Quantifying the economic benefit resulting from EURAMET's metrology research programmes

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Authorship and Imprint

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Further information

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List of Abbreviations

CEFTA	Central European Free Trade Agreement
DI	Designated Institute
EMRP	European Metrology Research Programme
EMPIR	European Metrology Programme for Innovation and Research
EC	European Commission
EU	European Union
EURAMET	European Association of National Metrology Institues
EFTA	European Free Trade Association
IEM	Integrated European Metrology
IOP	Intra-ocular pressure
JRP	Joint Research Project
KPI	Key Performance Indicator
LNG	Liquid Natural Gas
NMI	National Metrology Institute
NP	Nanoparticle
Metrology Partnership	European Partnership on Metrology
SME	Small and Medium sized Enterprise
TP	Targeted Programme

Executive Summary

Metrology, the science of measurement, extends far beyond precise measurements. It accelerates innovation, fosters Europe's competitiveness and underpins societal well-being. It is ubiquitous in all aspects of our daily lives - from clean water, trading energy or having an X-ray at hospital to consumer protection, security, and transport. EURAMET's European Partnership on Metrology programme (Metrology Partnership), part financed from the EU's Horizon Europe programme and part financed by EURAMET participating states, brings together experts from the metrology community and stakeholders from academia, industry and standards bodies to enhance this metrological infrastructure.

The programme is expected to provide a range of benefits from addressing societal and economic challenges through to developing new research capabilities and supporting the EU's goals for the digital and green transitions. This report is focused solely on economic benefit and quantifying the amount of European turnover that has been generated from new or significantly improved products and services that can be attributed to the research activities of the Metrology Partnership and its predecessors. At the time of writing this report, none of the Metrology Partnership projects have been completed and only data collected from completed projects of predecessor programmes, namely the European Metrology Research Programme (EMRP, Calls 2009-2013) and the European Metrology Programme for Innovation and Research (EMPIR, Calls 2014-2017) were used. EMPIR Calls 2018-2020 were still under investigation at the time of this study.

Completed projects, whose tangible results are known and whose outputs have begun to be taken up by early adopters and end users, were thoroughly investigated through interviews and case studies, and economic benefit data (5-year turnover and attribution) was collected from benefitting organisations where possible.

From the 250 projects investigated, 169 new or significantly improved products and services were identified as having resulted from those projects. The total expected economic turnover from these new or significantly improved products and services that can be attributed to the research activities of the Metrology Partnership and its predecessors at this point in the programme, is 1611 million Euro. The Metrology Partnership is targeted with attributing at least 50 million Euro of European turnover per year. The results from this study give the average attributed economic turnover per year for the predecessor programmes, as 179 million Euro. On average each Call year received 42.5 million Euro of EU funding. **Therefore, every 1 million Euro of EU funding generated more than 4 million Euro of turnover for the economy from the sale of new or improved products and services**. In the Metrology Partnership there are similar funding Calls with an even greater focus on creating impact. As a result, it is expected that the Metrology Partnership will meet this target, thereby significantly supporting the sales of new innovative products and services through the use and adoption of new metrology capabilities and furthering European competitiveness.

1 INTRODUCTION

1.1 Why metrology matters

Metrology, the science of measurement, extends far beyond precise measurements. Such measurements are needed to enable advancements in strategic technologies and accelerate innovation cycles. Innovators rely on accurate measurements to develop and validate their new products and to demonstrate quality and performance.

Accurate and reliable measurements also help to drive competitiveness and maintain economic efficiency. For example, precise measurements are essential for the manufacturing industry, ensuring the quality and efficiency of production processes and enabling organisations to increase their productivity. In addition, lower energy prices are strongly linked with the acceleration of the EU's transition to secure and clean energy sources. Metrology contributes to the optimisation of energy production processes leading to a more cost-effective and sustainable energy production. Furthermore, better measurements facilitate the introduction of renewable energy supplies to the gas and electricity grids.

Accurate measurements ensure that goods and services meet standards, which reduces trade barriers and provides a common framework that enables products to move freely across borders, meeting the same quality and safety documentary standards in all EU countries. This allows suppliers confidently to market their products internationally, while buyers can trust that they are receiving exactly what is advertised.

Beyond its industrial and economic impact, metrology plays a fundamental role in ensuring the safety, quality, and well-being of society. Consumers rely on accurate measurements for product quality, safety, and dosage accuracy in health-related goods. In the healthcare sector, precise measurements are needed to improve the diagnosis and treatment of medical conditions, as well as for monitoring and ensuring the efficacy and safety of medications. Metrology also underpins environmental monitoring and sustainability efforts. Measurement of pollution, emissions, and climate-related phenomena, are needed to enable scientists and policymakers to track environmental changes, respond accordingly, and evaluate the efficacy of the policies that are in place.

1.2 Overview of the European Partnership on Metrology and its predecessors

EURAMET's European Partnership on Metrology ('Metrology Partnership') is a 738 million Euro research and innovation funding programme, part financed from the EU's Horizon Europe programme (300 million Euro) and part financed by EURAMET member countries participating in the programme (participating states). The programme brings together experts from the metrology community and stakeholders from academia, industry and standards bodies, and it enables the provision of appropriate, integrated and fit-for-purpose metrology solutions and the creation of an integrated European Metrology Research system with critical mass and active engagement at regional, national, European and international level that would not be sufficiently achieved by the participating states alone. It aims to promote scientific excellence, generate new knowledge and technologies, tackle global challenges and strengthen European innovation and competitiveness by enhancing the metrological infrastructure that underpins daily life.

