Physics and the Economy: Measuring the value of physics-based industries in the Republic of Ireland

A Cebr report for the Institute of Physics

November 2021

Authorship and acknowledgements

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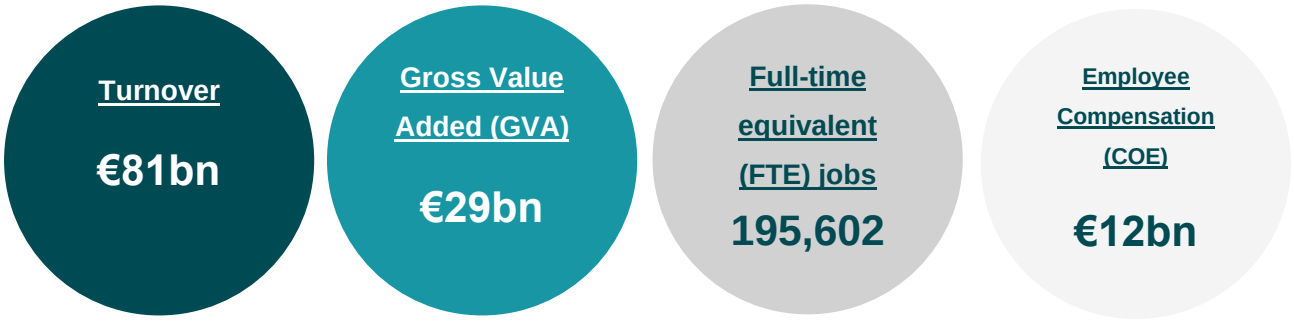
The report does not necessarily reflect the views of Institute of Physics.

London, November 2021

Contents

Headline findings

- This is a report by the Centre for Economics and Business Research (Cebr), on behalf of the Institute of Physics, detailing the **economic contribution of physics-based industries (PBIs) in the Republic of Ireland, to the Irish economy.**
- In the graphic below, we present the economic impact of the PBIs in the Republic of Ireland in 2019, although our analysis also covers trends over the nine preceding years.
- In 2019, it is estimated that in the Republic of Ireland, PBIs directly contributed to the Irish economy:



- Total GVA contributed by the PBIs in 2019 (€29 billion) represented 8.6% of the total Irish economy.
- The biggest PBI sub-sector in terms of GVA was Physics Manufacturing, which contributed €17.7 billion, followed by Physics Science & Technology (€4.58 billion) and Energy Production Transmission & Distribution (€2.56 billion).
- As of 2019, there were 19,994 PBI enterprises operating in the Republic of Ireland.
- In 2019 Physics Science & Technology was the PBI sub-sector with the greatest number of enterprises in the PBI sector, totalling 11,279 (55.7% of all PBI enterprises).
- Consistent with wider trends in the Republic of Ireland, 93.2% of PBI enterprises were considered micro enterprises. Of the remainder, 5.3% of enterprises were small (10-49 employees), and 1.5% were medium (50-249 employees) or large (250+). In Ireland as a whole, 91.4% of all enterprises were micro, 7.0% were small, and 1.6% were medium or large.
- Throughout the decade, the turnover of PBIs grew in nominal terms by 25.5%, from €64.8 billion to €81.3 billion. The highest absolute growth was experienced by the Physics Manufacturing sub-sector, which increased from €37.9 billion to €49.1 billion (29.6%), followed by Physics Science & Technology (from €9.5 billion to €11.5 billion, 20.6%)
- FTE employment in the PBIs reached nearly 200,000 in 2019, growing by 46.9% over the 2010-2019 period.
- Of the PBI sub-sectors, Physics Manufacturing employed the largest number of people in 2019; 108,798 or 54.5% of total Republic of Ireland PBI FTE employment. The Physics

Science & Technology sub-sector had the second largest share of employees, with 24.6%, after nearly trebling in size (growth of 197%) over the period 2010-2019.

- COE grew from €8.38 billion to €11.7 billion over the period (40.1%). This is a slightly smaller growth rate compared to employment, meaning that average COE decreased throughout the period. Employee compensation per FTE worker decreased overall across PBIs from €62,000 to €59,000.
- The Physics Manufacturing sub-sector experienced an increase (18%) in average COE over the period, reaching €59,000 by 2019. Of the major PBI sub-sectors, Telecoms and Physics Science & Technology reported the largest fall, with average COE shrinking by 42% and 39% respectively.
- The level of research and development (R&D) spending by PBIs broadly remained relatively stable in nominal terms, at around €1.4 billion over the decade. R&D activity increased in other, non-physics based sectors as the decade progressed, meaning that regardless of the high levels of R&D undertaken by the sector, the PBIs' share of total R&D decreased from nearly 80% in 2010 to 43% in 2019.

1. Introduction

This report by the Centre for Economics and Business Research (Cebr) on behalf of the Institute of Physics (IOP), considers the contribution and importance of physics-based industries (PBIs) to the Irish economy, an analysis that spans the period of 2010 to 2019. This report forms part of a series of six reports, which quantify the impact of PBIs on the UK and Irish economies.

1.1 Background and general purpose of the study

According to the IOP's definition, PBIs are those where either:

- Ongoing research and development (R&D) in the industry consistently makes use of physics knowledge in a way that can be expected to affect the fortunes of businesses within the industry

Or

- The underlying technology supporting the industry requires significant physics knowledge for continued operation

In other words, PBIs can be thought of as those industries in which the industrial and technical activities are based on the theories and results of physics to achieve their commercial goals.

This research provides up-to-date insights on the size and performance of the UK and Irish physics sectors, presenting a range of analyses which demonstrate different aspects of the economic value brought by the PBIs. The intention of this is to empower the IOP with a thorough and comprehensive knowledge and evidence base, such that they can support and advocate for the sector across the UK and Ireland.

An important task has been to develop an in-depth understanding of PBIs. To produce a robust study, it is necessary to analyse the available data to ensure that it captures the full range of activities that should be included in establishing the total economic 'footprint' of the industry. Following the collation of the necessary data capturing these activities, the values of key economic indicators were established to demonstrate the impact of the sector. The key macroeconomic indicators include:

- GVA[1] contributions to the Republic of Ireland and constituent regional GDP generated by the PBIs
- Full-time equivalent (FTE) jobs supported by the sector[2]

1 GVA, or gross value added, is a measure of the value of production in the national accounts. Conceptually it can be considered the value of what is produced, less the value of intermediate goods and services used to produce it. GVA is distributed in three directions – to employees, to shareholders and to government. It is often used as the proxy for the contribution of a sector or industry to GDP: strictly this relationship is GVA + Taxes on products - Subsidies on products = GDP.

2 The calculation of full-time equivalent (FTE) is an employee's scheduled hours divided by the employer's hours for a full-time workweek. When an employer has a 40-hour workweek, employees who are scheduled to work 40 hours per week are 1.0 FTEs. Employees scheduled to work 20 hours per week are 0.5 FTEs. We considered all parti-time workers to work 20 hours per week. Lastly, we subtracted the number of employees from the number of employment in order to get the number of self-employed individuals.

- The value of the turnover of the PBIs
- The value of employee compensation [3] generated by PBIs, representing the total remuneration of employees operating in the sector
- The productivity of the PBIs
- The number of PBI businesses operating in the Republic of Ireland
- The R&D undertaken by PBI enterprises

In addition to the core modelling and analysis, we also undertake a range of comparisons to contextualise the findings, including:

- How the economic indicators vary over the period 2010-2019
- How the economic indicators vary across different categories or groupings of the PBIs
- How the economic indicators for the PBIs vary between Ireland, the UK nations and other countries
- How the indicators for the PBIs compare with other important sectors of the Irish economy

Mapping Irish PBIs

Here we set out how PBIs have been defined for the purposes of the study. The PBIs consist of over 120 four-digit NACE codes, in which ongoing R&D in the industry consistently makes use of physics knowledge, or the underlying technology supporting the industry requires significant physics knowledge for continued operation. The full list of NACE codes used within this study can be found in Appendix I.

For the purpose of this report, these NACE codes are then aggregated into 11 sub-sectors.[4] These are:

- Oil & Gas Extraction
- Physics Manufacturing
- Physics Machine Services
- Energy Production, Transmission & Distribution
- Physics Waste & Recovery
- Physics Machine Sales
- Medical Equipment Sales
- Space Transport & Air Transport Services
- Telecoms
- Physics Science & Technology

3 Compensation of employees (COE) or employee compensation, is the total remuneration, in cash or in kind, payable by an employer to an employee in return for work done by the latter. This consists of wages paid to employees; employers' actual social contributions (excluding apprentices); employers' imputed social contributions (excluding apprentices); and employers' social contributions for apprentices.

4 In order to visualise the data better, and avoid some volatility, we aggregated several of these smaller sub-sectors into an 'Other' category. 'Other' consists of: Oil & Gas Extraction; Physics Machine Services; Physics Waste & Recovery; Physics Machine Sales; Medical Equipment Sales; Space Transport and Air Transport Services; and Defence

- Defence

1.2 Earlier research

The IOP previously commissioned Cebr in 2016 to produce studies focused on measuring the impact of the PBIs to the UK and Irish economies.

In this suite of six reports, we go beyond the 2016 research to present a range of new materials, including assessment of:

- How the full range of economic indicators for the PBIs vary across the UK nations and English regions, as well as the Republic of Ireland
- How the economic indicators for the PBIs vary between the UK and Ireland and other international comparable countries
- How the indicators for the PBIs compare with other important sectors in the UK and Ireland (such as Construction or Transportation & Storage), and how they are broken down by the UK's constituent nations and regions

In addition, the definition of the PBIs has been updated since the 2016 research; therefore figures between reports in the two series are not directly comparable. This report focuses on the Republic of Ireland specifically.

2. Enterprises in the PBIs

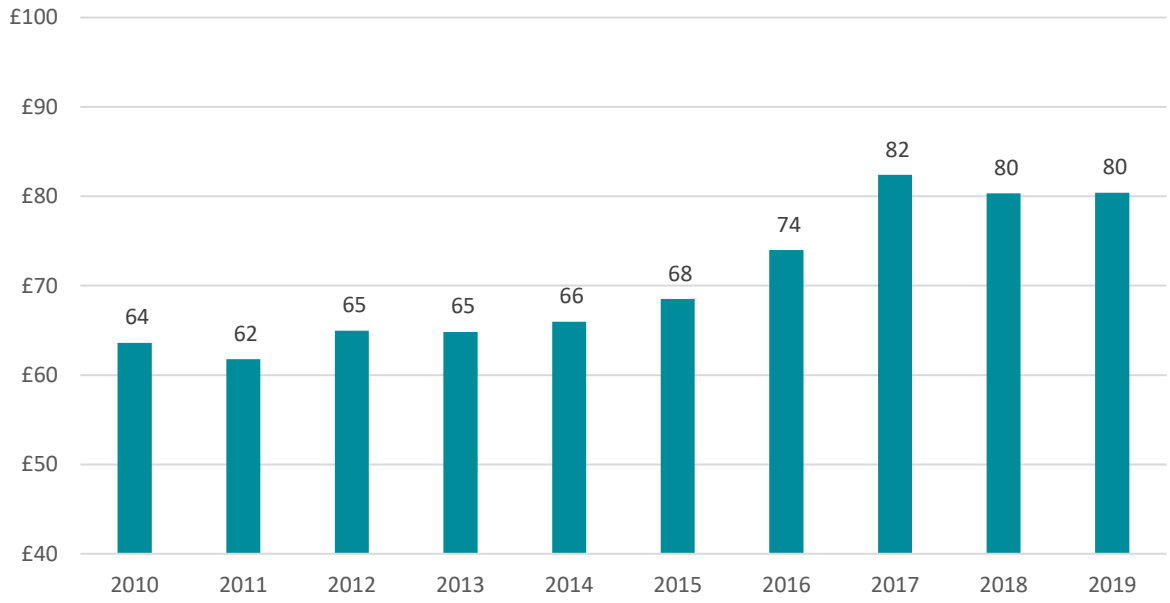
This section provides an assessment of the importance of PBIs to Ireland in terms of turnover and business demographics over the period 2010-2019.

2.1 Turnover

We firstly present the contribution of PBIs to the Irish economy in terms of the turnover generated by those industries. Figure 1 shows that Ireland's physics-based economic activities generated nearly €64 billion in turnover in 2010, which increased by 25.5% over the period 2010-2019 to around €80 billion in 2019 (slightly higher than the UK's 24.1% growth), meaning an average yearly increase of 2.6%.

After a period of relative stability through 2015, the value of PBI turnover grew significantly, reaching its highest peak in 2017 (€82 billion). The highest growth was registered in 2017, with an 11.3% increase.

Figure 1: Turnover in PBIs, € billions, 2010-2019



Source: PxStat, Eurostat, Cebr analysis

From 2015 onwards, the economic impact of the PBIs increased significantly, consistent with broader Irish economic trends. Irish GDP had a very strong increase in 2015, more than 25%, and the growth rate has remained high since.[5] A widely reported contributor to this high Irish GDP growth rate is the fact that in recent years, several large multinational corporations relocated their economic activities and underlying intellectual property to Ireland, attracted by low corporation tax rates. The value of this intellectual property is included within GDP

5 World Bank (2020). Annual % change in GDP

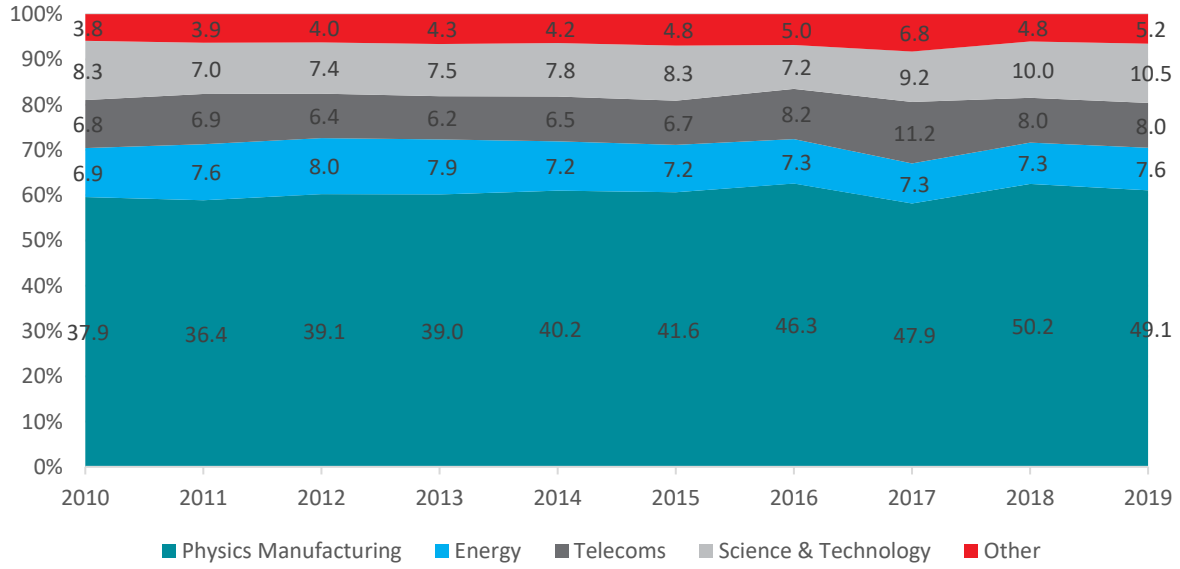
estimates, but does not necessarily correspond to underlying economic activity related to the PBIs.[6]

The following charts present a comparison of the different sub-sectors making up the PBI sector. Their composition remained reasonably constant throughout the 2010-2019 period. Nonetheless, whilst the share of turnover generated by Physics Manufacturing grew from 58.5% to 60.4%, the other largest sub-sectors (Energy Production, Transmission & Distribution; Telecoms; Physics Science & Technology) experienced a moderate fall in their share (although worth noting that turnover in absolute terms increased in each).

Those PBIs that are engaged in manufacturing generated the largest share of turnover, 60.5% on average over the period. This is significantly higher than the average contribution of this sub-sector in the UK (38%). The difference is attributed to two specific industries: NACE 32.5 (manufacture of medical and dental instruments and supplies) and NACE 32.99 (other manufacturing). The two generated more than 50% of the Physics Manufacturing turnover in 2019, while in the UK their share stood at 3.4%.

Physics Science & Technology was the second biggest sub-sector in terms of turnover (producing on average 11.8% of the wider physics sector's turnover), followed by Telecoms (10.6%) and Energy Production, Transmission & Distribution (10.5%). In absolute terms, the turnover of all the largest PBIs categories grew over the period 2010-2019. This can be seen graphically below, in Figure 2.

