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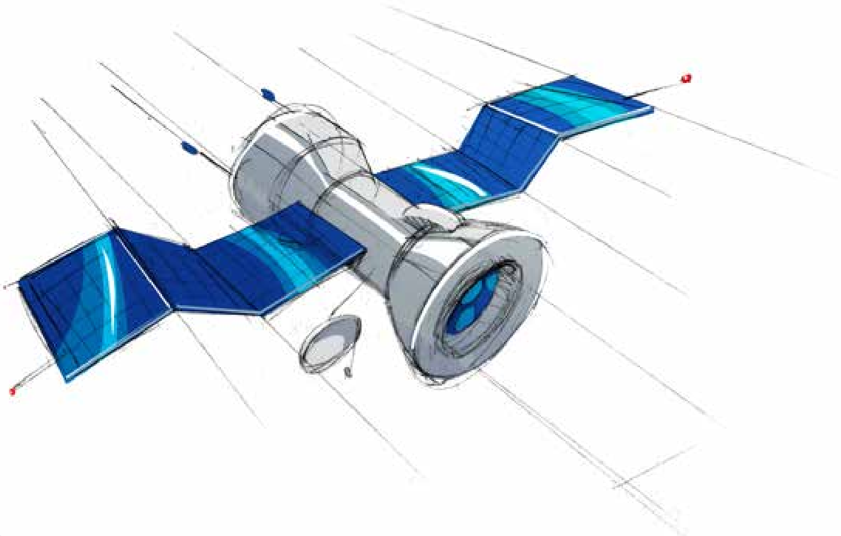
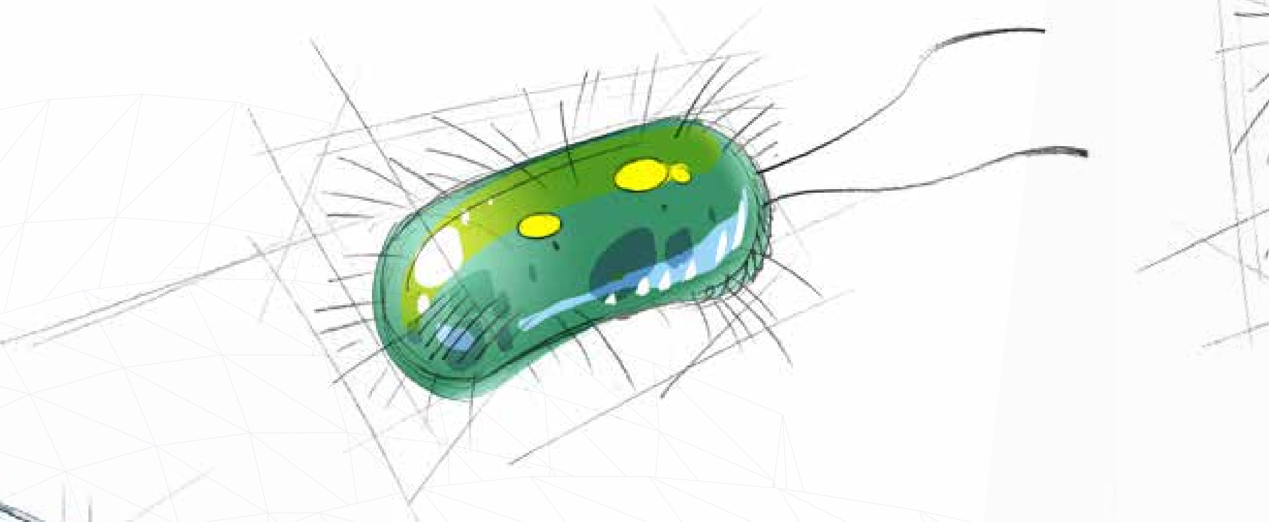
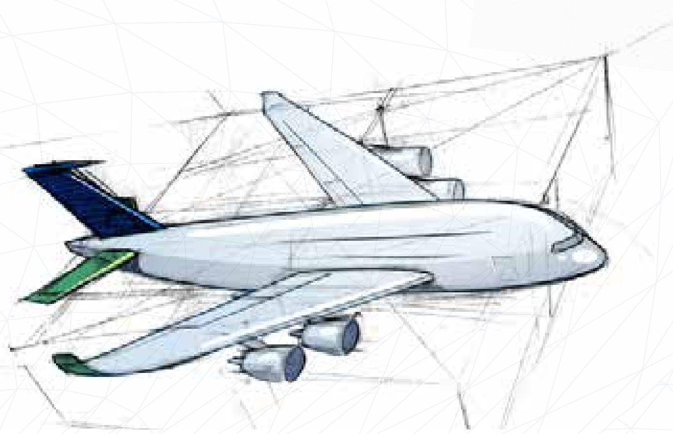


Why fund research?

A guide to why EU-funded research and innovation matters

The European Union is drafting its next 7-year budget plan.
How much should go to research and innovation?