The Metrology Partnership is a successor to three previous EURAMET research programmes, all part-funded by participating states and similar EU frameworks (see Figure 1).

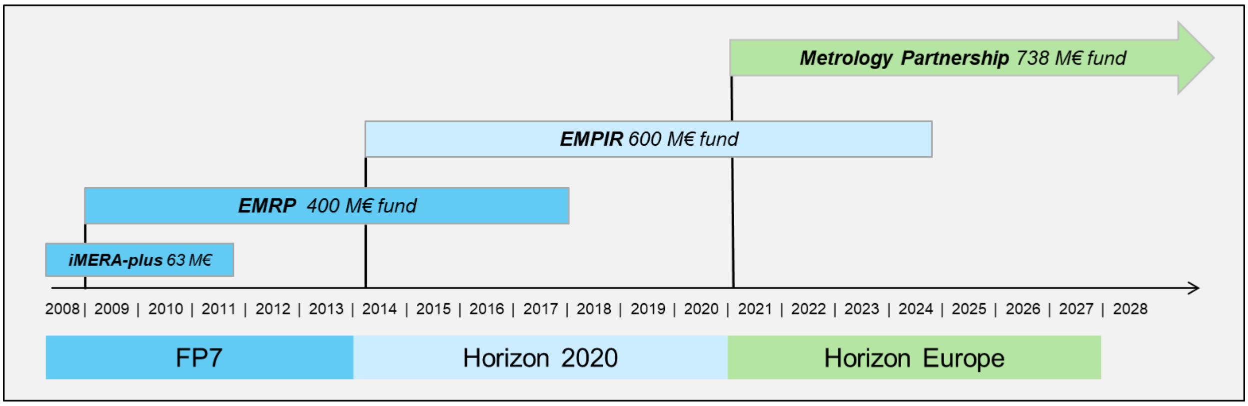

Figure 1: Timeline for EURAMET's research programmes and the EU's funding programmes

Projects within this programme fall into two main types – "Research and Innovation Actions" (also known as Joint Research Projects (JRPs)) and "Coordination and Support Actions". The first type contains research activities that aim primarily to establish new knowledge or to explore the feasibility of a new or improved technology, product, process, service or solution. This may include basic and applied research, technology development and integration, testing and validation on a small-scale prototype in a laboratory or simulated environment. The latter excludes research activities and is aimed at contributing to the objectives of Horizon Europe on a broader/wider level (e.g. promoting cooperation, capacity building). Across the seven years of calls, the Metrology Partnership will fund approximately 161 projects, organised across key themes (called TPs or Targeted Programmes) including:

- Green Deal
- Health
- Industry
- Normative
- Fundamental
- Integrated European Metrology
- Digital Transformation
- Research Potential

Similarly, the European Metrology Programme for Innovation and Research (EMPIR) and the European Metrology Research Programme (EMRP) funded a total of 241 and 119 projects respectively across a similar range of TPs. Table 1 below shows the distribution of projects across programmes and TPs. The projects from the iMERA+ programme were not included in this study.

Projects per Call																					
Project Type	**TP**	**Total**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
Research and Innovation Actions *(also known as Joint Research Projects (JRPs))*	Industry	104		17		13		14			14		9	13			14			10	
	Energy	40	9				13			9			9								
	Environment	29		9			10			10											
	Green Deal	29													10			11			8
	SI Broader Scope	44			10	14			10			10									
	IEM	15														7			8		
	Health	45			11				9			10				7			8		
	New Technologies	9			9																
	Open Excellence	4				4															
	Normative	70							4	8	5	7	7	6	6	7	5	3	4	4	4
	Research Potential	37						5	4	3	4	3	2			4	3	3	2	4	
	Fundamental	33									10			8			8			7	
	Digital Transformation	7														2		5			
	To be defined	4																			4
Coordination and Support Actions	Support for Network	12										5	4	3							
	Support for Impact	36						8	6	1	7	3	6	5							
	Coordination and Support	3															1	1			1
			EMRP					**EMPIR**							**Metrology Partnership**						
Total		459	9	26	30	31	23	27	33	31	40	38	37	35	16	27	31	23	22	25	17
			119					241							161						

Table 1: Number of projects per TP per programme. NOTE: Red numbers are estimates

2 BACKGROUND

2.1 Economic benefit

This report addresses key performance indicator (KPI)[1] 2.2 of the Metrology Partnership, and prepares for KPI 2.4, which together constitute the economic benefit metrics from the 21 KPIs and 5 underpinning objectives that were agreed between EURAMET and the European Commission when initiating the programme:

- **2.2 - Deliver a report on the trends in European turnover from new or significantly improved products and services that can be attributed to the research activities of the partnership and its predecessors by TP.**
- 2.4 - An average of at least EUR 50 million of European turnover from new or significantly improved products and services should be demonstrated to result from the research activities of the Partnership.

