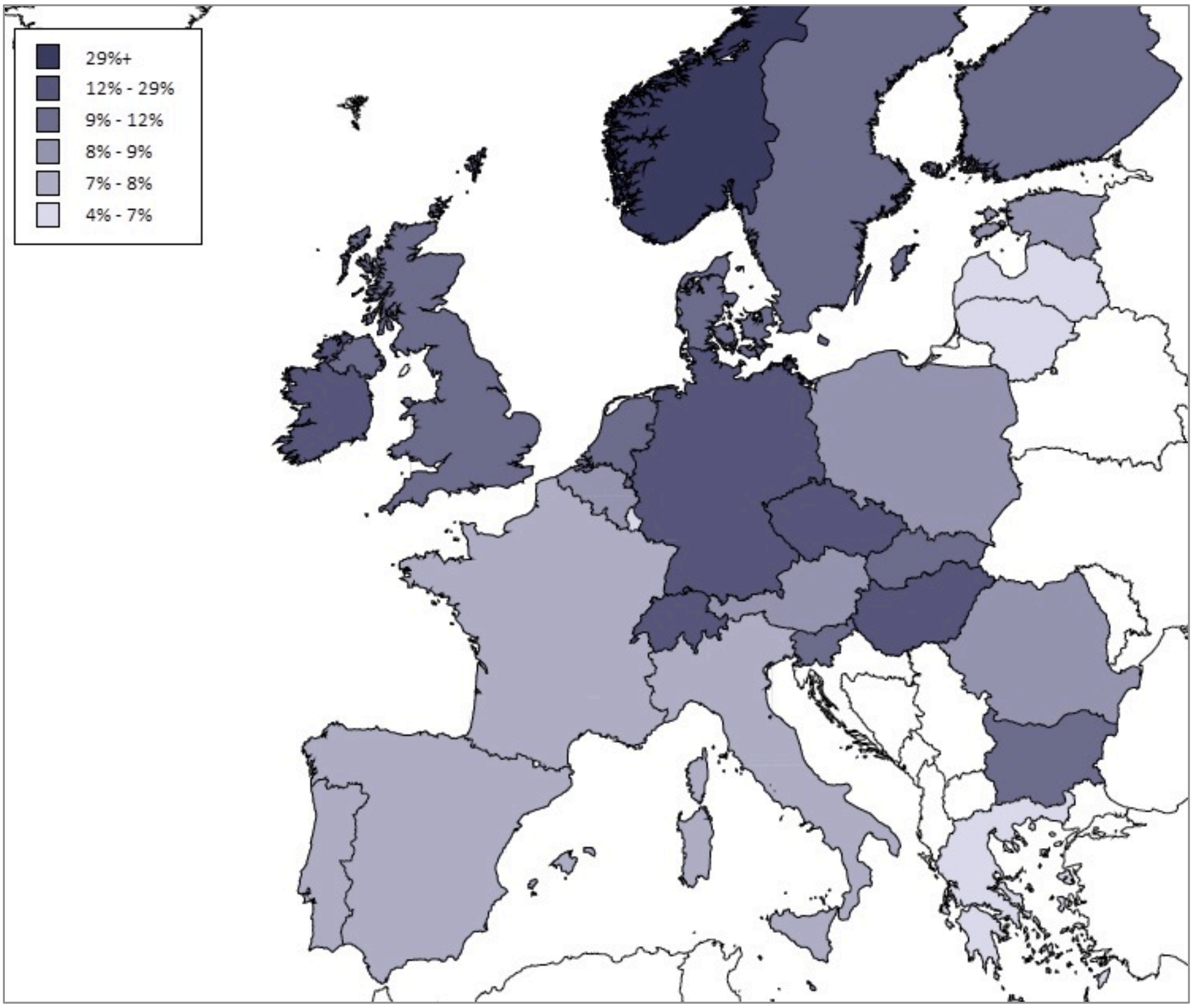


Source: Eurostat SBS, Cebr analysis

[6] Value added in the SBS context is distinct from the national accounting concept of gross value added (GVA). The latter is valued at basic prices while value added is expressed in terms of producers' prices. See Appendix III. See footnote 9 for a definition of GVA..

Figure 12 illustrates the differences in the importance of the physics-based industries in different countries across Europe in generating value and thereby contributing to their nations' overall economic performance, as measured by the physics-based sector's GVA contribution as a share of overall GDP.

Figure 12: Physics density: Map illustrating physics-based sector GVA as a proportion of GDP, average 2007-10

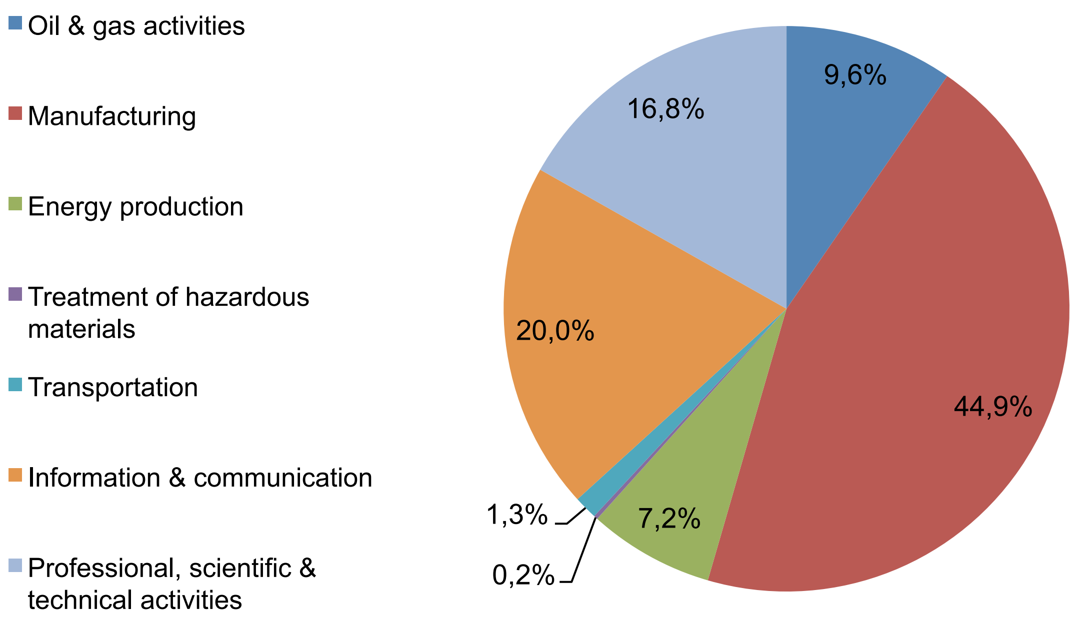


Source: Eurostat SBS, Cebr analysis

Each industry within the physics-based sector does not, however, contribute value added at the same rate. The majority share is again accounted for by physics-based manufacturing, as illustrated in

Figure 13. The period 2007-2010 saw physics-dependent manufacturing contributing just under half (44.9%) of the overall physics-based sector's GVA. The next largest contributor was the physics-dependent element of the broader information and communications industry, referring to telecommunications and broadcasting activities, which accounted for a fifth (20.0%) of the physics-based sector's GVA.

Figure 13: Physics-based GVA accounted for by physics-based industries, average 2007-10

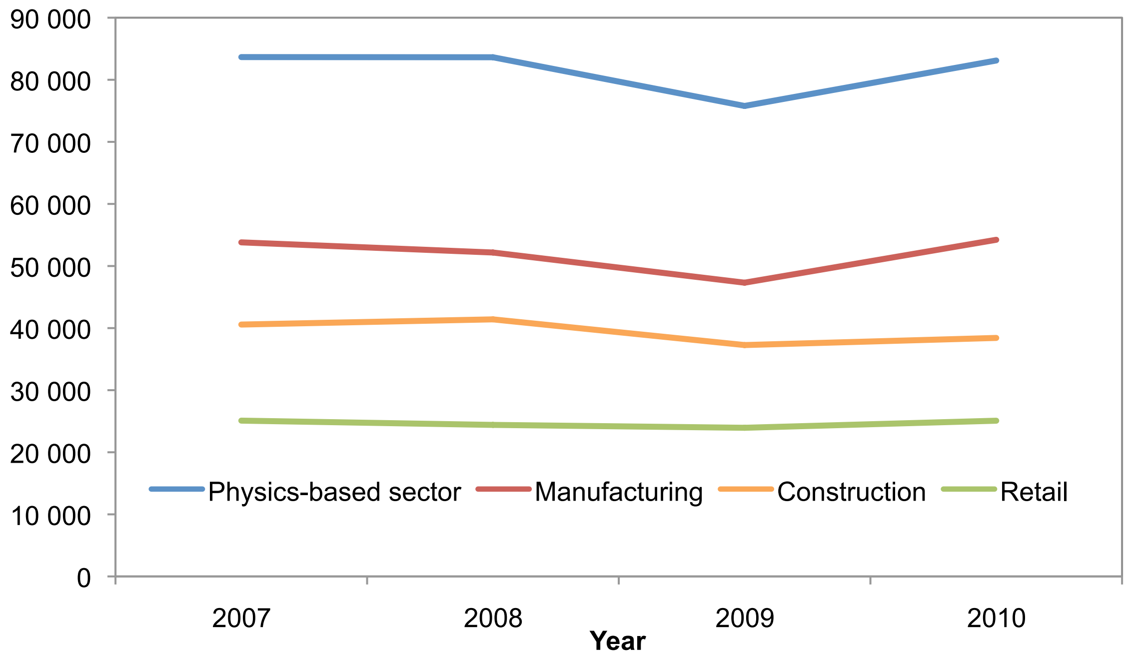


Source: Eurostat SBS, Cebr analysis

These GVA data can, in conjunction with corresponding employment data, be used to estimate labour productivity in the physics-based sector relative to other sectors. Figure 14 compares GVA per person employed in the physics-based sector relative to the same sectors that we have been using as comparators up to now. This suggests that the physics-based sector's labour productivity is significantly higher that any of these other broad sectors.

Throughout the period under consideration, an employee in the physics-based sector contributed an average of €81,600 per annum in value added. This is markedly above the manufacturing sector's productivity, which averaged €51,900 and over twice the equivalent figure of €39,500 in the construction industry.

Figure 14: Apparent labour productivity (value added per person employed per year), €, 2007-10



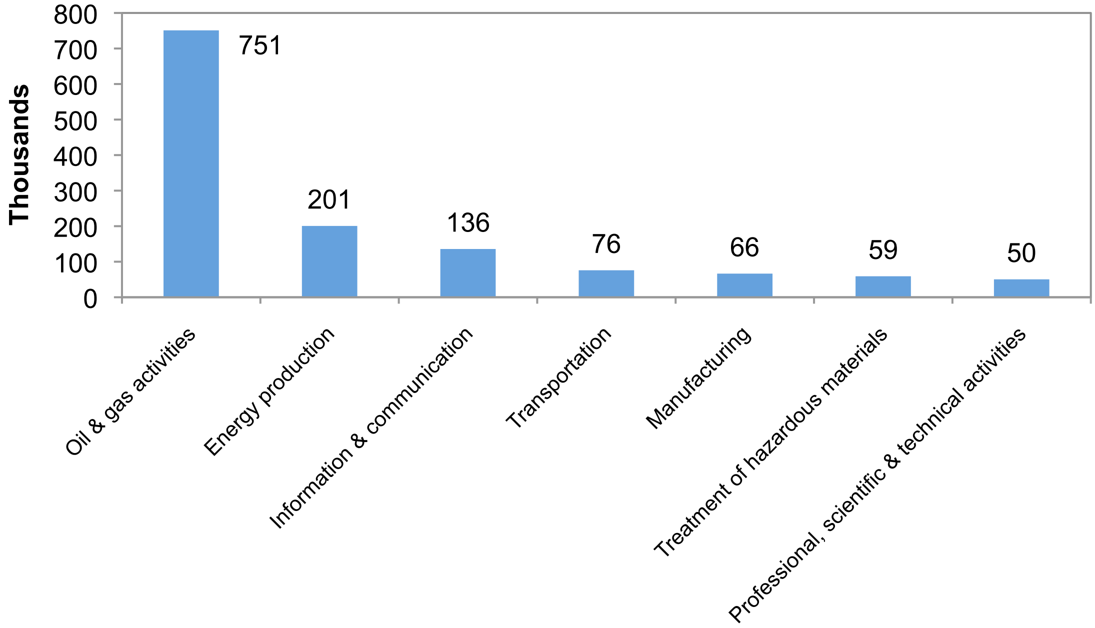
Source: Eurostat SBS, Cebr analysis

This suggests that the technology-intensive nature of physics-dependent activities produces greater labour productivity (GVA per worker) than is observed on average. Physics-based activities are not, of course, homogeneous and within the physics-based sector, significant disparities can be observed between the productivity levels of different types of physics-based activity.

Figure 15 illustrates the large divergence between GVA per person employed generated in those physics-based activities that belong to the wider mining & quarrying sector, which provides a significant boost to the physics-based sector's overall productivity levels. Without this boost and that provided by the physics-based productivity in the energy sector, the physics-based sector's average GVA per person employed would have only been €74,500, but this would still be markedly above the other broad sectors considered above. In other words, even if the mining and quarrying outlier is excluded, the physics-based sector outperforms the productivity of the manufacturing, construction and retail sectors.

Furthermore, physics-based manufacturing activities generate more value added per person employed (approximately €66,400 in the years 2007-10) than the wider manufacturing sector (averaging €51,900 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.