Figure 2: Turnover in the different sub-sectors of the PBIs in Ireland, % of PBI total (LHS axis) and monetary value (€ billions), 2010-2019

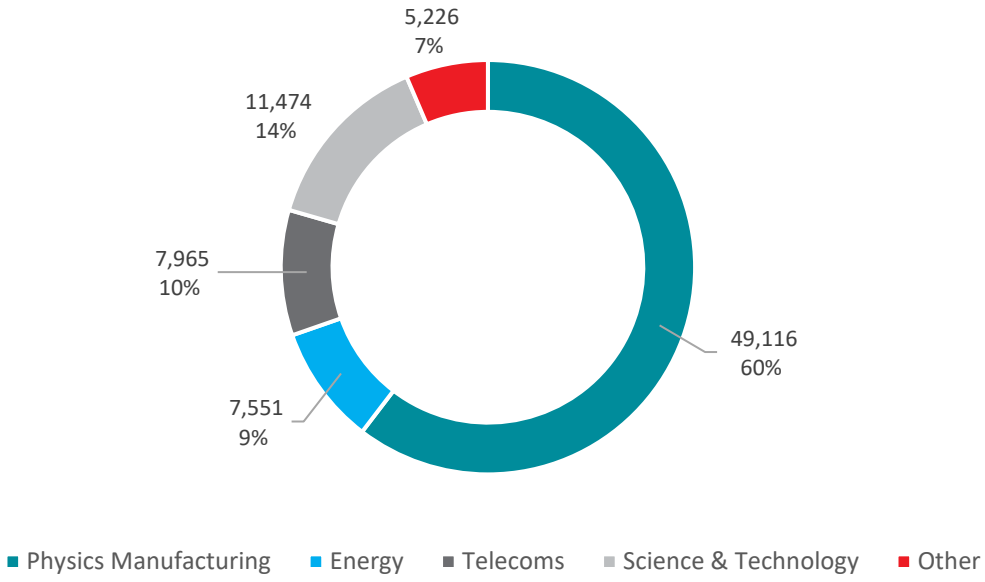


Source: PxStat, Eurostat, Cebr analysis

Figure 3 below visualises the breakdown of turnover in 2019.

6 OECD (2016). Irish GDP up by 26.3% in 2015?

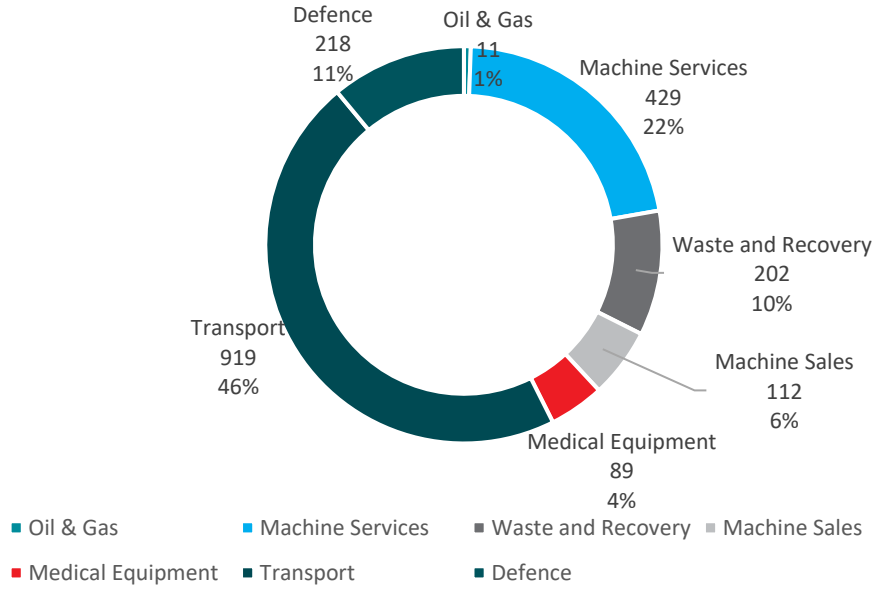
Figure 3: Turnover in the different categories of the PBIs in Ireland, € millions, 2019



Source: PxStat, Eurostat, Cebr analysis

Figure 4 below shows the full breakdown of the industries included within the 'Other' category.

Figure 4: Breakdown by turnover of industries included within 'Other', € millions and % of 'Other' total, 2019

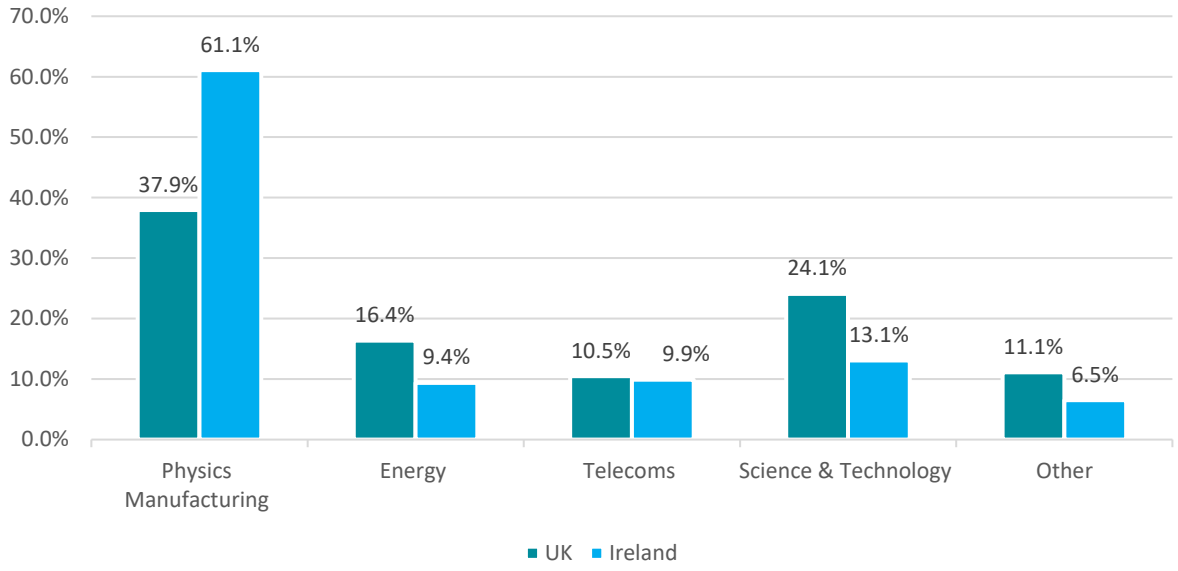


Source: PxStat, Eurostat, Cebr analysis

One can see a significant difference between the composition of PBI sub-sectors when comparing these results to the UK. In the UK, Physics Manufacturing had the largest turnover,

but its share was much lower than in Ireland: around 38%. Every other sub-sector highlighted, and most 'Other' sub-sectors, had a higher share in the UK than in Ireland.[7]

Figure 5: Turnover share in the different sub-sectors of the Republic of Ireland and UK PBIs, 2019



Source: PxStat, Eurostat, ABS, Cebr analysis

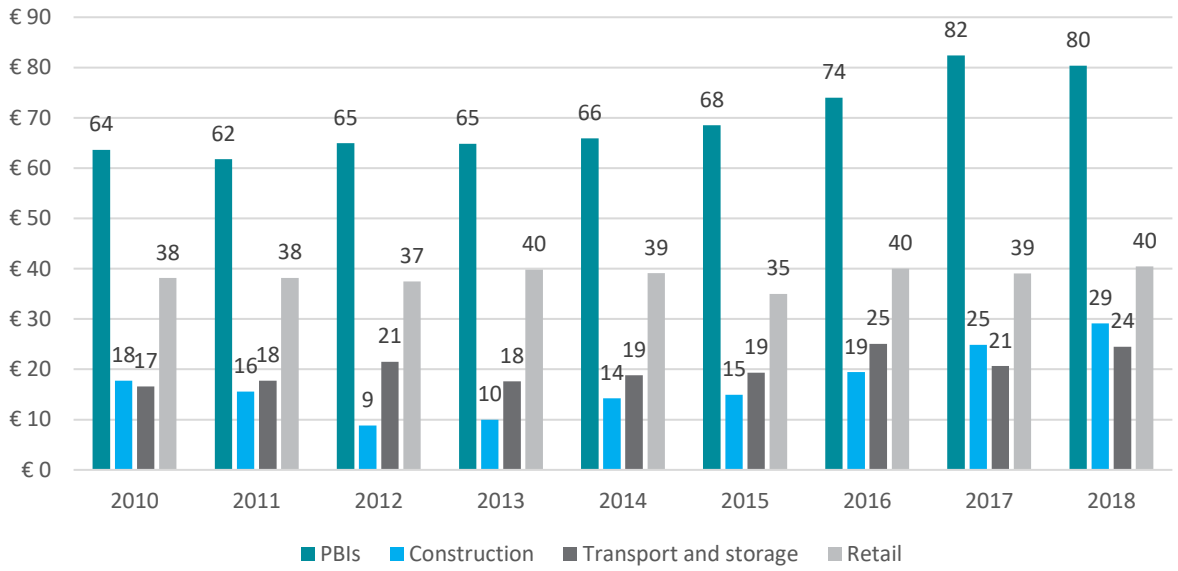
Industry comparison

The turnover of the PBI sector has also been compared to the turnover of three other significant sectors of the Irish economy: Construction, Transportation & Storage, and Retail[8]. The turnover of the PBI sector was much larger than that of the Retail, Construction, or Transportation & Storage sectors. In 2018, the PBI sector generated nearly double the turnover of the Retail sector, which is the second biggest sector. Construction and Transport & Storage, taken together, accounted for less than 70% of PBIs in terms of turnover. However, both the Construction and Transport sectors had a higher turnover growth rate: 64.6% and 47.4%, respectively over the period.

7 Interestingly, it is worth noting that Northern Ireland, being closely linked with both the UK and the Republic of Ireland, stood somewhere between the two: 49.6% of the PBI turnover came from the Physics Manufacturing sub-sector. When combining this with the Energy Production, Transmission & Distribution sub-sector, Northern Ireland's turnover is relatively distinct from both; combined turnover is 80%, compared to Ireland's 70% and the UK's 55%.

8 These sectors are selected for comparison, as three of the larger sectors, which do not already have significant overlap with the PBIs.

Figure 6: Turnover in selected Irish sectors, € billions, 2010-2018[9]



Source: PxStat, Eurostat, Cebr analysis

2.2 Business demography

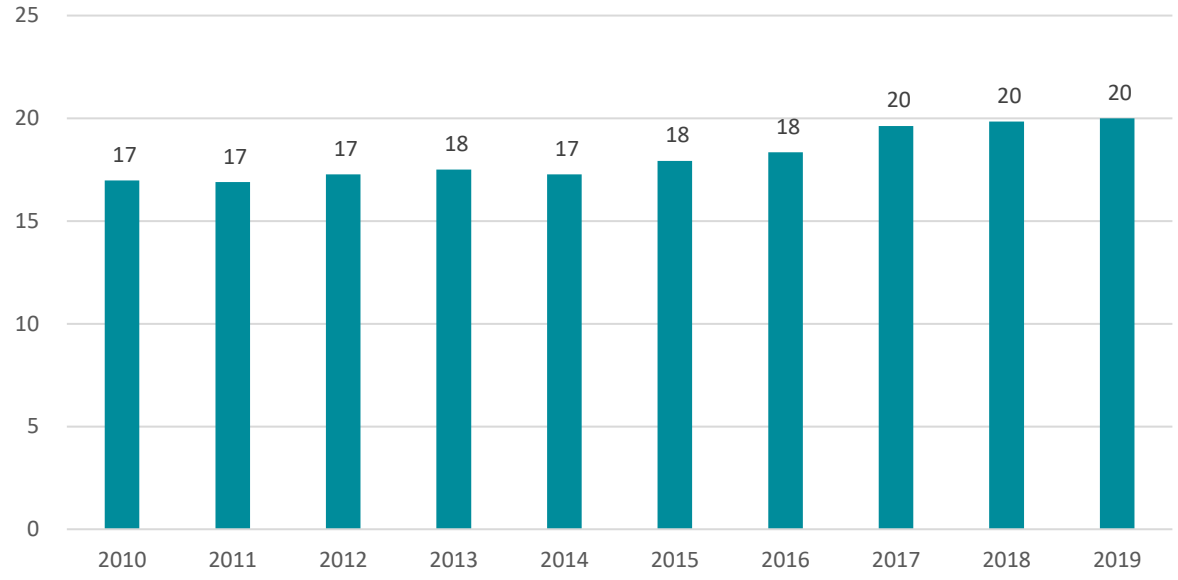
Business count[10]

In 2010 there were 16,972 PBI enterprises counted, which increased to 19,994 by 2019. The greatest change was seen in 2017, when the number increased from 18,346 to 19,625 (a 7% increase), while the majority of this increase occurred over the second half of the decade.

9 Due to a lack of data, we didn't include 2019 in the industry comparisons. NACE only provides limited data for the year, with nothing for Transportation or Retail.

10 Due to a lack of data, we didn't include the Defence sub-sector in the business demography analysis. NACE 84.22 is dominated by very few large enterprises, therefore omitting it doesn't alter the data on a significant level.

Figure 7: Number of physics-based enterprises in Ireland, thousands, 2010-2019



Source: PxStat, Cebr analysis

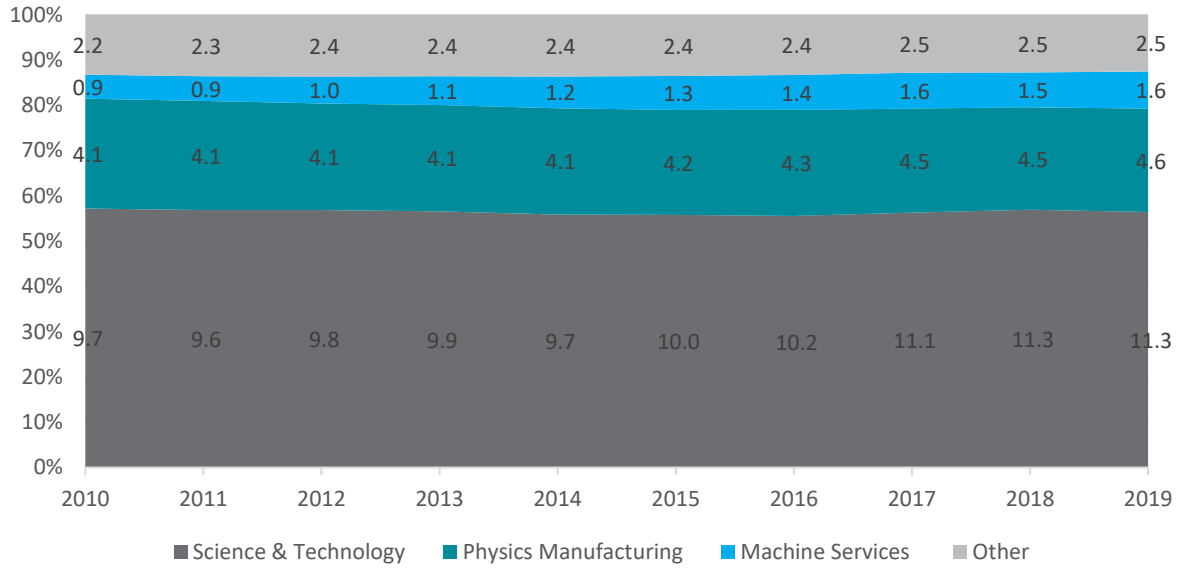
The number of enterprises rose by 17.8% over the period, which is slightly higher than the overall Irish average of 14.7% across all sectors.[11]

Figure 8[12] shows the composition of the number of Irish PBI enterprises by sub-sector. The Physics Science & Technology sub-sector provided the significant majority of PBI enterprises. On average, this sub-sector contributed 55.7% of all physics-related enterprises. In terms of the total number of enterprises, Physics Manufacturing had the second largest share, with 24.3%. These values were slightly different in the UK: 71.6% for Physics Science & Technology, and 18.8% for Physics Manufacturing.

11 From the overall Irish average, we omitted sectors Q (Human Health and Social Work Activities) and S (Other Service Activities) due to lack of data for 2010.

12 Here we included both the Energy Production, Transmission & Distribution and Telecoms sub-sectors to the 'Other' category, as they had few enterprises present.

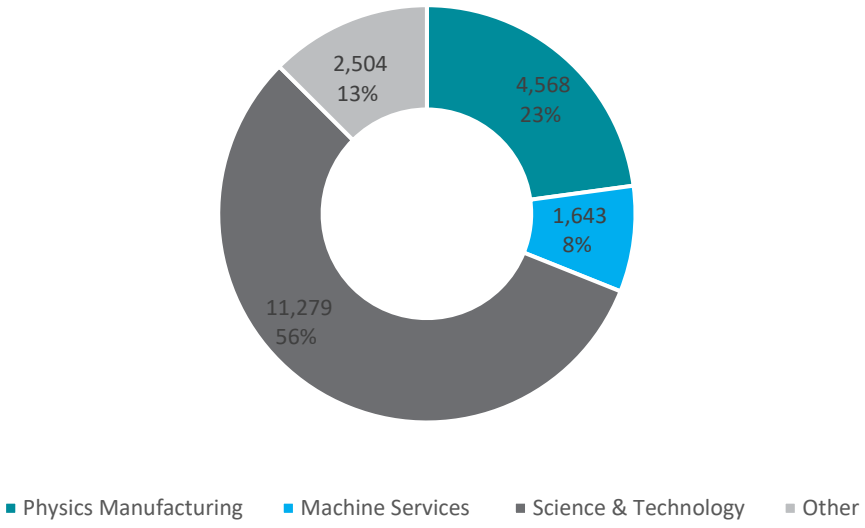
Figure 8: Number of enterprises in selected PBIs in Ireland, % of PBI total (LHS axis) and value (thousands), 2010-2019



Source: PxStat, Cebr analysis

Figure 9 visualises the distribution of enterprises within the PBI by sub-sectors for 2019. The UK's distribution is included in Figure 10 as a reference.

