Adding Value to Manufacturing: Thirty Years of European Framework Program Activity

Erastos Filos

European Commission, DG Research and Innovation, 1049 Brussels, Belgium
erastos.filos@ec.europa.eu

Abstract. In the last thirty years, Europe's research community has grown to be more networked and collaboration-minded. Businesses have started to see European supported research as an opportunity to engage in open innovation. Research, development and innovation in manufacturing have been a key activity area throughout this entire period. Dedicated collaborative research and innovation partnerships emerged as new paradigms to leverage business investment and increase researchers' orientation towards entrepreneurship and new collaborative business ventures. The paper provides a brief overview of European funded research in manufacturing in the past thirty years and highlights key developments and successes.

Keywords: Manufacturing, R&D, innovation, public-private partnerships, EU framework program, European projects, public funding, collaborative research.

1 Introduction

Manufacturing is key to Europe's welfare, its social and cultural development [1]. With its approximately 20 industrial sectors it is the backbone of the economy. More than 30 million people work in it and an additional 70 million are engaged in peripheral related sectors. Manufacturing, the activity to make goods on a large scale through processes involving raw materials, components, assembly and operations involving different workers and extensive engineering activity, is increasingly seen as a priority area in economies hit by the recent financial and economic crisis.

Manufacturing has a huge potential to generate wealth and high-quality, value-adding jobs. In 2006, the total number of manufacturing enterprises in the non-financial business economy was estimated to be 2.3 million, representing a little over one in every ten (11.5%) enterprises in the then 27 EU Member States (EU-27). Manufacturing enterprises provided employment to 34.4 million persons. This was equivalent to 27 per cent of all EU-27 employment. In 2006, the sector generated EUR 6,816 billion in turnover of which EUR 1,712 billion was value added. This was equivalent to 30 per cent of the value added in the EU-27 non-financial business economy. Each employed person in manufacturing generated on average EUR 49,700 of value added. Total investment by the EU-27 manufacturing sector was valued at EUR 238 billion in 2006, equivalent to almost 14 per cent of the manufacturing sector's value added [2].

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In the last 20 years, Europe's economy has lost approximately one third of its value adding capacity. If this de-industrialization trend continues, Europe might lose half of its employment in manufacturing in the next 30 years. Europe therefore needs to develop new ways in re-industrializing and reactivating its capabilities to add value.

2 The Network Effect of Collaborative R&D

The Framework Program has played a catalytic role in strengthening and integrating the European research infrastructure, impacting industry and the research community. Structural effects promoted by the Framework Program include the creation or the strengthening of knowledge networks often evolving into long-term strategic alliances; the integration of research and industry communities – cross-sectorial, interdisciplinary or transnational - and collaboration networks between and among European and national R&D policy makers, in a growing number of cases resulting in a joint-programming of research.

At the base of the knowledge networking impact is the collaborative R&D model [3] that was adopted by the Framework Programs since their very outset. Throughout the history of the Framework Programs, the collaborative research model evolved into a veritable European open research and innovation model and many consider this to be its major long-term effect.

2.1 Adding Value through Research Collaboration

In many cases it may be advantageous to collaborate than to "go it alone". Some research activities are of such a scale that no single country can provide the necessary resources and expertise. European projects are set-up to typically pool resources and expertise from actors across many countries. Thus, collaborative R&D under European framework programs allows research efforts to obtain the required “critical mass” and produce a leverage effect on private investment whilst lowering the risk for participants. European-scale actions play an important role in the transfer of skills and knowledge across the EU as well as in expanding existing networks of knowledge by enabling participants to be exposed to diverse research methodologies and new or improved research tools. Being part of a European consortium of highly qualified researchers provides "spill-over" effects that may be more important than the monetary investment involved. The experience of European framework programs shows that while all participating countries enjoy knowledge multiplier effects, their size is roughly inversely related to each country’s total number of participations.