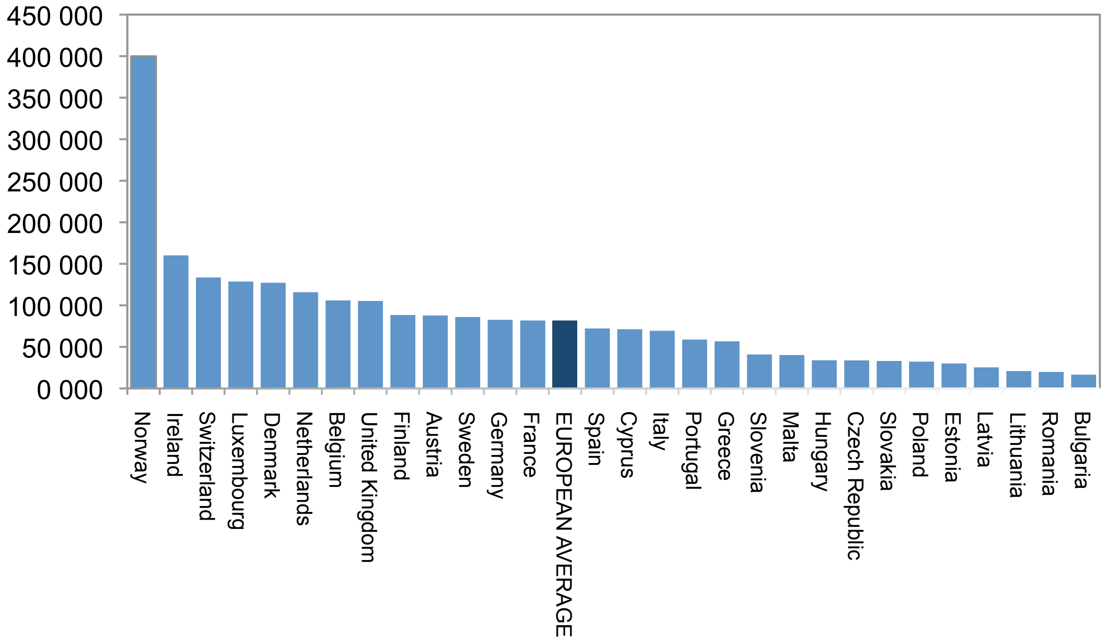
Figure 15: Average labour productivity (GVA per person employed) within different physics-based industries, 2007-10, €, current prices



Source: Eurostat SBS, Cebr analysis

This illustration of physics-based industries' average productivity can provide some insight into the variation in country-by-country productivity as illustrated in Figure 16 below. Norway has by far the highest rate of value-added per person employed – averaging nearly €400,000 over the four years under review – due to the predominance of extremely productive oil and gas activities within its physics-based sector.

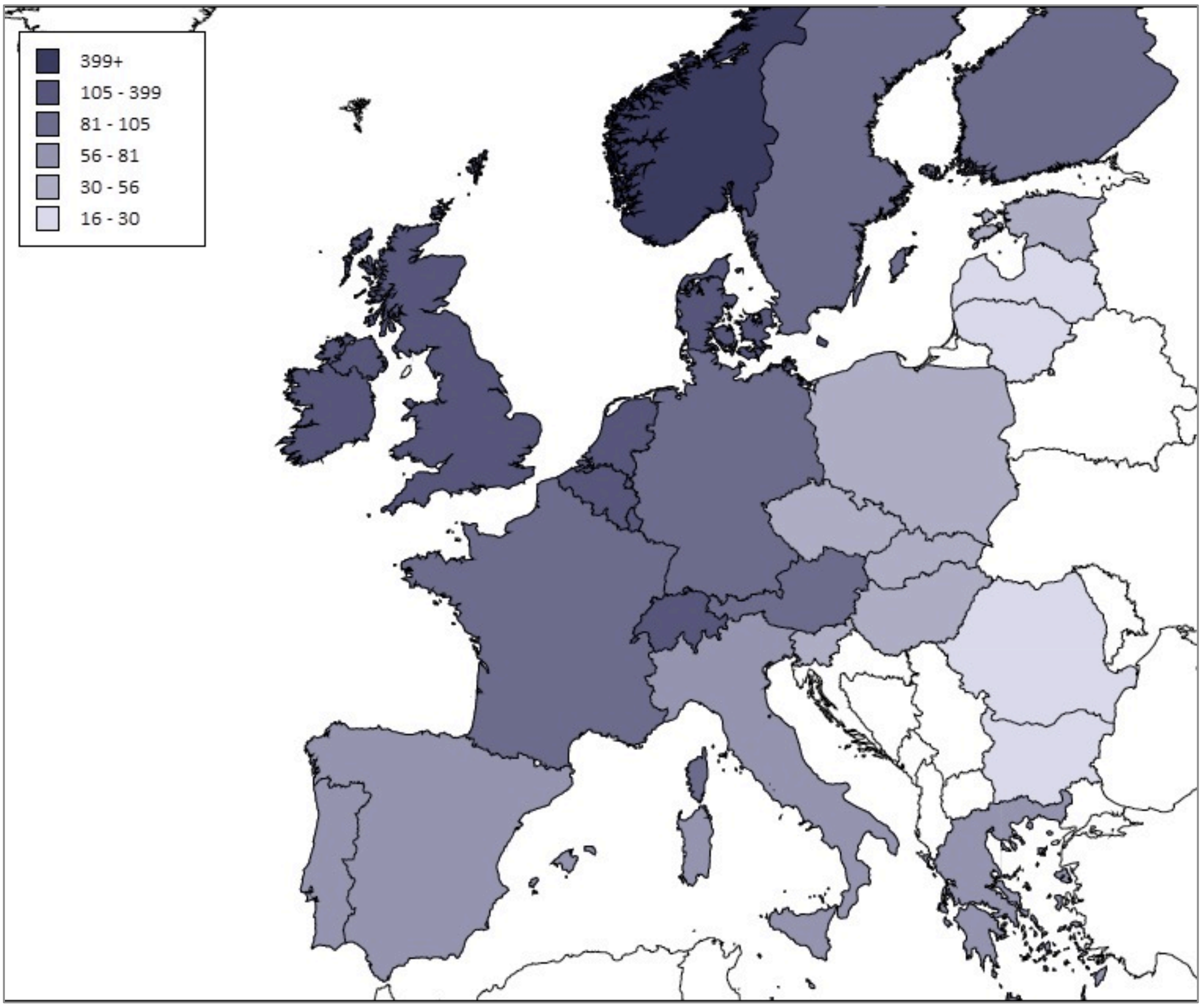
Figure 16: Comparison of country-level physics-based productivity, € per person per year, average over 2007-10



Source: Eurostat SBS, Cebr analysis

Figure 17 compares the productivity of the physics-based sectors of the different countries.

Figure 17: Productivity in physics-based sectors, €000 per person per year, average 2007-10



Source: Eurostat SBS, Cebr analysis

3 Direct economic contributions and multiplier impacts

This section provides our estimates of the direct economic contributions of physics suggested by the analysis of the physics-based industries within the 'national' accounting framework. This adapted framework, in which physics-based industries were given an explicit role, provided the basis for our estimates of the indirect and induced multiplier impacts of physics.

For this analysis, we used the EU27 SUIOTs (supply-use input-output tables) in conjunction with assumptions developed based on our analysis of the SBS datasets in Section 2. Due to this analysis drawing upon the consolidated EU-27 national accounting framework, the figures in this section refer to the EU-27 only, rather than to our broader definition of Europe used in Section 2, which included Switzerland and Norway.

3.1 Output at basic prices

The estimates of output in this section can be considered analogous to the turnover data presented in section 2.1 above. The conversion occurs through adjustments for:

- the transition from producers' prices (the basis for turnover) to basic prices, which is the subject of Box 1 in Appendix III; and
- the fact that all of the production activities of the physics-based industries (and businesses that make up those industries) may not be physics-based and that some non-physics-based industries might be engaged in activities that are physics-based.

These estimates of output at basic prices are presented immediately below, followed by the indirect and induced impacts of physics-based activities on output in the wider economy.

Direct impact

According to our estimates, **aggregate output at basic prices of the physics-based sector was €3.33 trillion in 2008**. This compares with an SBS-based turnover estimate of €3.62 trillion for the EU-27, the difference essentially amounting to Cebr's estimate of the impact of the aforementioned adjustments to SBS-based turnover data (at producers' prices) to arrive at estimates of output at basic prices. Of the €3.33 trillion of the sector's output, **94% is estimated to be output of physics-based goods and services**.[7]

The 94% or €3.11 trillion of supply of physics-based goods and services produced by the physics-based sector constitutes, in turn, over 75 per cent of the total EU-wide output of physics-based goods and services, that is, including the production of physics-based goods and services by industries that are not classified as physics-based. **Our estimate for the total supply of physics-based goods and services in the EU27 is €4.13 trillion**.[8]

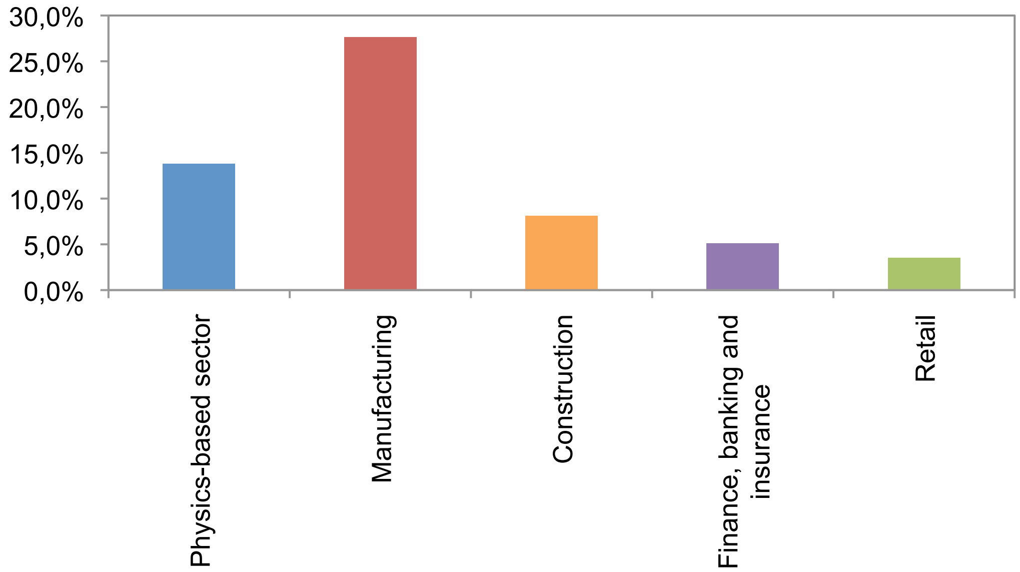
The estimated percentage contribution of the physics-based sector to EU-wide output at basic prices is compared with a selection of other sectors in

[7] This means that €211 billion of the physics-based sector's output is non-physics based. In adapting the EU-27 supply table, we assumed that the detailed 3-4-digit physics-based industries' production of non-physics based output followed the same pattern as the broader 2-digit industry of which they formed part. This controls for the expectation that it is unlikely that the physics-based industries would limit themselves to the exclusive production of physics-based goods and services.

[8] This was based on the assumption that production by non-physics-based industries of physics-based goods and services is proportional to the importance in the relevant 2-digit industry of the 3-4-digit physics-based elements. .

Figure 18 below.

Figure 18: Selected sectors' shares of EU27-wide output at basic prices



Source: Eurostat ESA95 Input-Output Tables, Eurostat SBS; Cebr analysis

However, whereas **the contribution of the physics-based sector is estimated at 13.8% of output** across all industries and sectors of the EU27 economy, the output of **physics-based goods and services is estimated to constitute 18.9%** of the output across all categories of goods and services produced in the EU27 economy.

The physics-based sector, as outlined in section 2.1 above, contributed more than the combined output contributions of the construction and retail sectors and approximately half the share of EU-27 output contributed by the entire manufacturing sector (which includes many of the physics-based industries presented in Appendix II).

Indirect and induced multiplier impacts

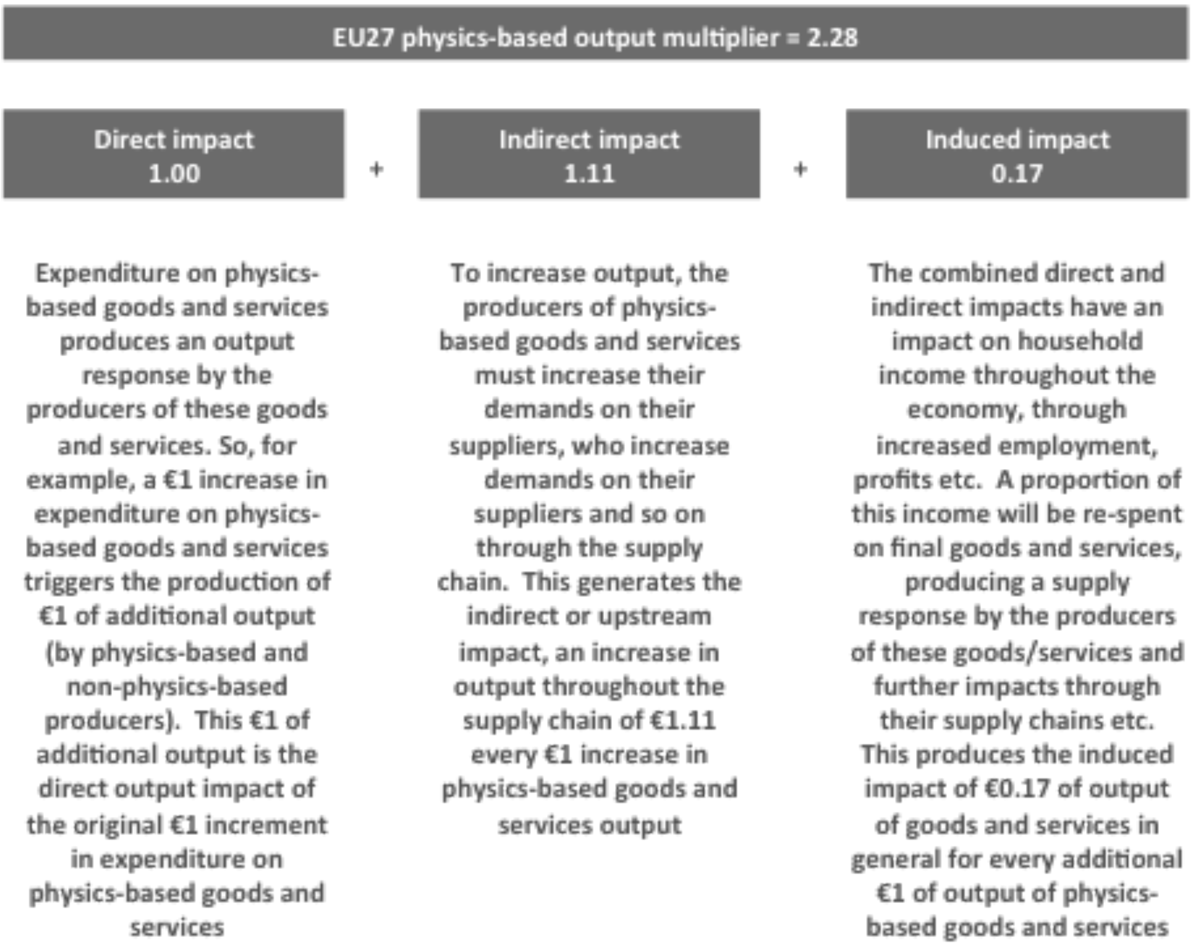
Figure 19 illustrates our estimate of the indirect and induced multiplier impacts of an increase in the production of physics-based goods and services.

