

THE IMPACT OF PHYSICS ON THE ITALIAN ECONOMY

Final Report by Deloitte



January 2014

FOREWORD

The aim of the Italian Physical Society (Società Italiana di Fisica – SIF) is to promote, favour and safeguard the study and the progress of physics in Italy and worldwide. SIF represents the Italian scientific community, in the research, educational and professional fields, both public and private, relevant to all areas of physics and its applications. The Society was founded in 1897 in connection with the renowned scientific journal “Il Nuovo Cimento”. Since then, the Society has undoubtedly expanded and acquired an international dimension concerning its scientific, societal and publishing activities. This expansion was accompanied by the foundation in 1953, of the International School of Physics in Varenna, Lake of Como, a School later named after Enrico Fermi, which has then acquired a worldwide fame. Since 1968, SIF is a Member Society of the European Physical Society (EPS).

Italy, by itself and as part of Europe, has a long tradition of excellence in science and technology, which altogether are the lever for progress, research and innovation. Italy hosts outstanding physics institutions, centres and laboratories, and also contributes, on an international scale, to the existence of many of these establishments in Europe. The connection between basic physics and technological applications is very tight and brings directly to the question of the appropriate level of support to physics as a whole, a discipline which impacts on the lives of all of us.

In 2012 EPS took the initiative to address the issue of how important is physics to the economies of nearly 30 European

states, including Italy, and of how crucial is the maintenance or even the increase of investment in physics. The result was the EPS-Cebr report on “The importance of physics to the economies of Europe”, published at the beginning of 2013 (see www.eps.org/?page=policy_economy). On the heels of the EPS initiative, in 2013 SIF has commissioned from Deloitte an independent and quantitative study concerning – for the first time – Italy alone. This study, referring to an analysis performed on data from the Italian National Statistical Service (Istituto Nazionale di Statistica – Istat), spanning the 4-year period 2008-2011 (2011 being the most recent year for which public data for Italy are available), was concluded by December 2013.

The approach adopted in this study by Deloitte, especially the definition of the so-called “physics-based” sectors of the Italian economy, was the result of a lively collaboration of SIF with a number of stakeholders, i.e. of national research institutions broadly involving the physics community in Italy:

Centro Fermi – Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi
CNR – Consiglio Nazionale delle Ricerche
INAF – Istituto Nazionale di Astrofisica
INFN – Istituto Nazionale di Fisica Nucleare
INRIM – Istituto Nazionale di Ricerca Metrologica.

The complete study carried out is available in this Final Report issued by Deloitte, while the main and most relevant results are highlighted in a separate Executive Summary. Please see www.sif.it/attivita/physics_economy for further details and downloads.

Across this recent 4-year period, physics-

based sectors have given a major contribution to the Italian economy. Although they have suffered a severe contraction in terms of employment from 2008 to 2011 (by 7%, more than the all-sector Italian average of 2%), physics-based sectors have shown a markedly higher than average (by more than 20%) productivity per worker, a parameter significantly contributing to a multiplier benefit to the whole economy. This productivity per worker even increased by 2.5% between 2008 and 2011 and outperformed Italian productivity which instead decreased by 1.5% over the same period. Just to give some reference numbers, in 2011 physics-based sectors have directly produced 1.51 million jobs (about 6% of total employment in Italy) and €118 billion of Gross Added Value output (more than 7% of Gross Domestic Product), with a productivity per worker exceeding €78,000.

The thorough and detailed analysis of Italian data contained in the Final Report by Deloitte can deliver a deeper insight of the many achievements and drawbacks within the physics-based sectors in Italy in the recent, difficult past.

Our hope is that this study, which refers to a definitely delicate phase for the Italian economy where physics-based sectors have badly suffered, will target the right audience of decision makers and will be highly inspiring for the future, providing a convincing case for a comprehensive support of physics in our Country, from education to research, from business to industry.

Luisa Cifarelli
SIF President



Measuring the economic contribution of physics-based sectors to the Italian economy

Final report

December 2013 – Revised January 2014



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Glossary of key terms

Broad effects	Wider impacts caused by the activities of businesses and employees in physics-based sectors. These impacts can sometimes be quantified and assigned a monetary value in GVA and job terms, but are not quantified here.
Chain-linked volumes	A means of accounting for inflation in national accounts such that output is given in constant prices with reference to a base year (as if there were no inflation) to strip out the effects of inflation on nominal economic growth. Growth in constant price terms is 'real' growth rather than nominal growth in current prices. The base year used here is 2011, such that constant and current prices are equal in 2011.
Direct impact of physics-based sectors	Those initial and immediate economic activities (jobs and GVA) attributable to the activities of organisations and employees in physics-based sectors, as defined in this study. These effects are often referred to as first-round impacts as they coincide with the first round of spending in the economy.
Gross Value Added (GVA)	A measure of the value of goods and services produced by a business, industry, sector or region of the economy. The Organisation for Economic Cooperation and Development defines Gross Value Added as the value of output less the value of intermediate consumption, though it can also be thought of as the sum of profits, employee remuneration and attributable taxes. It is analogous to Gross Domestic Product, which also measures economic output but additionally includes items that can only be included at aggregate level across all sectors such as taxes and subsidies on products.
Indirect impacts physics-based sectors	Changes in the number of jobs and GVA in associated industries that supply inputs to physics-based organisations (sometimes referred to as 'supply-chain' or impacts).
Induced impacts of physics-based sectors	The spending by households that result in changes to the number of jobs and GVA due to direct and indirect impacts. Indirect and induced effects are sometimes collectively referred to as 'downstream effects'.
Narrow effects	The economic impacts caused by the activities of businesses and employees in physics-based sectors. These traditionally cover jobs and GVA generated. These are the sum of direct, indirect and induced effects and are covered in this report.
Nomenclature statistique des activités économiques dans la Communauté européenne - NACE	'Nomenclature statistique des activités économiques dans la Communauté européenne', commonly referred to as NACE, is a European industry standard classification analogous to the UK's Standard Industrial Classification (CIS) and the North American Industrial Classification Systems (NAICS). NACE is used here to define physics-based sectors, with data provided at the 4-digit NACE level by Istat.
Physics	The pervasiveness of physics makes it hard to reach a single conclusive definition. A general definition is 'the branch of science that deals with the nature, structure, properties and interactions of matter, ranging from the smallest scale of elementary particles up to the immense one of the Universe'. Such definition does not adequately capture the detailed role of physics with respect to other disciplines and with respect to technology. The definition used here uses sectors which are deemed likely to be physics-based, in total or in part.
Physics-based sectors	Those sectors of the economy where the use of physics – in terms of technologies or expertise – is critical to their existence. The choice of which sectors constitute physics-based sectors was agreed with stakeholders and reflects previous definitions used across the EU as well as Italy-specific factors. A list of sectors that make up the list of physics-based sectors can be found in the main body of the report and Appendix 1.

Executive Summary

Introduction

Deloitte has been commissioned by Società Italiana di Fisica (SIF) to undertake a study that assesses the economic contribution of physics-based sectors on the Italian economy.

Physics refers to the science that deals with the nature, structure, properties and interactions of matter, at different scales. The study of these topics, in an academic capacity or in research establishments, and the subsequent innovation and commercialisation of ideas to develop tangible goods and services, has shaped the world we live in today.

The fruits of physics affect the daily lives of almost everyone in Italy and the application of contemporary physics can be seen in, for instance:

- The internet;
- Mobile telephony;
- Medical tools and instruments;
- Global positioning systems;
- Consumer durables;
- The built environment; and
- Transportation.

It is not just contemporary physics that can have an impact - research conducted during the last century and beyond has paved the way for the technology that has come to facilitate a range of activities, goods and services, for example, medical devices.

However, many people remain unaware of the importance of physics, despite the importance placed on physics by Governments and policy-makers around the world.

This study by Deloitte considers the ways in which physics-based sectors influence economic performance in Italy and quantifies the economic value of physics in terms of **direct employment supported** and **Gross Value Added (GVA)** generated over the period 2008 to 2011.

Our approach has been to first identify those sectors that can be classified as physics-based and then to use publicly available data Istat to examine how these sectors create turnover (or revenue), jobs and GVA in Italy.

These insights on direct employment in physics-based sectors are then introduced into a bespoke model of the Italian Economy to estimate GVA contribution. Where appropriate, this quantitative analysis has been supplemented by qualitative analyses in the form of case studies.

This is the first time such a detailed analysis has been attempted in Italy alone and, as such, the estimates represent a step in a longer process of impact evaluation for the physics-based sectors of Italy.

Deloitte thanks SIF, Centro Fermi, CNR, INAF, INFN and other stakeholders in the physics community for their valuable inputs and comments on the methodological approach and case studies throughout the study.

The Quantifiable Impacts of physics-based sectors in Italy, 2011: 60-second summary

THE DIRECT PHYSICS-BASED SECTOR IS A MAJOR CONTRIBUTOR TO THE ITALIAN ECONOMY...



... PRODUCTIVITY LEVELS ARE HIGH ...



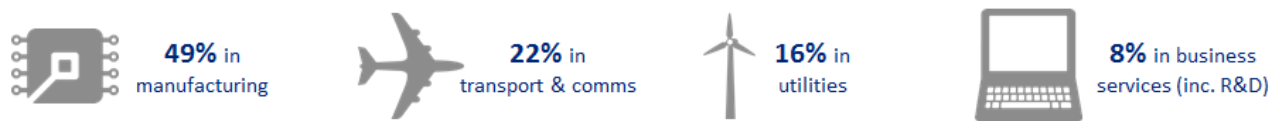
... AND HAVE INCREASED SINCE 2008 ...



... BUT EMPLOYMENT HAS SUFFERED BADLY



PHYSICS' DIRECT GVA CONTRIBUTION IS SPREAD ACROSS A RANGE OF ITALIAN INDUSTRIES IN 2011 ...



... WITH EXTRA IMPACTS IN MANY MORE INDUSTRIES FROM THE PHYSICS SUPPLY CHAIN AND CONSUMER SPENDING



Source: Deloitte

*All figures 2011 apart from growth rates which show annual change between 2008 and 2011. 7% of direct GVA contribution comes in other sectors including government services and extraction.

Since 2008 fortunes have been mixed for physics-based sectors. Employment has fallen markedly, by 7% from the 2008 peak up to 2011, which is well in excess of the all-economy contraction in employment of 2%.

Output, as measured by GVA has fared somewhat better. The direct GVA attributable to physics-based sectors has increased very marginally in current prices, but has contracted in real terms by -3.4%.

These contractions disguise the fact that the efficiency of the sector, as measured by the amount of output each worker produces – GVA per worker (or productivity) – has actually increased since 2008.

In 2011 each worker in the direct physics-based sectors generated an average of €78,100 in GVA. The equivalent average for the Italian economy as a whole was €64,000 per worker – meaning that each worker in physics-based sectors produces 22% more than the national average.

Moreover, since 2008, physics-based productivity has increased by 2.5% in real terms, whilst all-economy average productivity has fallen by 1.5%. Thus the productivity ‘gap’ between physics-based sectors and the economy as a whole has increased from 18% in 2008 to 22% in 2011.

Whilst international comparisons are complicated by the different end points used and thus price bases and exchange rates, productivity also increased slightly in the UK in the years up to 2010. Our estimates indicate that in 2010 (using an annual average exchange rate of €0.87 per £) UK productivity in physics-based sectors was €82,600, which is only some 8% higher than our estimate for Italy in the same year.

Around half the direct GVA contribution in physics-based sectors is in manufacturing sectors: with a further 45% of the contribution in transport and communications, utilities, and business services including R&D.

Other sectors such as finance, retail and wholesale, hotels and catering and other services have no direct physics-based contribution.

The indirect and induced impact of physics-based sectors in Italy

However, finance, retail and wholesale, hotels and catering, as well as other sectors, do each benefit from the direct physics-based contribution. This is because those organisations operating in physics-based sectors, purchase goods

and services from suppliers in these sectors, as well as paying wages to their employees, who go on to spend those wages across the Italian economy.

Adding these effects onto direct effects, known as indirect (business-to-business supply-chain spending) and induced (consumer spending) effects, gives an estimate of the total contribution of physics-based sectors in Italy.