Another feature of this type of research is that public R&D funding carried out by enterprises leads to what is called a "crowding-in" effect on investment. In other words, it stimulates firms to invest more of their own money in R&D than they would otherwise have done. A study [4] has estimated that an increase of EUR 1 in public R&D investment induces EUR 0.93 of additional private sector investment. In the case of the framework programs, there is even evidence that many projects would not have been carried out at all without EU funding. Large-scale European projects enable participants to access a much wider pool of firms in a certain industry domain than would be possible at purely national level. This offers internationalization advantages to enterprises, in particular to SMEs, and broadens the scope of research by allowing a division of work according to participants' fields of specialization.

In many projects work ultimately leads to patents. This can be seen as indicator for partners' intentions to exploit research results commercially. Framework program participants are more likely to apply for patents than non-participants and tend to be more innovative, irrespective of size. In Germany, for example, firms funded under the framework program make three times as many patent applications as non-participating firms [5]. Participating enterprises are also more likely to engage in cooperation with other partners of the innovation system, as well as universities. Although no causal links can be proven by such findings, they provide a strong indication that public funding for research strengthens innovation performance [6]. A wide range of ex-post evaluation studies [7] show that as a result of framework program participation firms are able to realize increased turnover and profitability, enhanced productivity, improved market shares, access to new markets, reorientation of companies' commercial strategies, enhanced competitiveness, enhanced reputation and image, and reduced commercial risks. Results of econometric modelling indicate that the framework program generates strong benefits for private industry in the EU. A 2004 study [8], commissioned by the UK Office for Science and Technology, used an econometric model developed by the OECD to predict framework program effects on total factor productivity. It was found that the framework program "generates an estimated annual contribution to UK industrial output of over GBP 3 billion, a manifold return on UK framework (program) activity in economic terms".

2.2 Thirty Years of Support to Manufacturing R&D

The European Commission has been supporting manufacturing since the first framework program. Table 1 shows the key programs involved. Research was first placed on a broader footing in the mid-1980s, when the then European Community launched its first framework program for research and technological development. The programs subsequently became a central part of the European Project, a key approach to addressing Europe's economic and societal challenges through pan-European, multidisciplinary, multi-sectorial projects that engaged the entire technology supply chain - universities, research institutes, test labs, large and small companies, user groups, and society at large.

Asked about the impact of the first research programs, Esprit and BRITE, the Vice-President of the European Commission from 1977 to 1985, Etienne Davignon [9] commented as follows: "There is no doubt that these programs had a positive impact. However, there is no point in trying to quantify this in a measurable way. Attempts to compare what would have happened had they not existed with what actually happened because of their existence are somewhat artificial. … European research policy has helped to create a genuinely transnational relationship between companies, universities and government bodies, which was never the case before. If

Table 1. EU R&D programs supporting manufacturing related topics

Period	Framework Program	Programs relevant to Manufacturing
1984-1988	FP 1	Esprit I (CIM), BRITE
1988-1991	FP 2	BRITE-EURAM I, Esprit II (CIME)
1991-1994	FP 3	BRITE-EURAM II, Esprit III (IiM)
1995-1998	FP 4	BRITE-EURAM III, Esprit IV (IiM)
1999-2002	FP 5	GROWTH, IST
2003-2006	FP 6	NMP, IST
2007-2013	FP 7	NMP (FoF), ICT (FoF)
2014-2020	Horizon 2020	NMP-B (FoF, SPIRE), ICT (FoF)

we wish to learn from the first 15 years of European research policy, basically we must admit that it needs to be adapted. … In other words, if we wish European research policy to meet vital strategic objectives and if we wish to prevent its added value from becoming bogged down in bureaucracy, technocracy or disputes over sharing out the benefits, it must have built-in flexibility. ..."

The European Strategic Program on Research in Information Technology (Esprit) was a series of integrated programs of information technology research and development projects and industrial technology transfer measures. Already the first Esprit program, part of Framework Program I, focused on R&D relevant to manufacturing [10]. Under "Computer integrated manufacture (CIM)" the program aimed to "establish the technology base for progressive introduction of IT to all phases of the manufacturing cycle leading ultimately to fully integrated production systems. The main emphasis is placed on manufacturing elements as they are needed for discrete batch manufacturing". In the next programming phase the area was widened to encompass the whole range of computer-integrated manufacturing activities including architectures and communications, management and design of enterprises, and mechatronics, robotics and sensing technologies. The main objective of the CIME sub-program of Esprit was to expand the Community's share of the market for CIM to a dominant level in the European market and to achieve a significant penetration of non-EC markets. In addition, it was expected that it would help accelerate the modernisation process in a wide range of industries, ranging from discrete parts production to continuous processes, and so to improve the competitiveness of European manufacturing industry as a whole. 40 per cent of organizations participating in Esprit projects were user industry enterprises. In total 65 per cent of participants were industrial companies. User-supplier collaborations, often with large companies as users and SMEs as suppliers, were growing.