From

Figure 19 can be derived two types of physics-based output multiplier. The Type I multiplier is the sum of direct and indirect impacts and equals 2.11. That is, for every €1 of additional physics-based output, the economy-wide increase in output due to direct and indirect supply chain impacts is €2.11. Note that **the indirect impact of €1.11 is equivalent to the upstream impact of physics-based production**, that is, the economic activity in the industries from which the providers of physics-based goods and services purchase other goods and services as inputs for their own production processes and in the industries that provide inputs to these suppliers and so on.

The Type II multiplier is the sum of the direct, indirect and induced impacts and equals 2.28. That is, for every €1 increase in physics-based output, the economy-wide increase in output due to direct, indirect and induced impacts is €2.28. Note also that **the induced impact of €0.17 represents the employee spending impact of physics-based production**.

Figure 19: Output multipliers for physics-based activities



Source: Eurostat Input-Output Tables; Eurostat SBS, Cebr analysis

Downstream impacts

By supplying goods and services to other industries, producers of physics-based goods and services help to support the economic activity carried out by these other industries. We estimate that other industries relied on physics-based goods and services (as intermediate inputs) valued at €2.23 trillion in 2008, with €1.10 trillion being consumed by the physics-based industries themselves.

The latter figure, along with €0.74 trillion of intermediate inputs supplied by other non-physics-based industries, supported the production of the €3.33 trillion of the physics-based and non-physics based goods and services output of the physics-based sector.

However, we estimate that the remainder of the €2.23 trillion figure above supported the production of €2.16 trillion of output in a wide range of other industries as well.

Final demand

The use of the remainder of the estimated €4.13 trillion of physics-based goods and services output (produced by the physics-based sector and non-physics-based sectors) comes from sources of final demand, including household and government consumption expenditure (approximately 16.1%), purchases for investment purposes (13.5%) and exports (15.9%).

3.2 Gross value added (GVA) and contribution to GDP

Direct impact

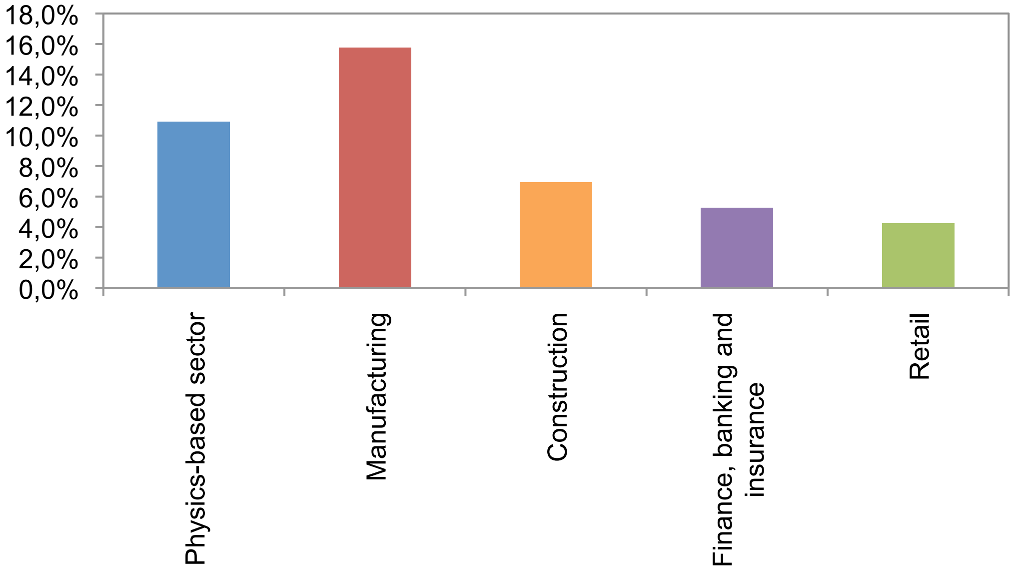
According to our estimates, **aggregate GVA of the physics-based sector was €1.22 trillion in 2008**.[9] This compares with a SBS-based estimate of €1.17 trillion for the EU-27, the difference again amounting to Cebr's estimate of the impact of the adjustments to SBS-based data outlined in Appendix III.

This €1.22 trillion of GVA **constitutes a 10.9% share of EU27-wide GVA**. This is compared with the same selection of other sectors in

[9] GVA or gross value added is a measure of the value from production in the national accounts and can be thought of as the value of industrial output less intermediate consumption. That is, the value of what is produced *less* the value of the intermediate goods and services used as inputs to produce it. GVA is also commonly known as income from production and is distributed in three directions – to employees, to investors and to government. GVA is linked as a measurement to GDP – both being a measure of economic output. That relationship is (GVA + Taxes on products - Subsidies on products = GDP). Because taxes and subsidies on individual product categories are only available at the whole economy level (rather than at the sectoral or regional level), GVA tends to be used for measuring things like gross regional domestic product and other measures of economic output of entities that are smaller than the whole economy, such as the physics-based sector. As noted in Section 2, GVA in the national accounts is valued at basic prices, as distinct from the value added concept used in section 2.3, which is based on producers' prices.

Figure 20 below.

Figure 20: Selected sectors' shares of EU27-wide GVA at basic prices



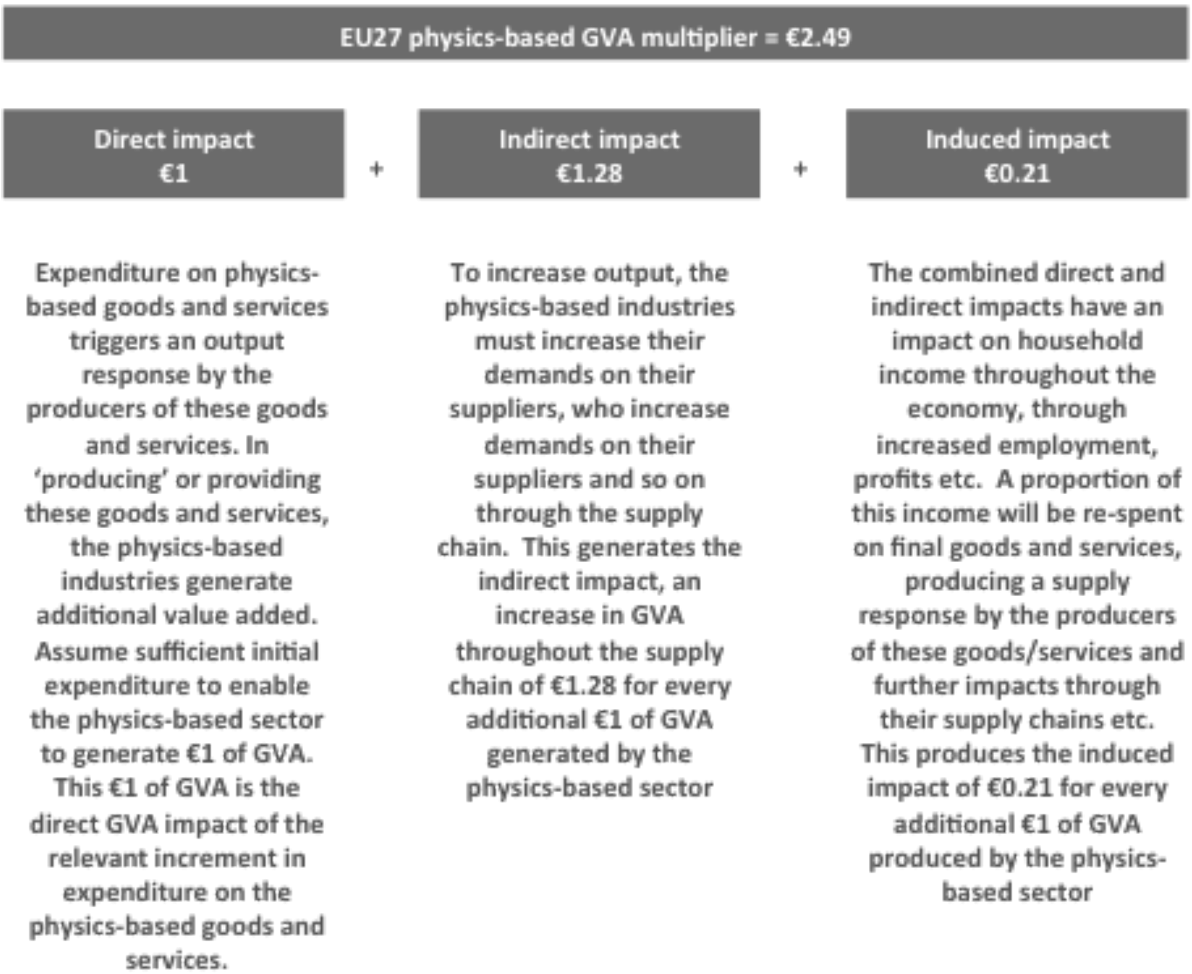
Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

As this figure shows, the physics-based industries provide a greater share of EU-27 GDP than either the construction, financial or retail sectors.

Indirect and induced GVA multiplier impacts

Figure 21 illustrates our estimates of the indirect and induced multiplier impacts of an increase in the production of physics-based goods and services.

Figure 21: GVA multipliers for physics-based activities



Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

From

Figure 21 again can be derived two types of physics-based GVA multiplier. The Type I multiplier is the sum of direct and indirect impacts and equals 2.28. That is, for every €1 of additional physics-based GVA, the economy-wide increase in GVA due to direct and indirect supply chain impacts is €2.28. Note that **the indirect impact of €1.28 is equivalent to the upstream GVA impact of physics-based production**, that is, the gross value added of the economic activity in the industries from which the providers of physics-based goods and services purchase other goods and services as inputs in their own production processes and in the industries that provide inputs to these suppliers and so on.

The Type II multiplier is the sum of the direct, indirect and induced impacts and equals 2.49. That is, for every €1 increase in physics-based GVA, the economy-wide increase in GVA due to direct, indirect and induced impacts is €2.49. This **induced impact of €0.21 represents the employee spending impact of physics-based production**.

We note that the GVA multipliers are higher than the corresponding output multipliers. The logic here is that the upstream industries supported by physics-based production have, on average, relatively high GVA-to-output ratios, so that the indirect GVA impact is proportionately greater than the indirect output impact.

Downstream impacts

Producers of physics-based goods and services, through their supply of intermediate inputs to other industries, help to support value-generation in those other industries. We noted our estimate that other industries relied on physics-based goods and services (as intermediate inputs) totalling €2.23 trillion in 2008, with €1.10 trillion being consumed by the physics-based industries themselves.

We also noted that this latter €1.10 trillion figure supported the production of the €3.33 trillion of physics-based sector output. Likewise, this €1.10 trillion, along with €0.74 trillion of intermediate inputs from other industries, supported the generation of €1.22 trillion of GVA by the physics-based sector in 2008.

The remainder of the €2.23 trillion figure is estimated to have supported the generation of €1.03 trillion of GVA in other industries across the economy.

3.3 Employment

The results presented in this section draw on data from the 2008 Labour Force Survey (LFS). SBS does not provide employment data for sectors that sit outside the business economy covered by SBS, whereas the LFS is economy-wide. Because the LFS is the dedicated survey for the labour market, it is also likely to be more robust and accurate than SBS. Furthermore, to estimate employment multipliers, we required employment data for all sectors that can only be sourced from LFS and so, for consistency purposes, the estimates in this section are all based on LFS data.

Direct impact

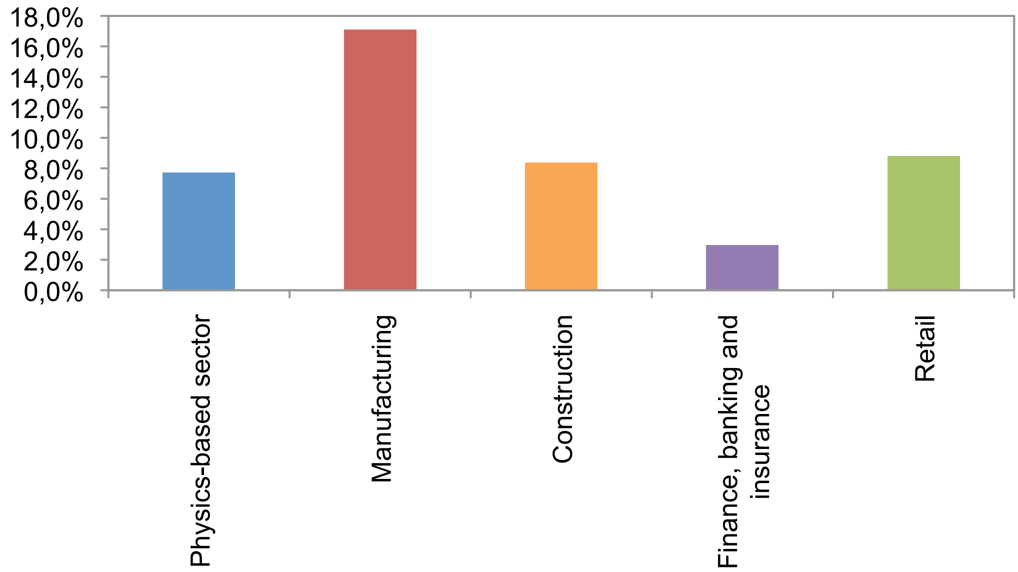
According to our LFS-based estimates, the **physics-based industries supported 17.1 million jobs across the EU27 in 2008**. This is about 1.9 million higher than the SBS-based estimate above. This means that the **physics-based sector accounted for a 7.7 per cent share of EU27-wide employment**.

This is compared with the same selection of other sectors as considered previously in

Figure 20 below, which suggests that the physics-based sector makes a contribution to EU27 employment equivalent to over 90% of that of the construction sector. This contrasts with the previous analysis, which shows the physics-based sector making substantially greater output and GVA contributions than construction. This is a function of the relatively higher labour intensities and lower labour productivity levels of these other sectors. The evidence presented in section 2 further supports these conclusions.