On this basis the total contribution (or footprint) in employment terms is 6.5 million jobs (25% of the Italian total), and €341 billion in GVA terms (22% of Italian GDP).¹

These total contribution/footprint measures should be taken in context. They illustrate the reach of the physics-based sector across the Italian economy rather than being an estimate that can be aggregated with other like-estimates across other cross-sections of the Italian economy.

Issues in considering physics’ economic contribution

Definition

Arriving at a working definition to use in a study to illustrate the quantum and breadth of contribution of physics has to be pragmatic, given significant limitations in the availability of data.

Figure 2.1a in the main body of the report provides the coverage of all 78 sectors included in the definition per discussions between SIF, Deloitte and stakeholders.

These sectors differ slightly from those used by Deloitte in the UK version of this research for the Institute of Physics, and also slightly differ from the sectors used in equivalent research by the Centre for Economic and Business Research for their study of the economic contribution of physics across EU member states.

¹ The indirect and induced employment effects are proportionately higher than the GVA effects because productivity in supplying industries tends to be much lower. Per worker productivity for the indirect effects is €47,700 in 2011 and for induced effects is €42,400 versus €78,100 in physics-based sectors.

The issue of time

The temporal contribution of physics should also be acknowledged and understood. This is why our sector-based definition acknowledges those sectors that are likely to rely on physics which was commercialised some time before the study time horizon of 2008-2011 – similarly activities undertaken in this period might have significant effects over the next few years.

A contemporary measure of physics might include only those individuals directly engaged in the generation and application of physics at present and the associated economic output on a variety of measures such as employment supported, GVA contribution, or patents. However, the full economic impact of a given piece of research may not be felt immediately due to time lags; indeed it may be many years until there is an impact on the economy.

Physics and interdisciplinary-relatedness

Physics is intertwined to a great extent with other disciplines. This interaction of physics with other disciplines makes it difficult to accurately segment what is truly physics and what is not. In this study we do not seek to make such a distinction.

A qualitative take on Physics' economic contribution

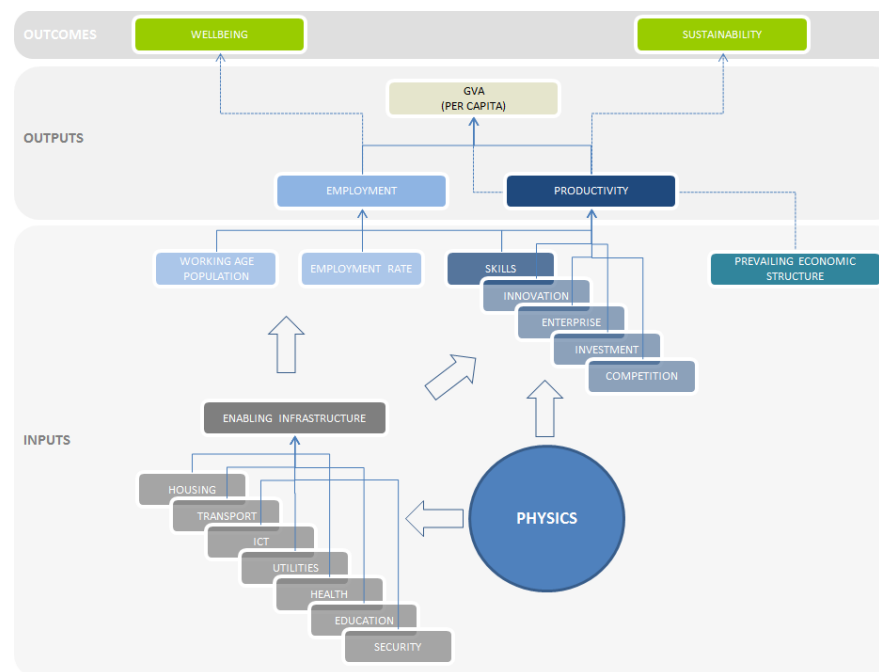
As well as the narrow economic impact on jobs and GVA, physics has **broader impacts** on society and the economy. There are many specific routes through which physics can impact the Italian economy and which do not come to light through an empirical analysis of physics.

Physics as a generic driver of long-term economic growth

Physics generates an increase in understanding, new tools and techniques and refinements to existing tools and techniques. These then give way to outcomes and applications, such as an increase in the skills-base of Italy; new patents and commercial applications; product and process innovation; improved decision-making and more efficient management practices.

The generation and application of physics can have a positive impact on enabling infrastructure, drivers of productivity, employment and in doing so overall levels of economic output. Indeed, physics cuts across the long-term economic growth drivers as shown below in Deloitte's Long-term Economic Growth Framework:

Figure 1a: Deloitte's Long-term Economic Growth Framework



Source: Deloitte

Physics can be leveraged by other disciplines to develop new products and services, promoting skills, innovation and increasing efficiency, which can result in economic growth, or hinder it in the long-term if physics skills and knowledge are not in sufficient supply. Ultimately, the level and type of economic output and employment generated by physics influences hard-to-measure outcomes such as societal wellbeing and sustainability.

Case study examples

The main body of this report considers a number of case studies showing the contribution of physics across specific sectors of the economy. Very broadly these contributions can be thought of as using physics to:

- make sense of, and better understand the world;

- safeguard society; and
- improve long-term outcomes for economy and society.

So What?

The message to those interested in physics as a discipline and as a driver of economic growth is both a negative and positive one.

This report clearly shows that physics-based sectors have suffered to a greater extent than many other areas of the Italian economy through the recession – predominantly due to their strong links with the manufacturing sector.

The number of jobs lost (114,000 from 2008 to 2011) is significant, but so is the way that the sector has increased its average productivity to make good some of the activity and output that might otherwise have been lost.

Jobs in physics-based sectors tend to be much more productive than the Italian average. Each worker in physics-based sectors produced c. €79,000 in GVA in 2011, which is 22% more productive than the all sector average in Italy.

This means (all else equal) they tend to pay more, generate more profit for organisations, and (although it has been beyond this studies' remit to consider tax) lead to more tax revenue for the Italian Government.

Deloitte's long-term economic growth framework suggests that investing in physics today through education and support for business is likely to deliver future benefits for the Italian economy, such as employment growth and productivity enhancements.

Whilst policy conclusions are also beyond the scope of this study, the focus on education in so-called STEM (Science, Technology and Mathematics) subjects and commercialisation of research in emergent economies, suggests that those industrialised economies deciding not to invest in STEM may see an erosion of domestic capability in sectors which depend upon physics and other scientific subjects.

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1 Introduction

1.1 Study Background

Deloitte has been commissioned by Società Italiana di Fisica (SIF) to undertake a study that assesses the economic contribution of physics-based sectors on the Italian economy.

Physics refers to the science that deals with the nature, structure, properties and interactions of matter, at different scales.

This report examines the contribution of physics to the Italian economy between the years 2008 and 2011 (the latest year of available data). This research highlights how physics-based sectors² can play an important part in generating economic growth and prosperity.

The focus of this report is the Italian economy as a whole.

Drawing on the Italian National Institute for Statistics (Istat) datasets and our own bespoke modelling analysis, the contribution physics-based sectors make to the Italian economy between 2008 and 2011 are summarised in the following pages.

1.2 Study Scope

The focus of the modelling element of the study is limited to the assessment of:

- Employment;
- Turnover (as a model input rather than a measure of economic output);
- GVA; and
- Productivity per worker (GVA per worker).

The study considers four types of impact on the Italian economy, namely:

- The direct impacts of physics-based sectors;
- The indirect effects of physics-based sectors – due to business-to-business supply chain purchasing within the Italian economy;
- The induced effects of physics-based sectors – due to consumer spending of wages throughout the Italian economy; and thus
- Total impacts – the three aforementioned metrics aggregated together to give a ‘footprint’ contribution.

The study also considers 5 case studies of Italian organisations operating in physics-based sectors, as well as a limited number of quantitative indicators that are examined in an off-model setting.

1.3 Document structure

This report is structured as follows:

- Chapter 2: The direct economic contribution of physics-based sectors to the Italian economy
- Chapter 3: The indirect, induced and total economic contribution of physics-based sectors to the Italian economy
- Chapter 4: Further measures of physics’ contribution
- Appendix 1: Methodology

² Physics-based sectors are defined as those sectors of the Italian economy where the use of physics – in terms of technologies and expertise – is critical to their existence, i.e. if there were no physics, these sectors would not exist. See chapter 2 for a full list of sectors.

2 The direct economic contribution

2.1 Definitions

“All science is either physics or stamp collecting”.

Ernest Rutherford.

A pragmatic definition

Physics intersects with many other disciplines, and in effect, some of the economic activity claimed here as ‘physics-based’ might also be claimed as ‘chemistry-based’ or ‘mathematics-based’.

Thus arriving at a working definition to use in a study to illustrate the quantum and breadth of contribution to an economy has to be a little more pragmatic than the black and white suggestion of Ernest Rutherford.

The thrust of the research, therefore, is not to stake a claim for this activity, rather it is to illustrate how the elements of the economy that rely in some form on physics, interact with the rest of the Italian economy.

Figure 2.1a (overleaf) provides the coverage of all sectors included and proportions of employment taken per discussions between SIF, Deloitte and stakeholders. The table also provides the direct employment contribution in each of the 78 sectors chosen for the study.

These sectors differ slightly from those used by Deloitte in the UK version of this research for the Institute of Physics, and also slightly differ from the sectors used in equivalent research by the Centre for Economic and Business Research for their study of the economic contribution of physics across EU member states.

NB – Analysis of specific NACE 4-digit sectors has not taken place in this study. The 4-digit information is used to arrive at a working definition of physics-based sectors that can then be analysed in a model which includes 37 sectors, and which is then displayed in the report, for reasons of brevity, in 10 aggregated industries.

Figure 2.1a: Direct physics-based employment by NACE 4-digit Industry, 2011 (% attributable refers to proportion of all sector activity counted as physics-based)