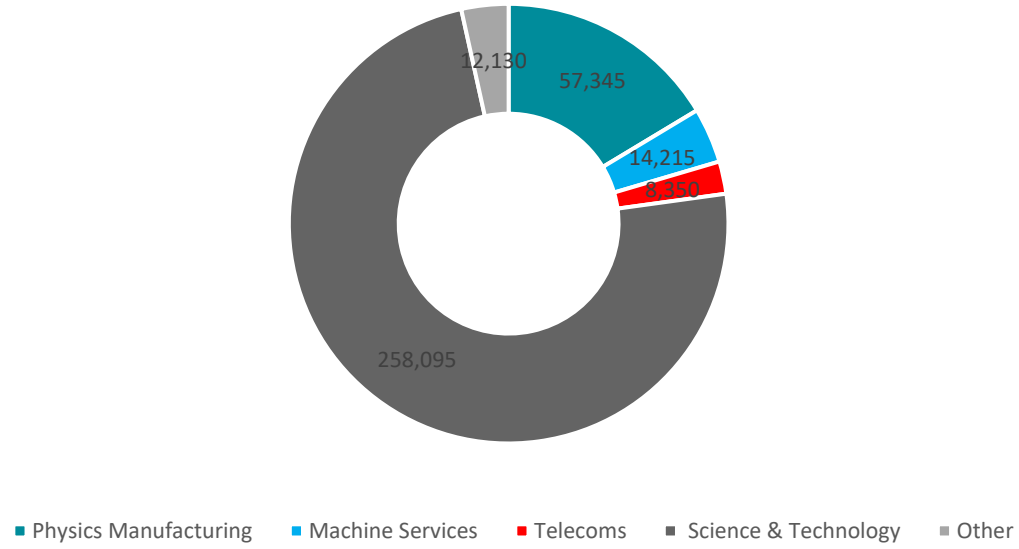
Figure 9. Number of enterprises in PBIs in Ireland, thousands, 2019



Source: PxStat, Cebr analysis

Note that the difference between the Physics Manufacturing and the Physics Science & Technology sub-sectors was not as high as in the UK. This is consistent with trends in other variables (such as business turnover); the Physics Manufacturing sector, relative to the aggregated PBIs, is slightly larger in Ireland than the UK.

Figure 10: Division of enterprises in UK PBIs, 2019

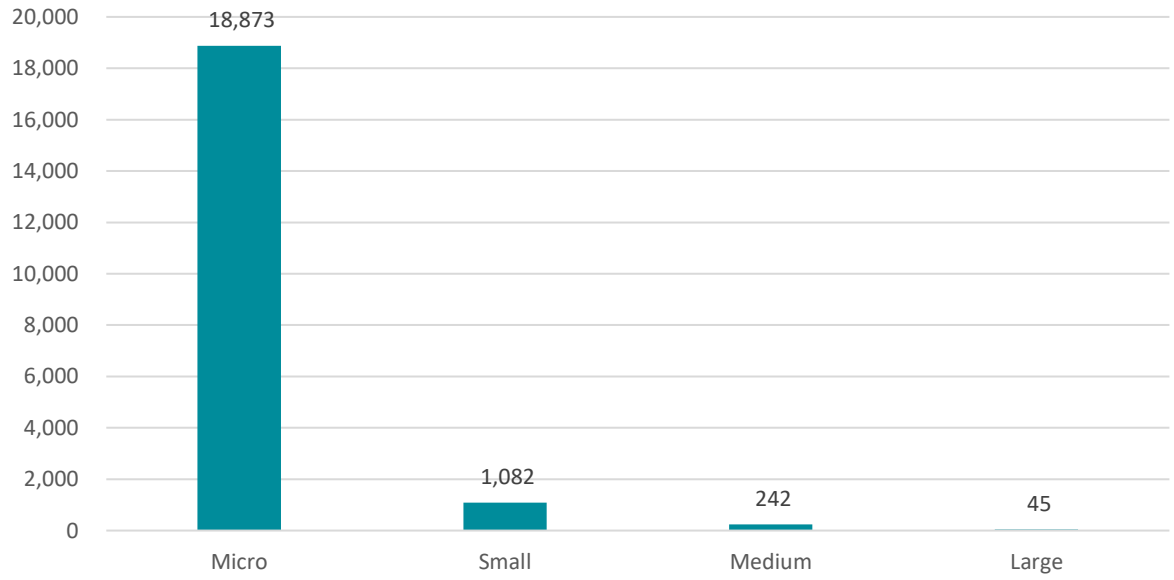


Source: Nomis, Cebr analysis

Size of enterprises

This section is focused on the size of Irish PBI enterprises in 2019. Consistent with wider trends in the economy, the PBIs were dominated by micro enterprises which employed a maximum of nine people: 93.2% of PBI enterprises were considered micro enterprises (18,873). Of the remainder, 5.3% (1,032) of enterprises were defined as small (10-49 employees), with the remaining 1.5% (287) medium (50-249 employees) or large (250+). By comparison, in the wider Irish economy, 91.9% of enterprises were micro enterprises, 6.7% small and the remaining 1.4% medium or large in the same year.

Figure 11: Number of enterprises in PBIs in Ireland, distinguished by size, 2019



Source: PxStat, Cebr analysis

The Energy Production, Transmission & Distribution sub-sector had the smallest-sized enterprises relatively, as almost 99% of all related enterprises were classified as micro enterprises. The Space Transport & Air Transport Services sub-sector had the lowest proportion of micro enterprises (103, 81.7%), whilst having the greatest proportion of large enterprises (2, 1.6%).

Table 1: Division of enterprises in PBIs in Ireland, distinguished by size, 2019

Sub-sector	Micro	Small	Medium	Large
Physics Manufacturing	4,282	386	120	28
Physics Machine Services	1,547	75	18	3
Physics Science & Technology	10,787	434	54	4
Other	2,257	187	50	10
Total	**18,873**	**1,082**	**242**	**45**

Source: PxStat, Cebr analysis

Age of enterprises

In addition, we present the average age of businesses in the PBI sector in 2018.[13] Due to data limitations, enterprises could only be broken down by year if they were less than five years old; all enterprises either six years old or older are aggregated. Table 2 shows the number of enterprises distinguished by age for the selected sub-sectors.[14]

Table 2: Division of enterprises in PBIs in Ireland, distinguished between age, 2018

Sub-sector	New	1 year	2 years	3 years	4 years	5 years	6+ years
Physics Manufacturing	188	269	270	197	186	152	3,460
Physics Machine Services	75	130	112	97	103	85	938
Physics Science & Technology	575	547	550	428	355	308	8,535
Other	137	151	131	131	103	93	1,771
Total	**975**	**1,097**	**1,063**	**853**	**747**	**638**	**14,704**

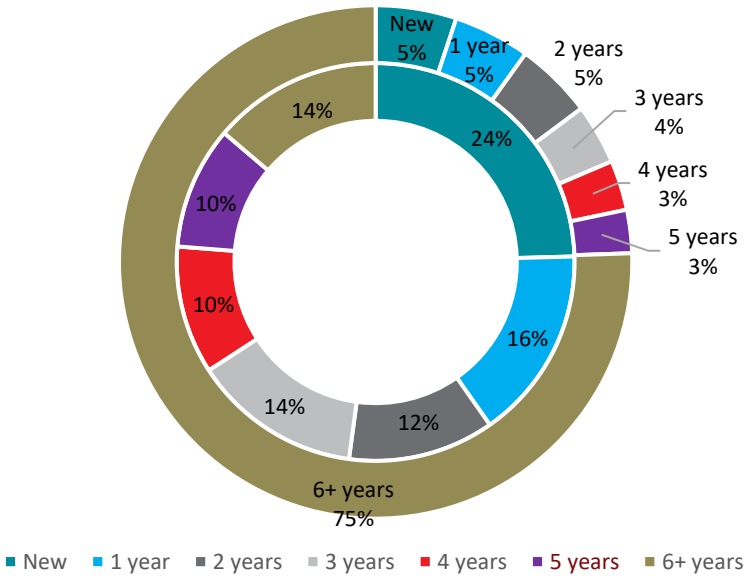
Source: PxStat, Cebr analysis

While in the UK, 86.2% of the enterprises in the sub-sector were at most five years old, in Ireland this share was only 24.5%. Figure 12 demonstrates this composition visually: 27% of all enterprises were founded in the five years preceding 2018, and 5% were newly created in 2018. This is remarkably different from the UK values, where less than a quarter of the enterprises were more than five years old, as of 2019. This is largely because the Physics Science & Technology enterprises in Ireland are more mature on average. In the UK, enterprises in this sub-sector started to rapidly increase from 2015 onwards, while in Ireland the rise was much lower. While in the UK, 86.2% of the enterprises in the sub-sector were at most five years old, in Ireland this share was only 24.5%.

13 At the time of analysis, there has been no data published yet for business survival rates for 2019.

14 The table draws a picture of PBI enterprises in 2018 – therefore, 'New' means the enterprise was founded in 2018, '1 year' means 2017, etc. '6+ year" means that the business was established in or before 2012.

Figure 12: Division of enterprises in PBIs in Ireland (outer) and the UK (inner), distinguished by age, 2018



Source: PxStat, Nomis, Cebr analysis

3. Economic contribution of PBIs to the Irish economy

This section provides an assessment of the importance of PBIs to Ireland in terms of GVA, employment and COE, over the period 2010-2019.

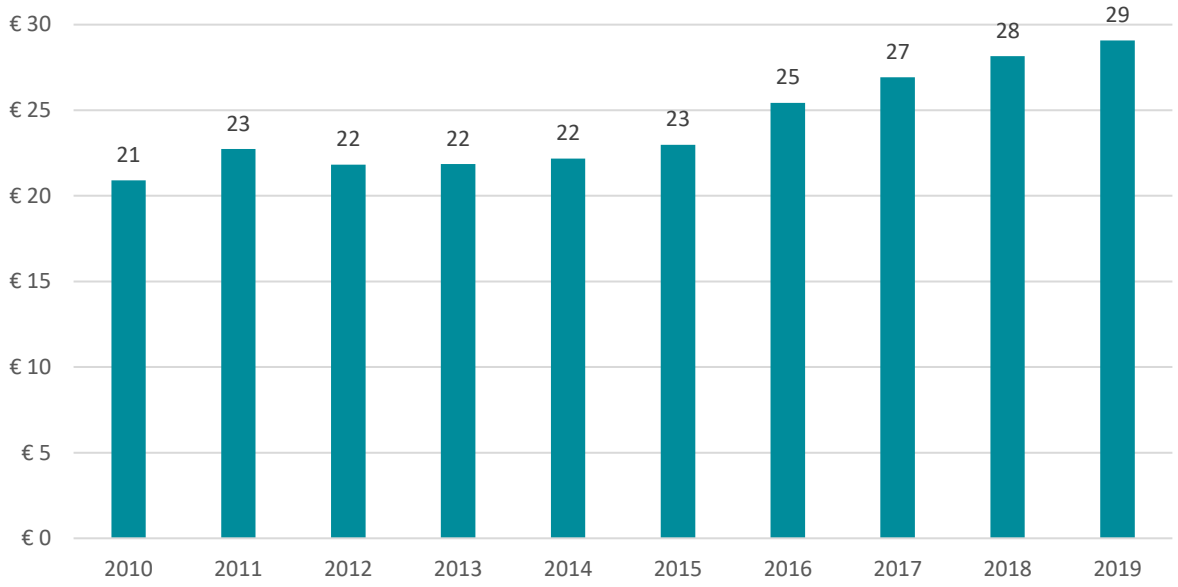
3.1 GVA

We now focus on the economic contribution of the PBIs to Ireland's economy in terms of their GVA contributions to GDP. GVA is a measure of the economic output of a sector, industry or economy; that is, the value of what they produce or provide after subtracting the inputs of goods and services required to do so.

We present our estimates of Irish PBIs' GVA contributions to Irish GDP. As shown in Figure 13, GVA stagnated in the first half of the period.

The latest data suggests a €29 billion GVA contribution in 2019: 8.7% of the total Irish economy, moderately less compared to the 10.6% contribution made by the UK PBI sector to the UK economy. Annual nominal growth was variable between 2010 and 2019. The value of GVA was relatively stable during the period 2010-2014 and then grew steadily through to 2019. This trend broadly aligns with the turnover values for the period.

Figure 13: GVA in PBIs, € billions, 2010-2019



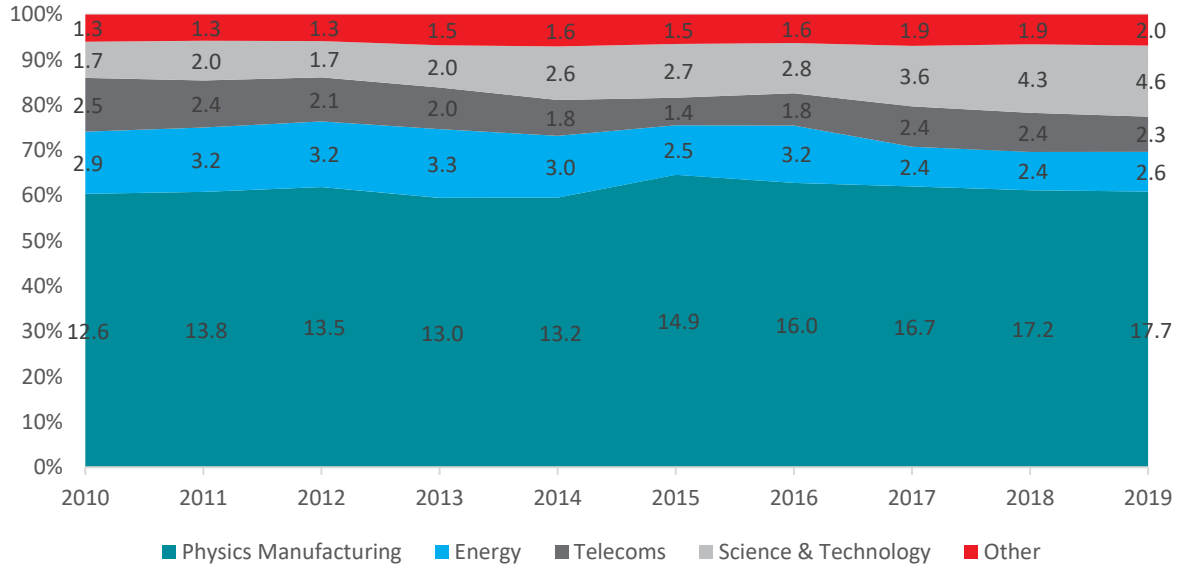
Source: PxStat, Eurostat, Cebr analysis

The large majority of the PBIs' GVA contribution was again accounted for by the Physics Manufacturing sub-sector, as illustrated in Figure 14, contributing on average 61.4% over the period 2010-2019. The next two largest-contributing sub-sectors were Physics Science & Technology and Energy Production, Transmission & Distribution, which accounted for 11.6% and 11.8% respectively.

Notably, GVA in the Physics Science & Technology sub-sector increased nearly threefold over the period, reaching €4.6 billion by 2019. This occurred despite the number of enterprises increasing by less than 20%, suggesting that GVA growth was likely driven by internal growth in existing enterprises, rather than growth in the number of enterprises.

Whilst the shares of GVA generated by Physics Manufacturing and Physics Science & Technology grew, the contribution of the Energy Production, Transmission & Distribution sub-sector to PBI GVA significantly fell over the period 2010-2019, as its share went from 13.7% to 8.8% (although in absolute terms, this decline was less extreme). Telecoms' contribution to the total PBI GVA also decreased over the period, from 11.9% to 7.7%.

Figure 14: GVA in selected PBIs in Ireland, % of PBI total (LHS axis) and monetary value (€ billions), 2010-2019



Source: PxStat, Eurostat, Cebr analysis

Looking at direct GVA per pound of turnover, Physics Science & Technology presented significantly larger ratios (43.5%) than Physics Manufacturing, Energy Production, Transmission & Distribution and Telecoms (36%, 34% and 28.3%, respectively).