The CIME strategy was based on four concurrent and interrelated lines: (a) To promote the use of open systems and develop the associated methods and tools, including those needed for migration from existing proprietary systems, (b) to develop modular and compatible system components capable of exploitation within this framework and which SMEs can afford, (c) to develop new generations of handling systems and (d) to demonstrate the success of this approach and its benefits by early implementation in a wide range of production environments. The joint involvement of vendors and leading-edge users was fundamental to the success of this approach.

BRITE-EURAM was the other important channel for much of the Commission's support for R&D and innovation in manufacturing. The main aims of this program were to stimulate technological innovation, encourage traditional industry sectors to use new technologies and processes and to promote a multi-sectorial approach and multidisciplinary scientific and technological collaboration. The program covered two totally different worlds: the internal world of the laboratory involving R&D staff, scientists and academics and the external world of the market place. What was created in the laboratory had to be produced on an industrial scale in a fast-changing technological and economic environment. And this means over-optimistic expectations were confronted with a reality that was beyond the control of those running the project. A set of studies therefore aimed to evaluate its impact [11] and led to interesting conclusions showing the value of Commission-funded research and development as a catalyst for innovation and growth:

Firstly, potential economic gain (from benefits such as improved productivity or quality) for the companies involved amounted on average to 6.5 euros for each euro invested by the European Commission and the industrial project partners. Secondly, the number of jobs created or maintained in the five years following the end of the 291 projects assessed, amounted to 1600 jobs created and 1000 jobs safeguarded. This translates into one job created or safeguarded by EUR 80,000 invested in R&D. Thirdly, about thirty per cent of the companies involved in the study flagged an increase in skills levels and qualifications of employees as a result of the introduction of new technologies and methodologies. Ten per cent also reported workplace health and safety improvements. Fourthly, more than a third of the industrial participants reported at least one environmental impact within their organisation, the vast majority of which (97%) were positive: 39 per cent cited savings in materials, 32 per cent energy savings and 32 per cent cuts in the release of dangerous materials.

Furthermore, some 50 per cent of the large companies and nearly 60 per cent of the SMEs participating in the program fully achieved their science and technology objectives. Even more important is that the majority of large companies and SMEs were still making industrial use of the project results three years later. In the projects of the study SMEs registered 27 new patents, against 12 by large companies and 30 by industrial and commercial research organisations partnerships. 90 per cent of the universities and research institutions reported a rise in publications, with the sample of projects generating 426 publications, and 109 new PhDs across 75 per cent of these types of participants. 71 per cent of the universities and research institutes reported that, as a result of their project, they had won other contracts leading to more funding.

2.3 Structuring the Manufacturing Landscape in Europe

A first attempt to structure the manufacturing/engineering landscape was through the Advanced Information Technology (AIT) initiative [12], launched in 1993 by the major European effort shared by both programs, BRITE-EURAM and Esprit. The initiative was run in two phases. The 24 month pilot phase consisted of identification of end user needs, consensus building and requirements specification. The main phase focused on performing the necessary R&D work intended to provide enabling IT tools and engineering techniques for the requirements of Europe's automotive and aerospace industries, as specified in the pilot phase. Almost 100 organizations participated in the initiative with a total budget in the range of EUR 130 million. The main objectives of AIT were (a) to provide industrial leadership and facilitate a co-operation between IT users, IT vendors, research organizations, academia and standardization bodies, (b) to identify and define technical domains and user requirements for innovative products, (c) to propose appropriate R&D projects relevant to the needs of the industries involved, (d) to promote international standards and contribute to their development and (e) to jointly develop and utilize effective organizational, technical and operational guidelines for co-operation.