NACE Code	% Attributable	Direct Physics-based Employment	NACE Code	% Attributable	Direct Physics-based Employment
0910 : Support activities for petroleum and natural gas extraction	100%	8,100	2841 : Manufacture of metal forming machinery	100%	17,200
2011 : Manufacture of industrial gases	2%	100	2849 : Manufacture of other machine tools	100%	21,500
2013 : Manufacture of other inorganic basic chemicals	100%	6,000	2892 : Manufacture of machinery for mining, quarrying and construction	100%	21,700
2059 : Manufacture of other chemical products n.e.c.	2%	300	2899 : Manufacture of other special-purpose machinery n.e.c.	100%	21,700
2110 : Manufacture of basic pharmaceutical products	1%	100	2910 : Manufacture of motor vehicles	47%	30,000
2120 : Manufacture of pharmaceutical preparations	100%	51,000	2931 : Manufacture of electrical and electronic equipment for motor vehicles	100%	11,200
2229 : Manufacture of other plastic products	2%	1,800	3011 : Building of ships and floating structures	100%	16,200
2319 : Manufacture and processing of other glass, including technical glassware	2%	200	3020 : Manufacture of railway locomotives and rolling stock	100%	10,400
2344 : Manufacture of other technical ceramic products	100%	500	3030 : Manufacture of air and spacecraft and related machinery	100%	31,900
2452 : Casting of steel	8%	200	3040 : Manufacture of military fighting vehicles	100%	1,300
2521 : Manufacture of central heating radiators and boilers	100%	4,200	3250 : Manufacture of medical and dental instruments and supplies	100%	61,800
2530 : Manufacture of steam generators, except central heating hot water boilers	100%	2,700	3299 : Other manufacturing n.e.c.	25%	4,500
2540 : Manufacture of weapons and ammunition	100%	7,000	3320 : Installation of industrial machinery and equipment	100%	52,700
2561 : Treatment and coating of metals	2%	700	3511 : Production of electricity	100%	25,200
2593 : Manufacture of wire products, chain and springs	2%	200	3512 : Transmission of electricity	100%	3,500
2599 : Manufacture of other fabricated metal products n.e.c.	100%	79,300	3513 : Distribution of electricity	100%	23,600
2611 : Manufacture of electronic components	100%	29,200	3514 : Trade of electricity	10%	700
2612 : Manufacture of loaded electronic boards	100%	9,000	3812 : Collection of hazardous waste	100%	2,600
2620 : Manufacture of computers and peripheral equipment	100%	6,800	3822 : Treatment and disposal of hazardous waste	100%	3,000
2630 : Manufacture of communication equipment	100%	26,800	4222 : Construction of utility projects for electricity and telecommunications	1%	200
2640 : Manufacture of consumer electronics	100%	2,500	4321 : Electrical installation	23%	54,800
2651 : Manufacture of instruments and appliances for measuring, testing and navigation	100%	22,400	4322 : Plumbing, heat and air-conditioning installation	19%	37,200
2660 : Manufacture of irradiation, electromedical and electrotherapeutic equipment	100%	12,700	5221 : Service activities incidental to land transportation	11%	8,800
2670 : Manufacture of optical instruments and photographic equipment	100%	2,100	5222 : Service activities incidental to water transportation	100%	12,200
2680 : Manufacture of magnetic and optical media	100%	100	5223 : Service activities incidental to air transportation	100%	26,900
2711 : Manufacture of electric motors, generators and transformers	100%	29,700	6110 : Wired telecommunications activities	100%	60,000
2712 : Manufacture of electricity distribution and control apparatus	100%	23,900	6120 : Wireless telecommunications activities	100%	22,100
2720 : Manufacture of batteries and accumulators	100%	2,900	6130 : Satellite telecommunications activities	10%	-
2731 : Manufacture of fibre optic cables	100%	1,300	6190 : Other telecommunications activities	2%	300
2732 : Manufacture of other electronic and electric wires and cables	100%	11,000	6209 : Other information technology and computer service activities	2%	500
2733 : Manufacture of wiring devices	100%	6,600	7022 : Business and other management consultancy activities	10%	9,600
2740 : Manufacture of electric lighting equipment	100%	17,100	7111 : Architectural activities	6%	4,500
2751 : Manufacture of electric domestic appliances	100%	38,400	7112 : Engineering activities and related technical consultancy	42%	81,900
2790 : Manufacture of other electrical equipment	100%	34,600	7120 : Technical testing and analysis	32%	10,400
2811 : Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	100%	17,300	7211 : Research and experimental development on biotechnology	100%	3,100
2821 : Manufacture of ovens, furnaces and furnace burners	100%	12,000	7219 : Other research and experimental development on natural sciences and eng	100%	17,000
2823 : Manufacture of office machinery and equipment (except computers and peripheral eq.	100%	2,100	7420 : Photographic activities	10%	1,900
2825 : Manufacture of non-domestic cooling and ventilation equipment	100%	31,300	7490 : Other professional, scientific and technical activities n.e.c.	100%	112,900
2829 : Manufacture of other general-purpose machinery n.e.c.	100%	72,400	8422 : Defence activities	33%	106,400

Source: Deloitte, Istat.

*Employment figures round to nearest 100 for disclosure purposes. May not sum to estimates presented in the remainder of the report due to rounding.

Also of relevance in a definitional sense are the major industry sectors we use in the remainder of the report to show the results of the analysis. Obviously it is impractical to present results for each of the 616 4-digit NACE codes, and for this reason results are presented at a more manageable level – 10 broad industries.

These broad industries, along with examples of the types of activity taking place within them are shown in figure 2.1b.

Figure 2.1b: 10 major economic sectors with examples of physics-based companies

Major sector	NACE Codes	Example Sectors	Example PBS Companies
Extractive	0100-0990	0910 : Support activities for petroleum and natural gas extraction	n/a disclosive
Manufacturing	1011-3319	2670 : Manufacture of optical instruments and photographic equipment	Phoenix RTO srl
Utilities	3320-3900	3511 : Production of electricity	Enel S.p.A.
Construction	4110-4399	4321 : Electrical installation	Cofely Italia SpA
Retail, Wholesale, Hotels & Catering	4511-4799, 5510-5630	5630 : Beverage serving activities	n/a
Transport & Communications	4910-5320, 5811-6399	6209 : Other information technology and computer service activities	Mavi srl
Finance	6411-6330	6630 : Fund management activities	n/a
Business Services inc R&D	6810-8299	7211 : Research and experimental development on biotechnology	Think Laser srl
Government Activities	8411-8899	8422 : Defence activities	Aeronautica Militare
Other Service Activities	9001-9609	9602 : Hairdressing and other beauty treatment	n/a

Source: Deloitte Analysis

Major sectors showing no example of physics-based companies in the above table, are those which have no direct physics-based activity within them. As the analysis goes on to show, there are secondary effects in these sectors due to business-to-business purchases and consumer spending.

2.2 Direct employment contribution

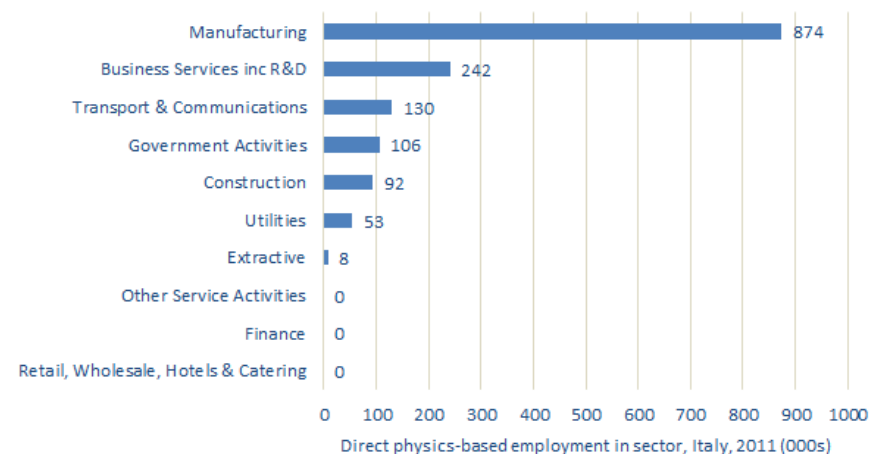
Aggregated together, the relevant physics-based sectors (PBS) accounted for 1.51 million jobs in 2011, representing 6.1% of the 24.7 million jobs in Italy.³

The industrial structure of the aggregate physics-based sector is skewed towards manufacturing industry. Approaching 900,000 people work in physics-based jobs in manufacturing in Italy. Contrasting this with the Italian economy as a whole – where manufacturing makes up c. 19% of all jobs – manufacturing in physics-based sectors accounts for a much higher proportion: 58% of all jobs.

Looking just at the manufacturing sector, this means that around 20% of all Italian manufacturing jobs can be classed as physics-based.

³ Source: Istat, Employment in persons – Total.

Figure 2.2a: Direct physics-based employment contribution, Italy, 2011



Source: Deloitte Analysis, Istat

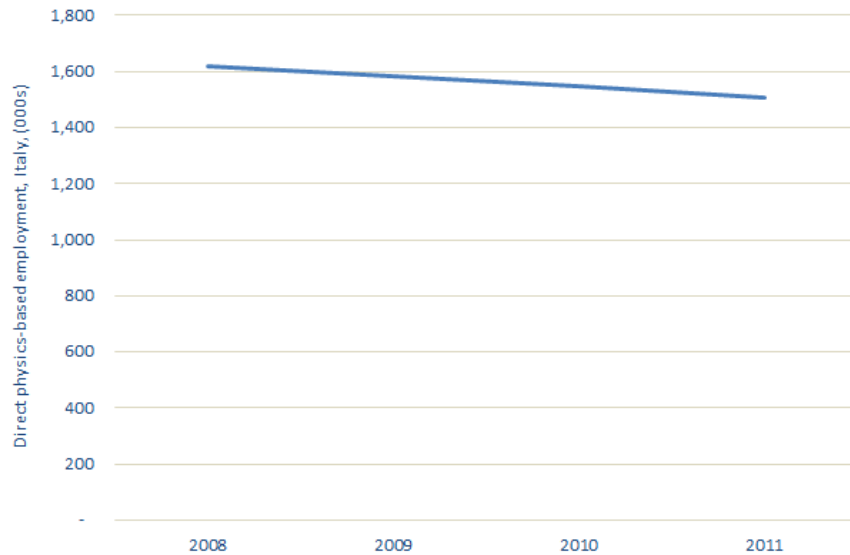
Other sectors where physics-based sectors are most prevalent include:

- Business services including R&D (16% of PBS)
- Transport and communications (9%)
- Government activities (7% – predominantly defence); and
- Construction (6%)

Extractive industries (and to a lesser extent utilities) tend to be reliant on physics, but being relatively capital intensive and having a relatively small employment footprint, do not support many jobs in comparison to other sectors.

Since 2008 the direct employment in Italy supported by physics-based sectors has fallen.

Figure 2.2b: Direct physics-based employment contribution, Italy, 2008-2011

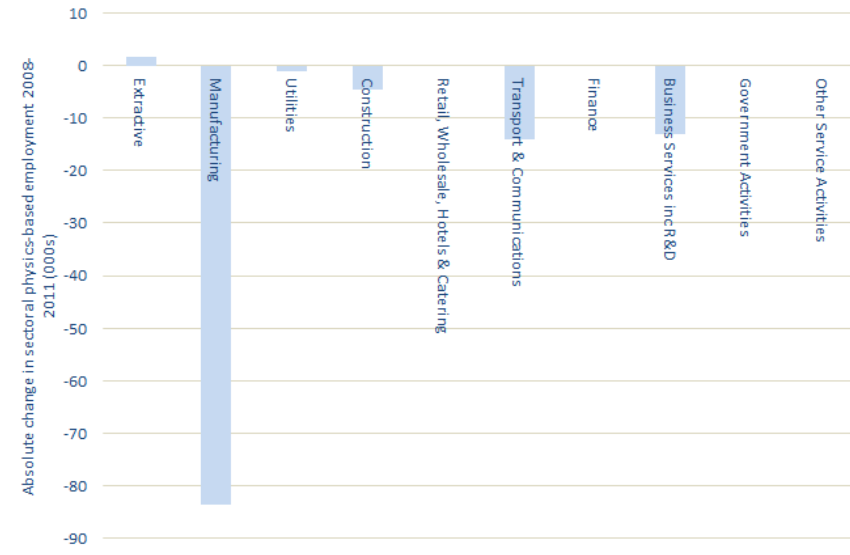


Source: Deloitte Analysis, Istat

Between 2008 and 2011, physics-based sectors lost 114,000 net jobs – a reduction of 7%. Over the same period the Italian economy shedded over 500,000 net jobs – a reduction of 2%. Over this period this means that more than 1 in 5 net jobs lost were in physics-based sectors. Thus physics-based sectors realised a more than proportionate hit from the recession than the Italian economy as a whole, given that they account for a relatively smaller proportion of the total.

Over the period 2008-2011, the make-up of physics-based sectors has changed in its absolute and relative make up. Of the 114,000 jobs lost over this period, more than 80% have come in manufacturing sectors. Accordingly, manufacturing’s share of physics-based employment has fallen by one percentage point from 59% to 58% in 2011.

Figure 2.2c: Changes in sectoral employment contribution, Italy, 2008-2011



Source: Deloitte Analysis, Istat

Only extractive industries have seen an increase in employment contribution since 2008.

By virtue of the absolute size of the sector, and relatively low levels of employment losses, business services including R&D have increased their share of physics-based sectors by 0.3 percentage points.