These KPIs are associated with Objective 2 of the Metrology Partnership's objectives, which are:

1. To develop, by 2030, new research capabilities which are built within the framework of new European Metrology Networks and which perform in terms of calibration and measurement capabilities at least equally to the leading metrology institutes outside the Participating States;
2. **To support, by 2030, sales of new innovative products and services through the use and adoption of the new metrology capabilities in key emerging and enabling technologies**.
3. To contribute to the creation and diffusion of high-quality new knowledge, competences and skills across the Union in the context of lifelong learning and with a view to achieving societal transformation, including through enhancing capability for innovation;
4. To contribute fully and effectively, by 2030, to the design and implementation of specific standards and regulations that underpin public policies addressing societal, economic and environmental challenges;
5. To unleash the potential of metrology among end-users, including SMEs and industrial stakeholders, as an instrument which contributes to the achievement of the Union goals for the digital and green transitions.

It is worth noting that for the EMPIR programme there was a similar objective of "*At least 400 M€ of European turnover from new or significantly improved products and services that can be attributed to the research activities of EMPIR and its predecessors"*.

Whilst KPI 2.2 and 2.4 focus solely on the European turnover resulting from sales of new or improved products and services, the economic benefit arising from the programme will in reality have a much broader reach. Expected economic impacts and benefits resulting from the projects include:

- Companies (or other organisations) implementing new devices, procedures, methods, protocols, data or software developed by the project in support of (or to support) the development or implementation of new and improved products, processes or services
- Companies (or other organisations) using the new measurement capabilities or infrastructure at National Metrology Institutes (NMIs) and Designated Institutes (DIs) developed by the project for test and validation
- Savings derived by efficiencies as a result of more accurate and precisely controlled processes
- Economic savings to society resulting from improved healthcare both in terms of more timely and accurate diagnosis and more precisely defined and controlled treatments

Examples of projects providing **economic benefits** include:

- Improved product: The '3DMetChemIT' project (2015-2018) characterised the *3D OrbiSIMS* instrument which incorporates dual beam technology to both analyse the composition of a

[1] Can be found in Financial Framework Partnership Agreement 2021/METROLOGY/01 Annex V

material and map its 3D surface features. This instrument is used for organic depth profiling demonstrating a significant improvement in mass resolving power and measurement accuracy compared to conventional techniques. IONTOF commercialised the instrument which is now used within the ‘high value-added manufacturing’ industry to characterise contaminants, at buried interfaces, in a wide range of products containing novel features such as 3D architecture, smart optical films or advanced coatings.

- New product: The nanoparticle concentration reference materials, developed within the ‘Innanopart’ project (2015-2018), were used to characterise a prototype particle analyser – the *Zetasizer Ultra*. As a result, Malvern Panalytical commercialised this instrument, with an improved capability for measuring particle number concentration, thereby enabling faster product development and commercialisation of nanoparticle products for the benefit of pharmaceutical and other industries.
- New service: The project ‘LNG III’ (2017-2020), developed and validated an innovative capacitive sensor array for measuring, in situ, the composition of Liquid Natural Gas (LNG) in its gas phase. TNO, an independent, not-for-profit-research organisation, offers this new service, innovative sensor along with the necessary modelling systems, to smart gas distribution networks. This enables fair billing of LNG during custody transfer and speeds up the integration of renewables such as biomethane or hydrogen into the grid.
- New reference facilities: The project ‘Ears II’ (2016-2019) developed new methodologies for measuring levels of occupational ultrasound. The consortium, along with the Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA) developed reference setups for high frequency sound measurements - at nineteen workplaces in Germany using ultrasound generating machines. The IFA can now accurately assess the levels of ultrasound in the workplace. These results will minimise the danger to health caused by occupational noise and reduce the economic burdens caused by noise-induced hearing loss.

2.2 Other types of benefit

With reference to the Metrology Partnership‘s objectives, economic benefit represents a small proportion of the overall impact intended. Even though the focus of this report is on economic impact – specifically European turnover from products and services - it is important to highlight that other types of impact are of equal importance to meet the aims of Horizon Europe, and the Metrology Partnership. Scientific and societal impacts such as improved healthcare, standardisation or a greater knowledge of fundamental physics reflects metrology’s ability to make a positive difference to long term health, energy, environment, security and other societal challenges.

Expected scientific and societal impacts and benefits include:

- Academia using new scientific breakthroughs from the project to further their knowledge
- NMIs/DIs establishing new measurement capabilities or infrastructure across Europe
- NMIs/DIs or other organisations (e.g. calibration and test labs) establishing new accredited calibration and test services (or soon to be available if the accreditation process is still in progress)
- Scientific community basing further significant collaborations and follow on initiatives on developments from the projects
- Standardisation and regulation bodies creating new or updated standards, technical specifications or regulations based on results from the projects
- Policy makers updating policies or making decisions based on developments within the projects

Examples of projects providing **non-economic benefits** include:

- Standardisation: The ‘nPSize’ project (2018-2021) developed a number of techniques for Nanoparticle (NP) identification that resulted in the publication of the first international ISO standard in this area. This is important because whilst the unique properties of NPs have led to advances in a wide range of industries, they can also confer toxicity. Size measurements are the main way NPs are identified but a lack of standardised methods for identifying ones with complex shapes has hindered evaluation of their potential harm.