This can also be seen clearly when comparing the physics-based sector with retail. The latter makes smaller output and GVA contributions than the physics-based industries but a significantly larger contribution to EU27-wide employment. From this can be concluded that the retail sector is more labour-intensive and/or less labour-productive than the physics-based sector.

Figure 22: Selected sectors' shares of EU27-wide employment



Source: Eurostat, Labour Force Survey (LFS), Eurostat SBS, Cebr analysis

Indirect and induced employment multiplier impacts

Figure 23 illustrates our estimate of the indirect and induced employment multiplier impacts of an increase in the production of physics-based goods and services.

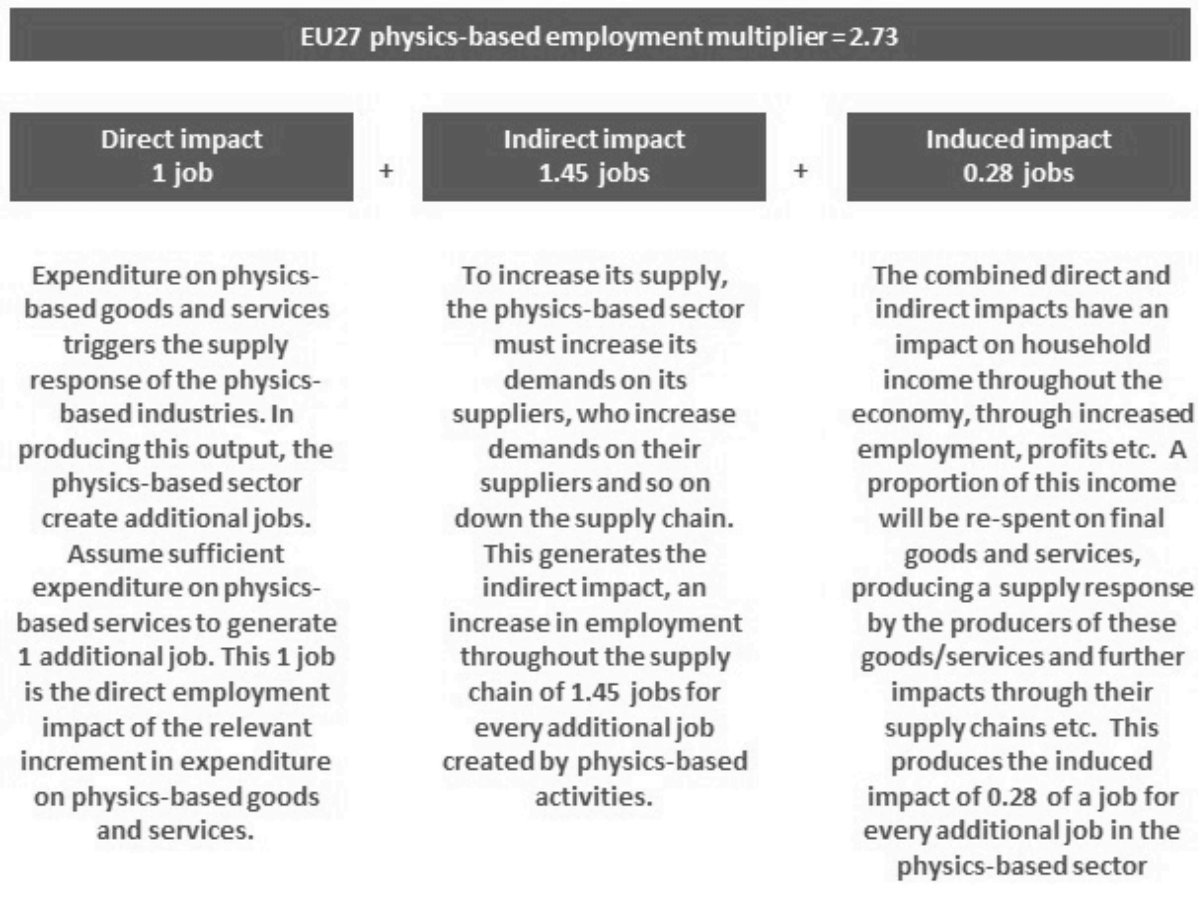
From

Figure 23, as before, can be derived two types of physics-based employment multiplier. The Type I multiplier is the sum of direct and indirect impacts and equals 2.45. That is, for every additional physics-based job, the economy-wide increase in jobs due to direct and indirect supply chain impacts is 2.45. Note that **the indirect impact of 1.45 jobs is equivalent to the upstream employment impact of physics-based production**, that is, the employment supported by economic activity in the industries from which the providers of physics-based goods and services purchase other goods and services as inputs into their own production processes and in the industries that provide inputs to these suppliers and so on.

The Type II multiplier is the sum of the direct, indirect and induced impacts and equals 2.73. That is, for every additional physics-based job, the economy-wide increase in employment due to direct, indirect and induced impacts is 2.73 jobs. This **induced impact of 0.28 of a job represents the employee spending impact of physics-based production**.

The fact that the employment multipliers are higher than the corresponding output and GVA multipliers reflects the relatively higher levels of labour intensity of the industries that supply the physics-based sector relative to the physics-based sector itself and of the industries that meet the demands generated by physics-based employee spending.

Figure 23: Employment multipliers for physics-based activities



Source: LFS, Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

Downstream impacts

We estimate that, through the supply of physics-based goods and services as intermediate inputs to other sectors, the physics-based sector supported 21.0 million jobs across the rest of the EU27 economy.

3.4 Incomes from employment

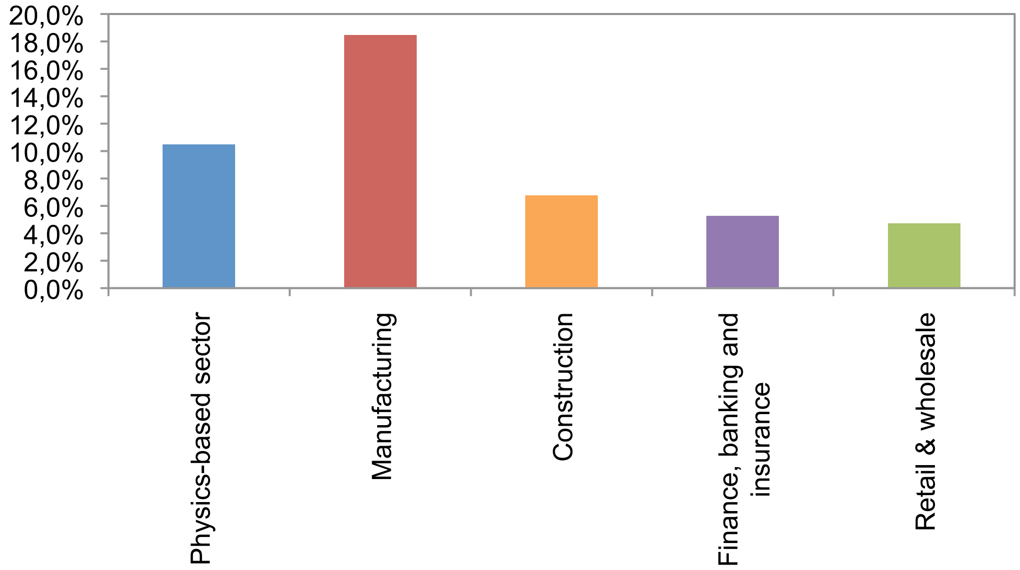
Direct impact

Our estimates suggest that the physics-based industries generated €0.64 trillion of employee compensation in 2008, including €0.51 trillion of wages and salaries. This constitutes a share of 10.5% of both EU27-wide employee compensation and wages and salaries.

This is compared with the same selection of other sectors in

Figure 24 below.

Figure 24: Selected sectors' shares of EU27-wide employee compensation



Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

We note, for example, that the differential between the physics-based sector's share of employee compensation and manufacturing's share is significantly smaller than the differential in employment. The logical explanation for this is higher average levels of pay in the physics-based industries than in manufacturing as a whole.

This can also be clearly seen by examining the physics-based sector relative to construction or the other sectors. For example, the direct employment contributions of the physics-based and construction sectors are on a par (see

Figure 22 above), but the physics-based sector's share of total employee compensation is significantly higher, again implying that physics-based jobs are generally higher paid than construction jobs.

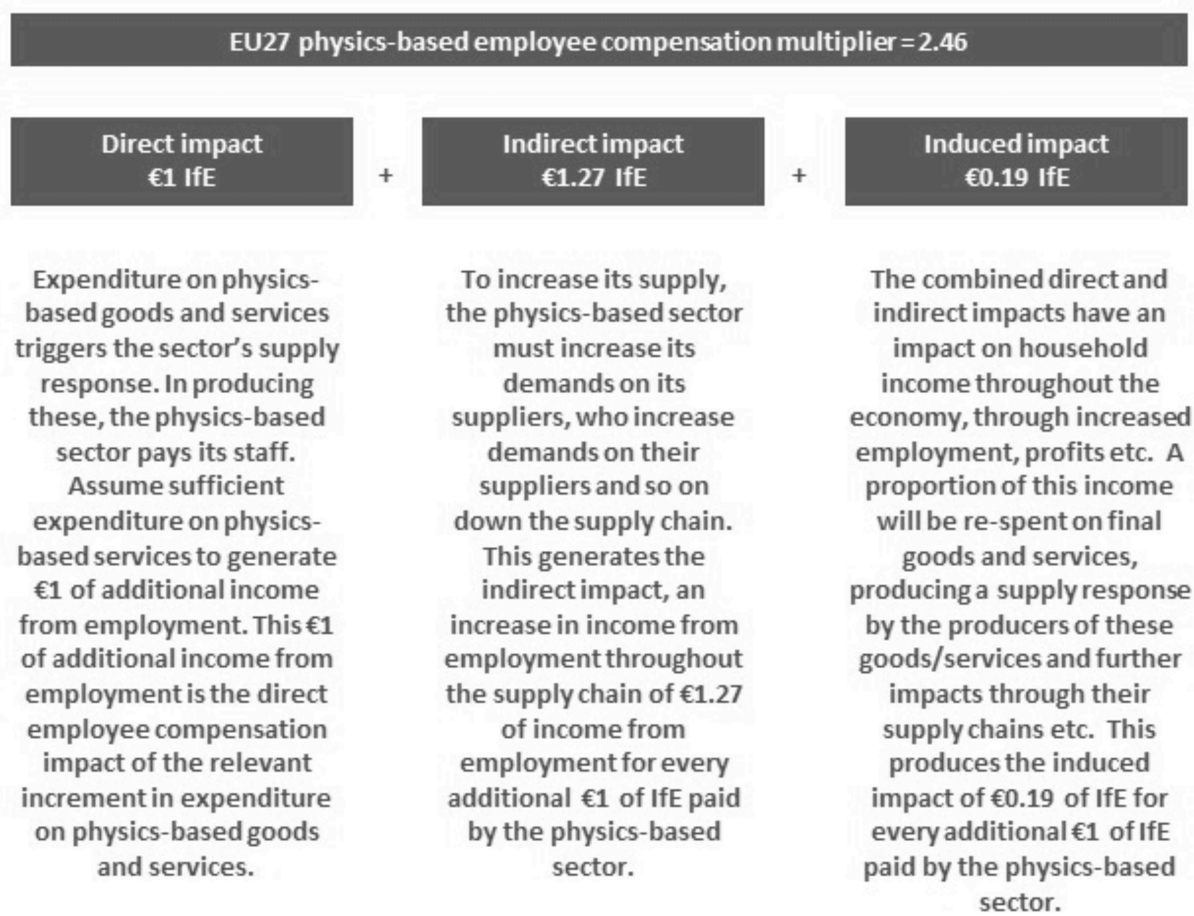
Indirect and induced incomes from employment multiplier impacts

Figure 25 illustrates our estimate of the indirect and induced multiplier impacts of physics-based activities for employee compensation.

The Type I employee compensation multiplier – the sum of direct and indirect impacts – equals 2.27. That is, for every additional €1 of physics-based employee compensation, the economy-wide increase in employee compensation due to direct and indirect supply chain impacts is €2.27. Note that **the indirect impact of €1.27 of employee compensation is equivalent to the upstream employee compensation impact of physics-based production**, that is, the employee compensation supported by economic activity in the industries from which the providers of physics-based goods and services purchase other goods and services as inputs in their own production processes and in the industries that provide inputs to these suppliers and so on.

The Type II multiplier is 2.46. That is, for every additional €1 of physics-based employee compensation, the economy-wide increase in employee compensation due to direct, indirect and induced impacts is €2.46. The **induced impact of €0.19 represents the employee spending impact on employee compensation as a result of physics-based production**.

Figure 25: Employee compensation multipliers for physics-based activities



Source: LFS, Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

The fact that the employee compensation multipliers are lower than the corresponding employment multipliers reflects the relatively lower average levels of employee compensation in the industries that supply the physics-based sector relative to the physics-based sector itself and of the industries that meet the demands generated by physics-based employee spending.

Downstream impacts

Employee compensation does not lend itself to the same type of analysis of downstream impacts as output, GVA or employment.

4 The survival of physics-based businesses

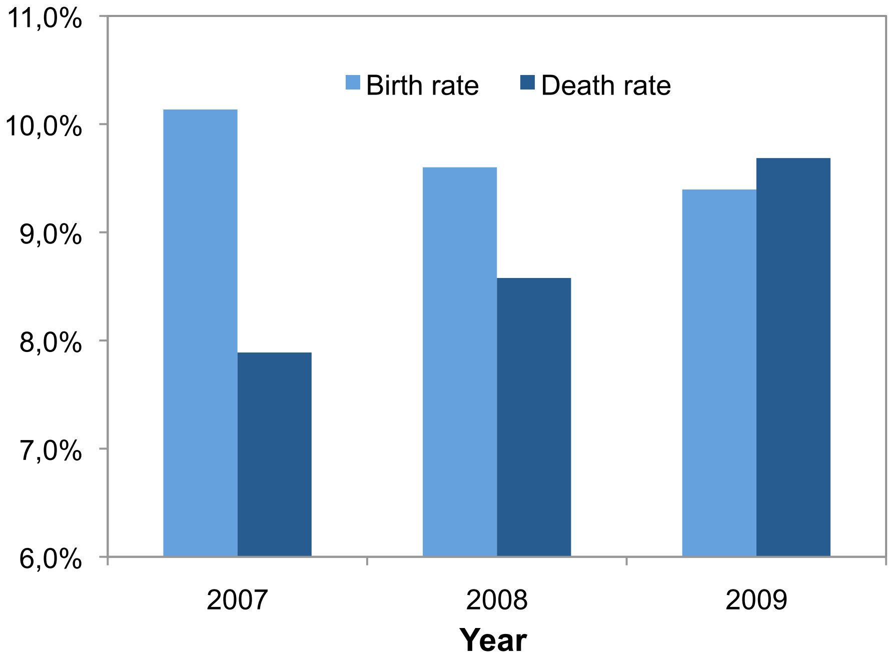
This section discusses enterprise demography within physics-based activities. The analysis measures trends in business inceptions and insolvencies within physics-based industries, with a view to assessing the endurance and survival of physics-based businesses in what was a vastly challenging period for the European economy.