2.3 Direct GVA contribution

Aggregated together, the relevant physics-based sectors accounted for €118 billion in Gross Value Added contribution to the Italian economy in 2011, representing 7.4% of Italy’s GDP.⁴

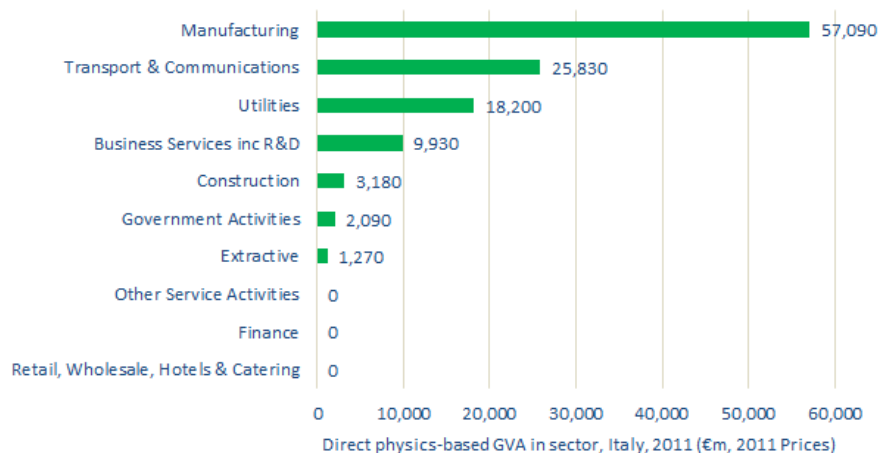
This means that physics-based sectors have a greater share of national economic output than the equivalent share of national employment. This is due to relative

⁴ Source: Eurostat – GDP and main components – volumes. Millions of euro, chain-linked volumes, reference year 2005 (at 2005 exchange rates) converted into 2011 prices.

productivity in physics-based sectors which is discussed in more detail in section 2.4

At a sectoral level, the picture is similar to that for the distribution of employment. Manufacturing accounts for the largest share of physics-based activity – some €57 billion or 49% of total physics-based GVA in Italy.

Figure 2.3a: Direct physics-based GVA contribution, Italy, 2011, Constant Prices



Source: Deloitte Analysis, Istat

There are some notable differences. Namely:

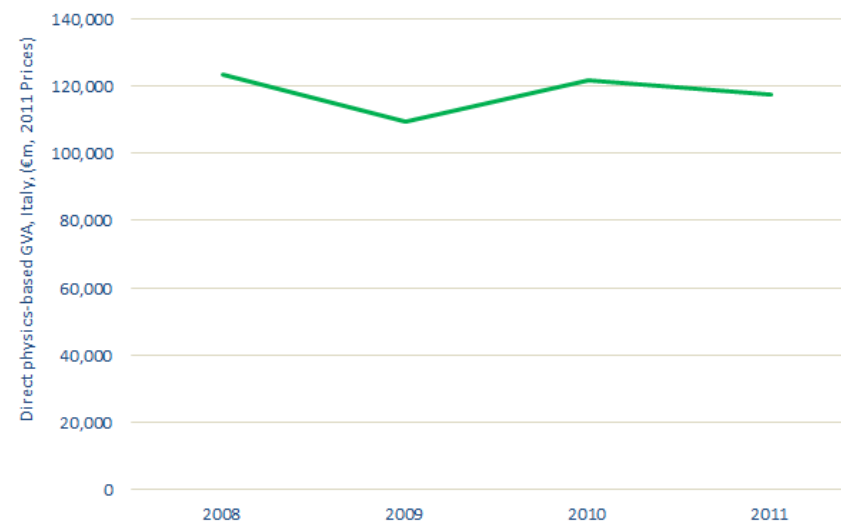
- Business services and R&D is 4th ranked in GVA terms (2nd in employment terms), accounting for 8% of all GVA in physics-based sectors
- Utilities is 3rd ranked in GVA terms (6th in employment terms) accounting for 16% of GVA

These sectoral differences in contribution are also due to variations in sectoral productivity in Italy.

Considering the direct GVA contribution of physics-based sectors over time, there was an effective rebound in output (in constant price terms) in 2010. By

2010 output levels had almost recovered to levels seen in 2008 (1.4% lower), after being as much as 11% lower in 2009, in real terms.

Figure 2.3b: Direct physics-based GVA contribution, Italy, 2008-2011



Source: Deloitte, Istat

In 2011 there was a further stutter in physics-based GVA contribution, with a year-on-year contraction from 2010 of 3.4%. By contrast, in 2011, the Italian economy as a whole grew by c. 0.5% in real terms.⁵

2.4 Productivity contribution

Productivity per worker refers to the amount of output produced each year by a worker.

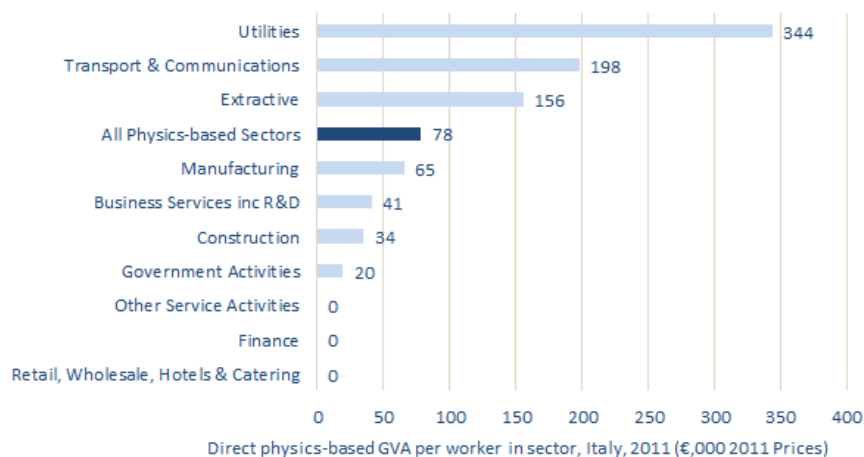
⁵ Source: Eurostat – GDP and main components – volumes. Millions of euro, chain-linked volumes, reference year 2005 (at 2005 exchange rates) converted into 2011 prices.

The two primary long-term drivers of economic growth (per the framework shown in the Executive Summary) are the number of people in employment and the amount they each produce – their productivity.

This study estimates the contribution of physics through defined physics-based sectors, but physics and the use of physics will also influence productivity in a positive manner across all sectors of the economy. These ‘broader’ effects are not considered in the study.

Within the tightly defined parameters of physics-based sectors, productivity per worker is highest in utilities, transport and telecommunications and extractive industries. Specifically these three sectors have above physics-based sector average productivity per worker, and all other sectors have below average productivity.

Figure 2.4a: Physics-based per worker productivity (GVA) within sectors, Italy, 2011



Source: Deloitte, Istat

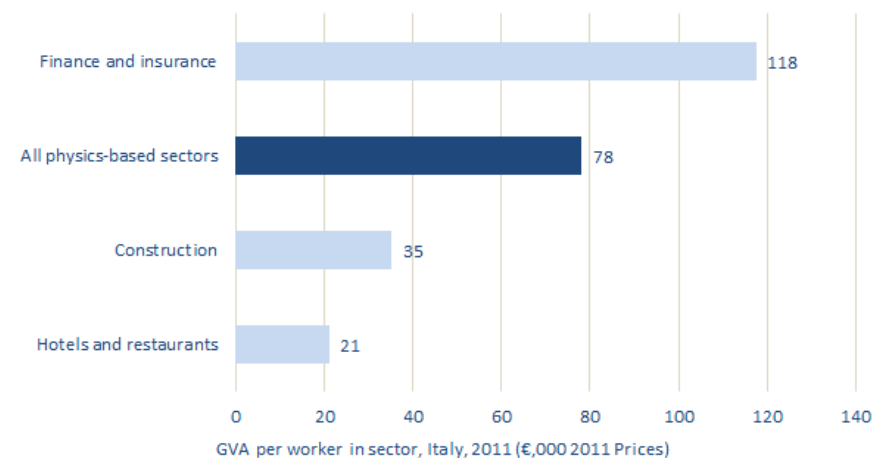
All-economy productivity per worker for Italy in 2011 was €64,000, only 82% of the physics-based sector average of €78,100.

Thus, industries defined as physics-based tend to be more productive than other industries, on average. Although per worker productivity in physics-based

manufacturing sectors is below average relative to other physics-based sectors, it is still in excess of the all economy average by around 2%.

Figure 2.4b shows physics-based per worker productivity relative to other selected sectors in Italy in 2011. These particular three examples have been chosen for comparison because there is either no, or very little overlap with physics-based sectors in Italy.

Figure 2.4b: Physics-based per worker productivity (GVA) versus productivity in other sectors, Italy, 2011



Source: Deloitte, Istat

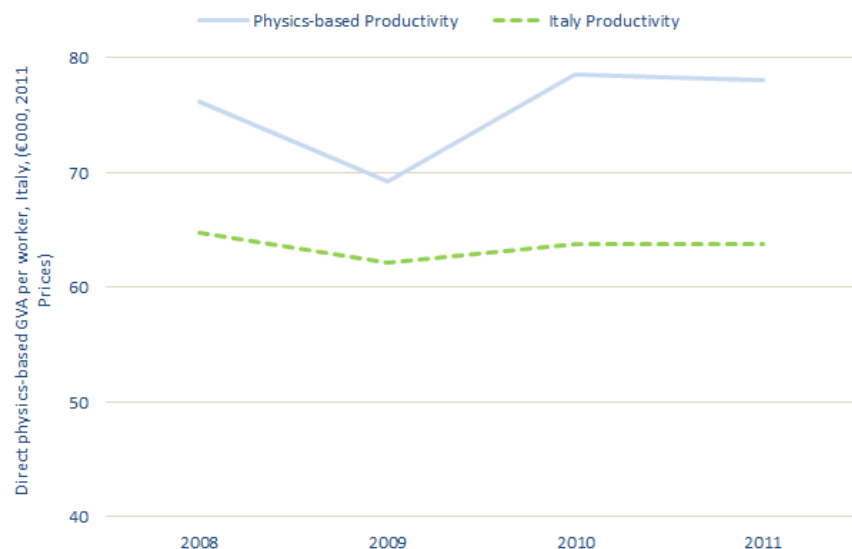
NB: these sectors differ to the 10 major sectors used elsewhere in the report because these are taken from the macroeconomic model used for Italy in the analysis based on data from Istat.

Workers in physics-based sectors are much more productive than their equivalents in hotels and restaurants or construction, but they trail finance and insurance employees by c. 50%. This is broadly equivalent to the differential found in Deloitte’s 2012 report for the UK – which found that productivity in finance was c. 35% higher than physics-based sectors.

Between 2008 and 2009 productivity per worker in physics-based sectors fell significantly, in real terms, by c. 9%. However in 2010 this reduction in GVA per worker was reversed according to statistics from Istat, which show that, GVA per

worker increased to €79,000 off the back of a further fall in employment and a significant increase in output.

Figure 2.4c: Direct physics-based per worker productivity (GVA), Italy, 2008-2011



Source: Deloitte, Istat

In 2011 productivity per worker in physics-based sectors dropped again, and was marginally lower than 2010, falling to just over €78,100 in real terms.

This behaviour: a dip and then effective flattening off in 2010 and 2011 is in keeping with productivity for the Italian economy as a whole, which in turn appears to be part of a wider trend amongst many western economies: the recession has been associated with real terms falls in productivity that have now persisted for a number of years. In 2011, real terms productivity per worker in Italy was 1.5% lower than in 2008.

Per worker productivity in physics-based sectors, however, increased by 2.5% between 2008 and 2011, and, in doing so, outperformed the Italian economy.

One feasible explanation for this might be those organisations suffering most through the recession in physics-based sectors, were the most inefficient

organisations and workers, such that after the recession induced correction, the remaining organisations and workers were able to be much more efficient and produce more output per capita, and therefore in aggregate, from a lower number of workers.

Because of this, the productivity gap between direct physics-based sectors and the economy as a whole has increased since 2008, from 18% to 22% in 2011 – i.e. physics-based sectors are 22% more productive than the all sector average.

2.5 The regional dimension

In absolute terms, data from Istat confirms that in 2011 the bulk of jobs in physics-based sectors are located in the North of Italy.⁶ The 929,000 jobs here account for 66% of all PBS jobs in Italy. Across the whole economy in Italy, the North accounts for approaching 60% of economic activity.

However, the analysis of regional PBS activity needs to be considered carefully, because of missing data in both PBS and non-PBS sectors (predominantly in defence and finance) which mean that both the numerator and denominator definitions are different to the one used at national level, where the data is more complete.