The performance of the Energy Production, Transmission & Distribution sub-sector also fluctuated up until 2015. In 2011, Ireland still imported 88% of the energy it required, and oil had been the most dominant energy force, which mainly comes from the UK.[15] In fact, the consequences of Brexit on the Irish energy sector have been debated at length.[16]

This strong dependence on the UK Oil & Gas Extraction sub-sector means that the oil price plunge of 2014-2016 had a strong effect on the Irish Energy Production, Transmission & Distribution sub-sector (the Irish Oil & Gas Extraction sub-sector is very small, therefore the effects there do not significantly drive wider PBI trends). Excess production and, therefore, supply of oil in 2014 was not met by the high levels of demand that was expected, due to the low responsiveness of economic activity in key oil-importing emerging markets.[17] Consequently, reserves of oil increased and prices declined rapidly. The UK oil and gas supply chain both supplies domestic activities and exports about £12 billion of goods and

15 REEEP (2014). Ireland (2013)

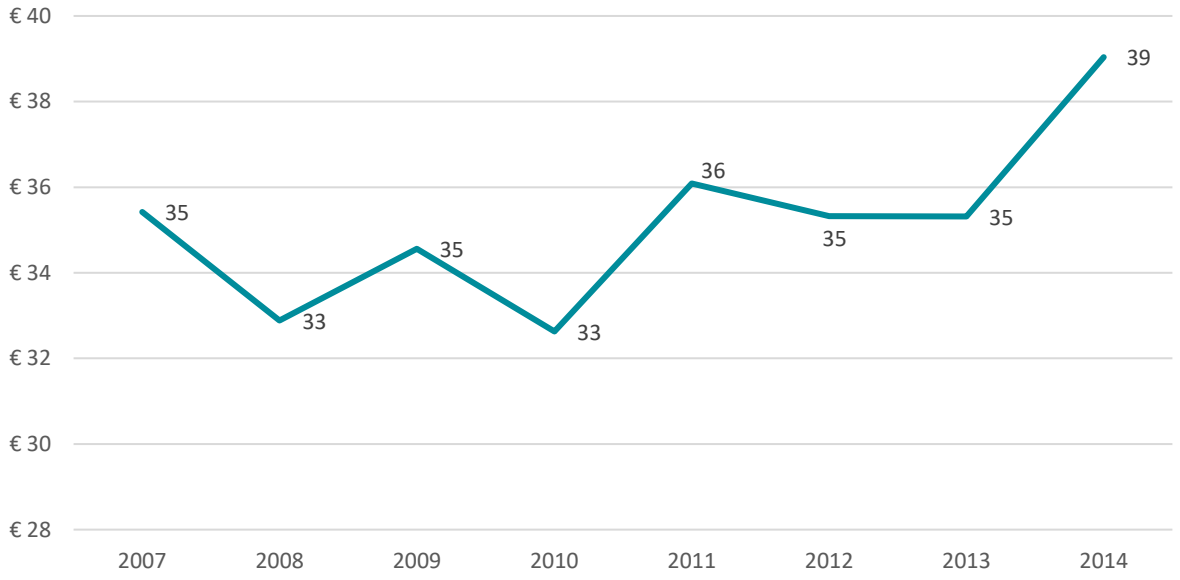
16 British Irish Chamber (2017). Ireland imports 90% of its oil and gas from UK – so energy must be near top of list of Brexit priorities

17 World Bank Blogs (2018). What triggered the oil price plunge of 2014-2016

services to the rest of the world, meaning the lack of demand for oil and resulting low prices impacted this industry strongly. This is evident in the drop in both GVA and employment in the Irish Energy Production, Transmission & Distribution sub-sector in 2015, as shown in the data.

Meanwhile, the wider Irish manufacturing sector also experienced some economic declines. GVA fell from €35 billion in 2009 to €33 billion in 2010, however this drop was lower than was first predicted due to the banking crisis, with output boosted by overseas demand, rather than manufacturers serving the domestic Irish market.[18] GVA recovered back to €35 billion by 2012.

Figure 15: GVA in the wider manufacturing sector in Ireland, € billions, 2007-2014



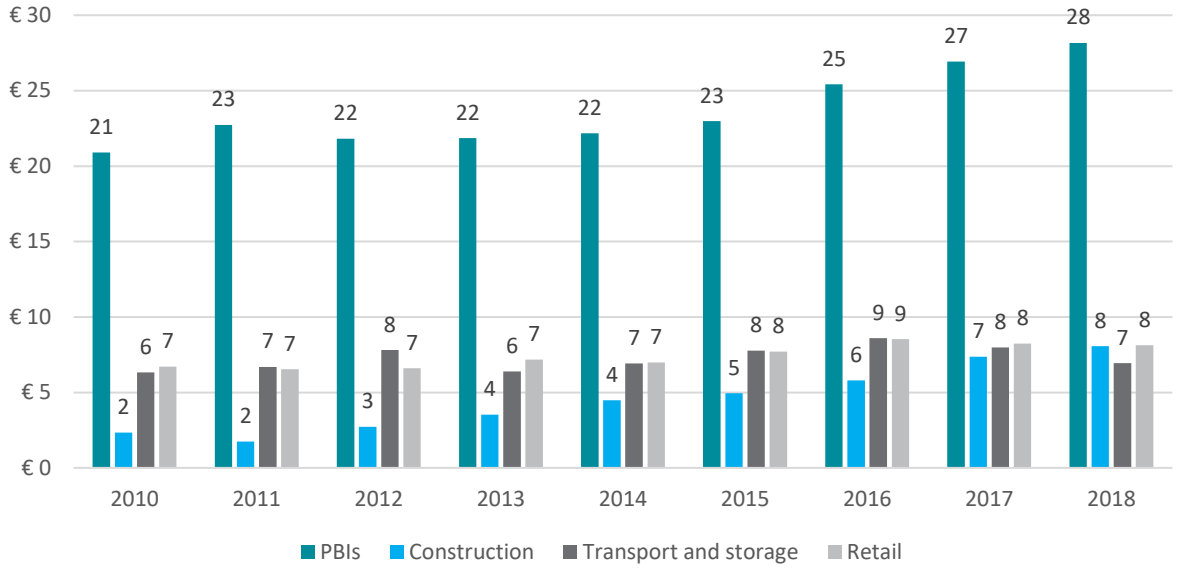
Source: Eurostat

Industry comparison

The GVA contributions of the entire PBI sector is compared with the same three other sectors in Figure 16 below. Using this measure, the gap is even wider than looking at turnover between PBIs and the other sectors: the PBIs directly generated close to three times the GVA of any of the three sectors across the entire period.

18 BBC News (2011). Irish manufacturing holding up, PMI survey suggests

Figure 16: GVA in selected Irish sectors, € billions, 2010-19

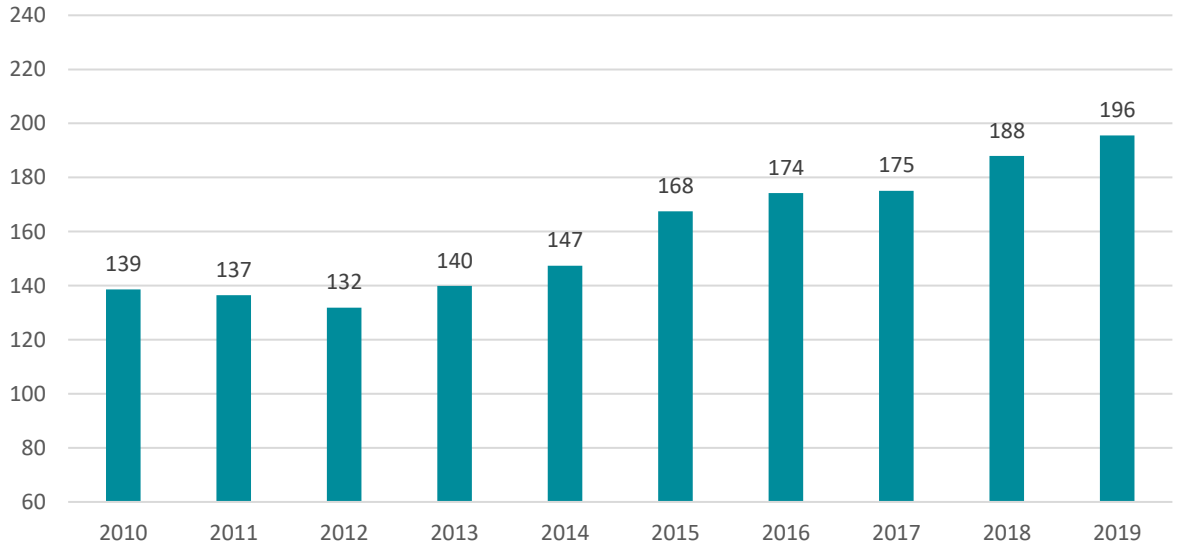


Source: PxStat, Eurostat, Cebr analysis

3.2 Employment

Cebr's estimates suggest that FTE employment in the PBIs was 195,602 in 2019, 8.6% of Irish employment as a whole. Like turnover and GVA, employment growth was variable over the period 2010-2019, averaging 4.5% annually, although stronger over the second half of the decade. The strongest growth was reported in 2015 (11.8%).

Figure 17: Physics-based employment in the Republic of Ireland, FTEs, thousands, 2010-19



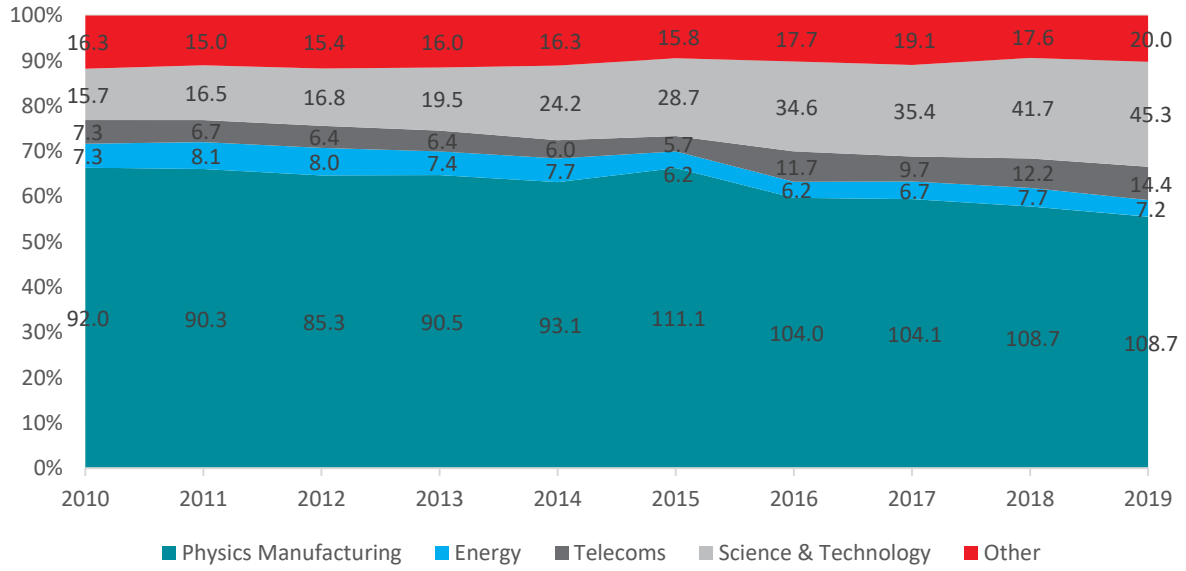
Source: PxStat, Eurostat, Cebr analysis

Broadly consistent with trends in other variables, more than half of employment in the PBIs was accounted for by the Physics Manufacturing sub-sector (54.5% recorded in 2019). The Physics Science & Technology sub-sector had the second largest share, accounting for 24.6% of PBI employment in 2019. The remainder was made up by Telecoms (7.2%), Energy Production, Transmission & Distribution (3.6%) and 'Other' PBIs (10%).

While employment in the Physics Manufacturing sub-sector was relatively steady (around 90,000 – 110,000 FTEs over the whole period), Physics Science & Technology drove much of the wider PBI growth, increasing significantly, from 16,000 to 49,000 (197.4%). This is consistent with the strong growth in GVA for this sub-sector. This broadly mirrors wider macroeconomic trends: by 2016, almost a third of all workers worked in a STEM-related role in the wider Irish economy.[19] Similarly, FTEs in the Telecoms sub-sector doubled over the period 2010-2019, from 7,250 to 14,400. Supporting this, the broadband market has developed strongly, supported by an improving economic climate which revived investment among the key players, as well as Government efforts to improve wholesale access.[20]

Employment in the Energy Production, Transmission & Distribution sub-sector was broadly stable over the period, at around 7,000 FTEs. However, this sub-sector's contribution to employment was relatively low (3.6%) when compared to its contribution to turnover and GVA (9.3% and 8.8%, respectively).

Figure 18: Employment in selected PBIs in Ireland, % of PBI total (LHS axis) and value (thousands), 2010-2019



Source: PxStat, Eurostat, Cebr analysis

Labour productivity

Labour productivity is defined as annual GVA over the number of FTE workers in the same year, or output per worker per year. For the PBIs in Ireland, in 2019, the labour productivity in Ireland as a whole stood at €147,000, slightly less than the PBI value for the same year.

Ireland was heavily dependent on two specific industries: NACE 32.5 (manufacture of medical and dental instruments and supplies) and NACE 32.99 (other manufacturing). These

19 Silicon Republic (2016). Almost one-third of Ireland's workforce working in STEM-related roles

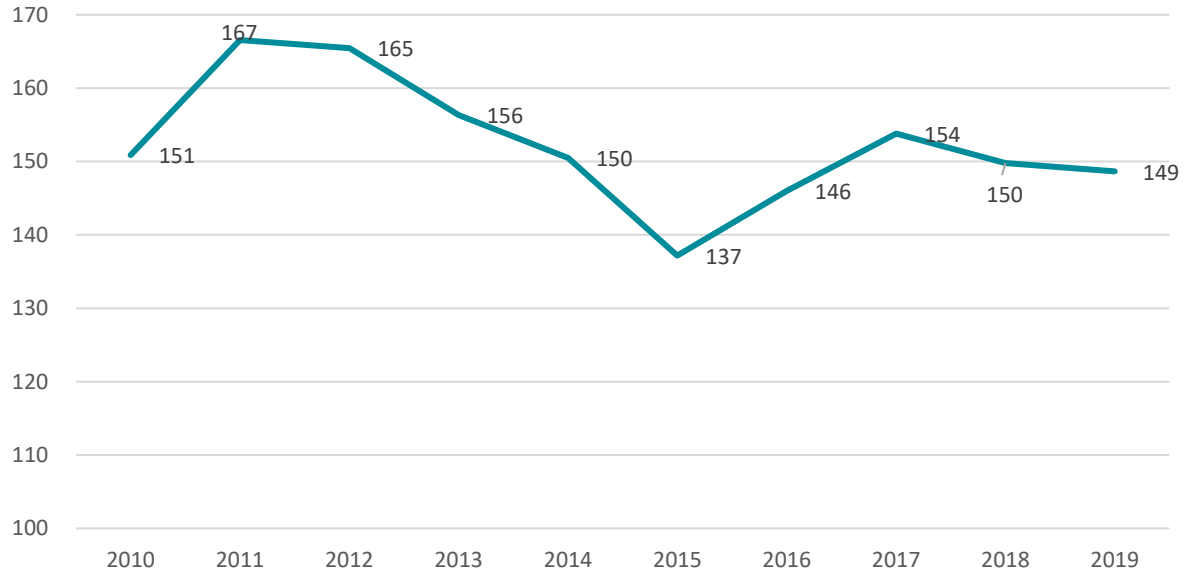
20 Business Wire (2018). Ireland Telecoms, Mobile and Broadband Statistics and Analyses 2018

collectively employed more than a quarter of all PBI workers, meaning they heavily influence the productivity rate - which is more than €200,000 for each.

The Physics Science & Technology sub-sector had a significant rise in employment from 2013 onwards, while its GVA only started to increase rapidly in 2016, which brought down its labour productivity. The Telecoms sub-sector's productivity also had a downward trend, as both its GVA and FTE values dropped over the period. Physics Manufacturing, on the other hand, had a positive growth: its productivity increased by 19%. Figure 20 below provides the growth rate of selected PBI sub-sectors, with 2010 being a base value.

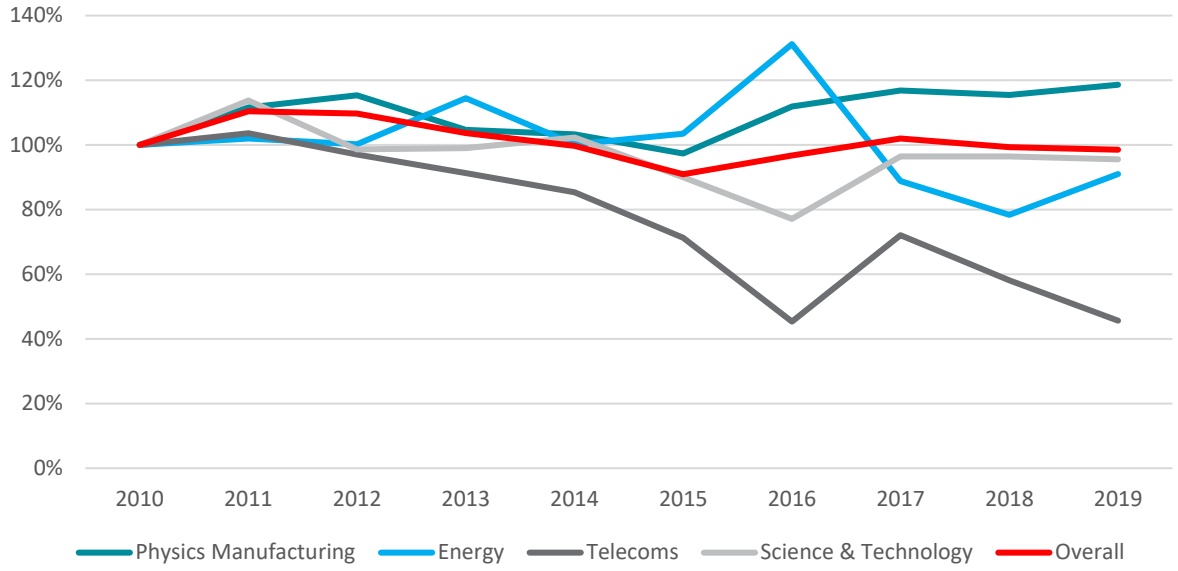
Figure 19 shows the evolution of this metric over the period. It was a fluctuating trend over the 2010 to 2019 period, but overall there was a labour productivity decrease of 1.5% from €151,000 to €149,000. There was a local peak in 2012 at €167,000 of output per worker. In 2019, the labour productivity in Ireland as a whole stood at €147,000, slightly less than the PBI value for the same year.