4.1 Physics-based enterprise birth and death rates

Figure 26 illustrates that physics-based enterprises in the EU27 economies had a birth rate of 10.1% in 2007, implying roughly 10 start-ups for every 100 physics-based enterprises active in that year. This enterprise birth rate declines marginally over the period under consideration, to 9.6% in 2008 and then 9.4% by 2009.

This is a downward trend that is in contrast to a much sharper upswing in the rate of enterprise deaths over the years 2007-2009. Insolvencies in physics-based enterprises occurred at a rate of 7.9% in 2007, rising to 8.6% in 2008 and to 9.7% in 2009. This rising death rate is not surprising given the marked economic downturn that occurred in the latter part of this period.

Figure 26: EU-27 birth and death rates for enterprises in physics-based sectors; 2007-2009

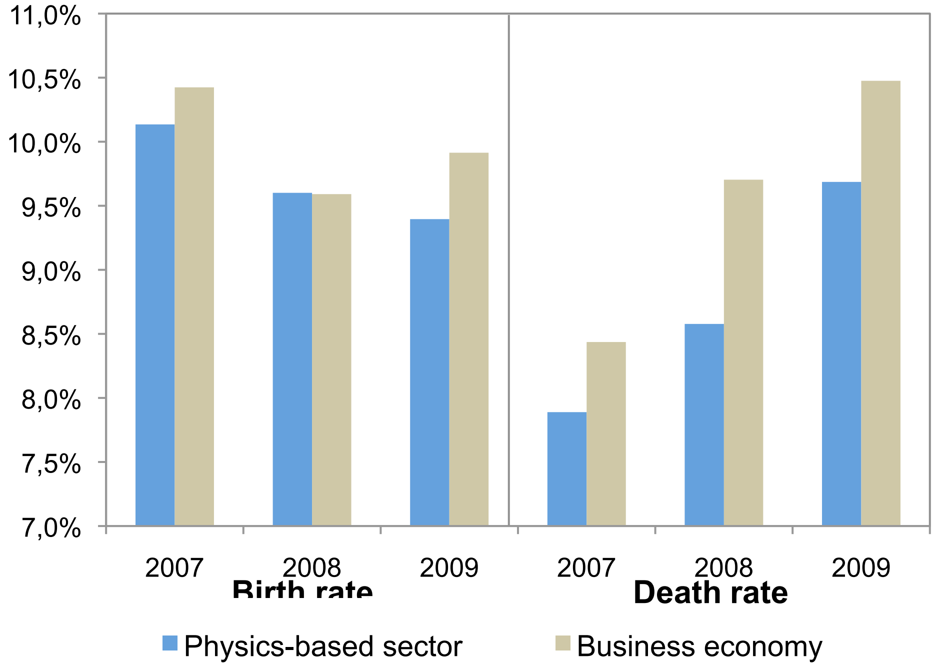


Source: Eurostat Business Demography statistics, Cebr analysis

Figure 27 illustrates a comparison between the rates of enterprise births and deaths in the physics-based sector and the wider EU business economy.[10] This suggests that, in the period under analysis, the rate of business births within the physics-based sector was lower than that of the wider business economy, except in 2008 where the two levels were broadly equivalent. This might be suggestive of greater barriers to entry to setting up a physics-based enterprise than for the average enterprise in the economy.

In the case of insolvencies, for both physics-based activities and the wider business economy we observe significant year-on-year increases in the rates of enterprise deaths across the period of analysis. However, the physics-based sector's death rate is markedly lower than that of the entire business economy in each year. This suggests that businesses utilising physics in their operations were able to remain relatively resilient during the years of economic slowdown and contraction, in comparison to the wider business economy.

Figure 27: Comparison between enterprise demography trends in the EU physics-based sector and business economy; 2007-9



Source: Eurostat Business Demography statistics, Cebr analysis

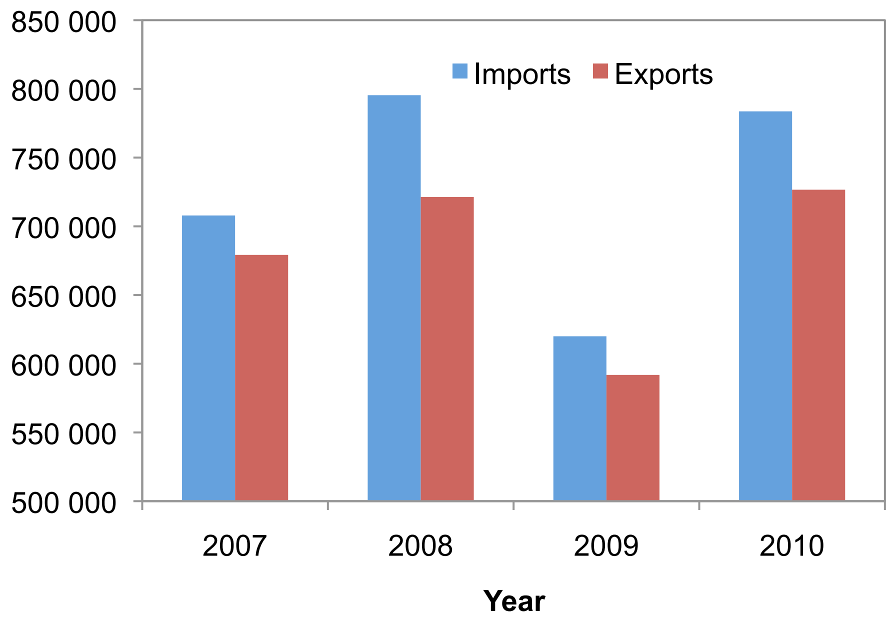
[10] The sectors comprising the business economy are defined as industry and construction, wholesale & retail, food & accommodation, transport, information & communications, finance (excluding holding companies), real estate, professional and business services.

5 International trade, investment and research & development

5.1 International trade

Figure 28 illustrates that the EU has a trade deficit in physics-based goods and services over all years under review. Physics-based imports into the EU peaked at €795 billion in 2008, before falling to €620 billion in 2009. This figure approached its peak by the following year, reaching €784 billion. The value of exports of physics-based goods and services to non-EU countries reached €721 billion in 2008, but plunged to €592 billion in the face of faltering global demand in 2009. By 2010, the value of exports had exceeded the pre-recession peak, reaching €727 billion.

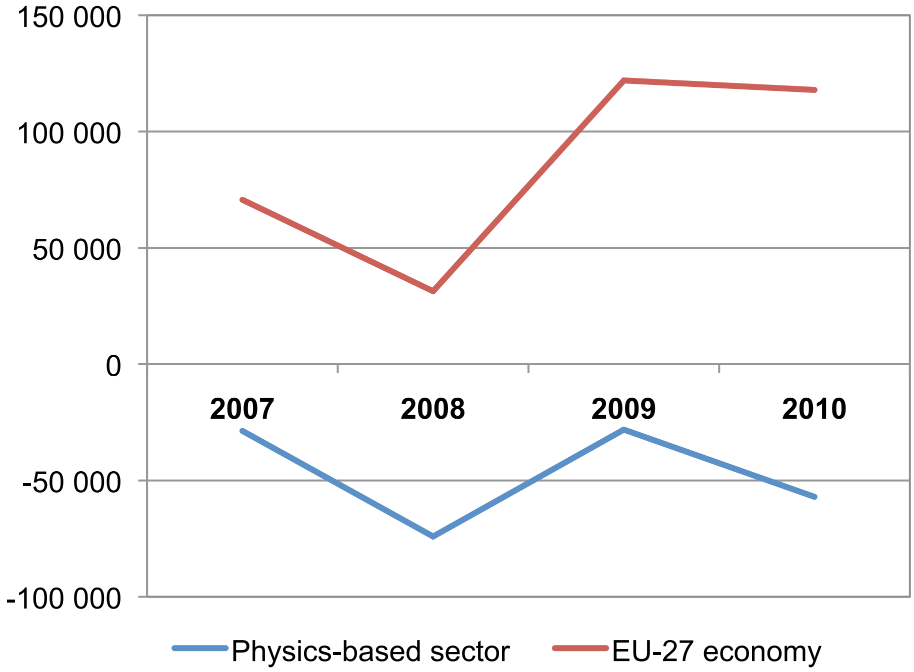
Figure 28: EU-27 imports and exports of physics-based goods and services to extra-EU trade partners, € million, current prices, 2007-10



Source: Eurostat Input-Output tables, Eurostat international trade statistics, Cebr analysis

Figure 29 compares the EU27's trade balance in physics-based goods and services with the overall EU-27 external trade balance with extra-EU countries. The gap between the two widens in each year of the analysis, starting from 2007 when an overall trade surplus of €70.7 billion was observed alongside a €28.7 billion deficit in physics-based trade. The physics-based trade deficit significantly increased (by 158%) in 2008 as imports rose more sharply than exports, before falling back to €28.1 billion in 2009. This was accompanied by a sharp increase in the EU-27's external trade balance, as weak domestic demand saw imports into the EU plunge by 17.7%. By 2010, the EU's external trade surplus grew to €117.9 billion, while the physics-based trade deficit widened again to €57.0 billion, as physics-based import growth outpaced export growth.

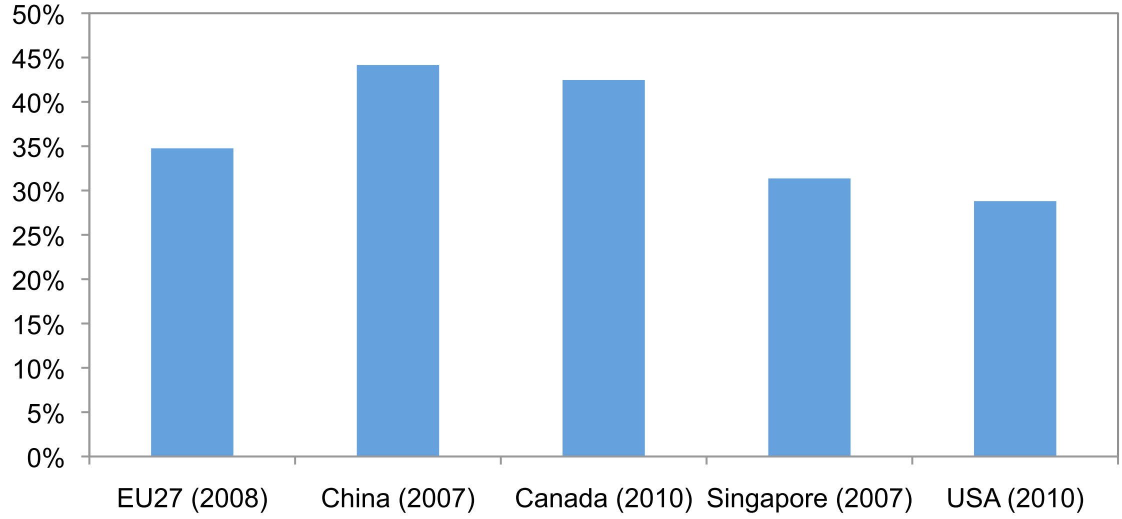
Figure 29: External trade balance, € million, current prices, 2007-10



Source: Eurostat Input-Output tables, Eurostat national accounts, Cebr analysis

Figure 30 compares the EU-27's physics-based exports as a share of overall exports with Cebr's estimates of the same indicator for selected other countries. These estimates draw on the latest available supply-use dataset for each country, so the estimates do not all refer to the same year.[11]

Figure 30: International comparison of physics-based exports as a share of total exports



Source: Eurostat, China National Bureau of Statistics, Statistics Canada, Statistics Singapore, US Bureau of Economic Analysis, Cebr analysis

We estimate that physics-based exports accounted for 44.2% of the China's total exports in 2007, with exports of industrial machinery and transport equipment contributing the lions share, while Canada's physics-based exports are boosted by its substantial oil and gas industries.

5.2 Investment

When taken in aggregate, the European Union economy invests more in economies outside of the EU27 than it receives in investment from outside the Union. This is illustrated in Figure 31 below, which shows that even in the deep recession year of 2009, the EU27 invested around €331 billion in extra-EU economies.

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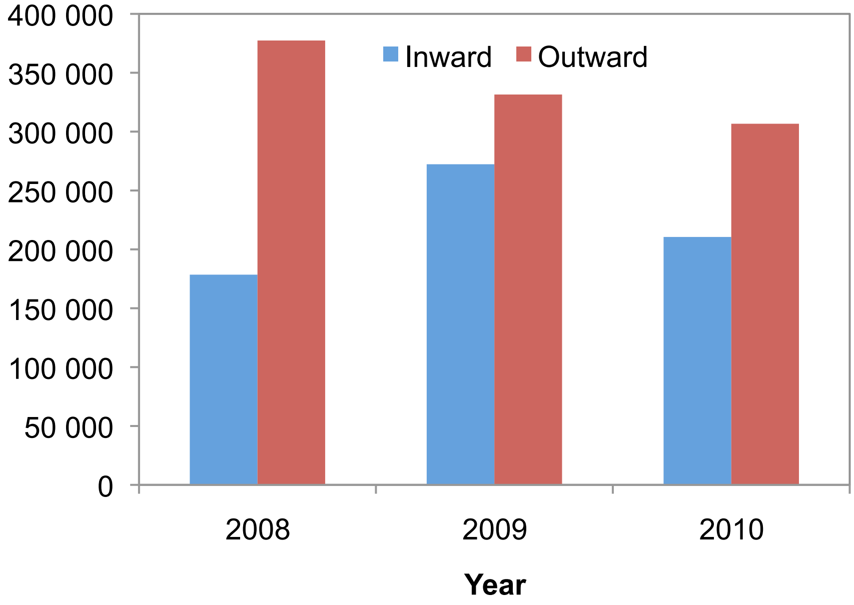
[11] These estimates were derived by applying the shares of each product category categorised as physics-based in our EU-27 analysis to the detailed national export breakdowns in each of the comparator countries.