Figure 2.5a: Physics-based sectors contribution across Italian regions, 2011

Region	All Economy		Physics-based sectors				
	Value Added (at production factor cost, €bn, 2011)	Number of people employed	Value Added (at production factor cost, €bn, 2011)	Number of people employed	Relative Productivity in PBS (Italy = 100)	% Regional GVA, 2011	% Regional Employment, 2011
North	457.8	9,513,000	67.5	929,000	96	14.7	9.8
Central	149.4	3,376,000	21.7	261,000	110	14.5	7.7
South	130.1	3,729,000	16.8	216,000	103	12.9	5.8
Italy	737.3	16,618,000	105.9	1,406,000	100	14.4	8.5

Source: Deloitte, Istat

There are 261,000 people employed in PBS in Central Italy in 2011, with just 216,000 in Southern Italy, including the Islands. PBS activity accounts for a

⁶ The North of Italy is defined as the NUTS regions ITC R1 NORD OVEST and ITH R2 NORD EST. Central Italy is defined as ITI R3 CENTRO, and the South of Italy is defined as ITF R4 SUD and ITG R5 ISOLE.

greater share of regional economic activity in the North (approaching 10% of employment and 15% of GVA), with PBS in the South accounting for the lowest proportion (less than 6% of employment and 13% of GVA).

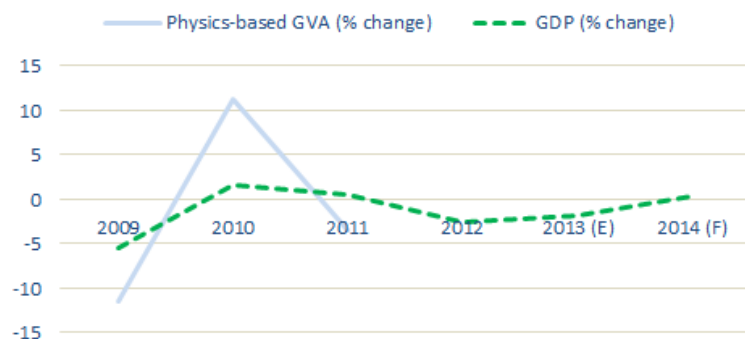
However, it is interesting to note that relative productivity per worker in the South of Italy is higher than in the North, and higher still in Central Italy. An explanation for this may be that the bulk of lower productivity PBS jobs are located in the North, or that there are a number of major institutions operating in Central and Southern Italy responsible for the higher productivity.

2.6 Looking to the future

Projections for PBS beyond 2011 are beyond the scope of this study, but we are able to comment on what has happened to the wider Italian economy since 2011 and what that may mean if trends continue.

Using projections from the Economist Intelligence Unit for Italy the year-on-year analysis below relates PBS performance between 2009 and 2011 to the performance of the Italian economy over that same period, as well as to 2014.

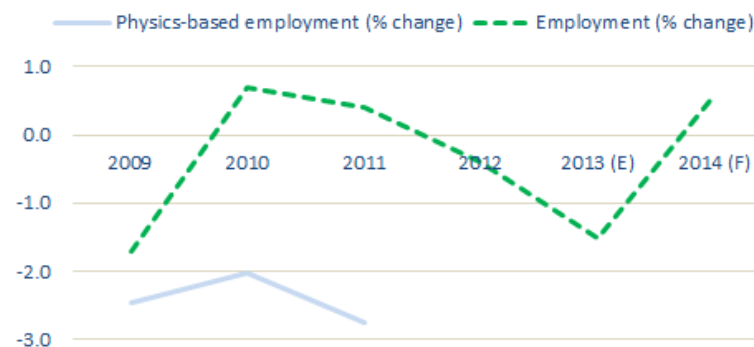
Figure 2.6a: Relating PBS to Italian economic performance, 2009-2014



Source: Deloitte, EIU Italy Country Forecasts 2013

Economic performance (GDP green); Physics-based GVA (blue); E = estimate; F = forecast.

Figure 2.6b: Relating PBS to Italian employment performance, 2009-2014



Source: Deloitte, EIU Italy Country Forecasts 2013

Employment performance (green); Physics-based employment (blue); E = estimate; F = forecast.

The key message here is that the Italian economy regressed significantly again between 2011 and 2013 in employment terms, and to a lesser extent, GVA terms. Across the economy this means that productivity levels are likely to have increased further in 2013.

Whilst there is no guarantee that previous relationships will have held between 2011 and 2013, it seems likely that physics-based sectors will have shedded yet more jobs between 2011 and 2013 in keeping with the rest of the Italian economy.

On a lighter note, expectations are for a marked improvement in fortunes in 2014 for the Italian economy with GDP growth and employment growth returning to positive territory.

2.7 Direct physics-based contribution: Summary

- Employment levels have continued to fall in direct physics-based sectors since 2008, now accounting for 1.5 million jobs, 6.1% of all employment – down from 6.4% of total in 2008;
- Around 1 in 5 of all net jobs lost since 2008 have been in physics-based sectors – 114,000 in total.

- Output in physics-based sectors (as measured by GVA), fell abruptly in 2009, in keeping with the rest of the Italian economy, but has since recovered in real terms to account for 7.4% of Italian GDP;
- Physics-based sector's output share is higher than the employment share because per worker productivity is 22% higher than the all-economy average for Italy. This represents an increase in the productivity gap from 18% in 2008;
- PBS activity is concentrated in the North of Italy, and accounts for 66% of jobs in PBS across Italy. Nonetheless PBSs are still very important to the other regions because they contribute a larger share of GVA than employment because they tend to be much more productive jobs than average.
- Therefore, whilst the sector has lost a significant number of jobs over the last 4 years, it has performed relatively well in terms of utilising resources in a productive fashion. This has meant that fall in economic output of the direct physics-based sectors has been significantly lower than it might have been on the basis of employment losses.
- Unfortunately, since 2011 the Italian economy has performed poorly and this may be reflected in further PBS job losses between 2011 and 2013. Until data is released in 2014, however, this is conjecture. To conclude on a positive note, expectations are for a return to economic growth in 2014.

3 Indirect, induced and total economic contribution

3.1 What is being measured

The input-output model of the Italian economy (described subsequently in section 3.2) permits a way of approximating the real-life means by which the direct physics-based sectors presenting in chapter 2, go on to interact with the rest of the Italian economy. These interactions are with domestic producers and consumers – as well interactions with overseas suppliers (in the form of import leakage).

Thus, the model is used to trace approximate transmissions to all other parts of the economy, including ‘knock-on’ activity within those sectors that are directly defined as physics-based.

As a worked example, industry 6120: wireless telecommunication activities will purchase inputs from other physics-based sectors such as industry 3512: transmission of electricity, who in turn will buy inputs in the form of services from providers of wireless telecommunications, in a virtuous cycle.

But what exactly is this method measuring?

Theoretically, if physics ceased to exist tomorrow and was removed from the system, this method measures the gap created in terms of physics’ economic contribution, directly and up the supply-chain to supplying industries and workers.

Critics of this approach have noted, with justification, that the equivalent analysis across a number of ‘sectors’ would quickly sum to a total in excess of the economic activity of the country in question.

Rather than being a figure to aggregate with other such analysis, the analysis in this chapter is meant to demonstrate breadth of coverage and linkages through the economy rather than as an additive piece with other like-sectors.

Moreover, defining the above impacts as ‘Narrow Impacts’ it would be possible, though difficult, to consider what might be termed the ‘Broad Impacts’ of

physics-based industries ‘down’ the supply-chain to industries. This would measure the share of the economic contribution generated in customer activity by the products sold to them physics-based sectors.

This ‘broader’ impact is beyond the scope of the study, but it should be noted that productivity gains will accrue to many organisations leveraging products and services, new and old, that rely on physics and which are not included in the direct definition outlined in Chapter 2.

3.2 The Input-Output Model

The model developed for this study makes use of a range of data for Italy and examines the direct, indirect and induced impacts of business and consumer spending arising from the stated definition of physics-based sectors, in terms of gross output/expenditure, value added output and employment.

The Deloitte methodology includes the use of mathematical and economic techniques to approximate the Italian economy in model form in terms of:

- Who might be expected to buy what from whom (business-to-business purchases);
- Who might be expected to pay whom for their work (compensation of employees); and
- Who might be expected to buy what from whom (consumption of goods and services).

To enable this, our analysis takes account relevant statistics from a range of sources including:

- Istat – for all necessary industry level statistics, where available;
- Eurostat – for aggregate real and nominal variables at Italy level.
- OECD Structural Analysis (STAN) Database – for the Italian Domestic Use Matrix (DUM) at the relevant level of sectoral detail;
- Various international sources such as the UK Office for National Statistics – in the cases where specific supporting data is not easily available for Italy within the scope of the contract to deliver the services embodied in the contract between SIF and Deloitte.

The model is then used to assess the likely knock-on or ‘multiplier’ benefits to the Italian economy:

- Type I, which gives the direct impact and the impact on business-to-business spending (indirect effect) in the economy; or
- Type II, which given the total impact of direct activity, business-to-business spending (indirect effect) AND consumer spending (induced effect).
- Thus deducting direct effects from the Type I result isolates the business-to-business (indirect) impact, and deducting the Type I result from the Type II result isolates the consumer spending (induced) impact of PBSs.

Actual values of expenditure/gross output multipliers in the model are:

- 1.83 for Type I, which gives the direct impact and the impact on business-to-business spending in the economy; or
- 2.45 Type II, which given the total impact of direct activity, business-to-business spending AND consumer spending.

This means that for every €1 of turnover in physics-based sectors a further 83 cents is generated in expenditure through the business supply chain, and a further 62 cents is generated through induced consumer spending.

The direct impact of physics-based sectors is estimated using data collected from Istat which summarises the contribution of each individual NACE 4-digit sector for years 2008-2011 across the Italian economy. These direct impacts are then applied to the model in terms of expenditure/gross output, Gross Value Added, and employment supported by defined physics-based sectors.

The model elements taken from OECD STAN are based around expenditure flows, and precise effects are dependent upon the direct impacts entered for the model, so employment and value added multipliers are implied in the model on the basis of:

- Industry level productivity per worker (GVA per worker) and
- Average levels of GVA per unit turnover in each sector.

As effective results from the model, these are presented later in the chapter.

(Gross) Value Added is a measure of economic output which controls for the double counting of inputs. Gross output is a less valuable indicator of economic contribution as it represents a financial flow rather than an economic value.

Value Added is defined as the level of economic contribution produced by an activity, intervention, business, or sector that when aggregated together across the economy (and adjusted) is analogous to GDP. Value Added excludes intermediate consumption of domestic products and imports (leakage), but includes profits, wages and applicable taxes to give a measure of economic output net of these economically non-additive financial flows.

This effectively means that for each €1 in expenditure in Italy flowing through the model, only a fraction of this expenditure (< 1.0) represents Value Added for the Italian economy.

Thus direct estimates of expenditure/gross output are used to generate indirect and induced expenditure/gross output along with direct, indirect and induced estimates of Value Added.

Estimates of productivity per worker (GVA per worker) for the relevant year 2008-2011 are then applied to the Value Added estimates to create the level of realised employment demand in Italy across all elements of the supply-chain including in consumer focused sectors.

3.3 Indirect & Induced Employment contribution

The macroeconomic model used in the study indicates that the levels of employment supported through the supply-chain and through consumer spending are significant, and in each case exceed the direct impact of the physics-based sectors – both business-to-business spending and consumer spending effects are estimated at 2.5 million jobs in 2011:

- Direct 1.5 million
- Indirect 2.5 million
- Induced 2.5 million

The implied TYPE I and TYPE II employment multipliers are, respectively, 2.67 and 4.29. This means that:

- for every job in direct physics-based sectors, another 1.67 jobs (2.67 – 1) are supported throughout the rest of the economy because of business-to-business purchases by physics-based sectors; and
- for every job in direct physics-based sectors, another 1.64 (4.29 – 2.67) jobs are supported throughout the rest of the economy because of consumer spending undertaken and induced by the c. 1.5 million people employed in physics-based sectors;

These implied employment multipliers are far in excess of the expenditure/gross output multipliers presented in section 3.2. This is because physics is a high productivity sector and the level of employment supported for a given level of turnover is lower than average. In turn this means that when physics-based sectors buy goods and services, or when physics-based employees spend their wages, that activity supports a greater number of jobs. It is common for high productivity sectors to have relatively high employment multipliers, as is the case here.