The Manufuture Technology Platform, ten years later, is a further example of incremental structuring [13] of the research and industry community: the platform itself as well as its strategic input in the form of a strategic research agenda are deeply rooted in activities promoted by the European Commission. It responded to the need for a horizontal technology platform related to the manufacturing industry, with particularly high expectations related to future economic impacts.

Manufuture was launched in 2004 as the result of a set of activities aiming at creating a platform for a more coherent definition of a European manufacturing strategy. At the beginning of the 2000s, the European Commission had started its activities to develop a Manufacturing Technology Action Plan. Among them was a range of foresight and road mapping exercises [14], such as FUTMAN and MANVIS. In the summer of 2003, DG Research established an Expert Group to discuss the future of manufacturing in Europe in a series of workshops. Its recommendations constituted a working document for the conference "European Manufacturing of the Future: role of Research and Education for European World Leadership" (Manufuture), held in Milan in December 2003. The conference led to the establishment of a High-Level Group with a balanced representation covering industry, research and education, trade associations and other stakeholders. Workshops were held around Europe culminating in "Manufuture, A vision for 2020 – Assuring the Future of Manufacturing in Europe", in December 2004. At the end of this exercise, representatives of four major stakeholders confirmed their support for a European Technology Platform on manufacturing and in 2005 work began on a Strategic Research Agenda [15]. In this agenda the priorities for maximizing added value were distilled into a strategic perspective linking the principal drivers of change with a series of activity pillars. The drivers identified were: (a) competition, especially from emerging economies, (b) the shortening life cycle of enabling technologies, (c) environmental and sustainability issues, (d) the socio-economic environment, (e) regulations and (f) societal values and public acceptance. To address these challenges of competitiveness and sustainability, five pillars of activity were considered necessary: new, added-value products and services; new business models; new advanced industrial engineering; new emerging manufacturing science and technology and the transformation of existing R&D and education infrastructures to support world-class manufacturing.

In November 2008 and as part of the European Economic Recovery Plan, the European Commission proposed the Factories of the Future (FoF) initiative with an estimated envelope of EUR 1.2 billion up to 2013. It was set up as a public private partnership (PPP) under the 7th Framework Program (FP7), shared between two R&D programs, NMP and ICT. Its aim was to improve manufacturing enterprises' technological capability of adapting to environmental pressures and of adequately responding to increasing global consumer demand for greener, more customized and higher quality products. It was expected that accelerated research and innovation efforts would lead to a paradigm shift towards a demand-driven industry with lower waste generation and less energy consumption. Four annual calls for proposals resulted in the launching of 151 projects, most of them running. At the end of FP7 participation of industry had increased to an unprecedented level of more than 50 per cent (30 per cent SMEs).

The Recovery Plan PPPs have significantly contributed to structuring the academic and industrial research communities Europe-wide by encouraging strategic thinking (in terms of road mapping, investment, generation of impact). Also the formation of industrial research associations, such as EFFRA [16], alongside the four calls in the PPP areas, in synergy with contributions of the European Technology Platforms - which in the case of Manufuture have also led to the creation of national technology platforms in almost every EU Member State and beyond.

2.4 Factories of the Future Project Examples

The Factory-in-a-Day [17] develops a robotic system which is inexpensive, leasable, and can be set up within 24 hours. The goal is to make advanced robotic systems, which currently take weeks or months to deploy, more attainable for small and medium sized enterprises. SMEs have not tended to invest much in robotics technology because human workers are more efficient at adapting to the small production batches typical of most SMEs, and state-of-the-art systems are not flexible enough to adapt to changing processes, making large financial investments in these systems infeasible even when the processes are easily automated. Factory-in-a-Day is such a system that can be easily re-purposed for new product lines. By reducing the system integration time to a single day, the project hopes to minimize investment risk for SMEs.

PlantCockpit [18] has developed research prototypes and demonstrators for software architectures envisioning a fully integrated, highly accurate and timely production cockpit. In order to achieve this goal, modern developments from all disciplines of computer science were considered. A description of various uses of how such a system can work in factories is offered in a dedicated brochure [19].