Figure 31: Extra-EU foreign direct investment flows in and out of the EU, € million, 2008-10



Source: Eurostat Direct Investment statistics, Cebr analysis

This feature – of outward investment being significantly higher than inward – is also observed in the EU27's physics-based sector.

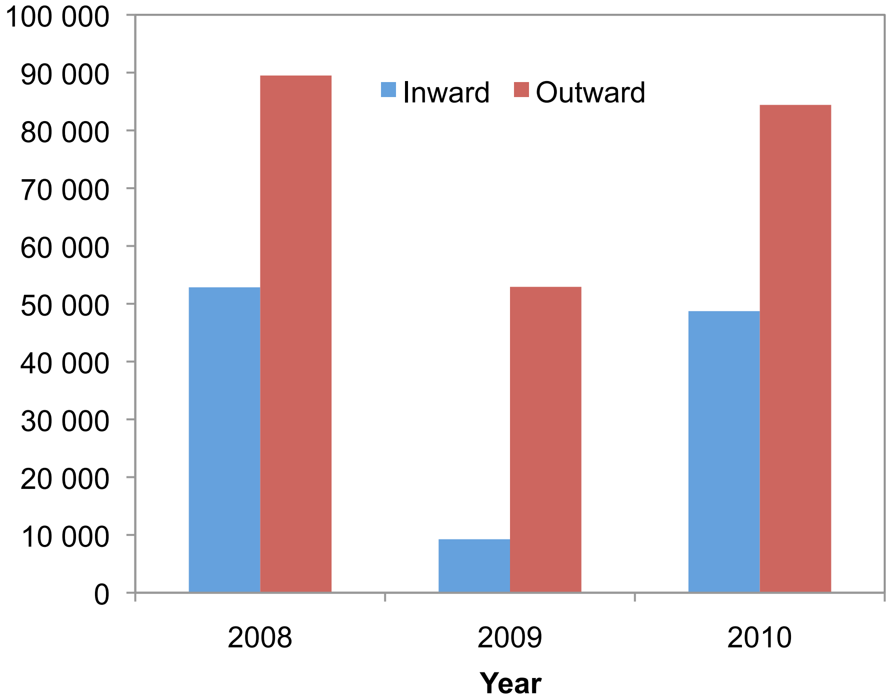
It is illustrated in

Figure 32, which shows that the countries of the EU invest much more heavily in physics-based activities outside of the EU, than extra-EU countries invest in the physics-based sector within the European economy.

The EU27's physics-based sector benefited from €53 billion of investment from extra-EU27 countries in 2008. This figure fell significantly in 2009 to just €9 billion, constituting a fall of over 80%. By 2010, however, inward investment had almost recovered to 2008 levels, reaching €49 billion.

Outward investment into physics-based sectors was higher in value terms in each year under review. The EU is estimated to have invested €90 billion in extra-EU physics-based industries in 2008, falling by 41% to €53 billion by 2009. In 2010, the figure reached €84 billion. These sums illustrate how the European Union economies are more significant investors in physics-based industries globally than global physics-based sectors are in the EU.

Figure 32: Extra-EU physics-based FDI flows in the EU, € million, 2008-10

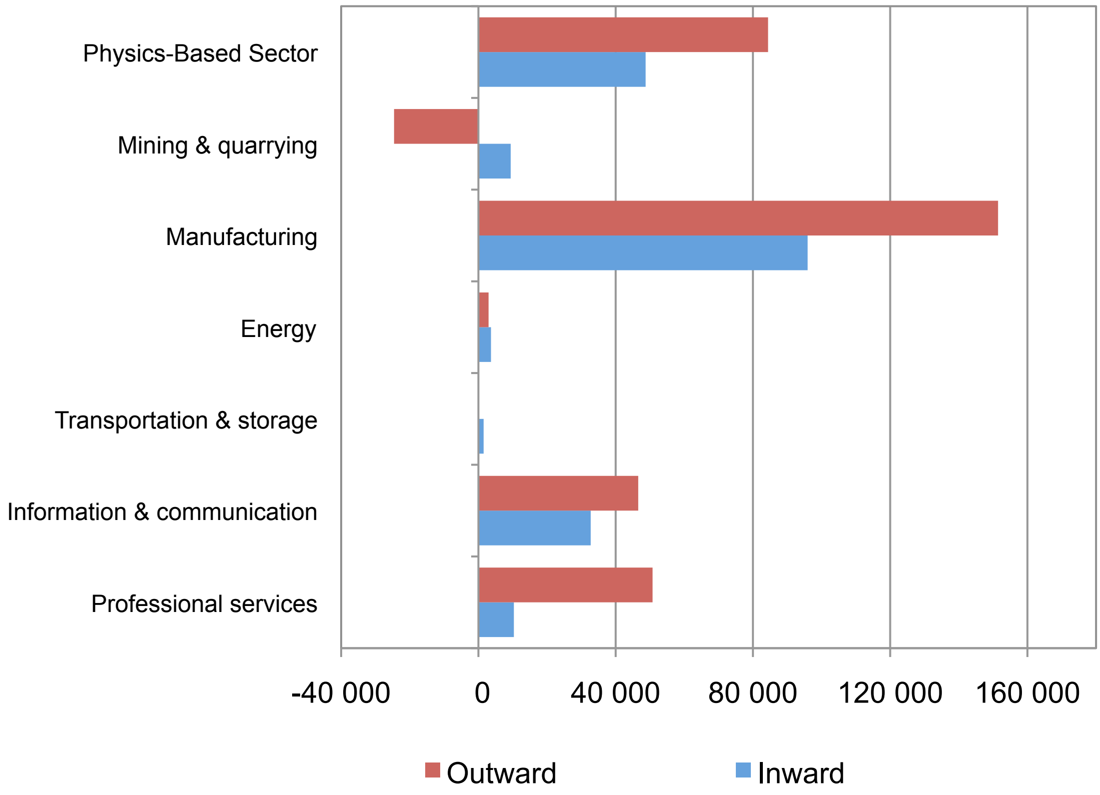


Source: Eurostat Direct Investment statistics, Cebr analysis

The significant extent to which Europe's physics-based sectors are inter-linked with the global economy is illustrated in

Figure 33, which compares Foreign Direct Investment (FDI) flows in 2010 across various EU-27 broad sectors. The manufacturing sector – of which physics-based activities are an important part – is the only sector in which higher levels of extra-EU investment flows are observed.[12]

Figure 33: Net extra-EU foreign direct investment flows among selected EU sectors, 2010



Source: Eurostat Direct Investment statistics, Cebr analysis

5.3 Research & development

Research and development (R&D) activities are an important investment function in the business economy, with continuing innovation of new technologies, processes and products contributing much to improving efficiency and generating economy-wide productivity growth. The EU's physics-based sector is unsurprisingly a highly R&D-intensive industry.

To measure the extent to which the physics-based sector undertakes R&D activities, we utilised our customised EU27 supply-use framework. This was used to calculate each

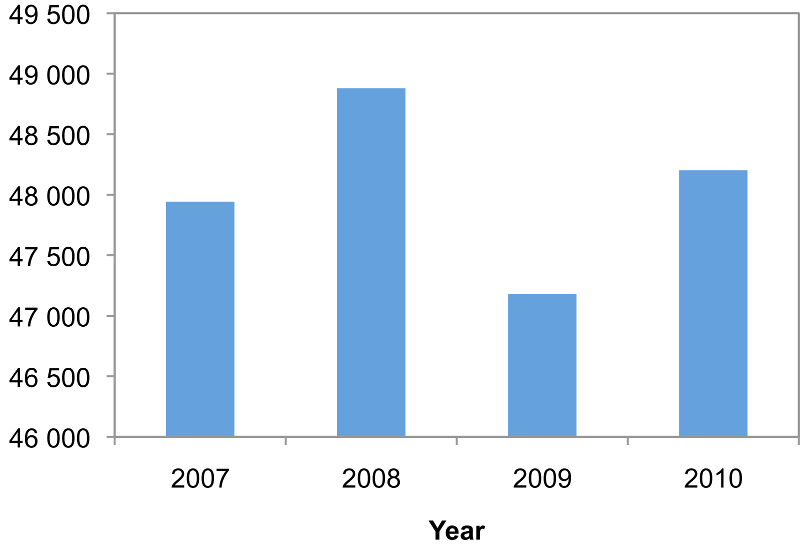
[12] Note that the negative outward figure for the Mining and Quarrying sector reflects a net return of outward capital to the EU. This can be attributed to depreciation – that is, the value of the investment falling – and from withdrawal of investment – taking cash out of a country, selling off factories, shrinking operations etc.)

physics-based industry's consumption of scientific research and development services as intermediate inputs.[13] We drew on Eurostat's Business Enterprise R&D expenditure (BERD) dataset to infer comparable estimates for 2007 and 2009-10. The results are presented in

Figure 34 below.

Note, however, that these estimates capturs the physics-based industries' external expenditure on scientific R&D only. Were it possible to also estimate internal R&D expenditure, the estimates presented in this section could be expected to be higher, possibly significantly.

Figure 34: Physics-based sector expenditure on scientific research & development, € million, 2007-10



Source: Eurostat Input-Output Tables, Eurostat Business Enterprise R&D (BERD) statistics, Cebr analysis

In 2007, we estimate the EU27's physics-based sector spent €47.9 billion on scientific R&D services. This expenditure rose by 2.0% to €48.8 billion in 2008, before falling by 3.5% during the economic malaise of 2009. By 2010, we observed a year-on-year rise of 2.2%, to reach just over €48.2 billion.

Notably, external expenditure on R&D by the physics-based industries within the EU represented over 49% of total external expenditure on R&D in 2008.

The EU physics-based sector, in other words, also buys in R&D services from outside the EU, with 13.4% (or €6.6 billion in 2008) of the sector's total external R&D expenditure

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[13] BERD measures trends in R&D expenditure in different sectors under the NACE Rev. 2 classification, disaggregating mainly to a 2-digit NACE level, with a minority of sectors disclosed at the 3- or 4-digit level. Hence, we used the expenditure trends revealed in the BERD data – at the deepest level of disaggregation possible – to aim off the physics-based industries' intermediate consumption of R&D services in 2008,

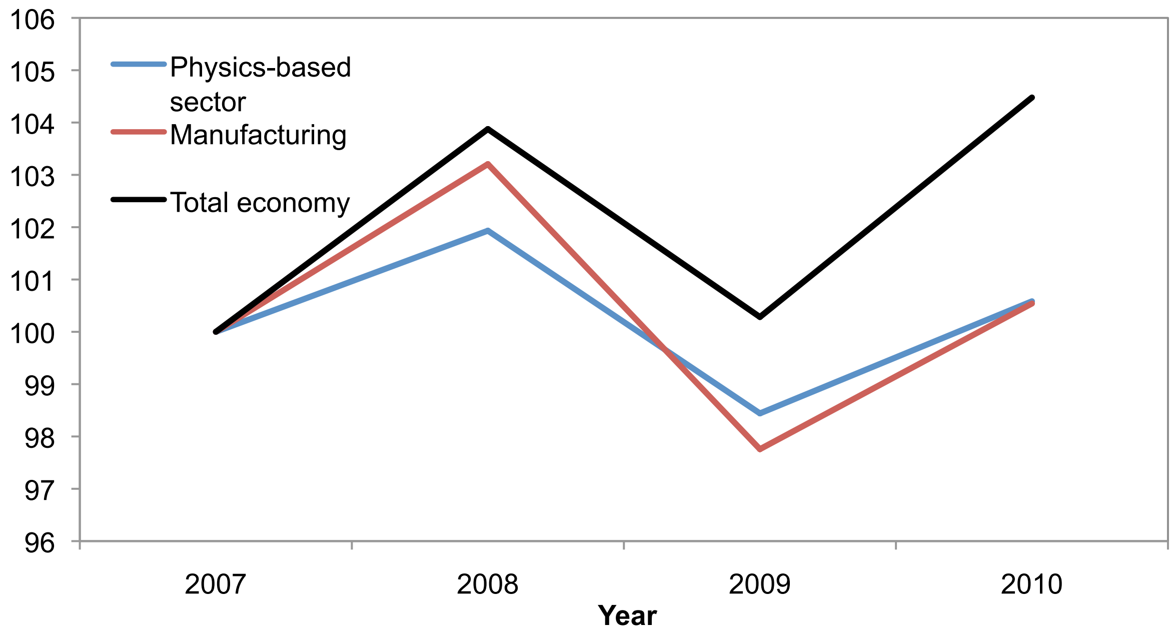
imported from outside the European Union. This is comparable to 12.3% seen in the EU economy as a whole but is significantly larger than, for example, the equivalent figure for EU national governments' expenditure on non-EU businesses' R&D services, which averaged just 2.6% in 2008.

This comparison is illustrated with manufacturing as a whole and the overall EU economy in

Figure 35. While R&D expenditure in the physics-based sector grew more slowly than in manufacturing in 2008, its spending downturn during 2009 was less pronounced than for the manufacturing sector. By 2010, R&D expenditure in both the physics-based sector and the overall manufacturing industry had recovered to above 2007 levels.

R&D expenditure in the EU economy as a whole grew faster in 2008 than in either the manufacturing or physics-based sectors. Furthermore, the downturn of 2009 did not see economy-wide R&D expenditure fall below its 2007 level, unlike in both the physics-based and overall manufacturing sectors.