The industry breakdown of each of these effects is shown in the aggregate in section 3.5.

3.4 Indirect & Induced GVA contribution

This chapter presents GVA as the monetary metric for economic contribution, because turnover (expenditure/gross output) is not a measure of economic value. In keeping with the definitions used in section 3.3, the 3 narrow impacts in GVA terms for the Italian physics-based sectors in 2011, are:

- Direct €117.6 billion
- Indirect €119.1 billion
- Induced €104.1 billion

The implied direct, TYPE I (indirect) and TYPE II (indirect & induced) GVA multipliers with respect to expenditure are, respectively, 0.33, 0.67 and 0.97. This means that:

- For every €1 of direct turnover in physics-based sectors, 33 cents represents direct economic contribution through GVA. This means that 67% of turnover is spent on intermediate inputs to production that do not count as GVA in direct physics-based sectors;

- for every €1 of direct turnover in physics-based sectors, another 34 cents (0.67 – 0.33) is generated as GVA throughout the rest of the economy because of business-to-business purchases by physics-based sectors; and
- for every €1 of direct turnover in physics-based sectors, another 30 cents (0.97 – 0.67) is generated as GVA throughout the rest of the economy because of consumer spending undertaken and induced by the c. 1.5 million people employed in physics-based sectors;

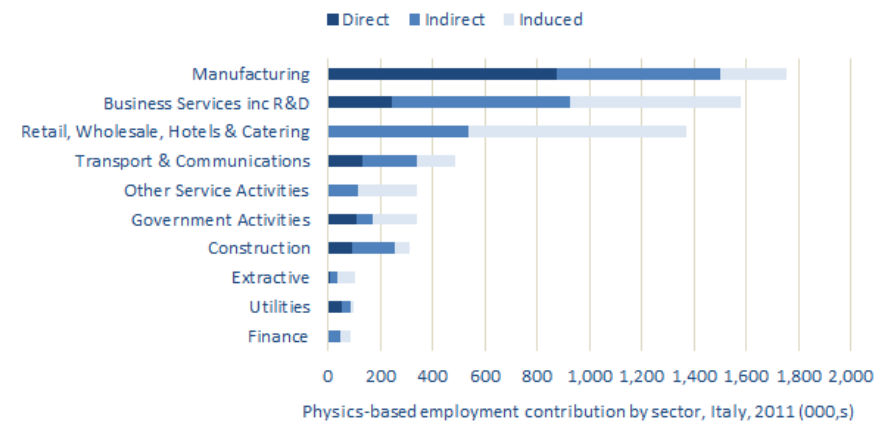
The industry breakdown of each of these effects is shown in the aggregate in section 3.5.

3.5 Total Impacts

Aggregating together the direct physics-based contribution, with indirect and induced contributions through the supply-chain and consumer spending, the total footprint of physics-based sectors in Italy is 6.5 million employees – which is roughly 25% of all employment in Italy.

On a sectoral level, all sectors have a total employment footprint that can be traced back to the direct physics-based sectors – even those which do not appear in the definition of physics-based sectors such as finance, extractive and retail.

Figure 3.5a: Total physics-based employment contribution, Italy, 2011



Source: Deloitte, Istat

Manufacturing again accounts for the greatest amount of employment due to physics-based sectors – in excess of 1.75 million, with 600,000 of these in other manufacturing organisations supplying the physics-based sectors.

Physics-based sectors are big buyers of business services and R&D, which means that the supply-chain and consumer spending effects on jobs are particularly strong. Here, whilst only 240,000 jobs are supported directly in physics-based sectors, 85% of the total employment footprint of c. 1.6 million is generated through the supply-chain and consumer spending.

The third most significant sector in job terms is retail, wholesale, hotels and catering. Despite having zero jobs based on physics in the definition, the fact that business organisations and individuals spend a significant proportion of income on their services means that approaching 1.4 million jobs are supported through this sector.

The picture is similar when considering the total GVA footprint of physics-based sectors in Italy – although it should be noted that the ‘knock-on’ effects account for a much lower proportion of total contribution.

Of the total GVA footprint of €341 billion, 65% of the contribution is non-direct and comes from the way in which physics-based sectors interact with the wider economy. This contrasts with 77% of the employment contribution of physics-based sectors coming from that same interaction.

The explanation for this can again be found in per worker productivity. Direct physics-based sectors provide fewer jobs per unit of output because productivity is higher, so when expenditure permeates the rest of the economy the level of employment supported per unit expenditure is much higher in the rest of the economy.

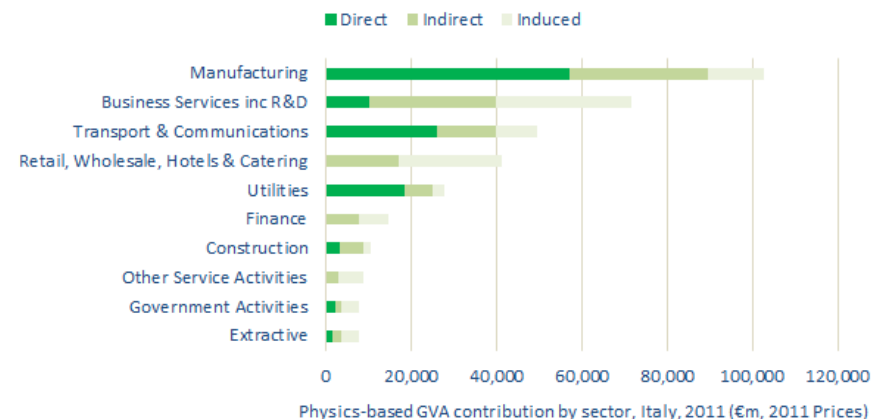
This is illustrated most starkly in two examples at opposite ends of the productivity spectrum:

- the retail, wholesale, hotels and catering sector, where the total GVA contribution is just over €40 billion. This represents 12% of the total contribution, but in terms of the total employment contribution the sector share is 21% of total. Productivity per worker in the sector is €30,000 per annum.

- the finance sector, where the total GVA contribution is €15 billion. This represents 4% of the total contribution, but in terms of the total employment contribution the sector share is 1% of total. Productivity per worker in the sector is €167,000 per annum.

Manufacturing accounts for over 30% of physics-based sector total contribution to the Italian economy in 2011.

Figure 3.5b: Total physics-based GVA contribution, Italy, 2011, constant prices

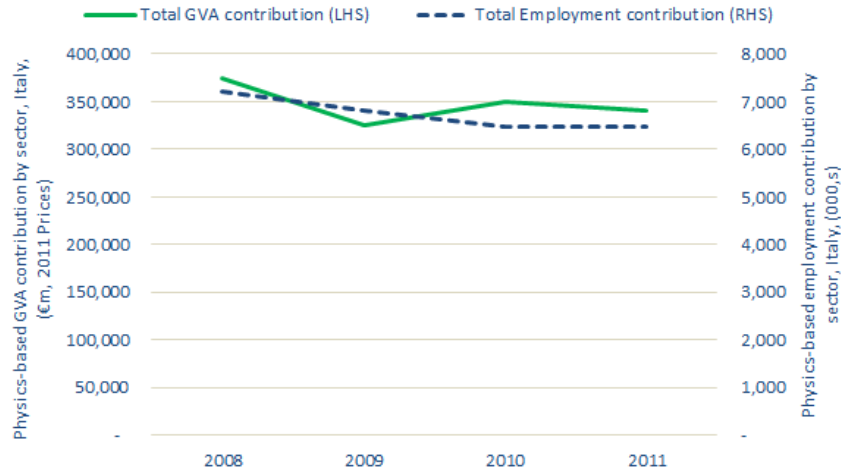


Source: Deloitte, Istat

Business services including R&D, and transport and communications account for 21 and 14% of the total GVA contribution respectively, meaning that the three major sectors together account for 65% of the sum total contribution of physics. Across the whole economy, these three sectors account for 27% of GVA – which illustrates how important they are for the economy, but also how much activity is generated in these sectors through physics-based activity.

Considering the total impacts on a time-series basis, the overall effects are broadly similar to the direct physics-based contribution shown in figures 2.2b and 2.3b.

Figure 3.5c: Total physics-based GVA and employment contribution, Italy, 2008-2011



Source: Deloitte, Istat

However, because of changes in the relative mix of 4-digit sectors over time – because the constituent NACE 4-digit sectors have all grown or contracted at different rates over time – the overall employment contribution from physics-based sectors across the economy has held steady at 6.5 million between 2010 and 2011.

This is in spite of a contraction in the number of direct physics-based jobs between 2010 and 2011, and illustrates the way in which physics can contribute to the Italian economy, even as elements of the sector contract in employment terms.

4 Further measures of physics' contribution

4.1 Trade: physics-based organisations

Using the same definition of physics-based sectors described in chapter 2 and used in the modelling in chapter 3, it is possible to arrive at estimates of imports, exports and a net trade position in physics-based sectors.

The analysis has some shortcomings: notably that trade data is only available for physical goods (i.e. manufactured products) and thus excludes 24 of the service sector components of physics-based sectors.

Nonetheless the data shows how physics-based sectors have imported manufactured goods from overseas and exported their own manufactured products overseas over the period 2008-2011, and thus through the recession.

The data suggests that imports of products made by and used by physics-based sectors are much more volatile over this period than equivalent measures of exports.

Imports halved in current prices (non-inflation adjusted) in 2009 relative to 2008. This is a major fall and can be attributed to a lack of demand for products in the wake of the 2008 credit crunch and subsequent recession.

Between 2008 and 2009 exports only fell by 25%. This might be attributed to Italian exports being tied into long-term contracts, or, more likely, exports to areas of the globe not affected by the recession to a great extent in the first instance – such as China.

The net effect of these two trends is a significant improvement in what is known as the 'visible balance of trade' in Italian physics-based sectors in 2009 – when more products are exported than imported.

Subsequently however, as demand for imports increased faster than the demand for exports in 2010, and the visible balance of trade in physics-based sectors turned negative.

Figure 4.1a: International trade in physics-based sectors (visibles only), 2008-2011, current prices (CP)



Source: Deloitte, Istat

* Only includes data for PBS where that data exists and therefore excludes some 4-digit sectors.

** Current prices due to issues with deflating imports and exports at a disaggregate level.

For context, Istat data suggests that Italy generally returns a visible trade surplus in most sectors apart from energy where it is a net importer. In 2011, the €134 billion of physics-based exports accounted for 36% of all Italian physical goods exports.

Deloitte's work for the UK Institute of Physics (IoP) suggests that the trade deficit in UK physics-based sectors is of a similar magnitude to that seen in Italy.

Also, in the UK, exports from physics-based sectors accounted for c. 26% of total turnover in physics-based sectors between 2005 and 2009. In Italy, this figure is closer to 35% for the period 2008-2011. Whilst the two periods are not entirely comparable, these are reasonably similar estimates when taken in that context.

4.2 Research and development

The sectoral coverage of R&D statistics in Italy does not afford us the opportunity to assess a point-in-time, or undertake time series analysis on how physics-based sectors contribute to R&D in Italy through government-funded research and development, and business enterprise research and development.

However, the following two case studies demonstrate respectively how physics R&D in Italy has been commercialised for economic benefit, and how an emergent technology is in the process of being commercialised.

CAEN - Costruzioni Apparecchiature Elettroniche Nucleari S.p.A. – A successful worldwide leading company

CAEN was established in 1979, as a company providing electronic designs. It was initially an organization primarily composed of electronic engineers. Nevertheless, throughout the years and in parallel with the prodigious development of electronic components, the demands of its customers had become increasingly sophisticated.

As a result, CAEN focused on becoming a highly specialized player in its field and reinforced itself by inserting a “massive” number of young physicists in all of its business activities – currently physicists represent 10% of the total CAEN’s employees. This choice revolutionized the way CAEN offers its instruments to the market. Today, CAEN is recognized as one of the most important industrial players in the nuclear physics research market and its turnover has grown constantly in the last three years achieving €15.6 million in 2013. Its products are currently used in the most prestigious laboratories, research centers, and universities worldwide. CAEN operates in a highly specialized international market: the design, the production and the supply of electronic instrumentation for radiation and low light sensors.