Figure 19: Overall labour productivity for PBIs in Ireland, € thousands, 2010-2019



Source: PxStat, Eurostat, Cebr analysis

Figure 20: Labour productivity in selected PBIs in Ireland, % of 2010 value, 2010-2019



Source: PxStat, Eurostat, Cebr analysis

Table 3 presents a comparison between the share of total FTE employment in PBIs in Ireland for each PBI and the share of the total GVA that is contributed by that respective sub-sector. In 2019, we find that these shares were broadly proportional, with the exception of two industries: Energy Production, Transmission & Distribution, and Physics Science & Technology. The Physics Science & Technology sub-sector's employment share was more pronounced than its GVA contribution; meanwhile, the Energy Production, Transmission & Distribution sub-sector's contributions to the total GVA generated by the Irish PBIs was greater than its respective shares of FTE employment. This suggests that labour productivity – defined as GVA per FTE employee – is higher in this sub-sector than the PBI average, while the reverse is true in the Physics Science & Technology sub-sector.

Table 3: Comparison between the shares of GVA and FTE employment by Irish PBIs, 2019

Sub-sector	Share of 2019 GVA	Share of 2019 employment
Oil & Gas Extraction	0.04%	0.01%
Physics Manufacturing	60.9%	55.6%
Physics Machine Services	1.5%	3.4%
Energy Production, Transmission & Distribution	8.8%	3.7%
Physics Waste & Recovery	0.7%	0.9%
Physics Machine Sales	0.4%	0.5%
Medical Equipment Sales	0.3%	0.4%
Space Transport & Air Transport Services	3.2%	2.8%
Telecoms	7.7%	7.4%
Physics Science & Technology	15.7%	23.2%
Defence	0.8%	2.1%

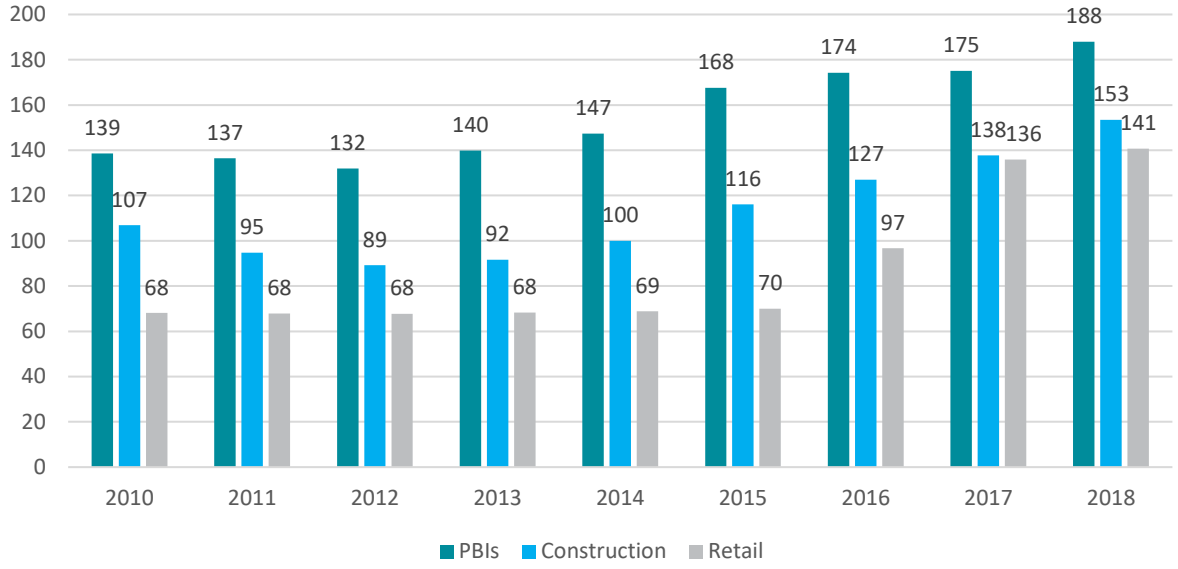
Source: PxStat, Eurostat, Cebr analysis

Industry comparison

Compared to the same three sectors, the PBI sector contributed the greatest share of employment, as seen in Figure 21. However, this trend is not as pronounced as when

considering turnover and GVA, suggesting a labour productivity advantage of the PBIs over the other sectors. For a similar share of Irish employment, the PBIs generated a greater GVA contribution than the Retail and Construction sectors.

Figure 21: Employment in selected Irish sectors, thousands, 2010-2019[21]

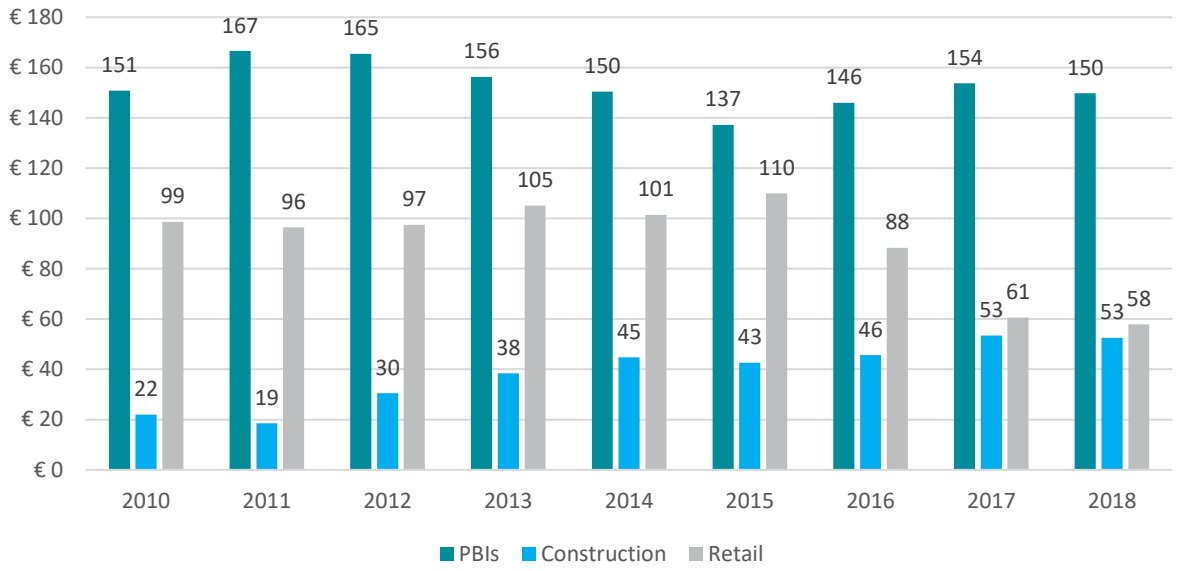


Source: PxStat, Eurostat, Cebr analysis

Figure 22 compares labour productivity (the GVA-FTE ratio) in the selected Irish sectors. Looking at this metric, the PBI sector reported the highest figure, with a GVA per FTE of around €150,000. For comparison, the UK had productivity of £86,000 (slightly less than €100,000).

21 Due to significant volatility raising questions about the validity of the underlying data, the Transportation & Storage sector has not been included within this comparison.

Figure 22: Labour productivity in selected Irish sectors, thousands, 2010-2019[22]



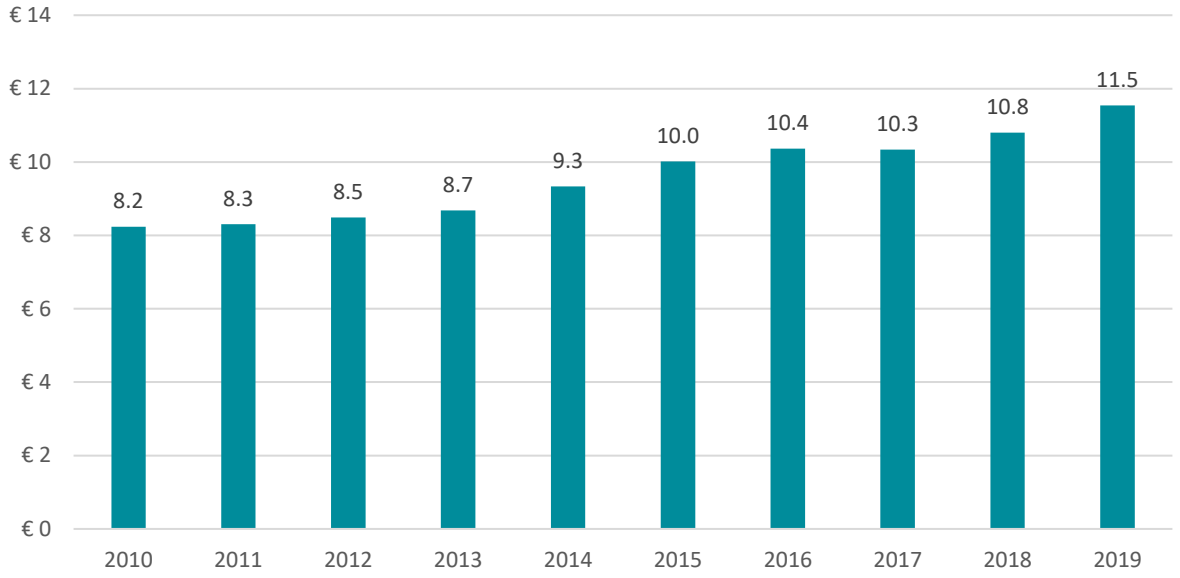
Source: PxStat, Eurostat, Cebr analysis

3.3 COE

When it comes to COE, the PBIs experienced a 40% cumulative growth, from €8.3 billion to €11.8 billion over the period. This is a slightly lower growth rate relative to employment, meaning that the average compensation per FTE worker decreased slightly over the period from €59,400 to €59,000.

22 Due to significant volatility raising questions about the validity of the underlying data, the Transportation & Storage sector has not been included within this comparison.

Figure 23: Physics-based COE in the Republic of Ireland, € billions, 2010-19



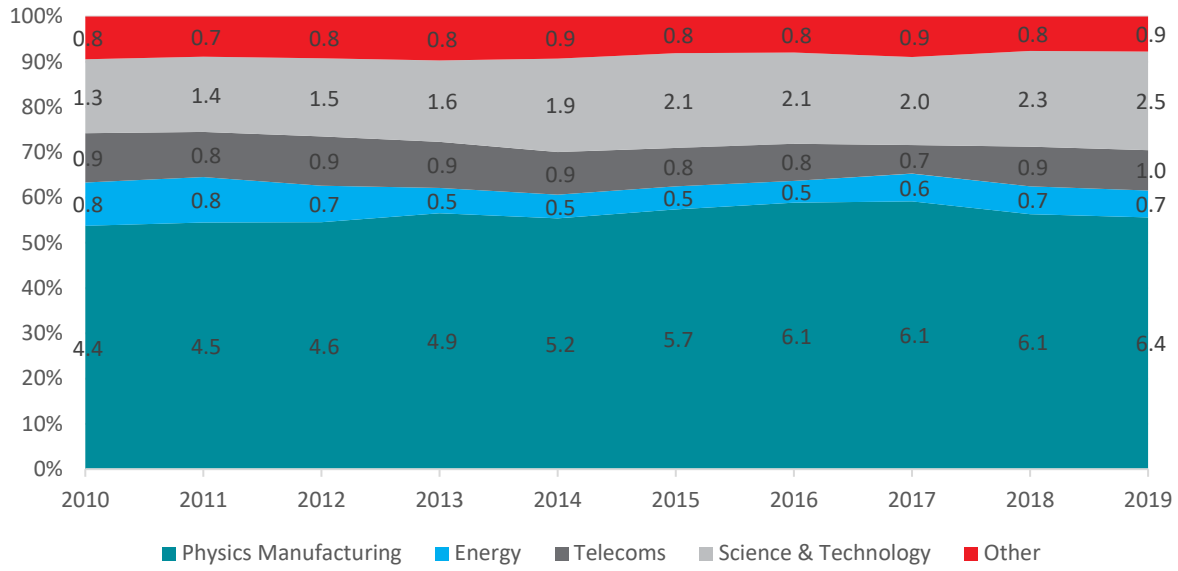
Source: PxStat, Eurostat, Cebr analysis

As with the other metrics, the Physics Manufacturing sub-sector was the largest contributor, accounting for 56.3% of all PBI COE, and Physics Science & Technology was the second largest contributor, with 19.4%. The Telecoms sub-sector had a surge in terms of turnover and GVA in 2017, while its FTE and COE decreased significantly. Consistent with broader trends, BT Ireland also announced an increase in both revenues and profits in 2017, despite a decline in the number of employees at the same time.[23]

Between 2010 and 2019, Physics Science & Technology was the fastest growing sub-sector in terms of COE, with 86.8%. However, this was still much slower compared to its FTE growth of 188%. This resulted in a drop of the Physics Science & Technology sub-sector COE/FTE value, from more than €85,000 to less than €56,000.

23 *The Irish Times* (2017). Pretax profits up 28% at BT Ireland as turnover jumps 14%

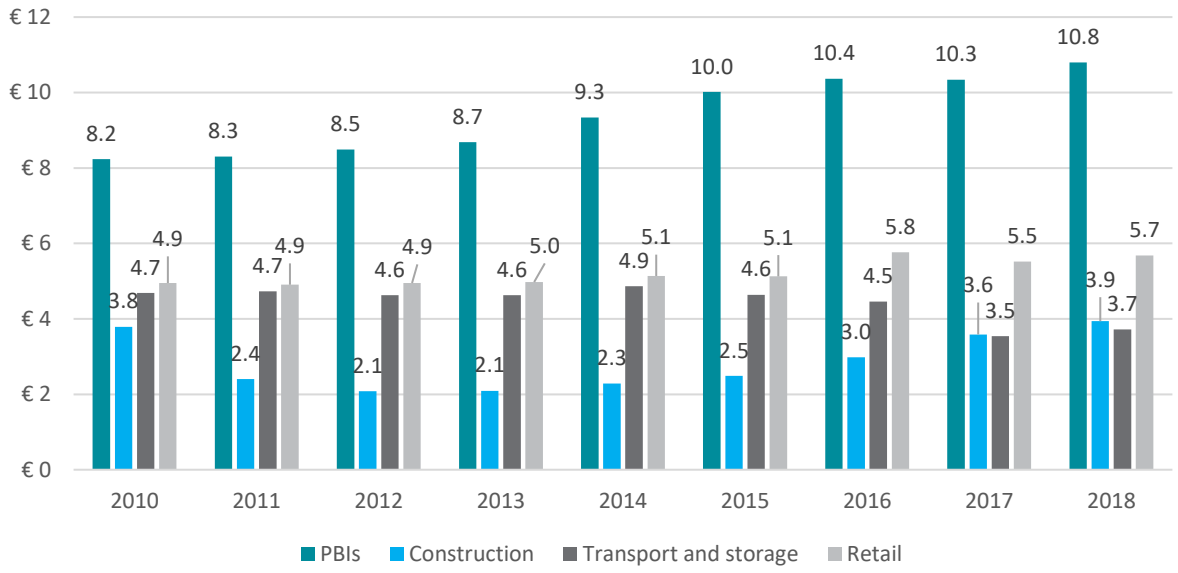
Figure 24: COE in selected PBIs in Ireland, % of PBI total (LHS axis) and monetary value (€ billions), 2010-19



Source: PxStat, Eurostat, Cebr analysis

Figure 25 shows the COE of the comparator sectors. Unsurprisingly, the trend is very similar to that seen for turnover. While the number of employees was also greater within the PBI sector, the difference was smaller, meaning the average COE/FTE is higher in the PBI sector than in the comparators. Furthermore, the PBI sector reported the largest cumulative growth in total COE over 2010-2018 (31.2%). Both the Construction and Retail sectors experienced a lower cumulative growth than the PBI sector: 3.9% and 14.7%, respectively. The Transport & Storage sector's cumulative growth was negative (-20.6%).

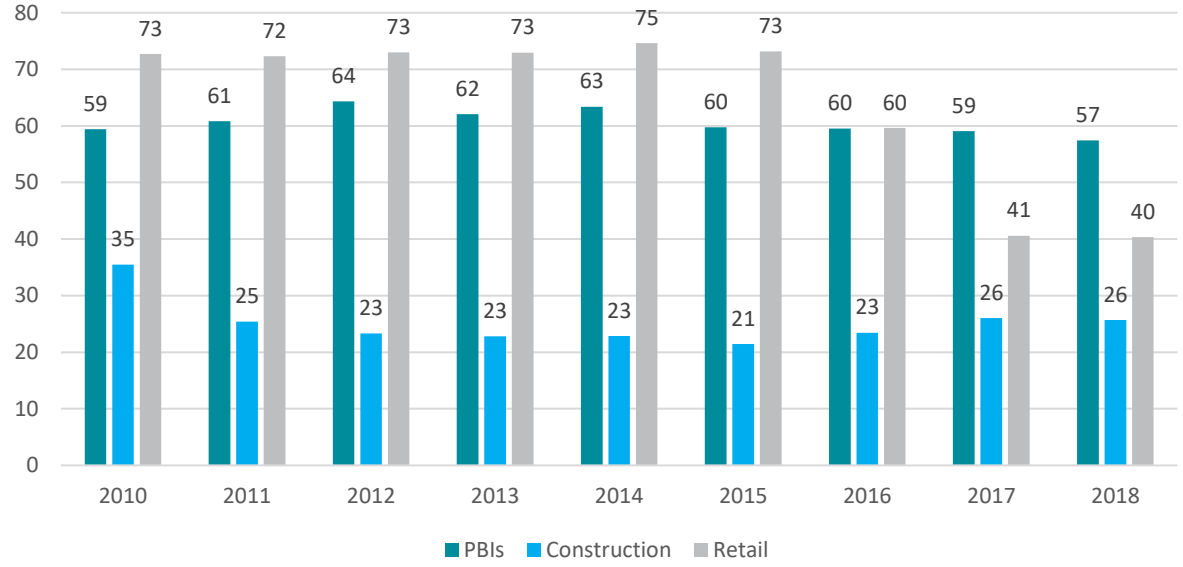
Figure 25: COE in selected Irish sectors, € billions, 2010-19



Source: PxStat, Eurostat, Cebr analysis

As with productivity, the PBI sector had a higher average employee compensation per FTE worker than the comparator sectors, at slightly more than €57,000 in 2018. Interestingly, whilst employee compensation decreased across the four sectors, the PBI sector registered the lowest fall (-6.1%). It is worth noting that this doesn't align with broader trends in Ireland. On average, the compensation per FTE worker increased in the country, from €37,000 in 2010 to €42,000 in 2018 – nonetheless, this was still much less than the PBI sector's €57,400.