- Healthcare: During the 'InTense' project (2017-2020) a new centre for intra-ocular pressure (IOP) measurements was established in Europe. Prior to this, only one European institute offered state-of-the-art measurements for IOP metrology. Improving this situation was important as an increase of pressure inside the eye is the only identifiable treatable factor for glaucoma - which causes over a third of permanent blindness worldwide. The new centre, with a concentration of instrumentation and know-how for IOP metrology that is more extensive than anywhere else in the EU, EFTA or CEFTA regions, has drawn clients not only from Europe but also countries such as Israel, Japan, and South Korea.
- Social: The 'MetroMMC' project (2018-2021) helped develop improved code that is used to simulate radioactive decay and it is now the *de-facto code* used by the European nuclear industry. Prior to its development, decay simulations were based on a code originally developed in the 1970s. The improved software not only allows an increased knowledge of the types of radiation present in waste and adherence to relevant directives, but it will also impact other areas, such as the accurate dosing of patients in medical physics and in understanding the formation of our universe.

3 METHOD

3.1 Data collection

To identify demonstrable economic impact and calculate the European turnover arising from the programme and its predecessors, investigations must necessarily focus on completed projects, whose tangible results are known and whose outputs have begun to be taken up and exploited by early adopters and end users.

At the time of writing this report, none of the Metrology Partnership projects have been completed (the first Call 2021 projects are due to finish in August 2025 and will be submitting final reports from October 2025 onwards).

This report can therefore only use economic data collected from completed projects of predecessor programmes, namely EMRP (Calls 2009-2013) and EMPIR (Calls 2014-2020).

As mentioned, EMPIR had a similar economic objective, "*At least 400 M€ of European turnover from new or significantly improved products and services that can be attributed to the research activities of EMPIR and its predecessors"*. At the start of EMPIR in 2014, a decision was made to use case studies and project investigations as the basis for economic data collection. Each project was thoroughly investigated after completion to find **real examples of uptake of project results** through a series of interviews with individual project coordinators and other beneficiaries. These interviews would be used to articulate case studies highlighting the impacts of the project. Where possible, any economic data from new or significantly improved products and services that was collected as part of this process would be used to calculate the economic benefit of the programmes.

To date, Calls 2009 to 2017 have been fully investigated in this way, and data from these projects are included in the report. Calls 2018, 2019 and 2020 of EMPIR are in the process of being investigated and do not yet have available data.

Of the 250 projects that were funded in Calls 2009-2017, coordinators of each project were contacted and the projects were investigated. During these investigations, project coordinators were asked to provide contact details of companies that have benefitted from the results of the project. Representatives of these companies were then interviewed extensively to determine the nature of the uptake of results from a technical, organisational and end-user perspective. Where a demonstrable uptake had been achieved, a full case study report was written for publication on the EURAMET website. During this interview the impact was categorised (e.g., social, economic) and, where a new or improved product or service resulting from the project was identified, the interviewees were asked to estimate the following economic data:

1. **The turnover (in Euros) that the work will generate over the next five years, also referred to as 'revenue'**
2. **The percentage of these potential sales that can be assigned to the project (e.g., 100 %, 10 %, 1 % or less than 1 %), also referred to as the 'attribution'**

If the organisation was able to provide economic data for a new or improved product or service, then the data associated with this economic impact was placed into Category A. If the company benefitted with a new or improved product or service but was unable to give any economic data, the economic impact was placed into Category B. Categories were therefore defined as:

- Category A - economic impact in the form of new/improved products and services has been verified and the benefiting organisation has provided economic benefit data
- Category B - economic impact in the form of new/improved products and services has been verified but the benefiting organisation was not able to provide economic benefit data

3.2 Data analysis and calculating economic benefit

An analysis of the reasons for economic data not being provided for Category B organisations shows a random nature which is independent of the impact (i.e., the lack of data is independent of both observed and unobserved data). Reasons include sensitivity and confidentiality issues or lack of sales knowledge by the interviewee. Therefore, statistically, Category A and Category B are assumed to be part of the same overall population. **Hence, whilst it is only category A organisations that provided turnover and attribution data to capture the economic benefit arising from their specific uptake of project results it is reasonable to assume that this data can be extrapolated out to category B cases**. It is important to note that this is still an underestimate as the case study process only represents a fraction of organisations that have benefitted.

The detailed statistical tools used to calculate the missing data from category B cases, are detailed in Annex 1. In summary,

i. The data (turnover and attribution) for Category A was segregated into organisation size (large vs SME) and analysed to check for outliers
ii. The data for Category A was analysed using the regression method to provide key numbers about the distribution of the data i.e., the coefficient of large firms, coefficient of non-large firms, and the standard deviation of residuals
iii. These key numbers were then used to simulate/assign a value for the unknown i.e., the Category B data, using the values from the known i.e., the Category A data

4 MEASUREMENT NEEDS

4.1 Number of cases

For EMRP (Calls 2009-2013) and EMPIR (Calls 2014-2017):

A total of 169 cases of new or significantly improved products and services were identified and verified as having resulted from the projects funded in the programmes. These were broken down into:

- Category A – 71 sets of economic impact data in the form of new and improved products and services that have been verified and the benefiting organisation has provided economic benefit data
  - 63 datasets were verified via the case study process
  - 8 datasets were verified via DataBuild (independent organisation contracted to evaluate early impact from EMRP)
- Category B – 98 sets of economic impact data in the form of new and improved products and services that have been verified but the benefiting organisation was not able to provide economic benefit data
  - All datasets were verified via the case study process

The breakdown of data across Category A and Category B can be shown in Table 2 and Table 3 respectively.