The company operative field targets two main areas: nuclear physics research (both high and medium-low energies) and its fall-out applications. CAEN is involved in several leading-edge R&D collaborative projects, each of them with these common goals: to continue to expand and develop their expertise in high-level electronic design, and to extend this expertise into complementary and relevant applications for the benefit of the community as a whole.

CAEN has also been involved collaborative R&D projects have in the fields of security (radiation monitoring of sensitive locations; etc.) and the environment (recognition of radioactive contamination threats, etc.).

Concentrated Photovoltaics – An example of a promising spin-off

Technology Transfer Centro Fermi/Unitek srl, Unica srl, PiazzaRosa srl

Centro Fermi (Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi") is a research institute devoted to interdisciplinary studies. It aims to integrate knowledge generated in different fields, and promote discussion among top scientists within different areas of expertise, in order to create a centre dedicated to frontier research in physics and its wide applications for the benefit of mankind. The Centro Fermi conducts interdisciplinary research activities in the most advanced fields of modern physics, and is particularly attentive to the discovery of new talents for whom it offers grants that will enable them to sustain their activities in the Italian physics industry.

A research on concentrated photovoltaics (CPV) started when Centro Fermi decided to fund the activities with a grant. This enabled the research group to start an University-participated spin-off, AtemEnergia s.r.l., that succeeded in involving three private companies acting within the manufacturing industry into the project: Unitek s.r.l., Unica s.r.l. and PiazzaRosa s.r.l.. Centro Fermi studied and measured innovative solutions, whereas the companies, covering different phase of the value chain funded the industrialization of the product (a very high efficiency concentrated photovoltaic module).

All the companies give their know-how in different production technologies for the development of the module. In particular Unitek designs and constructs molds for plastic components, above all in the automotive sector. PiazzaRosa is able to work extremely accurate optical surfaces in the mold, necessary to make high performance mirrors. Unica has the machines in which the molds are placed and produces the mirrors that make the CPV module.

Ongoing physic-based R&D, run by Centro Fermi, allowed to sensibly increase the capabilities of concentrated photovoltaics, developing a product that will perform up to twice the power and energy with respect to the current technology existing in the market.

This is thanks to the use of triple junction solar cells, having efficiency of about 40%, and the use of automotive best practices in production of the mirrors: the mirrors used as the heart of the photovoltaic module use the knowledge of the headlamps technology.

Overall, five physicists are employed in the project, representing 50% of the workforce involved in the R&D activities. Two more people are involved in management and marketing.

So far, the trial production has been developed and it needs to be tested before marketing it. The solution will be commercialized in the first half of 2014.

4.3 Enterprise

From the generation of ideas, research and commercialisation process, physics is responsible for the creation of and support of enterprises in the Italian economy.

Istat data suggests that in 2010 (2011 data in terms of business units are not yet available) there were around 262,000 organisations operating in physics-based sectors throughout Italy. This represented a slight fall from 2009, but at the peak of the recession, between 2008 and 2009, there was a net loss of over 5,600 physics-based organisations in Italy: a 2% fall.

Figure 4.3b: Business units in physics-based sectors, 2008-2010

	2008	2009	2010
# Physics-based Enterprises (000s)	268	262	262
Absolute change in # PBS Enterprises (y-o-y)	-	5,665	49
% change in # PBS Enterprise (y-o-y)	-	2	0
Analogous Direct GVA (CP, €m)	113,100	120,400	118,500
GVA per Enterprise (CP, €,000)	422	459	452
Absolute change in GVA per PBS Enterprise (y-o-y, CP, €,000)		37	7
% change in GVA per PBS Enterprise (y-o-y)		9	2

Source: Deloitte, Istat

* Only includes data for PBS where that data exists and therefore excludes some 4-digit sectors.

** Current prices due to missing data. *** Y-o-Y = year on year.

Adjusting for missing data (some 4-digit sector data is suppressed), the analogous GVA for those sectors where data is available can be used in conjunction with enterprise numbers to examine output per enterprise in physics-based sectors.

Given the extent to which the recession ended the activities of a significant proportion of organisations, GVA per enterprise jumped to €460,000 in 2009 by 9% from 2008 levels. In 2010, GVA per enterprise fell back slightly, due to lower levels of GVA, rather than any change in the number of organisations – where the change was minimal. It remains to be seen how enterprise creation/destruction has resulted in a rise/fall in the number of physics-based organisations more recently.

In keeping with previous case studies, the three following examples illustrate the way in which enterprise has flourished, and how a recent start-up company is contributing to the Italian economy.

HS Hospital Services S.p.A – 35 years of significant and continued contribution through physics

HS was founded in 1980 with the objective to promote and make available new methods and tools for minimally invasive interventional and diagnostic technologies, introducing on the Italian market a new generation of ultrasound-guided biopsy products. Over the years, HS has consolidated its leadership on the worldwide markets of interventional radiology, critical care, interstitial therapies, minimally invasive surgery and, today, also in oncologic home therapies. HS is committed to deliver top quality medical devices and systems for the benefit of patients and the comfort of physicians, striving to yield maximum efficacy, accuracy and reliability for its products, while minimizing pain and enhancing clinical outcomes. This is the key concept driving design, development and manufacturing of all HS products, such as:

- the original “TrapSystem” bone marrow biopsy needle, featuring a unique, non-deflective technique for atraumatic bone marrow samples retrieval
- the state-of-the-art dual ablation system "HS AMICA", with its patented microwave and radiofrequency applicators and generators (licensed by the Italian National Research Council - CNR) delivering incomparably safe, controlled and consistent thermocoagulative treatments of solid tumors
- the unique “CIP” drugs infusion system for in home therapies, such as chronomodulated chemotherapies: fully disposable, portable, pre-programmed, with a huge potential for substantial improvements in the oncologic patients’ quality of life and in cost reduction.

HS features three main product lines:

- Interventional (catheters; manual, semi-automatic and automatic soft tissue and bone marrow biopsy needles)
- Critical care (drugs infusion systems; ventilation devices; loco-regional anesthesia needles; lumbar puncture needles)
- Interstitial therapies (generators and applicators for microwave and radiofrequency ablation of solid tumours)

The R&D unit of HS hosts multidisciplinary competences and skills in the electronic, mechanical, clinical and biomedical fields, in order to generate top-level innovation and drive the change in minimally invasive medicine.

The HS technical staff comprises: 2 electronic engineers, 2 biomedical engineers, 1 physicist, 1 mechanical engineer and 2 senior mechatronic designers. Products development is carried out side by side with clinical key opinion leaders in the fields of surgery, anesthesiology, interventional radiology and oncology. A wide network of technical, industrial and academic consultants provides an enlarged and multidisciplinary team of experts, covering all the critical areas from the initial concept to the final manufacturing and clinical use of innovative medical devices.

Despite the international financial crisis, the company has reached and maintained a €12 million turnover over the last 3 years. HS staff is composed by 53 full-time employees and more than 20 other collaborators at the commercial, technical and scientific level, covering the whole range of business, marketing, financial, engineering and clinical skills required for a small-medium enterprise in the field of medical devices to successfully compete on the worldwide market.

Media Lario Technologies – A high-tech, high-precision component supplier

Media Lario Technologies is a leading supplier of cost effective high-precision reflective optical components and systems for a variety of advanced applications in semiconductor lithography, semiconductor processing capital equipment, space & terrestrial science, and medical & life science devices, thereby serving the desired radiation spectrum from X-ray to millimeter waves.

The Company's broad spectrum of competencies combined with its in-house facilities allows Media Lario Technologies to perform the entire process from developing and testing prototypes through to delivering customized turnkey products.

The Company was founded in 1993 in order to respond to the urgent need of a reliable high-precision technology for X-ray optics applications in space science. Media Lario Technologies was the first company to successfully implement and industrially manufacture its unique electroforming technology, offering a new cost effective way for serial production of high-precision optical components and systems. The Company's proprietary technology emerged from the Italian National Research Council (CNR) and the National Institute of Astrophysics (Istituto Nazionale di Astrofisica, INAF / Osservatorio Astronomico di Brera, OAB).

Media Lario Technologies builds on more than 10 years of experience and success in space & terrestrial precision optics due to the Company's longstanding cooperation with renowned astrophysical institutions such as the U.S., European, and Italian Space Agencies (NASA, ESA, ASI) in various notable space missions.

Media Lario Technologies was a key contributor to the success of ESA's cornerstone mission, the XMM-Newton, the most powerful X-ray telescope ever built. Launched in 1999, this telescope is still orbiting Earth. In addition, the Company manufactured X-ray mirrors for BEppo Sax and participated in NASA's SWIFT project.

Based on this invaluable experience, Media Lario Technologies continuously enhances its core technologies, namely the high-precision electroforming replication process, and the physical vapor deposition coating process, enabling the Company to additionally serve emerging markets such as the EUV lithography.

Media Lario Technologies is a privately held company owned by its management and a group of leading international venture capital organizations including Draper Fisher Jurvetson, Intel Capital, TLcom Capital Partners, Vision Capital, and PolyTechnos. The Company is represented in Bosisio Parini near Milan, Italy (headquarters), and Pleasanton, CA, USA

ThunderNIL S.r.l – A tech start up showing how physics aids enterprise creation

ThunderNIL was founded in 2009. Its business is to provide services and produce equipment to imprint macro, micro and nano structures onto surfaces of goods in a single ultrafast process step. The features are transferred with the proprietary technology pulsed-NIL (pulsed Nano Imprint Lithography) that provides imprint time of 100 microseconds. ThunderNIL outperforms the popular Nano Imprint Lithography (NIL), considered nowadays an ideal tool except for insufficient throughput for mass production.

Its enabling technology fits to a large class of applications, ranging from anti-counterfeiting features, miniaturized Quick Response (QR) codes and decorations in luxury goods, to functional structures in high tech applications such as in high brightness LEDs, photovoltaics and biosensors.

Markets of prime interests are the personalized luxury goods, with products such as glasses, watches, jewellery; plastic disposables for medical analysis, plastic cards with personalized features, plastic packages for food industry, external cases of electronic gadgets; high tech applications where stringent requirements in lithographic performances can only be met by the combination of high resolution, high accuracy high throughput of ThunderNIL technology.

The company has attracted investments from a seed investor and a private investor. The offices are located in Italy (Padova and Trieste). Currently ThunderNIL's staff consists of 6 employees and 5 external collaborators, with a turnover of 250,000 € in 2013; it invests 40% of its annual budget in R&D activities.

5 Appendix 1: Methodology

5.1 Measuring the impact of physics on the economy

The pervasiveness of physics makes it hard to reach a single conclusive definition.⁷ For the purposes of this report the following broad categories can be considered physics.

What is physics?	
Broadly speaking, physics can be split into the following broad categories:	
<ul style="list-style-type: none"> • Astronomy and astrophysics • Chemical physics • Materials physics • Nanotechnology • Optics and photonics • Superconductivity 	<ul style="list-style-type: none"> • Biophysics • Electricity and magnetism • Mechanics • Nuclear, particle and high-energy physics • Semiconductor physics • Thermodynamics

Source: UK IOP

Physics is seen as having an impact on the Italian economy through three main routes:

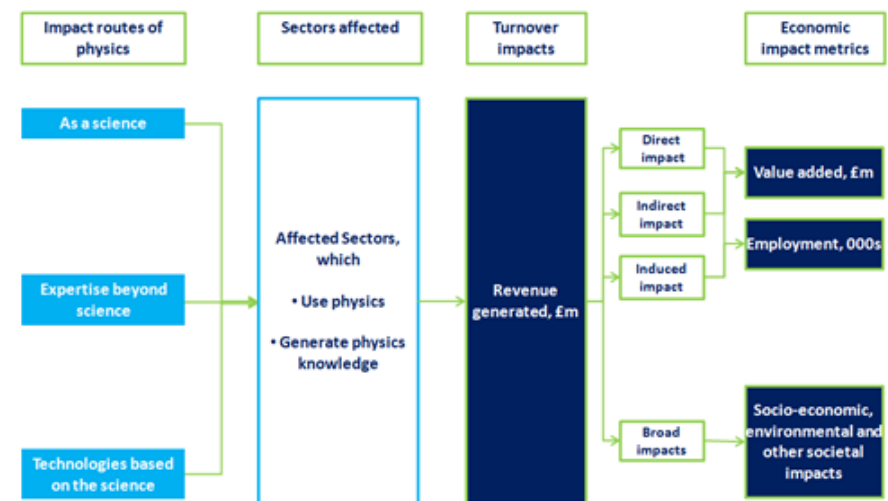
- As a science – through employees who are in occupations that are engaged in physics as a scientific discipline. This includes teachers, academics and other researchers.
- In a role that uses expertise beyond the science – through businesses that employ staff who use expertise from physics.
- Through technologies that have been developed based on the science – through employees who use technologies based on an understanding and application of physics.