Figure 26. COE - FTE ratio in selected Irish sectors, 2010-2019[24]



Source: PxStat, Eurostat, Cebr analysis

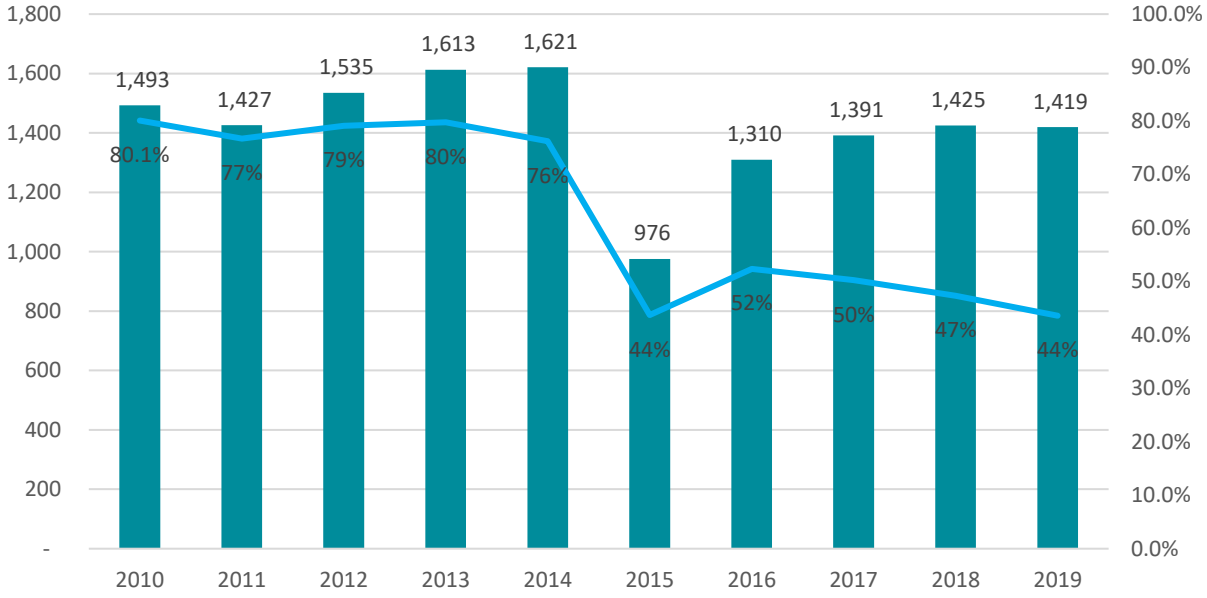
24 Due to significant volatility raising questions about the validity of the underlying data, transportation and storage has not been included within this comparison.

4. The level of PBI R&D investment

This section outlines the level of R&D spending in the PBIs over the period 2010-2019.

The level of R&D spending of the PBIs remained relatively stable over the period 2010-2019, but saw a significant single-year decline in 2015. In 2010, R&D expenditure was around €1.49 billion, but fell to €0.98 billion in 2015. By 2019, the value reached again nearly €1.4 billion. Overall, R&D expenditure decreased by 4.9% (or €0.07 billion) between 2010 and 2019.

Figure 27: R&D expenditure in PBI, % share of R&D expenditure in the Republic of Ireland and € millions, 2010-2019



Source: PxStat, Eurostat, Cebr analysis

Despite contributing just under 9% of national GVA, PBI investment in R&D comprises more than 40% of total R&D in Ireland across the years 2010-2019.

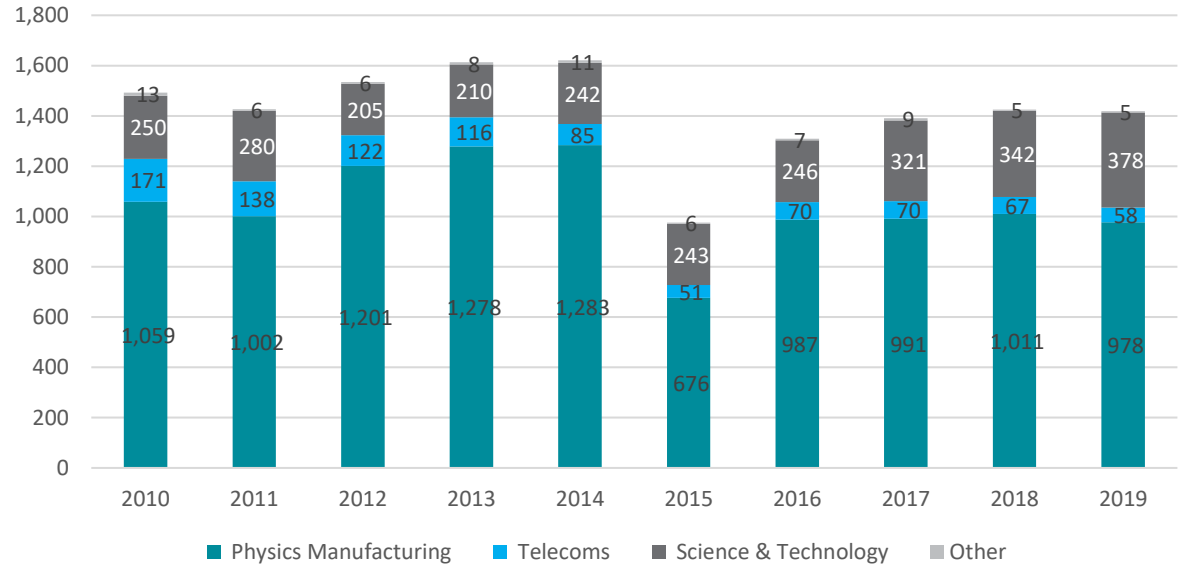
However, this share has been declining significantly since 2010, when PBI R&D was 80% of total R&D in the Republic of Ireland. Looking at Figure 27, we note that the decline in the share of PBI R&D is greater than the decline in the value of PBI R&D. This suggests that other sectors have significantly increased their R&D investment, as opposed to the trend being driven by declining PBI R&D.

R&D is heavily dominated by the Physics Manufacturing sub-sector, which accounted for 74% of all expenditure on average over the period. The sharp PBI R&D decline observed in 2015 was also driven by the Physics Manufacturing sub-sector, which reduced its R&D expenditure from €1.3 billion to €0.7 billion in that year.[25] Physics Science & Technology was the second

25 Granular data on R&D at a four/five-digit NACE is not published, so this is a modelled estimate. In 2015, PBI manufacturing GVA increases very slightly from €13 billion, to €15 billion, however per PxStat data, GVA in the wider manufacturing sector increased from €39 billion to €92 billion. R&D conducted by the manufacturing sector as a whole only increased marginally, and we have therefore assumed that based on this evidence, the share of manufacturing R&D conducted by the Physics Manufacturing sub-sector decreased significantly.

biggest contributor to R&D expenditure, accounting for 18% of all expenditure on average. We estimate that the sub-sector increased its R&D spending by 10.5% in 2019, as a result of the increase in R&D investment experienced by the wider industries comprising the Physics Science & Technology sub-sector[26]. Telecoms, the third biggest PBIs sub-sector, significantly reduced R&D spending over the period 2010-2019, from €171 million to €58 million. In 2019, Telecoms' share of PBIs R&D was only 4%. This trend mostly reflects the decreasing size of the Telecoms sub-sector as a share of the wider Information and Communication Services industry (in terms of GVA shares, this decreased from 18% in 2010 to 4.5% in 2019).

Figure 28: R&D in the different categories of the PBIs in Ireland, € millions, 2010-2019



Source: PxStat, Eurostat, Cebr analysis

26 Physics Science & Technology forms part of Real Estate & Professional, Scientific and Technical Activities (sectors L - M) and Administrative and Support Service Activities (sector N). R&D spending by these two industries nearly doubled over the period 2010-2019 (from £304m to £560m).

5. Impact of Ireland's PBIs relative to international comparators

This report so far has shown the significant contributions that PBIs make to the Irish economy. This section shows that the role of PBIs is just as important in other major economies, and how the contribution of PBIs to these other countries differs from in Ireland.

5.1 International comparisons

According to a previous Cebr report[27] commissioned by the European Physical Society (EPS), the PBIs are worth more to the economy[28] of the EU than both the Retail and the Financial Services sectors. The report found that in the EU, the PBIs made a net contribution of at least €1.45 trillion per year to the economy, equivalent to 12% of total GVA – which is slightly higher than for the Republic of Ireland, where this figure stood at around 9% (in 2019) of the equivalent Irish GVA in this report. This compares to 4.5%, 5.3% and 5.3% for the Retail, Construction, and Financial Services sectors, respectively.[29] In addition, European PBIs contributed, on average, 44% of all exports from the EU28 during the period 2011-2016.

Germany's status as a leader in PBIs is reflected in the Cebr report for the EPS. In 2016, German PBIs contributed just over €396 billion of GVA, making the German PBI sector the largest in Europe.

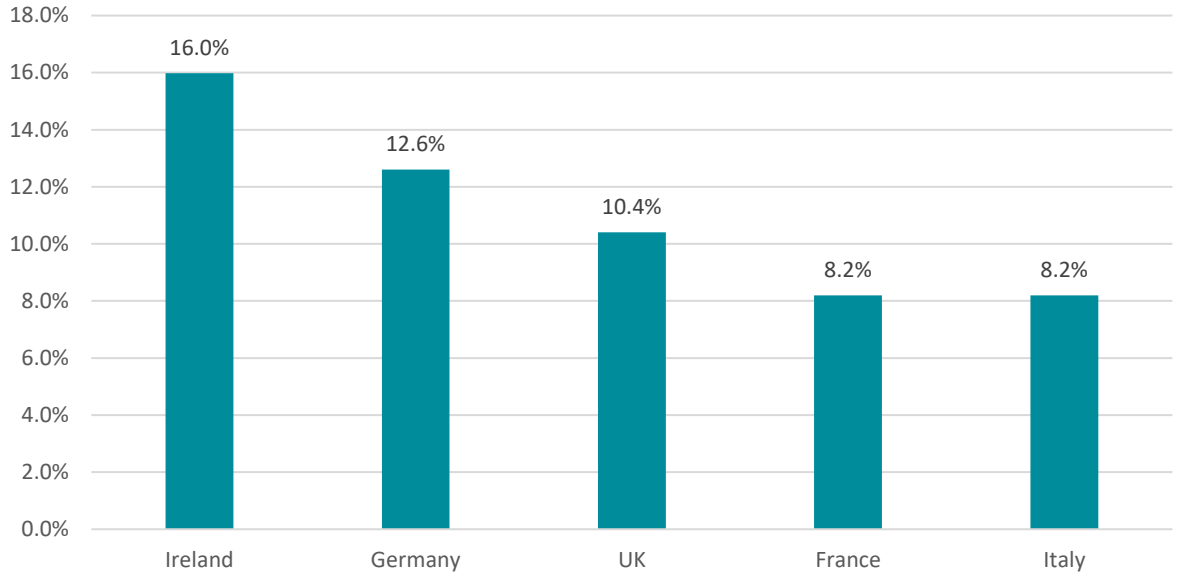
The next three largest European PBI sectors are the UK, France and Italy, with Figure 29 showing the relative contribution of PBIs to the respective nations' economies, by estimating the share of their GDP attributable to PBIs. The figure shows that the relative importance of PBIs to Ireland was larger than for the four biggest EU economies in 2016. This result should be treated with care, because it is driven by analysis from a previous Cebr report that used a different sectoral alignment and definition of PBIs. Based on the definitions used in this report, we estimate the share of Ireland's GDP attributable to PBIs in 2016 to be 9.4%, which is 6.6% below the estimate in Figure 29.

27 Data points taken from the previous report are based on the definitions used by Cebr in 2019 for the European Physical Society and are subtly different to the PBI definition used in this report for the Institute of Physics, hence are suitable to provide context, but should not be directly compared with the results from the analysis in this report.

28 Note that this report was published in 2019 and looked at the 2011-2016 period, so the UK was still a member of the EU at the time of writing this report.

29 Science Business (2019). Physics worth more to EU economy than retail and financial services

Figure 29: Share of GDP attributable to PBIs, 2016



Source: Eurostat., (EPS-*Cebr report)*

The contributions of PBIs in the USA are also significant. A report published by the American Physical Society found that physics-based companies directly contributed approximately $2.3 trillion to the U.S. economy (12.6% of GDP) and exported approximately $1.1 trillion of goods in 2016.[30] Meanwhile, for Ireland, the PBIs (per the definition in this report) directly contributed 9.4% of Irish GDP in 2016

With regards to employment, U.S. physics-based companies employed 11.5 million people in 2016, which amounted to 6% of total employment in the USA. It was reported that this is significant due to them being innovative and pioneering, which attracts highly skilled and talented individuals from not only the USA, but also internationally.[31] In comparison, companies in Irish PBIs accounted for approximately 8% of total employment in Ireland in 2016.

Although the US is still the biggest spender in terms of PPP-adjusted[32] R&D spending, it is expected that China will soon overtake it to become the biggest spender in absolute terms. This is owed to the rapid development of China's science landscape, which has seen significant growth over the last four decades. It has also been highlighted as a top policy priority: 'innovation' was the main guiding principle in China's 13th Five Year Plan as the path to sustainable economic growth, which set the framework for government policies from 2016-2020. In 2019, China's R&D expenditure stood at approximately RMB 2.17 trillion (or £245 billion), of which 83% is spent on late-stage commercialisation.[33]

30 Note that due to the difference in source, the definition for the PBIs in the USA may differ to that used in this report.

31 American Physical Society (2019). Summary of Economic Impact Report

32 Purchasing power parity (PPP) is a popular metric used by macroeconomic analysts that compares different countries' currencies through a "basket of goods" approach. Purchasing power parity (PPP) allows for economists to compare economic productivity and standards of living between countries.

33 UK Science & Innovation Network (2020). Country Snapshot – China

Japan is another major economy in which physics plays an important role, and which actively invests in R&D. According to the Statistics Bureau of Japan, Japan's total expenditure on R&D during 2019 was ¥19.58 trillion (£130 billion[34]), equivalent to 3.5% as a share of Japan's GDP.[35] Many of the economic gains that Japan made since the last World War can be largely attributed to the contributions and growth of its Physics Science & Technology sub-sector. However, over the last few years, Japan has been experiencing a decline in the academic output of Japanese physics, with decreasing numbers of people pursuing PhDs in the subject.[36]

India has also experienced rapid growth in the Physics Science and Technology sub-sector. Since the start of the century, there has been a significant increase in funding for research projects in India; its research base has expanded substantially, with several new institutions having been set up, and an increase in the number of people employed in research.[37] In 2013, India was ranked sixth in the world for scientific output (seventh for output directly related to physics research), while since 2004, India has increased its scientific output 3.8 times in the Scopus database.[38]

Figure 30 looks at different countries' gross domestic expenditure on R&D (GERD) as a percentage of GDP. Although this is not an exact representation in absolute values of the PBIs in these countries, and thus not directly comparable, it can be viewed as illustrative of the relative performances of PBIs across regions. The top four countries are the Republic of Korea, which went from 2% to 4.5% GERD as a share of GDP across this time period, followed by Japan, Germany and the US.

34 Based on the exchange rate at the time of writing this report, where 1 JPY = 0.006656 GBP.

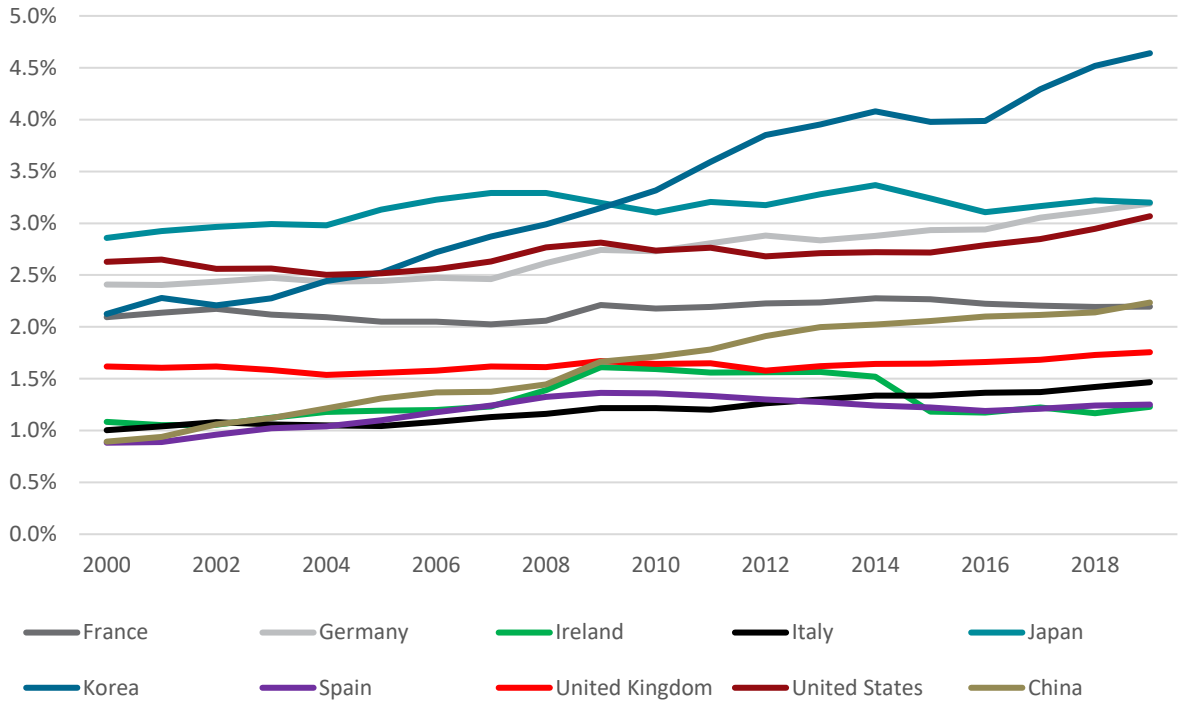
35 Note that this 3.5% figure for R&D expenditure as a percentage of GDP differs from the one presented in Figure 30, which is sourced from the OECD instead.