Number of case studies with data - CATEGORY A										
TP	**Total**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Industry	20				11		6			3
Energy	13	4				4			5	
Environment	11		6			4			1	
SI Broader Scope	11				7			4		
Health	7			6				1		
New Technologies	4			4						
Normative	3							1	2	
Research Potential	2							1	1	
Fundamental	0									
Total	71	4	6	10	18	8	6	7	9	3

Table 2: Breakdown of data in Category A across TP and year

Number of case studies with no data - CATEGORY B										
TP	**Total**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Industry	48		23		9		9			7
Environment	12		3			7			2	
SI Broader Scope	9			2	6			1		
Energy	8	3				3			2	
Research Potential	6						3	2	1	
Health	6			3				3		
New Technologies	4			4						
Normative	4							3	1	
Fundamental	1									1
Total	98	3	26	9	15	10	12	9	6	8

Table 3: Breakdown of data in Category B across TP and year

4.2 Economic benefit

Category A cases

The actual European turnover from new or improved products and services that can be attributed to results of the programmes, for the 71 cases in Category A was reported as 517 million Euro.

Category A + Category B cases

Figure 3 shows the results of the analysis used to calculate the results for Category B cases, as described in the previous section. It shows the calculated (lower bound, median and upper bound) total economic turnover from new or significantly improved products and services that can be attributed to the research activities of the Metrology Partnership and its predecessors, up to Call 2017. It also shows the total for Category A and B.

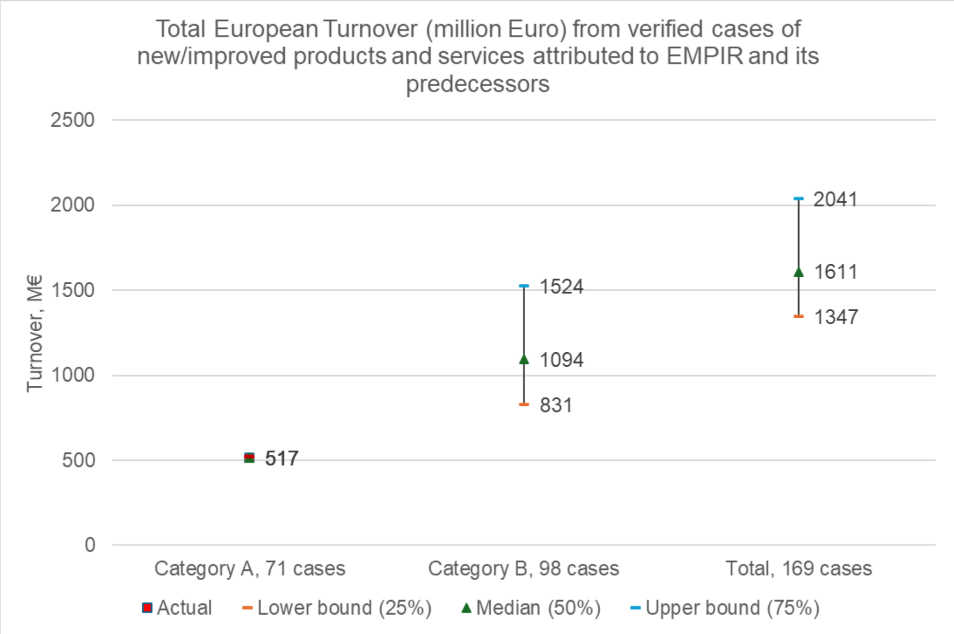

Figure 2: Total European Turnover (M€) from verified cases of new/improved products and services attributed to EMPIR and its predecessors

The median calculated economic turnover value for Category B case studies is 1094 million Euro, with a lower bound (25th percentile) value of 831 million Euro and higher bound (75th percentile) value of 1524 million Euro.

It was not possible to do the full statistical analysis described above according to TP. This is due to the limited number of datasets and hence an inability to model the distribution of data per TP in a robust manner.

Summary - KPI 2.2

Therefore, taking the results from all 169 identified examples of new products and services resulting from the projects, and using the median value for Category B cases, **the total economic turnover from new or significantly improved products and services that can be attributed to the research activities of the Metrology Partnership and its predecessors at this point in the programme, is 1611 million Euro, with a lower bound of 1347 million Euro and an upper bound of 2041 million Euro.**

4.3 Organisations

To understand the types of organisations who developed new products and services as a result of the research programme, a breakdown is shown in Figure 4. The following definitions[2] were used:

- micro enterprises: fewer than 10 persons employed
- small enterprises: 10 to 49 persons employed
- medium-sized enterprises: 50 to 249 persons employed

[2] Taken from EC website - Glossary:Enterprise size - Statistics Explained

- large enterprises: 250 or more persons employed

Figure 4 shows that most organisations which have developed new or significantly improved products as a result of the programme, are medium to large organisations.