Figure 35: R&D expenditure in the EU physics-based and manufacturing sectors, 2007-10, index (2007=100)



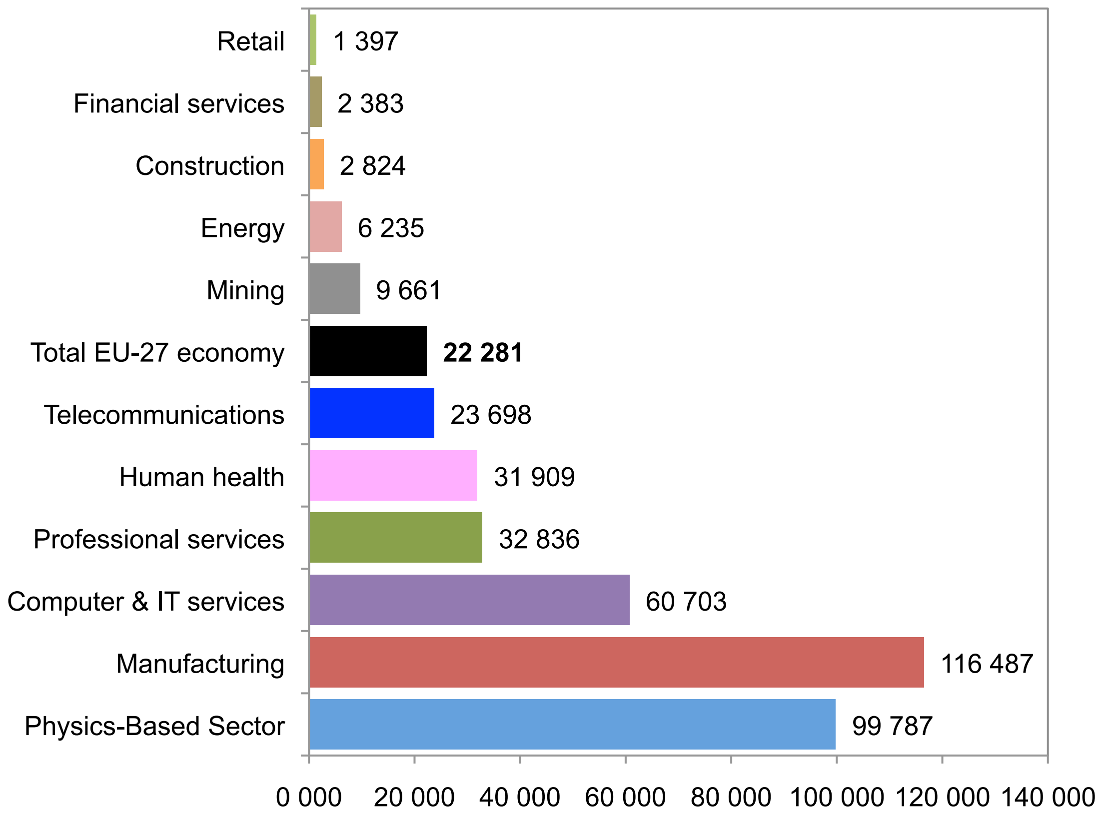
Source: Eurostat Business Enterprise R&D (BERD) statistics, Eurostat Input-Output Tables, Cebr analysis

However, while these indices reveal developments in R&D expenditure in various segments of the economy over the years under review, they do not reveal the relative importance of R&D activities to each sector.

Figure 36 compares the degree of scientific R&D services consumption among selected sectors that typically undertake a relatively high degree of R&D, analysed in terms of expenditure as a proportion of gross operating surplus (GOS). In 2008, physics-based activities within the EU spent approximately €99,800 on scientific R&D per million euro of GOS.

This dwarfed the rate of R&D expenditure in the overall EU economy, in which approximately €22,300 of R&D services per million euros of GOS were consumed. The rate of R&D expenditure by the physics-based sector is exceeded in our sample only by the overall manufacturing industry, which in 2008 spent around €116,500 per million euros of GOS.

Figure 36: EU-27 sector expenditures on scientific research and development services, per € million of gross operating surplus, € 2008



Source: Eurostat Input-Output Tables, Cebr analysis

Appendix I: Compendium of national-level results

Here we present our estimates of turnover, employment and GVA in each of the countries analysed during this study. Please note that the column totals may not sum due to rounding.

	Turnover in Physics-Based Industry, millions of Euro, current prices			
	2007	2008	2009	2010
Austria	62,488	65,782	59,726	61,266
Belgium	89,380	94,509	87,371	92,622
Bulgaria	8,786	8,529	7,950	8,268
Cyprus	1,834	2,180	1,984	2,275
Czech Republic	66,039	73,046	61,453	66,554
Denmark	56,504	62,568	55,921	56,553
Estonia	3,532	3,727	3,222	4,114
Finland	72,845	76,326	63,122	64,260
France	483,489	485,409	448,098	466,678
Germany	944,003	975,675	863,880	952,284
Greece	23,904	25,216	23,635	22,989
Hungary	52,042	54,261	44,311	51,892
Ireland	71,649	72,300	65,538	61,627
Italy	421,475	416,288	347,600	370,632
Latvia	2,992	3,116	2,438	2,440
Lithuania	3,935	4,062	3,015	3,020
Luxembourg	6,664	7,018	8,639	7,600
Malta	852	905	915	897
Netherlands	138,572	151,466	151,297	159,954
Norway	133,960	211,784	169,746	196,604
Poland	78,052	93,304	76,463	88,320
Portugal	31,879	33,309	30,679	32,113
Romania	29,446	32,618	26,720	29,999
Slovakia	26,041	27,822	24,683	28,986
Slovenia	12,637	12,435	10,970	11,221
Spain	228,900	235,751	199,931	209,244
Sweden	108,548	106,750	84,330	100,347
Switzerland	161,446	164,553	146,890	159,065
United Kingdom	527,740	498,021	410,015	448,153
Total	**3,849,635**	**3,998,732**	**3,480,542**	**3,759,979**

Source: Eurostat SBS, Cebr analysis

	Number of persons employed in Physics-Based Industry			
	2007	2008	2009	2010
Austria	254,900	271,700	265,200	266,600
Belgium	262,400	264,600	268,600	259,800
Bulgaria	185,500	193,800	188,500	182,800
Cyprus	13,700	14,100	14,000	15,900
Czech Republic	527,300	536,800	495,800	491,900
Denmark	206,600	204,200	182,200	179,800
Estonia	41,200	40,500	36,300	35,900
Finland	201,800	211,200	202,500	195,600
France	1,725,800	1,740,400	1,702,900	1,729,500
Germany	3,442,200	3,520,800	3,460,300	3,503,900
Greece	193,200	202,500	204,700	204,400
Hungary	351,000	356,300	333,800	340,900
Ireland	141,400	144,900	129,300	123,000
Italy	1,647,000	1,672,300	1,631,500	1,640,200
Latvia	47,900	47,300	40,500	38,700
Lithuania	66,400	65,900	59,000	55,200
Luxembourg	16,100	17,100	16,800	17,000
Malta	12,200	12,400	12,600	12,700
Netherlands	419,900	436,300	436,800	430,000
Norway	199,800	214,900	218,100	219,700
Poland	877,000	896,100	832,700	836,800
Portugal	193,100	192,400	189,800	188,900
Romania	513,300	524,200	484,900	456,100
Slovakia	165,800	179,200	156,400	182,600
Slovenia	97,400	90,300	85,100	84,900
Spain	1,017,400	1,042,200	984,700	965,500
Sweden	401,300	404,000	391,100	388,900
Switzerland	441,000	447,700	429,100	421,200
United Kingdom	1,952,600	1,955,600	1,848,000	1,887,500
Total	**15,615,200**	**15,899,700**	**15,300,900**	**15,356,200**

Source: Eurostat SBS, Cebr analysis

	GVA in Physics-Based Industry, millions of euro, current prices			
	2007	2008	2009	2010
Austria	22,680	24,574	22,279	23,419
Belgium	27,305	27,092	26,858	30,562
Bulgaria	2,855	3,172	3,120	3,294
Cyprus	964	1,006	997	1,149
Czech Republic	17,715	19,038	15,775	16,739
Denmark	23,381	27,025	22,936	24,961
Estonia	1,154	1,188	1,114	1,165
Finland	20,659	20,192	14,943	15,892
France	145,843	142,879	133,994	141,380
Germany	294,398	291,348	263,129	301,062
Greece	10,835	11,683	10,719	12,429
Hungary	11,386	12,301	10,926	12,225
Ireland	20,273	23,382	20,888	21,735
Italy	115,593	116,576	105,289	119,840
Latvia	1,194	1,281	971	977
Lithuania	1,487	1,442	1,093	1,127
Luxembourg	2,316	2,336	1,979	1,991
Malta	503	509	471	524
Netherlands	46,877	49,749	50,385	52,569
Norway	82,975	101,931	74,218	81,782
Poland	25,659	30,847	25,716	28,705
Portugal	12,704	10,677	10,519	11,041
Romania	9,384	10,908	9,251	9,751
Slovakia	5,445	5,512	5,301	6,332
Slovenia	3,821	3,856	3,259	3,693
Spain	74,279	77,252	70,094	67,928
Sweden	36,395	33,745	29,050	37,163
Switzerland	59,884	60,024	53,536	58,849
United Kingdom	228,317	218,129	170,746	187,844
Total	**1,306,284**	**1,329,655**	**1,159,556**	**1,276,125**

Source: Eurostat SBS, Cebr analysis

Appendix II: NACE Rev. 2-based definition of physics-based activities

Code	Description	Code	Description
6.1	Extraction of crude petroleum	27.51	Manufacture of electric domestic appliances
6.2	Extraction of natural gas	27.9	Manufacture of other electrical equipment
9.1	Support activities for petroleum and natural gas extraction	28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
20.13	Manufacture of other inorganic basic chemicals	28.21	Manufacture of ovens, furnaces and furnace burners
21.2	Manufacture of pharmaceutical preparations	28.23	Manufacture of office machinery and equipment (except computers and peripheral equipment)
23.44	Manufacture of other technical ceramic products	28.25	Manufacture of non-domestic cooling and ventilation equipment
24.46	Processing of nuclear fuel	28.29	Manufacture of other general-purpose machinery n.e.c.
25.21	Manufacture of central heating radiators and boilers	28.49	Manufacture of other machine tools
25.3	Manufacture of steam generators, except central heating hot water boilers	28.92	Manufacture of machinery for mining, quarrying and construction
25.4	Manufacture of weapons and ammunition	28.99	Manufacture of other special-purpose machinery n.e.c.
25.99	Manufacture of other fabricated metal products n.e.c.	29.1	Manufacture of motor vehicles
26.11	Manufacture of electronic components	29.31	Manufacture of electrical and electronic equipment for motor vehicles
26.12	Manufacture of loaded electronic boards	30.11	Building of ships and floating structures
26.2	Manufacture of computers and peripheral equipment	30.2	Manufacture of railway locomotives and rolling stock
26.3	Manufacture of communication equipment	30.3	Manufacture of air and spacecraft and related machinery
26.4	Manufacture of consumer electronics	30.4	Manufacture of military fighting vehicles
26.51	Manufacture of instruments and appliances for measuring, testing and navigation	30.91	Manufacture of motorcycles
26.6	Manufacture of irradiation, electromedical and electrotherapeutic equipment	32.5	Manufacture of medical and dental instruments and supplies
26.7	Manufacture of optical instruments and photographic equipment	32.99	Other manufacturing n.e.c.
26.8	Manufacture of magnetic and optical media	33.11	Repair of fabricated metal products
27.11	Manufacture of electric motors, generators and transformers	33.12	Repair of machinery
27.12	Manufacture of electricity distribution and control apparatus	33.13	Repair of electronic and optical equipment
27.2	Manufacture of batteries and accumulators	33.14	Repair of electrical equipment
27.31	Manufacture of fibre optic cables	33.15	Repair and maintenance of ships and boats
27.32	Manufacture of other electronic and electric wires and cables	33.16	Repair and maintenance of aircraft and spacecraft
27.33	Manufacture of wiring devices	33.17	Repair and maintenance of other transport equipment
27.4	Manufacture of electric lighting equipment	33.2	Installation of industrial machinery and equipment

Code	Description	Code	Description
35.11	Production of electricity	**61.9**	Other telecommunications activities
38.12	Collection of hazardous waste	**62.09**	Other information technology and computer service activities
38.22	Treatment and disposal of hazardous waste	**71.11**	Architectural activities
51.22	Space transport	**71.12**	Engineering activities and related technical consultancy
52.21	Service activities incidental to land transportation	**71.2**	Technical testing and analysis
52.22	Service activities incidental to water transportation	**72.11**	Research and experimental development on biotechnology
52.23	Service activities incidental to air transportation	**72.19**	Other research and experimental development on natural sciences and engineering
60.1	Radio broadcasting	**72.2**	Research and experimental development on social sciences and humanities
60.2	Television programming and broadcasting activities	**74.2**	Photographic activities
61.1	Wired telecommunications activities	**74.9**	Other professional, scientific and technical activities n.e.c.
61.2	Wireless telecommunications activities	**95.12**	Repair of communication equipment
61.3	Satellite telecommunications activities		

Appendix III: Methodology and data sources

TURNOVER, EMPLOYMENT & GVA

The data underlying the analysis presented in section 2 are drawn entirely from Eurostat's Structural Business Statistics (SBS). The SBS database is based on data provided by enterprises and is categorised according to a classification of economic activities called NACE. Under NACE, enterprises are assigned industry classifications according to their principal activity, meaning that the value added and turnover that they generate, the persons they employ, and the values of all other variables will also be classified under the same principal activity or industry.[14]

The SBS database provides information on the structure, conduct and performance of businesses across the European Union. The statistics are broken down to a very detailed sectoral level – several hundred economic activities – and are more detailed than national accounting data.

Under NACE Rev. 1.1, the national accounts contained data for 61 NACE Rev. 1.1 divisions (categories of economic activities or industries), of which 48 are within the 'business economy' covered by SBS.[15] With the recent switch to NACE Rev. 2, there are 65 divisions, 49 of which are within this "business economy, which includes industry, construction and distributive trades and services" covered by the SBS database.[16]

The level of detail offered by the SBS which, as already noted, goes well beyond these 49 divisions, facilitates the analysis of economic indicators at the required level of industry disaggregation for the relevant physics-based activities.[17]

SBS datasets based on NACE Rev 1.1 only go as far as 2008, while those based on NACE Rev. 2 begin in 2008 and have recently been updated to 2010. The switch reflects structural changes in the economy involving the emergence in importance of new industries and the decline of others. The timing of the switchover had implications for the present study because the period to be covered, 2007-2010, spans both industrial classification systems.

To produce a working definition of physics-based activities, they were identified with the relevant industries at the 3-digit and 4-digit levels. Because the data available under NACE Rev 2 covers 3 of the 4-year timeframe for this study, we adopted NACE Rev 2 as our starting point. We present 2007 data, which are only available under NACE Rev 1.1, alongside these 2008-2010 data, having used a Eurostat correspondence system defining NACE Rev. 2 activities in terms of their analogous sectors under the NACE Rev. 1.1 framework, to estimate the 2007 economic indicators under the NACE Rev 2 classification.

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14 This principal activity is generally the one that generates the largest amount of value added for the enterprise.