⁷ Dictionary definitions are often along the lines of “the study of matter, energy, and the interaction between them”. Such definitions do not adequately capture the role of physics in asking fundamental questions and trying to answer them by observing and experimenting (source: www.physics.org).

These routes have an impact on those sectors of the economy which use and generate physics knowledge (physics-based sectors). In turn, the employees in these sectors generate turnover which have wider spillover effects that can impact across the entire economy. These spillover effects can be measured in terms of jobs and Gross Value Added⁸ (GVA), as well as the number of new businesses, export performance, R&D expenditure and Foreign Direct Investment (FDI). There may also be broader social impacts of physics – these are not considered in this report.

The impact chain of physics is summarised below.

Figure 5.1: The physics ‘logic-chain’



Source: Deloitte

The key metrics used to measure the impact of physics on the Italian economy in this Report are:

- Employment supported by physics in direct, indirect and induced terms.

⁸ This analogous to GDP, except that it only includes relevant value added at each stage of production.

- GVA due to physics in direct, indirect and induced terms.
- Turnover of physics-based sectors physics in direct, indirect and induced terms; and
- Productivity of physics-based sector workers (€ per worker).

Where appropriate, we also make comparison with other sectors and internationally.

5.2 Our approach

In order to measure the impact of physics on the Italian economy, we have carried out a three-stage approach.

- Confirm definitions and data collection – collecting data from public sources and ensuring it is consistent.
- Economic modelling and data analysis – using a bespoke input-output model of the Italian economy to quantify the economic impact of physics.
- Iterations with SIF and stakeholders.

Below we briefly set out the steps involved in each stage. Specific assumptions used to calculate individual metrics are not detailed.

Definitions

The first step in this stage is to identify which sectors of the economy can be classed as ‘physics-based’ sectors. These are those sectors of the economy where the use of physics is critical to their existence. In hypothetical terms, the counterfactual scenario of there being no physics would imply these sectors not existing as they are dependent on physics.

It is important to note that the definition of physics based sectors refers to the use of physics rather than the background of employees. For example, there may be many physics graduates in the professional services sector, but because they do not make direct use of physics this sector would not be classed as physics-based. In contrast, an employee involved in the manufacture of fibre optic cables may not have a physics qualification, but their work directly uses physics knowledge and is hence a physics-based sector.

The criteria used to identify physics-based sectors are:

- Is expertise from the field of physics required?
- Is technology that uses advanced principles of physics required?
- If the use of physics is required, how dependent is the sector on it?

In order to isolate physics-based sectors, we have used NACE in segmenting the Italian economy. NACE classifies businesses and other statistical units by the type of economic activity in which they are engaged. NACE is a hierarchical five digit system, with the latest revision being Rev 2. NACE first divides the economy into broad sections with these sections then disaggregated a further four times to reach a more detailed picture of the economy. Figure 5.2a provides an example.

Figure 5.2a: Example NACE classification

Level	Description
Section C	Manufacturing (comprising divisions 10 to 33)
Division 13	Manufacture of textiles
Group 13.9	Manufacture of other textiles
Class 13.93	Manufacture of carpets and rugs
Subclass 13.93	Manufacture of woven or tufted carpets and rugs

Source: ONS

There are 21 sections, 88 divisions, 272 groups, 615 classes and 191 subclasses. Using the aforementioned criteria, Deloitte has worked with SIF and stakeholders to identify which classes (4 digit NACE) can be identified as ‘physics critical’, i.e. as physics based. Given the fine granularity of this level of NACE for most cases it is a binary choice whether a sector is physics critical or not. However, in some larger classes (such as defence activities) an adjustment is necessary to recognise that there will be a proportion of jobs that do not involve physics, but a

proportion that do.⁹ The figure below sets out the classes chosen to be included in the definition of physics-based sectors.

⁹ In this case 30% of defence activity is assumed to be physics-based due to the reliance on defence activities on physics to collect information, deploy and operate.

Figure 5.2b: Direct physics-based employment by NACE 4-digit Industry, 2011 (% attributable refers to proportion of all sector activity counted as physics-based)

NACE Code	% Attributable	Direct Physics-based Employment	NACE Code	% Attributable	Direct Physics-based Employment
0910 : Support activities for petroleum and natural gas extraction	100%	8,100	2841 : Manufacture of metal forming machinery	100%	17,200
2011 : Manufacture of industrial gases	2%	100	2849 : Manufacture of other machine tools	100%	21,500
2013 : Manufacture of other inorganic basic chemicals	100%	6,000	2892 : Manufacture of machinery for mining, quarrying and construction	100%	21,700
2059 : Manufacture of other chemical products n.e.c.	2%	300	2899 : Manufacture of other special-purpose machinery n.e.c.	100%	21,700
2110 : Manufacture of basic pharmaceutical products	1%	100	2910 : Manufacture of motor vehicles	47%	30,000
2120 : Manufacture of pharmaceutical preparations	100%	51,000	2931 : Manufacture of electrical and electronic equipment for motor vehicles	100%	11,200
2229 : Manufacture of other plastic products	2%	1,800	3011 : Building of ships and floating structures	100%	16,200
2319 : Manufacture and processing of other glass, including technical glassware	2%	200	3020 : Manufacture of railway locomotives and rolling stock	100%	10,400
2344 : Manufacture of other technical ceramic products	100%	500	3030 : Manufacture of air and spacecraft and related machinery	100%	31,900
2452 : Casting of steel	8%	200	3040 : Manufacture of military fighting vehicles	100%	1,300
2521 : Manufacture of central heating radiators and boilers	100%	4,200	3250 : Manufacture of medical and dental instruments and supplies	100%	61,800
2530 : Manufacture of steam generators, except central heating hot water boilers	100%	2,700	3299 : Other manufacturing n.e.c.	25%	4,500
2540 : Manufacture of weapons and ammunition	100%	7,000	3320 : Installation of industrial machinery and equipment	100%	52,700
2561 : Treatment and coating of metals	2%	700	3511 : Production of electricity	100%	25,200
2593 : Manufacture of wire products, chain and springs	2%	200	3512 : Transmission of electricity	100%	3,500
2599 : Manufacture of other fabricated metal products n.e.c.	100%	79,300	3513 : Distribution of electricity	100%	23,600
2611 : Manufacture of electronic components	100%	29,200	3514 : Trade of electricity	10%	700
2612 : Manufacture of loaded electronic boards	100%	9,000	3812 : Collection of hazardous waste	100%	2,600
2620 : Manufacture of computers and peripheral equipment	100%	6,800	3822 : Treatment and disposal of hazardous waste	100%	3,000
2630 : Manufacture of communication equipment	100%	26,800	4222 : Construction of utility projects for electricity and telecommunications	1%	200
2640 : Manufacture of consumer electronics	100%	2,500	4321 : Electrical installation	23%	54,800
2651 : Manufacture of instruments and appliances for measuring, testing and navigation	100%	22,400	4322 : Plumbing, heat and air-conditioning installation	19%	37,200
2660 : Manufacture of irradiation, electromedical and electrotherapeutic equipment	100%	12,700	5221 : Service activities incidental to land transportation	11%	8,800
2670 : Manufacture of optical instruments and photographic equipment	100%	2,100	5222 : Service activities incidental to water transportation	100%	12,200
2680 : Manufacture of magnetic and optical media	100%	100	5223 : Service activities incidental to air transportation	100%	26,900
2711 : Manufacture of electric motors, generators and transformers	100%	29,700	6110 : Wired telecommunications activities	100%	60,000
2712 : Manufacture of electricity distribution and control apparatus	100%	23,900	6120 : Wireless telecommunications activities	100%	22,100
2720 : Manufacture of batteries and accumulators	100%	2,900	6130 : Satellite telecommunications activities	10%	-
2731 : Manufacture of fibre optic cables	100%	1,300	6190 : Other telecommunications activities	2%	300
2732 : Manufacture of other electronic and electric wires and cables	100%	11,000	6209 : Other information technology and computer service activities	2%	500
2733 : Manufacture of wiring devices	100%	6,600	7022 : Business and other management consultancy activities	10%	9,600
2740 : Manufacture of electric lighting equipment	100%	17,100	7111 : Architectural activities	6%	4,500
2751 : Manufacture of electric domestic appliances	100%	38,400	7112 : Engineering activities and related technical consultancy	42%	81,900
2790 : Manufacture of other electrical equipment	100%	34,600	7120 : Technical testing and analysis	32%	10,400
2811 : Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	100%	17,300	7211 : Research and experimental development on biotechnology	100%	3,100
2821 : Manufacture of ovens, furnaces and furnace burners	100%	12,000	7219 : Other research and experimental development on natural sciences and eng	100%	17,000
2823 : Manufacture of office machinery and equipment (except computers and peripheral eq.	100%	2,100	7420 : Photographic activities	10%	1,900
2825 : Manufacture of non-domestic cooling and ventilation equipment	100%	31,300	7490 : Other professional, scientific and technical activities n.e.c.	100%	112,900
2829 : Manufacture of other general-purpose machinery n.e.c.	100%	72,400	8422 : Defence activities	33%	106,400

Source: Deloitte

*Figures round to nearest 100 for disclosure purposes. May not sum to estimates presented in the remainder of the report due to rounding.

Data collection

The data used in this report to construct the impact metrics has predominately come from publicly available sources. These include:

- Istat structural business statistics
- Istat employment statistics
- Istat National Accounts
- OECD STAN – Structural Analysis Database
- UK ONS occupational data – SIC SOC Matrix 2011 – to inform thinking on relevant shares within sectors.

Where appropriate, adjustments have been made to allow for comparability between surveys and between time periods.

Economic modelling and data analysis

The bulk of the method employed in modelling ‘knock-on’ impacts of physics-based sectors, is discussed in chapter 3.

Having collected the data and identified which sectors can be categorised as physics-based, we were able to construct a number of impact metrics. In order to calculate the total number of jobs attributable to physics and GVA, we have made use of an Italian Input-Output model, devised for the study, to approximate supply chain linkages.

This Input-Output model allows us to quantify three different categories of input:

- **The direct impact of physics** – those initial and immediate economic activities (jobs and GVA) generated by physics-based sectors (often referred to as first-round impacts as they coincide with the first round of spending in the economy).
- **The indirect effect of physics** – changes in employment and income in associated industries that supply inputs to physics-based sectors.
- **The induced effect of physics** – spending by households in the overall economy as a result of direct and indirect effects from the generated economic activity of physics-based sectors and associated sectors.

The process behind constructing bespoke Input-Output models for Italy is complex¹⁰ and involves creating a ‘Leontief Inverse’ matrix to generate relevant multipliers and differentiating between financial flows and economic outcomes, such that the analysis only represents additional economic activity as compared to the counterfactual case of there being no physics. In this case, a detailed counterfactual case is not necessary given the definition of physics-based sectors implying these sectors not existing in the absence of physics.

¹⁰ Broadly speaking, the Domestic Use Matrix (differentiating between domestic purchases and imports) is used to give a matrix of coefficients, detailing the proportion of inputs sourced by an industry from all other industries and labour. The matrix of coefficients is then subtracted from the identity matrix before being inverted to give the *Leontief Inverse*. This matrix then details Type II multipliers for each country, such that a multiplier of, for example, 1.8 in a physics-based sector means that for a direct impact of €1 million in Gross Revenue terms, a further €0.8 million would be generated by business-to-business purchases in the supply chain and induced consumer spending for a total expenditure (or Gross Output) impact of €1.8 million.



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