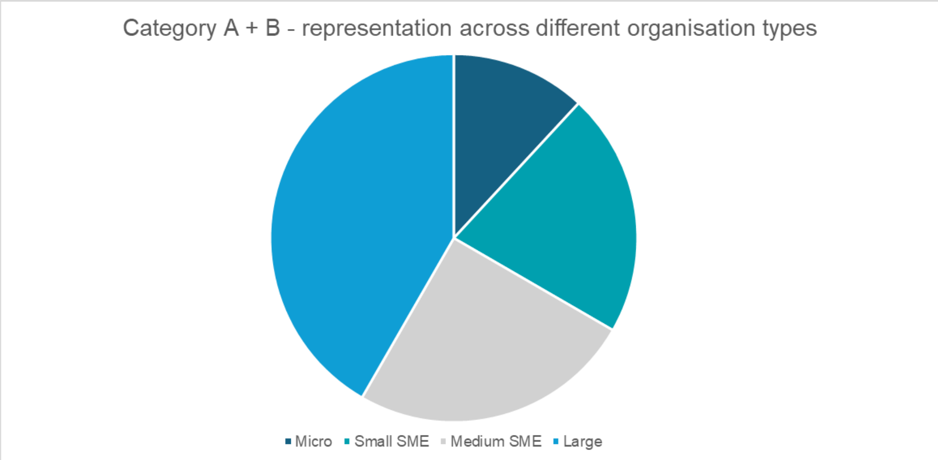

Figure 3: Data distribution across different organisation types based on the number of cases

In addition to the case study investigation process, as part of EMPIR final reporting, consortia that contained SMEs were asked for the following information:

- Turnover of the company at the beginning of the project/most recent accountability period from the beginning of the project
- Turnover of the company at the end of the project / most recent accountability period

- Number of employees at the beginning of the project/most recent accountability period from the beginning of the project
- Number of employees at the end of the project / most recent accountability period

In total there were 74 usable sets of data across the whole of the EMPIR programme – collected between 2018 and 2024. This data showed that 68 % of SMEs saw an increase in the number of employees and 76 % of SMEs saw an increase in their turnover across the duration of the project. The change in employment was an average of +30 % and the change in turnover was an average of +1.45 million Euro across the course of the project for each SME. Whilst the attribution of these increases has not been directly related to participation in the project, the latest Annual Report on European SMEs 2023/2024[3] published by the EC states that '*SME employment increased by 1.8 % in 2023, following its already significant growth in 2022, when the increase of persons employed reached 2.9 %*'. Even though these referenced percentages are for annual growth and the studies are not directly comparable, the figures collected for EMPIR do suggest a higher change in employment and hence an additional benefit from participating in the metrology research programmes. It was not possible to reference figures for turnover for comparison.

[3] JRC Publications Repository - Annual Report on European SMEs 2023/2024, SME performance review

5 ANALYSIS AND DISCUSSION

As shown in Figure 1 there has been more than 1000 million Euro of funding provided to the EMRP and EMPIR research funding programmes (part financed by the European Commission and part financed by EURAMET participating member states). For the Calls analysed in this study this represented 382.5 million Euro of EU funding.The results in this report show that so far (with around half of the data available for EMPIR) this has resulted in 1611 million Euro of demonstrated turnover from new or significantly improved products, attributable to the programmes. This also equates to approximately 179 million Euro per Call year. Therefore, for every 1 million Euro of EU funding, more than 4 million Euro of turnover has been generated for the economy.

These results far exceed the objective of EMPIR which was to achieve at least 400 million Euro of turnover across the programme and its predecessors.

In terms of distribution of turnover across the different TPs, the TPs health, industry, and energy & environment have the largest economic turnover. This is expected as results from these types of projects are more likely to be immediately taken up by industry soon after the end of the project, and they are more likely to result in new or improved products or services. The other TPs (SI broader scope, normative, research potential and new technologies) have a lower economic turnover. These TPs are more likely to be addressing social or normative needs that either do not directly relate to new or improved products or services, or will provide benefit in a much longer-term such as upgrades to the energy grid (e.g. > 5 years).

There is a substantial breadth of impact over the variety of Calls and TPs, due to the large range of projects within the research programmes. Metrology research is fundamental to all scientific fields including biological science, chemistry, engineering, and medicine. Within these fields there are also many different types of metrology, such as scientific metrology (e.g., establishing the unit system), industrial metrology (e.g., applying measurement for industrial use), and legal metrology (e.g., for uptake into laws and regulations). In addition, the scope of projects within each TP is wide – for example the health TP may cover topics as varied as magnetic resonance imaging (MRI) and antimicrobial resistance to hearing loss.

It is worth noting that the case studies, used as the basis for this report, only represent a small fraction of the true economic benefit from new or improved products and services resulting from the programme. For example, in some projects known to have 10 - 20 organisations that may have taken up results, the coordinator may not respond or only provide contacts at 2 - 4 companies. Of the contacts provided, only half may reply to requests for interview or result in a published case study. Reasons for this include companies unwilling to share their contact details or commercially sensitive results, not all beneficaries being known to coordinators in the case of very large consortia and out of date company contact details.