15 These national accounting data – provided in Eurostat's supply-and-use and input-output tables - are used in conjunction with the Structural Business Statistics for the analysis in Section 3. Note that the national accounting data have other advantages relative to SBS, which also become apparent in the section on direct, indirect and induced impacts below.

16 Financial services do not feature because of their specific nature and the limited availability of most types of standard business statistics in this area. Neither does SBS cover agriculture, forestry and fishing or public administration and (largely) non-market services like education and health.

17 Note that the 61 NACE Rev. 1.1 divisions that feature in the national accounts are at the 2-digit level of industrial classification. SBS data for the 2007-2010 period are provided at the 4-digit level of industrial classification. Our aggregate 'physics based sector', as outlined in Appendix II – Measuring physics in the economy, includes a range of industries classified at the 3-digit and 4-digit levels. Some data for certain indicators were incomplete at the required level of detail, especially at the national level (see Appendix I), which necessitated the estimation of values drawing on wider European trends in the detailed (4-digit) industries, trends in related variables that provided a reasonable proxy for the statistic being measured, or trends observed at higher levels of industrial aggregation.

Adjustments were made to some industries to estimate the proportion of these industries that are physics-based. These adjustments draw upon Human Resources in Science and Technology (HRST) employment statistics, which measure the numbers of workers who are highly-qualified in science and technology among various industry sectors. The number of such people, as a proportion of total employment in those sectors, was used as a proxy to estimate the physics-based elements of such sectors.

DIRECT, INDIRECT, AND INDUCED IMPACTS

Section 2 of the report shows the direct impacts of physics on the “business economy” through SBS datasets that are based on information provided by enterprises. These ‘raw’ estimates of the economic activity, through employment, turnover and value added, generated by the ‘physics-based industries’ are subject to a number of caveats. This subsection of the appendix explores these caveats and explains our analysis of the economic contribution of physics as derived using the EU ‘national’ accounting framework, the results of which are presented in section 3 of the report.

The use of a different framework inevitably means the derivation of alternative estimates of some of the same (or closely related) indicators of direct economic impact featured in the last section. However, these are arguably more robust for reasons elaborated on below and as long as the assumptions made in using the national accounting framework are believable.

What EU-level national accounting data definitely does provide is a robust framework for the analysis of the indirect and induced multiplier impacts of the physics-based industries. This is provided through Eurostat’s supply, use and input-output datasets.[18] We use this important part of the national accounting framework in conjunction with the Leontief matrix multiplier approach as the basis for our estimates of the indirect and induced impacts of physics on the EU economy.[19]

This section focuses then on the direct, indirect and induced impacts of the physics-based industries on output, gross value added (GVA), employment and incomes from employment across the EU27. These indirect and induced contributions are also examined in the context of the following impacts:

Upstream through the economic activity supported in sectors that supply goods and services to the physics-based industries;

Employee spending through the economic activity supported in the economy through the spending of employees within the physics-based industries;

Downstream through the economic activity supported in sectors that use goods and services provided by the physics-based industries.

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18 See http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/introduction for further details and http://epp.eurostat.ec.europa.eu/portal/page/portal/esa95_supply_use_input_tables/data/workbooks for the datasets.

19 Supply-use tables provide the most detailed official record of how sectors of the economy interact with other sectors, with consumers and with international markets in producing the nation’s GDP and national income. Input-output analysis, due largely to the work of Wassily Leontief (see, for example, Leontief, Wassily W. *Input-Output Economics.* 2nd ed., New York: Oxford University Press, 1986.), while macroeconomic in the sense that it involves analysing the economy as a whole, owes its foundations and techniques to the microeconomic analysis of production and consumption. (See ten Raa, Thijs (2005), *The Economics of Input-Output Analysis*, Cambridge University Press.) According to ten Raa (2005), some people argue that input-output analysis is at the interface of both, defining it as the study of industries or sectors of the economy.

The new data underlying the analysis in section 3 are drawn from Eurostat's supply, use and input-output datasets (or SUIOTs for short). These provide detailed information for a given year on production activities, the supply and demand for goods and services, intermediate consumption, primary inputs (factors of production) and foreign trade. We noted in above that national accounting data are less detailed than the SBS statistics, containing data for only 65 NACE Rev. 2 divisions (categories of economic activities or broad industries). However, the national accounting data are broader in scope because, as already described, 16 of their 65 divisions are not within the business economy covered by SBS.

The supply-and-use tables are matrices by product and industry showing the production processes and transactions of industries in respect of products (goods or services). The symmetric input-output tables are product-by-product or industry-by-industry matrices showing the production process for a given product in terms of its reliance on other products or for a given industry in terms of its reliance on other industries.

When we commenced our study, the latest supply, use and input-output tables available from Eurostat related to 2007. These are based on the NACE Rev. 1.1 classification of economic activities. Datasets for 2008 based on the NACE Rev. 2 classification have since appeared on the Eurostat website. We have used these 2008 NACE Rev. 2 based SUIOTs for the EU27 to estimate the direct and indirect and induced multiplier impacts of the physics-based industries.

Consolidated tables for each of the Euro and EU27 areas have been provided by Eurostat since 2011. These are consolidated from the tables transmitted by the Member States for their national economies, which is a compulsory requirement (every 5 years) under the European System of Accounts (ESA95).

The tables provide valuable insights that cannot be accessed via the SBS datasets such as:

- the structure of the costs of production and the value added generated in the production process;
- the inter-industry dependencies within the economy;
- the flows of goods and services produced within the national economy; and
- the flows of goods and services with the rest of the world.

There are also, as previously noted, caveats associated with the 'raw' estimates of economic activity provided by the SBS datasets. These relate principally to the methods used to value the economic indicator under consideration and are given due consideration in Box 1 below.

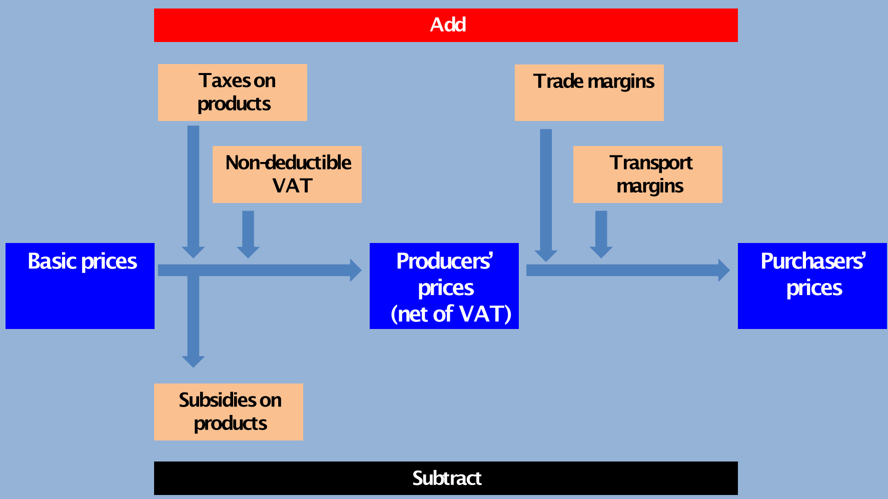
Box 1: Valuing economic indicators under SBS vs. ESA95

The EU-wide and national accounting methodologies represented by ESA95 combine different types of valuation for the same variable or transaction, thereby showing different actual prices depending on the type of unit implied in the economic transaction. For example, a household that purchases a consumer good in a retail shop does not perceive its price in the same way as the producer who produced the good in question. Different types of valuation of economic indicators like production and contribution to national product (GDP) are, therefore, borne out of different definitions of the price paid in different types of transaction.

The flowchart below shows that production (or 'industrial' output) can be valued according to two principal criteria, namely whether it's a price paid by a purchaser (what the buyer has to pay) or by a producer or 'basic' price (a price concept from the producer's point of view). Producer price is an intermediate concept that is closer to the basic price but which includes taxes and subtracts subsidies on products and adds non-deductible VAT. ESA95 and national accounts use basic prices and purchasers' prices and do not explicitly define "producer price".

Businesses' turnover is generally recorded at producers' prices. The SBS datasets therefore value production by the hundreds of NACE economic activities at producers' prices. But it is evident that the basic price is the best option from a theoretical point of view (that is, in terms of more accurately measuring economic impacts), reflecting more exactly than other price concepts the costs of the elements inherent in the product. In other words, the other price concepts disguise the real costs of the product and may be influenced by changes in fiscal policy or in trade and transportation. ESA95 and therefore the consolidated EU27 supply, use and input-output tables value production at basic prices, thus providing a bridge between the 'raw' estimates of the economic impact of physics and the real costs and value of production.

Flowchart - Valuing production or output



Source: Eurostat input-output methodology

The economic impacts presented in this section of the report are expressed in basic prices unless otherwise indicated.

The other principal reason to expect variability between the direct economic impact estimates based on SBS and those based on ESA95 is the fact that businesses' and, therefore, SBS industries' employment, turnover and value added contributions are based on all of their economic activities, regardless of whether they are physics-based or not. Likewise, businesses classified in industries that do not fall within our NACE-based definition of the physics-based industries may produce goods and services that are physics-based, even though their principal activity may not be physics-based (which would have led to their classification in non-physics-based industries in the first place).

The supply, use and input-output tables facilitate, therefore, the exclusion in our economic impact valuations of economic activities or production of physics-based industries that might not be physics-based or the inclusion of the production of non-physics-based industries that is physics-based.

These tables are thus used in conjunction with the results of our analysis of the SBS datasets in the previous section to produce estimates of the economic contribution of physics that are consistent with EU-wide and national accounting frameworks. Specifically, we acknowledged that each of the more detailed NACE 3-4-digit physics-based industries forms part of one of the 65 broader 2-digit industries contained in the NACE Rev. 2 based ESA95 framework. To assign the physics-based industries – which, combined, we label the physics-based ‘sector’ – an explicit role within the supply, use and input-output framework, we isolated and attributed shares of supply-and-use 2-digit industries to the 3-4-digit physics-based industries.

These attributions were based on the ratio of SBS turnover in the relevant 3-4-digit industry to SBS turnover in the relevant 2-digit industry of which it forms part.[20]

This amounts to a simplifying assumption that all 3-4-digit physics-based industries are levied (or endowed) with the same proportions of taxes (or subsidies) on products and are subject to the same proportions of non-deductible VAT as the broader 2-digit industries to which they belong (which often include non-physics-based elements). To the extent that the physics-based industries are levied with less taxes and in receipt of less subsidies on products[21] and are subject to lower proportions of non-deductible VAT, the ESA95-based estimates of the economic contribution of the physics-based industries presented in section 3 could be considered underestimates.

The sum of the attributions across the detailed 3-4-digit physics-based industries together constitute the physics-based sector within the ESA95-based EU-wide and national accounting frameworks.

Through the supply and use tables, we produced the estimates of the direct output and GVA contributions (at basic prices) of the physics-based sector, as well as estimates of the direct contribution to EU-wide income from employment. The symmetric input-output tables are used to produce Leontief matrix multipliers that are used to estimate the monetary scale of the upstream impacts of the physics-based sector as well as the physics-based employee spending (or induced) impacts. The result of all of this analysis is presented in section 3 of the report.

PHYSICS-BASED BUSINESSES AND THEIR SURVIVAL

Section 4 draws upon the business demography statistics provided by Eurostat, which measure the numbers and rates of enterprise births and deaths on an annual basis.[22] Since the demography dataset extends only to 2009, analysis was only possible on the first three years of the 2007-2010 period under consideration for the broader study.

These data are largely presented at a 2-digit level under the NACE Rev. 2 framework (with only a few sectors presented at a 3- or 4-digit level), necessitating an estimation procedure in order to measure demographic trends within the more detailed physics-based industries.

In order to estimate the business populations that can be characterised as physics-based under our definition, we utilised ratios derived from the SBS datasets. Within each 2-digit aggregate sector, we measured the proportion of enterprises that are defined as physics-

[20] The SBS turnover data are, as outlined in Box 1, based on producers’ prices whereas the ESA95 data are valued at basic prices. The former could not, therefore, be supplanted on the latter without significant adjustment first. Undertaking such adjustments for specific categories of industries or products, such as physics-based, was beyond the scope of this research. This is why we used proportional relationships between the detailed physics-based industries and their corresponding broader 2-digit industries for the purposes of incorporation in the ESA95 framework.

[21] This would certainly be the case in respect of, for example, on the tax side industries like tobacco and alcohol and, on the subsidy side, like agriculture, forestry and fishing.

[22] Some demographic events leading to creations or closures of enterprises are not classified as births or deaths: these include firms’ break-ups, split-offs, mergers, takeovers and restructurings; as well as the re-activation of businesses which closed down within the previous two years. In addition, creations of enterprises solely for the provision of one production factor or an ancillary activity (such as real estate or personnel) are excluded from these measures, as are enterprises with governmental legal forms.

based at the constituent 4-digit levels, and applied these proportions to the lesser-disaggregated business register data. Once these physics-based populations had been isolated, we applied the birth and death rates at the greatest level of disaggregation available (as noted previously, in most cases this was at the 2-digit level) in order to derive the count of physics-based enterprise births and deaths in each time period.

Where birth or death rates were not available, we utilised the total count of enterprise births or deaths in each sector, and applied the SBS-derived proportions in order to estimate the demographic events that are accounted for by physics-based enterprises.

INTERNATIONAL TRADE

Section 5 analyses the value of trade in physics-based goods and services. From our adapted supply-and-use tables, in which the physics-based sector is assigned an explicit role, we are able to measure the level of extra-EU imports and exports of physics-based goods and services in the base year of 2008. To measure trade developments over the 2007-10 timeframe, we used goods trade statistics classified in the SITC framework, which we have adapted to account for the physics-based goods and commodities as defined in our NACE Rev. 2 classification (see Appendix II). For trade statistics for the physics-based services industries, we have drawn upon data from the EU national accounts.

FDI

This analysis, the results of which are also presented in section 5 of the report, draws upon direct investment statistics provided by Eurostat, which detail financial investment flows into and out of the EU economy, according to the NACE Rev. 2 activity of the businesses being invested in. While the FDI dataset does not disaggregate fully to the many 4-digit NACE sectors in our physics-based definition, statistics were sourced at the greatest level of disaggregation possible (predominantly at the 2- and 3-digit NACE level), and the assumption made that the physics-based businesses received proportions of these investments equivalent to their share of the 2- or 3-digit sector’s turnover.

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