36 IOP Publishing: Physics World (2018). Revitalizing Japanese physics

37 The Economic Times (2013). Will India be among the top 3 nations in science output by 2030?

38 Scopus is Elsevier's abstract and citation database of peer-reviews literature including scientific journals, books, and conference proceedings, and it provides a comprehensive overview of the world's research output.

Figure 30: Gross domestic expenditure on R&D (GERD) as a percentage of GDP, 2000-2001



Source: OECD

5.2 Comparison with the UK

Table 5 through Table 4 provide an assessment of the performance of PBIs in Ireland compared to the four UK nations, in terms of business demographics, turnover, GVA, employment, and COE, over the period 2010-2019.[39]

In general, the data suggests that the key metrics for PBIs in Ireland were broadly in line with, if not slightly below, Scotland in 2010. Then, over the period, Ireland's PBIs grew strongly in comparison, and by 2019, were slightly above Scotland, particularly if PBI performance is evaluated on a per-firm basis.

39 In this section, the UK, England, Scotland, Wales, and Northern Ireland figures for turnover, GVA, and COE have been converted from Sterling into Euros, per HMRC annual average exchange rate data.

Table 4: Division of enterprises in PBIs, distinguished between UK nations and Ireland, thousands, 2010-2019

Nation	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ireland	**17.0**	**16.9**	**17.3**	**17.5**	**17.3**	**17.9**	**18.3**	**19.6**	**19.8**	**20.0**
UK	239.1	233.7	247.5	254.2	275.7	324.1	342.2	364.1	346.6	350.1
England	210.1	204.6	216.2	221.5	239.8	282.7	299.4	320.1	302.9	305.4
Scotland	16.9	17.5	19.4	20.6	22.8	26.1	26.8	27.1	26.8	27.2
Wales	8.3	8.0	8.2	8.3	9.2	11.3	11.7	12.1	11.8	12.2
Northern Ireland	3.8	3.7	3.7	3.8	3.9	4.1	4.4	4.8	5.1	5.3

Source: PxStat, Eurostat, Nomis, Cebr analysis

To contextualise the following performance metrics, the number of enterprises in PBIs in Ireland and the UK are presented in Table 4, above. Over the period, the net number of firms increased by approximately 18% within Irish PBIs (3,000 firms). This is compared to a larger net increase in the number of firms within UK PBIs, which grew by 46% (111,000 firms).

This is an important point to note as the comparatively strong growth between 2010 and 2019 in turnover, GVA, employment, and COE for Irish PBIs is set against the backdrop of improved firm-level performance, rather than just by a general increase in the overall number of firms in the sector.

This is illustrated when the 2010 and 2019 turnover per firm figures are compared between Ireland and the UK. In 2010, the average turnover per firm was €3.7 million in Irish PBIs, compared to €2.5 million turnover per firm for the UK's PBIs. By 2019, the figure for Ireland grew to €4 million, while in the UK, the figure fell to €2.1 million.

When evaluating GVA per firm, Ireland again performs strongly in comparison with the UK, increasing from an average of €1.2 million GVA per firm in 2010 to €1.5 million in 2019. Over the same period, the UK fell from an average of €0.9 million GVA per firm to €0.7 million.

These patterns still hold after accounting for the impact of the exchange rate, albeit to a slightly smaller extent, as the Euro appreciated against the pound between 2010 and 2019.[40]

For completeness, the tables comparing turnover and GVA in Ireland with the UK are presented below. Table 5 highlights how the PBIs in Ireland generated 17% less turnover than Scottish PBIs at the start of the period, but by 2019, they generated 11% more. Table 6 presents the same comparison for GVA, showing that the overall GVA contribution to Ireland and Scotland's respective economies was much more closely aligned in absolute terms. However, in relative terms, PBIs in Scotland accounted for 17% of Scottish GDP in 2019, whereas for Ireland, PBIs contributed 9% of the total Irish economy, and in the UK, PBIs contributed to 11% of total GDP.

40 In this analysis, the exchange rates used are €1 = £0.86 in 2010 and €1 = £0.88 in 2019.

Table 5: Turnover in PBIs, distinguished between UK nations and Ireland, € billions, 2010-2019

Nation	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ireland	**63.6**	**61.8**	**65.0**	**64.8**	**65.9**	**68.5**	**74.0**	**82.4**	**80.3**	**80.4**
UK	595.6	628.1	669.3	662.5	695.3	771.2	720.5	705.3	710.6	718.8
England	486.5	509.1	557.9	545.4	571.9	632.2	600.5	592.6	600.9	604.7
Scotland	76.9	81.6	71.6	75.5	77.6	81.9	75.6	67.0	68.4	72.3
Wales	22.8	27.1	28.6	30.5	31.7	41.9	32.4	34.6	30.3	30.2
Northern Ireland	9.3	10.3	11.2	11.1	14.2	15.3	11.9	11.1	10.9	11.5

Source: ABS, BRES, Cebr analysis

Table 6: GVA in PBIs, distinguished between UK nations and Ireland, € billions, 2010-2019

Nation	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ireland	**20.9**	**22.7**	**21.8**	**21.9**	**22.2**	**23.0**	**25.4**	**26.9**	**28.2**	**29.1**
UK	209.3	219.9	241.7	244.9	265.6	295.3	271.4	259.0	258.8	258.9
England	179.5	189.0	205.9	208.0	223.6	243.4	225.2	215.3	215.4	215.8
Scotland	19.8	20.2	23.9	24.3	28.2	35.9	33.3	31.1	30.3	30.9
Wales	7.2	7.6	8.5	8.9	10.1	11.3	9.1	9.3	9.2	8.3
Northern Ireland	2.8	3.1	3.4	3.7	3.7	4.7	3.8	3.3	3.8	4.0

Source: ABS, BRES, Cebr analysis

Table 7 and Table 8 show the PBIs' contribution to employment and COE in Ireland, compared to that in the UK. Considering the number of employees in Irish PBIs, the absolute number sat between the Scottish at the higher end, and Wales at the lower end over the period. However, it is also important to consider the share of all FTE employees in PBIs for each nation. In both Scotland and Wales, 9.8% of FTE employees were in the PBI sector for 2019. In Ireland, meanwhile, 8.6% of Irish employment as a whole was attributable to the PBI sector in the same year.

COE in Irish PBIs grew over the period, from €8.2 billion in 2010 to €11.5 billion in 2019 (Table 8). From 2010 to 2019, the level of the UK's COE across PBIs grew by 31.4%[41] compared to a 40.2% growth in Irish PBI COE.

This, and the above analysis, provide evidence to suggest that in comparison to PBIs the UK, PBIs in Ireland performed well over the period relative to their size, especially on a per-firm basis.

41 This value is for the growth in Sterling values. After the exchange rate is applied, the UK COE growth rate falls to 27.8%, as a result of the pound's depreciation against the Euro.

Table 7: Employment in PBIs, distinguished between UK nations and Ireland, thousands, 2010-2019

Nation	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ireland	**139**	**137**	**132**	**140**	**147**	**168**	**174**	**175**	**188**	**196**
UK	2,403	2,383	2,311	2,339	2,458	2,581	2,580	2,615	2,650	2,720
England	2,055	2,037	1,971	1,991	2,075	2,187	2,211	2,237	2,257	2,338
Scotland	203	197	193	196	217	211	207	218	220	220
Wales	104	106	105	109	123	131	118	119	125	113
Northern Ireland	40	44	41	44	43	52	44	41	48	49

Source: ABS, BRES, Cebr analysis

Table 8: COE in PBIs, distinguished between UK nations and Ireland, € billions, 2010-2019

Nation	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Ireland	**8.2**	**8.3**	**8.5**	**8.7**	**9.3**	**10.0**	**10.4**	**10.3**	**10.8**	**11.5**
UK	101.5	103.4	113.0	111.6	120.7	137.9	130.0	121.8	123.2	129.7
England	86.5	88.2	96.8	95.0	101.9	116.3	110.4	103.0	104.9	111.4
Scotland	10.2	10.1	10.4	10.8	12.4	13.4	12.1	11.4	11.3	11.7
Wales	3.4	3.6	4.2	4.2	4.6	5.8	5.6	5.5	5.0	4.6
Northern Ireland	1.4	1.6	1.6	1.6	1.9	2.4	1.9	1.9	1.9	1.9

Source: ABS, BRES, Cebr analysis

Appendix I: NACE-based definition of PBIs and sectoral alignment

Code	Description	Code	Description
Oil & Gas Extraction			
06.1	Extraction of crude petroleum	06.2	Extraction of natural gas
Physics Manufacturing			
13.95	Manufacture of non-wovens and articles made from non-wovens, except apparel	26.4	Manufacture of consumer electronics
13.96	Manufacture of other technical and industrial textiles	26.51	Manufacture of instruments and appliances for measuring, testing and navigation
13.99	Manufacture of other textiles nec[42]	26.52	Manufacture of watches and clocks
18.12	Other printing	26.6	Manufacture of irradiation, electromedical and electrotherapeutic equipment
20.12	Manufacture of dyes and pigments	26.7	Manufacture of optical instruments and photographic equipment
20.13	Manufacture of other inorganic basic chemicals	26.8	Manufacture of magnetic and optical media
20.17	Manufacture of synthetic rubber in primary forms	27.11	Manufacture of electric motors, generators and transformers
20.3	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	27.12	Manufacture of electricity distribution and control apparatus
20.51	Manufacture of explosives	27.2	Manufacture of batteries and accumulators
20.59	Manufacture of other chemical products nec	27.31	Manufacture of fibre optic cables
23.11	Manufacture of flat glass	27.32	Manufacture of other electronic and electric wires and cables
23.12	Shaping and processing of flat glass	27.33	Manufacture of wiring devices
23.13	Manufacture of hollow glass	27.4	Manufacture of electric lighting equipment
23.14	Manufacture of glass fibres	27.51	Manufacture of electric domestic appliances
23.19	Manufacture and processing of other glass, including technical glassware	27.9	Manufacture of other electrical equipment
23.2	Manufacture of refractory products	28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
23.31	Manufacture of ceramic tiles and flags	28.21	Manufacture of ovens, furnaces and furnace burners
23.43	Manufacture of ceramic insulators and insulating fittings	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
23.49	Manufacture of other ceramic products	28.41	Manufacture of metal forming machinery
24.1	Manufacture of basic iron and steel and of ferro-alloys	28.49	Manufacture of other machine tools
24.2	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel	28.91	Manufacture of machinery for metallurgy
24.31	Cold drawing of bars	28.92	Manufacture of machinery for mining, quarrying and construction
24.32	Cold rolling of narrow strip	28.94	Manufacture of machinery for textile, apparel and leather production

42 'Nec' means not elsewhere classified.

24.33	Cold forming or folding	28.95	Manufacture of machinery for paper and paperboard production
24.34	Cold drawing of wire	28.96	Manufacture of plastics and rubber machinery
24.41	Precious metals production	28.99	Manufacture of other special-purpose machinery nec
24.46	Processing of nuclear fuel	29.1	Manufacture of motor vehicles
25.11	Manufacture of metal structures and parts of structures	29.31	Manufacture of electrical and electronic equipment for motor vehicles
25.12	Manufacture of doors and windows of metal	29.32	Manufacture of other parts and accessories for motor vehicles
25.21	Manufacture of central heating radiators and boilers	30.11	Building of ships and floating structures
25.29	Manufacture of other tanks, reservoirs and containers of metal	30.12	Building of pleasure and sporting boats
25.3	Manufacture of steam generators, except central heating hot water boilers	30.2	Manufacture of railway locomotives and rolling stock
25.4	Manufacture of weapons and ammunition	30.3	Manufacture of air and spacecraft and related machinery
25.5	Forging, pressing, stamping and roll-forming of metal; powder metallurgy	30.4	Manufacture of military fighting vehicles
25.61	Treatment and coating of metals	30.91	Manufacture of motorcycles
25.62	Machining	30.92	Manufacture of bicycles and invalid carriages
26.11	Manufacture of electronic components	30.99	Manufacture of other transport equipment nec
26.12	Manufacture of loaded electronic boards	32.5	Manufacture of medical and dental instruments and supplies
26.2	Manufacture of computers and peripheral equipment	32.99	Other manufacturing nec
26.30	Manufacture of communication equipment	33.16	Repair and maintenance of aircraft and spacecraft
Physics Machine Services			
33.11	Repair of fabricated metal products	33.17	Repair and maintenance of other transport equipment
33.12	Repair of machinery	33.19	Repair of other equipment
33.13	Repair of electronic and optical equipment	33.2	Installation of industrial machinery and equipment
33.14	Repair of electrical equipment	33.15	Repair and maintenance of ships and boats
Energy Production, Transmission & Distribution			
35.11	Production of electricity	35.13	Distribution of electricity
35.12	Transmission of electricity	35.22	Distribution of gaseous fuels through mains
Physics Waste & Recovery			
38.12	Collection of hazardous waste	38.32	Recovery of sorted materials
38.22	Treatment and disposal of hazardous waste	39	Remediation activities and other waste management services
38.31	Dismantling of wrecks		
Physics Machine Sales			
46.14	Agents involved in the sale of machinery, industrial equipment, ships and aircraft		
Medical Equipment Sales			
47.74	Retail sale of medical and orthopaedic goods in specialised stores		
Space Transport & Air Transport Services			
51.22	Space transport	52.23	Service activities incidental to air transportation
Telecoms			
61.1	Wired telecommunications activities	61.3	Satellite telecommunications activities

61.2	Wireless telecommunications activities	61.9	Other telecommunications activities
Physics Science & Technology			
71.12	Engineering activities and related technical consultancy	74.1	Specialised design activities
71.2	Technical testing and analysis	74.9	Other professional, scientific and technical activities nec
72.11	Research and experimental development on biotechnology	82.99	Other business support service activities nec
72.19	Other research and experimental development on natural sciences and engineering		
Defence			
84.22	Defence activities		

Appendix II: Supplementary figures and tables

Table 9: Turnover in the different sub-sectors of PBIs in Ireland, € billions, 2010-2019

Sub-sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Oil & Gas Extraction	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.02	0.02
Physics Manufacturing	37.89	36.39	39.14	39.01	40.22	41.57	46.31	47.93	50.24	49.11
Physics Machine Services	0.82	0.78	0.79	1.03	1.00	0.97	1.07	1.39	0.91	1.08
Energy Production, Transmission & Distribution	6.89	7.62	8.05	7.89	7.20	7.16	7.26	7.29	7.30	7.55
Physics Waste & Recovery	0.49	0.47	0.45	0.45	0.48	0.50	0.50	0.59	0.59	0.62
Physics Machine Sales	0.94	0.99	1.06	0.98	0.85	1.38	1.46	2.67	1.21	1.30
Medical Equipment Sales	0.28	0.32	0.37	0.36	0.36	0.32	0.39	0.43	0.31	0.29
Space Transport & Air Transport Services	0.82	0.98	1.06	1.14	1.18	1.30	1.34	1.39	1.42	1.55
Telecoms	6.76	6.86	6.38	6.19	6.55	6.70	8.19	11.19	7.96	7.97
Physics Science & Technology	8.31	7.02	7.36	7.47	7.79	8.29	7.18	9.18	10.01	10.53
Defence	0.39	0.33	0.30	0.30	0.32	0.31	0.27	0.31	0.37	0.38
Physics Total	63.61	61.77	64.97	64.83	65.95	68.50	73.97	82.39	80.34	80.39