For the Metrology Partnership, the Partnership Committee have agreed that there will be a mandatory questionnaire for consortia to complete, relating to projected economic benefit as part of each project's final reporting. Each participating organisation will be required to report their own, and collaborators', new or improved products or services developed as a result of the project and this should therefore significantly increase the sample size and lead to a more robust calculation of attributed economic benefit overall.

6 CONCLUSIONS

The Metrology Partnership is targeted with attributing at least 50 million Euro of European turnover per year, from new or significantly improved products and services as a result of research within the programme. For its predecessors EMPIR (including only Calls 2014 – 2017) and EMRP, the average attributed economic turnover per year is shown in this report as 179 million Euro. On average each Call year received 42.5 million Euro of EU funding, therefore, every 1 million Euro of EU funding generated more than 4 million Euro of turnover for the economy. In the Metrology Partnership there are similar TPs with an even greater focus on creating impact. As a result, it is expected that the Metrology Partnership will meet this target.

7 ANNEX 1

Methodology for calculating Category B data

The detailed statistical tools and methodology for the calculation of total attributed economic benefit presented below was performed by Dharani Reddy Katanguru, Magda Sulek, Roshni Bhambra and Mike King from the National Physical Laboratory (NPL, United Kingdom) analysis and evaluation team. This team supports NPL by providing data and analysis to assess and improve performance. Example of their *latest published* work:

Assumptions

1. Larger firms to have a sizeable impact but the non-large firms (micro, small, medium firms) are grouped together presuming they all will have the same impact.
2. Hurdle models assume that the process generating zero values is distinct from the process generating positive values i.e., these two processes are independent.
3. The missingness is independent of both observed and unobserved data. The missing values are essentially a random sample from all possible values.
4. The distribution is fitted based on the known values. However, the sample of known observations is small and assumes that the model will appropriately extrapolate it to gain values for the unknown.

Category A data: Variable for analysis

Attribution that has been either self-identified by subjects themselves, or assigned by interviewers based on qualitative discussions, have been taken into consideration for the analysis. Cases where no clear attribution could be assigned will be considered as Category B, even if turnover data was supplied. For further analysis, a binary for large firms has been created, using 1 to represent a large firm, and 0 to represent a non-large firm i.e. micro, small, or medium firms.

Category A data: Economic benefit

Step 1:

Taking the total economic benefit in millions of euros, Y, rank this column in ascending order (the lowest value at the top and the greatest value at the bottom).

Step 2:

Take the natural logarithm, $\ln()$, of each benefit Y to give $y = \ln(Y)$. The purpose of this is to normalise our data and stabilise any variances.

Step 3:

Calculate the mean of the logged values y, using the formula below:

$$\mu = \frac{\sum y}{n}$$

Where:

- μ represents the mean
- $\sum y$ represents the sum of all the logged benefits
- n represents the number of benefits in our sample (sample size)

The mean tells us the average of the dataset and acts as a measure of central tendency.

Step 4:

Calculate the standard deviation of y, using the formula below:

$$\sigma = \sqrt{\frac{\sum(y_i - \mu)^2}{n}}$$

Where:

- σ represents the standard deviation
- y_i represents the i-th logged benefit y
- μ represents the mean
- n represents the sample size

The standard deviation tells us how much each data point differs from the mean.

Step 5:

Calculate the Z-scores using the formula below:

$$z = \frac{y - \mu}{\sigma}$$

Where:

- z represents the z-score
- y represents the logged benefit
- μ represents the mean
- σ represents the standard deviation

The z-score tells us how many standard deviations a data point is from the mean and standardises the data, allowing for easy comparison across dataset and calculation of probabilities.

Step 6:

Calculate the Cumulative Distribution Function (CDF) of the ranked values as a percentage, using the formula below.

$$CFD(y) = \frac{rank\ of\ y_i}{n}$$

Where:

- $CFD(y)$ represents the cumulative probability of y
- $rank\ of\ y_i$ represents which place the logged benefit y_i is in the sample
- n represents the sample size

This will provide the probability that the ranked values will take a value less than or equal to a particular number.

Step 7:

Calculate the Cumulative Distribution Function of the Z-score values as a percentage.

Step 8:

Typically, the distribution would follow a bell-shaped curve but as the values are logged, we would expect the distribution to become an S-shaped curve (sigmoid shape). Plotting the CDF(y) and CDF(z) curves against one another will allow us to check this.

Plot the following graph:

- $CFD(y)$ and $CFD(z)$ on y-axis with z-scores on x-axis

Note that Y was skewed i.e., has a long tail and does not follow the normal distribution. However, when natural log was applied, it transformed into a normal distribution, the CDF of which produces an S-shaped curve.

Step 9:

Plot the following graph:

- Box plot of the logged benefits, $\ln(y)$

Observe that there is an outlier in the box plot.

Step 10:

Plot the following graph:

- Box plot of the z-scores

Observe there is no longer an outlier. This is because the z-scores normalise the data.

Step 11:

In Excel, conduct a regression on the variables y (dependant variable) and Large (independent variable). This is to check if there is a "size effect" i.e., if large firms have more impact than the small or medium firms.