To manufacture microsystems and devices expensive large-scale infrastructures may not always be required. Project FEMTOPRINT [20] successfully developed and demonstrated a table-top printer that is capable of producing microsystems with nano-scale features. The development is likely to see further applications such as the production of optical and opto-mechanical devices, lab-on-chip devices used in opto-fluidics and optical memory marking. The printer has a strong potential to boost a series of further innovations in microsystems manufacturing and in particular to provide affordable rapid prototyping capability to SMEs. In addition to developing a prototype table-top printer, the project partners have filed applications for two patents and have set-up of a spin-off company to further develop and to market their innovative printing device.

A major challenge facing European factories is how to adapt existing machinery and tools to meet increasing demands for more precision in production. Project HARCO [21] has provided a solution by showing how “plug-and-produce” modules can reduce vibrations and shaking, helping to make production line machines more precise. Plug-and-produce technology borrows from the popular “plug-and-play” computing concept, where a user literally only needs to ‘plug’ in an additional device, such as a USB stick, to a PC and it will start working or ‘play’. Being able to ‘add on’ software or hardware as needed to improve manufacturing quality or output is a major step in industrial production. Smart actuators and sensors perform a range of actions, including regulating damping and stiffness, conducting measurements, and controlling temperature and motion. The smart – hardware and software – components are then fitted together to create adaptable modules that can be plugged into machines as versatile and dynamic add-ons.

3 Outlook: Manufacturing in Horizon 2020

The new EU Framework Program for research and innovation, Horizon 2020 [22], has started in January 2014 and is due to run over seven years with a total budget of around EUR 80 billion. Its structure consists of basic priorities (see fig. 1).

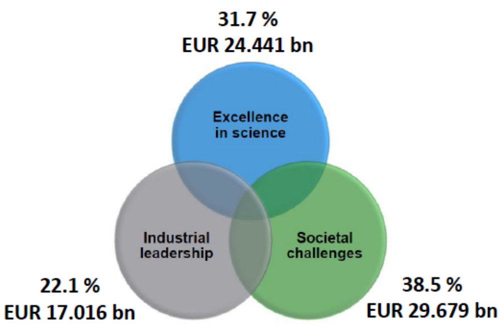

Fig. 1. The Horizon 2020 Framework Program (major elements)

Compared to previous EU Framework Programs Horizon 2020 brings together research and innovation in a single program, it focuses on multidisciplinary societal challenges European citizens face and it aims to simplify the participation of companies, universities, and other institutes in all EU countries and beyond.

The program's activities related to manufacturing are mostly concentrated in the area called "Leadership in enabling and industrial technologies". Key activities here focus on roadmap-based research and innovation involving relevant industry and academic research stakeholders.

Following a positive assessment of FP7 PPPs [23], the Commission decided to continue and even increase its stake in manufacturing R&D&I in the new Horizon 2020 program by launching the FoF PPP with a funding envelope of EUR 1.15 billion and a new PPP, addressing continuous process manufacturing (SPIRE), with funding envelope of EUR 900 million over the next 7 years [24].

The FoF PPP and other, similar PPPs operate based on industry-defined multi-annual roadmaps [25] which identify priority areas for R&D and innovation calls issued and administered by the Commission, thus ensuring that whilst there is an ongoing dialogue with industry and the research community regarding the scope and the content of the calls, fairness and transparency is maintained by the use of standard EU rules and mechanisms provided by the Framework Program.

4 Conclusions

In its evolution throughout human history, manufacturing has proven to be an important value creation activity. Its impact on the economy, society and the environment started to be felt on a massive scale through the industrial revolution's introduction of the steam engine. Machine intelligence began raising manufacturing productivity even further through automation and networking.

After a period of decline in developed economies, and following the detrimental effects of the banking crisis on the rest of the economy, manufacturing as a key value adding business activity appears to be firmly back on the political agenda. Recent econometric research points to the fact that a country's or a region's capacity to export products only few others can make is based on an accumulation of manufacturing knowledge and capability leading to its competitive advantage over others [26].

The question to research is: How can manufacturing continue to be a value adding activity in modern, Internet-driven economies?