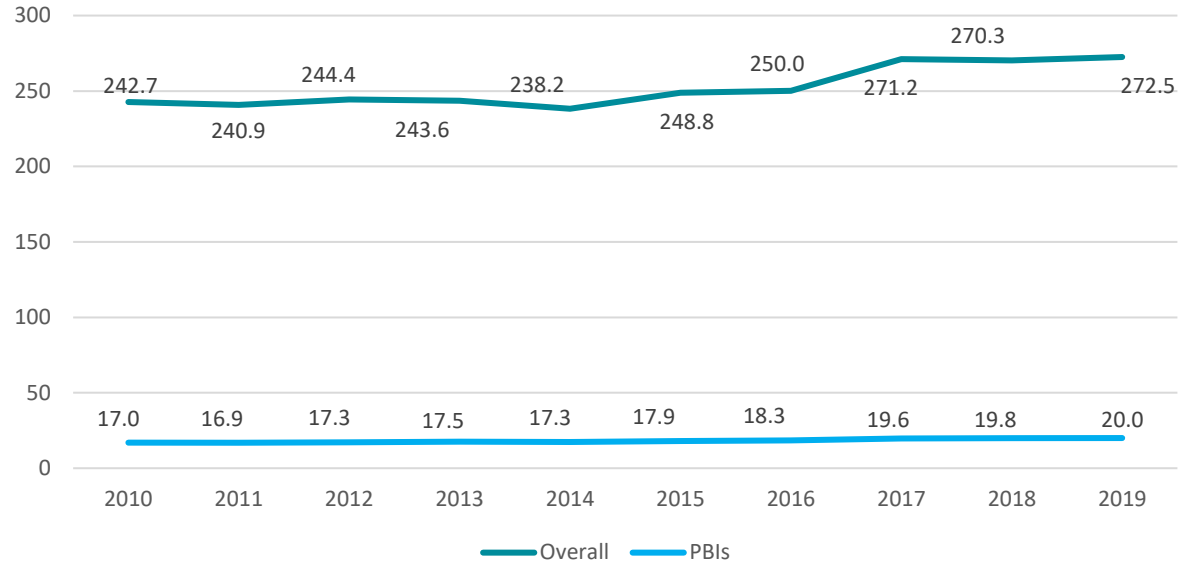
Source: PxStat, Eurostat, Cebr analysis

Table 10: Number of enterprises in the different sub-sectors of PBIs in Ireland, thousands, 2010-2019

Sub-sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Oil & Gas Extraction	11	10	14	16	17	21	19	20	25	25
Physics Manufacturing	4,342	4,293	4,297	4,339	4,283	4,385	4,530	4,749	4,722	4,816
Physics Machine Services	900	924	1,017	1,113	1,206	1,341	1,415	1,559	1,540	1,643
Energy Production, Transmission & Distribution	350	323	362	394	403	442	473	542	560	556
Physics Waste & Recovery	582	616	636	625	638	650	646	649	645	619
Physics Machine Sales	355	351	356	348	307	308	318	329	327	317
Medical Equipment Sales	166	169	177	185	183	179	182	199	205	209
Space Transport & Air Transport Services	147	158	154	157	155	157	158	106	93	126
Telecoms	633	663	661	651	652	668	642	664	662	652
Physics Science & Technology	9,711	9,607	9,820	9,901	9,654	10,001	10,195	11,053	11,298	11,279
Total	17,197	17,114	17,494	17,729	17,498	18,152	18,578	19,870	20,077	20,242

Source: PxStat, Cebr analysis

Figure 31: Number of enterprises in Ireland, thousands, 2010-19



Source: PxStat, Cebr analysis

Table 11: Division of enterprises in Irish PBIs, distinguished by size, 2019

Sub-sector	Micro	Small	Medium	Large
Oil & Gas Extraction	23	1	1	-
Physics Manufacturing	4,282	386	120	28
Physics Machine Services	1,547	75	18	3
Energy Production, Transmission & Distribution	550	5	1	-
Physics Waste & Recovery	527	75	16	1
Physics Machine Sales	298	18	1	-
Medical Equipment Sales	195	13	1	-
Space Transport & Air Transport Services	103	15	6	2
Telecoms	561	60	24	7
Physics Science & Technology	10,787	434	54	4
Total	**18,873**	**1,082**	**242**	**45**
Overall in Ireland	**249,126**	**19,053**	**3,620**	**732**

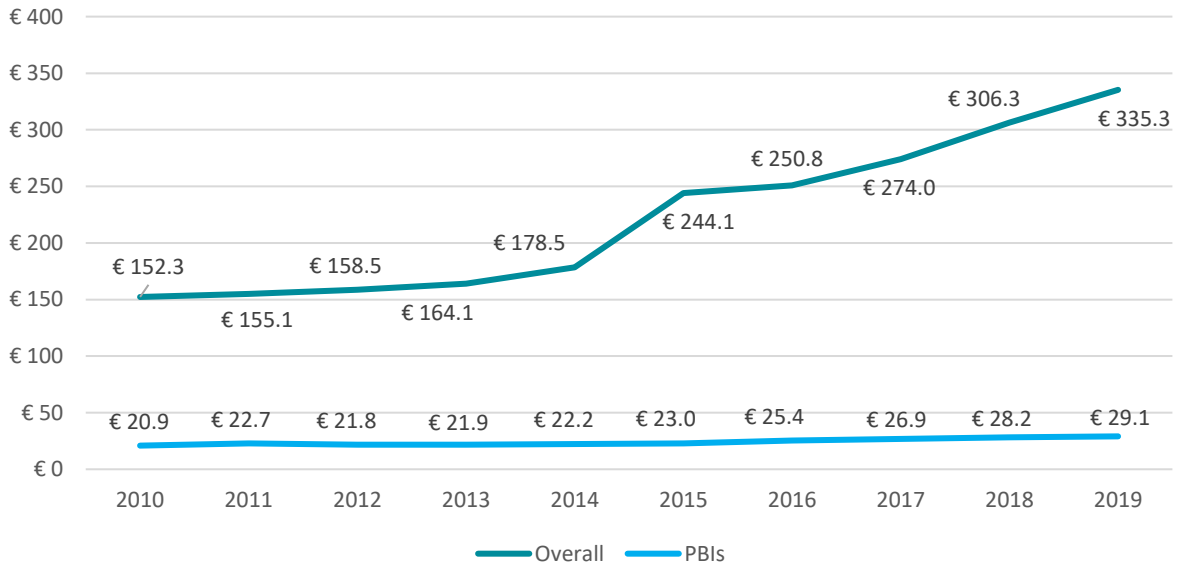
Source: PxStat, Cebr analysis

Table 12: GVA in the different sub-sectors of PBIs in Ireland, € billions, 2010-2019

Sub-sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Oil & Gas Extraction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01[43]	0.01	0.01
Physics Manufacturing	12.63	13.83	13.51	13.01	13.20	14.85	15.98	16.71	17.24	17.70
Physics Machine Services	0.34	0.34	0.34	0.43	0.46	0.37	0.41	0.51	0.34	0.43
Energy Production, Transmission & Distribution	2.87	3.24	3.16	3.32	3.04	2.51	3.22	2.35	2.37	2.56
Physics Waste & Recovery	0.16	0.16	0.13	0.12	0.15	0.18	0.18	0.20	0.20	0.20
Physics Machine Sales	0.06	0.06	0.05	0.08	0.09	0.07	0.10	0.20	0.13	0.11
Medical Equipment Sales	0.05	0.04	0.05	0.06	0.05	0.03	0.05	0.06	0.08	0.09
Space Transport & Air Transport Services	0.40	0.52	0.53	0.63	0.63	0.68	0.71	0.73	0.88	0.92
Telecoms	2.48	2.36	2.12	2.00	1.76	1.39	1.82	2.40	2.44	2.25
Physics Science & Technology	1.66	1.99	1.75	2.04	2.62	2.73	2.82	3.61	4.25	4.58
Defence	0.25	0.18	0.16	0.17	0.17	0.17	0.15	0.18	0.21	0.22
Physics Total	20.91	22.74	21.82	21.86	22.18	22.98	25.43	26.93	28.16	29.08

Source: PxStat, Eurostat, Cebr analysis

Figure 32: GVA in Ireland, € billions, 2010-2019



Source: Eurostat, Cebr analysis

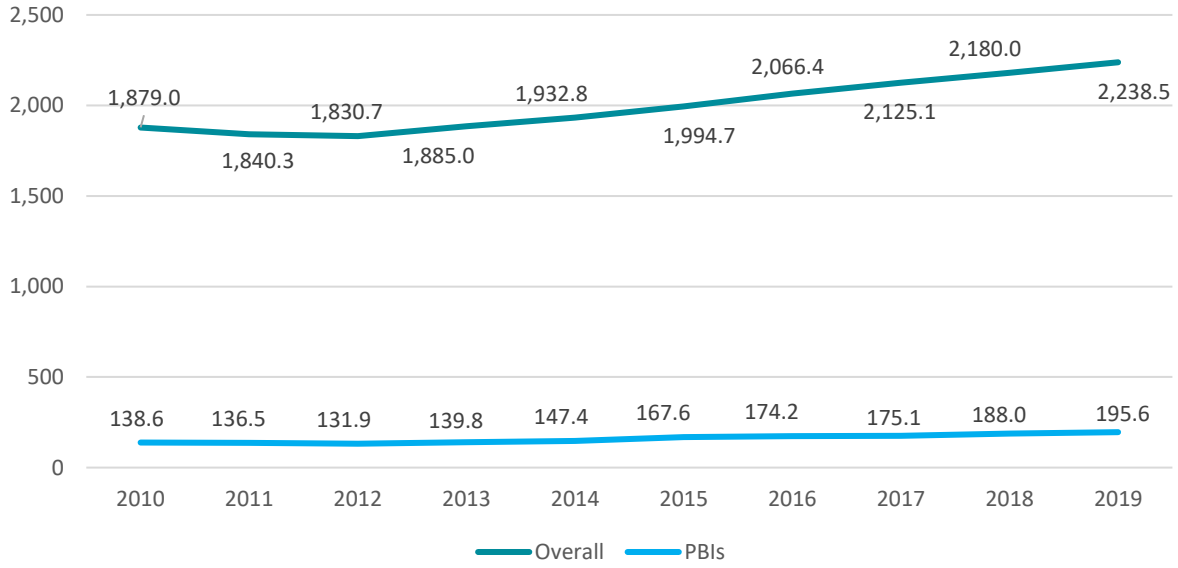
43 This negative value comes directly from Eurostat, which states that GVA in SIC 06.1 (extraction of crude petroleum) stood at -€5.6 million in 2017; this is likely driven by negative operating profits in that year.

Table 13: Employment (FTE jobs) in the different sub-sectors of PBIs in Ireland, thousands, 2010-2019

Sub-sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Oil & Gas Extraction	0.02	0.02	0.02	0.00	0.01	0.01	0.02	0.01	0.01	0.01
Physics Manufacturing	92.02	90.26	85.32	90.53	93.11	111.13	103.99	104.14	108.70	108.72
Physics Machine Services	4.15	4.24	4.69	5.74	5.84	5.38	6.90	7.52	5.00	6.64
Energy Production, Transmission & Distribution	7.30	8.07	8.03	7.38	7.71	6.17	6.24	6.73	7.70	7.17
Physics Waste & Recovery	2.01	2.28	2.17	2.02	2.13	1.93	1.99	2.54	1.76	1.83
Physics Machine Sales	0.23	0.23	0.25	0.26	0.27	0.30	0.70	0.74	0.83	1.02
Medical Equipment Sales	0.56	0.51	0.51	0.60	0.50	0.57	0.58	0.60	0.62	0.78
Space Transport & Air Transport Services	3.78	3.63	3.68	3.90	4.00	4.19	4.23	4.39	5.45	5.51
Telecoms	7.25	6.66	6.39	6.40	6.00	5.70	11.70	9.73	12.23	14.42
Physics Science & Technology	15.74	16.55	16.76	19.50	24.22	28.74	34.59	35.38	41.75	45.33
Defence	5.55	4.06	4.09	3.51	3.57	3.44	3.28	3.34	3.90	4.18
Physics Total	138.60	136.52	131.90	139.85	147.37	167.55	174.21	175.13	187.96	195.60

Source: PxStat, Eurostat, Cebr analysis

Figure 33: Employment in Ireland, FTEs, thousands, 2010-19



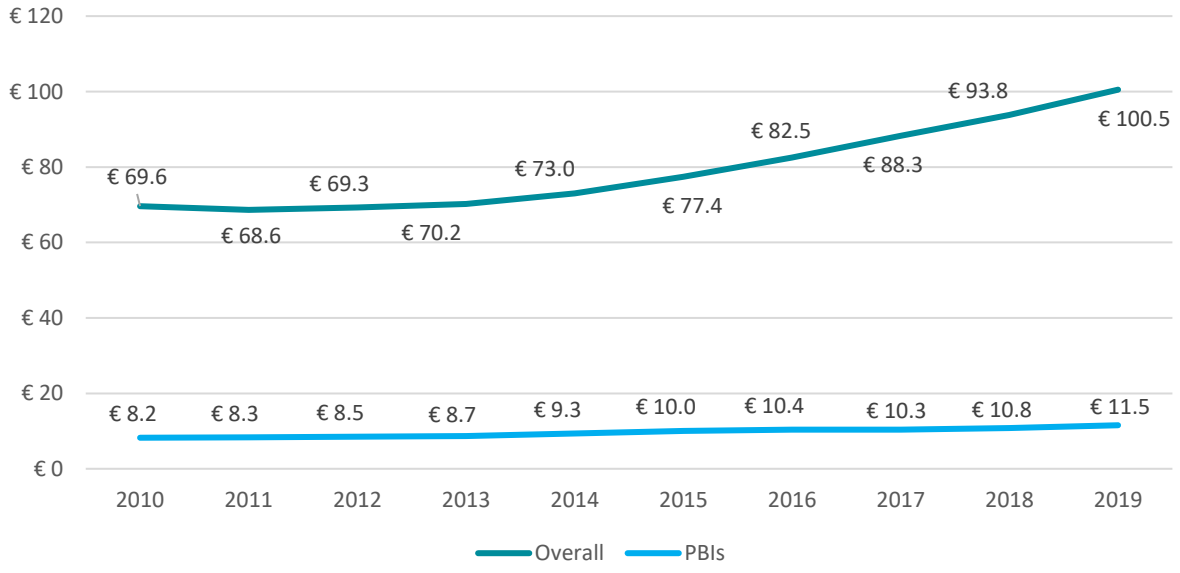
Source: Eurostat, Cebr analysis

Table 14: COE in the different sub-sectors of PBIs in Ireland, € billions, 2010-2019

Sub-sector	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Oil & Gas Extraction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physics Manufacturing	4.43	4.53	4.63	4.91	5.18	5.75	6.11	6.12	6.08	6.42
Physics Machine Services	0.24	0.23	0.25	0.29	0.29	0.20	0.24	0.30	0.20	0.23
Energy Production, Transmission & Distribution	0.79	0.83	0.69	0.48	0.49	0.51	0.50	0.63	0.67	0.68
Physics Waste & Recovery	0.08	0.09	0.09	0.08	0.09	0.12	0.10	0.10	0.07	0.08
Physics Machine Sales	0.03	0.03	0.04	0.04	0.04	0.05	0.03	0.04	0.04	0.04
Medical Equipment Sales	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04
Space Transport & Air Transport Services	0.22	0.22	0.26	0.28	0.29	0.29	0.31	0.32	0.33	0.35
Telecoms	0.89	0.83	0.92	0.88	0.88	0.85	0.85	0.65	0.94	1.03
Physics Science & Technology	1.35	1.38	1.47	1.56	1.93	2.10	2.09	2.01	2.29	2.51
Defence	0.19	0.13	0.12	0.12	0.12	0.12	0.11	0.12	0.15	0.15
Physics Total	8.24	8.30	8.49	8.68	9.34	10.01	10.37	10.34	10.80	11.54

Source: PxStat, Eurostat, Cebr analysis

Figure 34: COE in Ireland, € billions, 2010-19



Source: Eurostat, Cebr analysis

Appendix III: Methodology

The following section lays out our methodology.

In order to provide a well-rounded summary of the PBIs in the Republic of Ireland, we worked with the turnover, GVA, total full-time employees and COE, as well as with the number of enterprises. For these, we used data from Eurostat from the European Commission, and PxStat from the Central Statistics Office.

In most cases, we used Eurostat to get data on the industries, and had PxStat as a backup when further information was needed. The only section where we relied on PxStat exclusively is analysis on business demography, where it provides much more detailed analysis. Both Eurostat and PxStat have detailed data on the Irish economy, however, there have been cases where at a four-digit NACE level, some of this data was missing. When this occurred, we estimated the data we needed to provide a more exact estimate of the total impact of the PBIs and not omit estimates from any industry. If an employment datapoint was missing, we used the average of the employment in the industry one year earlier and one year later. In cases where the turnover, GVA or COE was not written, we used the turnover-FTE, the GVA-FTE or the COE-FTE ratio for the previous year where we had the full data. Whenever we encountered a NACE 4-digit level industry, where none of them had data, we used the 3-digit level values and the ratio of the 4- and 3-digit level Eurostat FTE values in order to estimate the specific data on these:

$$4\ digit\ GVA_i = 3\ digit\ GVA_i \times \frac{4\ digit\ FTE_i}{3\ digit\ FTE_i}$$

Where again GVA_i is the gross value added in year *i,* and $FTE_i$is the number of full-time employees in year *i.*

In some cases, the databases did not have data on any of the four variables we were looking at for numerous years. In such cases, as a backup, we either used the 2-digit level value of the industry and multiplied it by the 4/2-digit level ratio of the UK data or used the growth rate of the respective UK SIC. Multiple methods were tested in these cases, with typically the more conservative and least volatile estimates used on a best effort case-by-case basis.

Once we had all the data, we aggregated the industries into 11 sub-sectors. These are: Oil & Gas Extraction; Physics Manufacturing; Physics Machine Services; Energy Production, Transmission & Distribution; Physics Waste & Recovery; Physics Machine Sales; Medical Equipment Sales; Space Transport & Air Transport Services; Telecoms; Physics Science & Technology; and lastly, Defence. Appendix I shows which industries belong to which sub-sector.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