Step 12:

If we look at the 'Residuals Output' table, for each logged benefit y, the residuals, e, are calculated by subtracting predicted logged benefits $\hat{y}$ from actual logged benefits y.

$$e = y - \hat{y}$$

Step 13:

A standardised residual is calculated by dividing a raw residual (the difference between an observed value and a predicted value) by an estimate of the standard deviation of the residuals. This process transforms the raw residual into a z-score.

The standard residuals are calculated using the formula:

$$Standard\ Residual = \frac{e}{\sigma_e}$$

Where:

- e is the residual
- σ_e is the standard deviation of the residuals

A standard residual is used to identify outliers in the regression model.

Step 14:

Rank the standard residuals column observations in ascending order (the lowest standard residual at the top and the greatest standard residual at the bottom).

Step 15:

Calculate the Cumulative Distribution Functions (CDFs) and plot the following graph:

- A scatter plot of the CDFs on the y-axis with standard residuals on the x-axis.

This graph would also follow a sigmoid curve.

Step 16:

Plot the following graph:

- A box plot of the standard residuals

Observe that there is no outlier in this box plot because the size effect is corrected for, while retaining all the data points.

Category A data: Attribution

Step 1:

Create a table for the % attribution, ranking them in an ascending order, along with the values of their respective economic benefit.

Step 2:

Calculate the logit(p) of the attributions using the formula:

$$logit(p) = \ln\left(\frac{p}{1-p}\right)$$

The logit function is defined to be the logarithm of the odds of the probability p of a certain event occurring, where p is the probability of the event, which will be the attribution.

Note that the logit transformation does not work with 100% attribution, therefore can't be used in the distribution.

Step 3:

Calculate the mean and standard deviation of $logit(p)$.

Step 4:

Calculate the z-scores of $logit(p)$ and the CDFs to plot the following graphs:

- A scatter plot of the CDFs, with $logit(p)$ z-scores on the x-axis and CDFs on the y-axis
- Box plot of $logit(p)$
- Box plot of the z-scores of $logit(p)$

Hurdle Model

The calculations are based upon the Hurdle Model (John G. Cragg, 1971). The hurdle model is a two-part statistical model used for count data (the number of occurrences, i.e. the number of firms) with a lot of zeros. It allows us to model our data effectively, as its use is often motivated by an excess of zeroes in the data that is not sufficiently accounted for in more standard statistical models. The first part models the probability of attaining the value 0, and the second part models the probability of the non-zero values.

Of the 71 observations with known attribution values (which are the attribution types ‘Self’ and ‘Assumption’), 12.7% were at 100% attribution, meaning that EMRP/EMPIR support was essential to the benefits created by the project. For the remaining 87.3%, EMRP/EMPIR support was helpful, but not essential.

Category B: Calculated data

In the simulation, we are essentially trying to assign a value for the unknown i.e., the Category B data, using the values from the known i.e., the Category A data. We are essentially trying to “impute” or fill in the missing values of the economic benefits.

The calculated data consists of 94 firms from the Category B data, and an additional 4 firms that are marked as ‘default’ within the attribution type from the Category A data.

Step 1:

Calculate $\ln(Y)$ using the formula:

$$y = \beta_0 + \beta_1 x + \varepsilon$$

$$\ln(Y) = Coefficient\ of\ non - large\ firms + Coefficient\ of\ large\ firms$$
$$+(Random\ term * SD\ of\ residuals)$$

The random term gives us the expected value of logged benefit. We then use the inverse standard normal distribution so we can convert probabilities into z scores. As random variables can have varying SDs, we use the SD of the residuals to scale the normal values to match the variability of our data.

Step 2:

As the values are logged, take the exponent of these values to normalise them, producing Benefit (Y).

$$Benefit(Y) = Exp(ln(Y))$$

Step 3:

Now, let's recollect that, within category A data, 12.7% were at 100% attribution, meaning that EMRP/EMPIR support was essential to the benefits created by the project. For the remaining 87.3%, EMRP/EMPIR support was helpful, but not essential.

Based on this, we randomise this level support for category B data.

Step 4:

Compute the $logit(p)$ for 'helpful' by using the formula:

$$logit(p)\ if\ 'helpful' = Mean\ of\ logit(p) + Random\ term * SD\ of\ logit(p)$$

Now, to back-transform the logit, you apply the exponential to the logit value. The formula for back-transformation is:

$$Attribution(p) = \frac{Exp(logit)}{1 + Exp(logit)}$$

Note that the attribution for 'helpful' is calculated using the logit transformation, and the attribution for 'essential' is given as 100%.

Step 5:

The attributed benefit is then calculated using the formula:

$$Attribution\ benefit = Benefit\ (Y) * Attribution\ (p)$$

Step 6:

As a random variable is used in calculating the attribution benefit, hardcode the values of the attributed benefit for 100 times. Vertically sum the attributed benefits, column by column, producing one total for each of the hundred values.

After ranking the totals in an ascending order, take the 50th percentile i.e., median as the average value, the 25th percentile as the lower bound, and the 75th percentile as the upper bound.

Results

As we have now calculated a value for the 'unknown' i.e., the attributed benefit for category B data, we now add on the 'known' i.e., the attributed benefit of the category A data to get the total attributed benefit to EMPIR/EMRP programmes. The average i.e., the median can be reported along with the upper and lower bounds.

References

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