4.1 Manufacturing Intelligence: from New Products to New Business

Today's products and processes are characterized by the growing level of intelligence [27] embedded in them. Smart products, such as the ones developed in the PROMISE project [28], enable the feeding back of up-to-date lifecycle information into design and production (adaptive production). Some examples:

(1) Product dematerialization: Mechanical parts are replaced by electronic parts and functions realized through software components making products lighter, smaller, cheaper and smarter.

(2) Product complexity: The ever growing product complexity is addressed through data and configuration management and radical modularization strategies.

(3) Customization: Software-enabled adaptation to customer requests facilitating personalization of product functions along a product's entire lifecycle.

(4) Internet-of-Things capability: The integration of microsystems integrating sensing, actuating and information processing facilitating product interactivity, networking and M2M capability for on-board maintenance and other add-on services.

Intelligence not only affects the products but also the processes, in particular those related to material flows, distribution, delivery and operation. It improves activities related to the product's lifecycle. Real-time simulation and visualization increase process transparency and drive down costs. Virtual manufacturing thus drastically increases planning accuracy, ramp-up speed and shop floor productivity in discrete and continuous manufacturing. Embedded intelligence in manufacturing equipment allows for higher levels of accuracy while minimizing machine downtime and waste of energy and resource use. It further enables items tracking along transport and logistic chains and thus contributes to better process transparency [29].

Manufacturing innovation is about the creation of value. The production of high-tech products requires joint and multi-disciplinary efforts. As many products are becoming highly complex, the amount of multiply engineered components, their complex interoperation, the degree of sophistication and the number of possible variants have to be managed in a consistent way.

4.2 From Products to Value Propositions

The current focus of industrial companies is on the profitable development, manufacturing and selling of innovative high-tech products. Increasing global competition, decreasing differentiation of product features and shrinking project margins drive companies to rethink their actual business models. On the other hand, customers increasingly ask for a function to solve a problem, rather than a product. Furthermore, with increasing trends like "the sharing economy", traditional product ownership models are being substituted by models that focus on the provision of a function. As products increasingly have to comply with regulations that mandate end-of-life take-back, recycling or disposal, they are increasingly required to ensure value maximization, optimal energy and material consumption over their entire lifecycle.

In this global context, the manufacturing industry is undergoing a transition towards providing customer value via product-related services or solutions for individual customers including integrated product/service schemes. These schemes may offer opportunities and benefits to both, providers and customers. Providers generate additional profit from offering value-adding services across the product lifecycle and by engaging into a longer-term relationship with customers. By using product/service systems, customers reduce their initial investment, limit their risks and may thus achieve more individual value. Increased intelligence of products facilitates this integration. Thus the transition of enterprises from mere product suppliers to value providers generates a new kind of business and new dynamic cooperation models.

To exploit the potential of these new opportunities, novel methodologies, tools and platforms are needed. Understanding the impact of such business models and the degree of complexity of relevant methodologies and tools requires research and innovation efforts to be across multiple stakeholders and involving a multitude of scientific disciplines.

4.3 A Holistic View of the Lifecycle

The traditional ways of developing and producing goods are driven by market needs and by profitability considerations in highly competitive environments. The growing global industrialization, an increasing world population and standards of living are the cause of an ever-growing consumption of resources and energy as well as higher CO_2 emissions. These developments create an enormous sustainability pressure both on governments and the industry. Industrial enterprises have a key role to play in increasing the environmental compatibility of new products and processes. One of the major challenges for industry today is to be competitive on the market, whilst achieving sustainability objectives.

Today's product development, however, is mainly driven by functionality and cost, while considering constraints such as compliance with safety, reliability or regulatory requirements. In addition to these aspects, product development has to consider the whole product lifecycle and its costs but also the environmental "footprint", e.g. resource use efficiency and impact on CO_2 emissions. Companies are increasingly held responsible also for the social impact of their economic activities. These have to be analyzed and taken into account via holistic LCA approaches [30].

The industrial transition from "products selling" towards "solutions provisioning" contributes to raising responsibility for products across the whole lifecycle and will ultimately stimulate demand for lifecycle analysis and synthesis. The development of powerful tools for integrated lifecycle analysis and synthesis is a very complex task. Hence the need for joint R&D efforts.

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