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A shortened, interactive summary of this document may be found on www.sciencebusiness.net

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"Learned Institutions ought to be favourite objects with every free people. They throw that light over the public mind which is the best security against crafty & dangerous encroachments on the public liberty."

US President James Madison (in private correspondence, 1822.)

1. Summary & Introduction

Since their founding, the European institutions have been spending money on science and technology. Why? What do we get from it? And why not leave it to national governments or the private sector? This report aims to answer as succinctly as possible.

Asking such questions matter – if only because the money involved in European Union research and innovation (R&I) is huge. The largest EU R&I programme, Horizon 2020, is slated to spend €77 billion from 2013 to 2020, or an average €11 billion a year. And the budget has grown spectacularly – nearly fourfold since 2006 (Figure 1). So, clearly, the EU member-states that pay the bills for this think it's worthwhile. But are they right?

Budgets of the EU's Research and Innovation Framework programmes

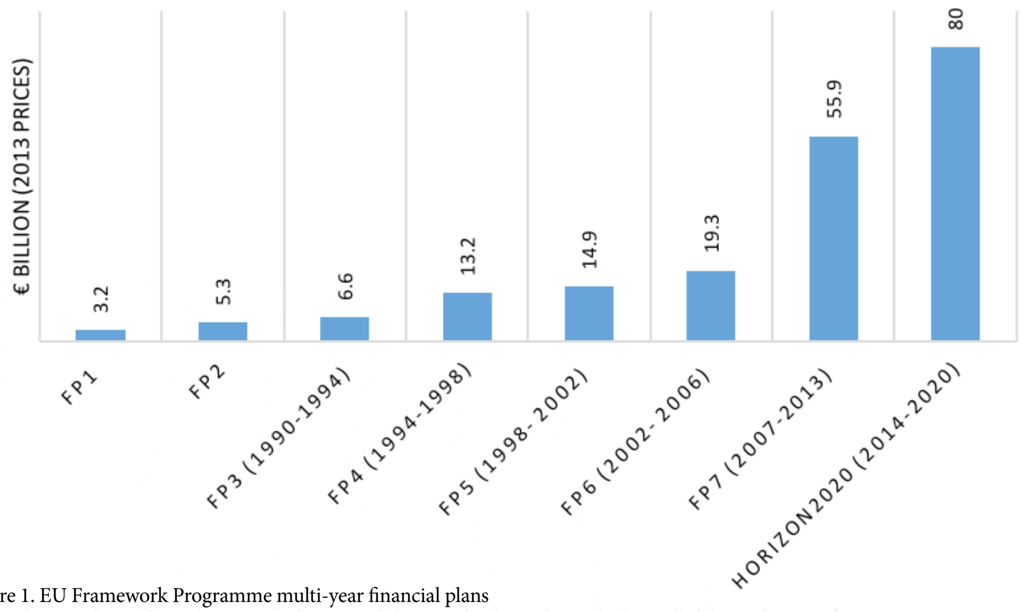


Figure 1. EU Framework Programme multi-year financial plans
Note: Horizon 2020 figure has been reduced to €77 billion since 2015.
Source: European Commission, 2015

These questions also matter because present deliberations will be critical in deciding how this story evolves over the next decade. In 2018 and 2019, the EU is developing its next seven-year budget plan, the Multiannual Financial Framework, or MFF. Research and innovation are part of that – and a battle is already underway to shuffle money among competing priorities, such as agriculture and regional development. Then there is the uncertain, but profound, budgetary impact of Britain leaving the EU; less money may be available for Horizon 2020's successor programme, provisionally called Framework Programme 9 (FP9). And finally, we feel compelled to counter the anti-science, anti-'elite' backlash from resurgent populists around the developed world.

This guide is designed to inform the above discussions – in particular over the EU's MFF allocations –by laying out the case for expenditure on research and innovation. In the past decade, as science and technology funding around the world has climbed, the number of economic studies of R&I policy has risen even faster; there is by now a sizeable body of literature, on which this report draws. We have also drawn on the views of our members – the more than 50 universities, companies and public-sector organisations that belong to the Science|Business Network (though, as with all our reports, this document does not necessarily reflect the views of any individual member), as well as our Big Science report (Science Business Publishing, 2015).

Here, we look first at the economics behind publicly funded EU R&I and then at the broader qualitative arguments for and against such funding.

Conclusions in Brief

- The many **economic measurements** of returns on investment to publicly funded R&I vary wildly in range, but seem to cluster at around a 20% annual return on investment. This can be compared to 6.8% for the past 10 years of the US stock market (S&P 500) or the 3.1% for 10-year Euro Area (19 countries) Government Bonds. In short, publicly funded R&I is a good investment.

- The **added-value of European Union programmes** comes in several forms. Being continent-wide, the programmes generate critical mass of money and talent for complex research and innovation projects, and supply chains that could not otherwise happen. The increased competition for grants also raises the quality of projects that gets funded – creating a "Champion's League" of top researchers and innovators. They also help member-states coordinate their national R&I and policies, creating opportunities for synergy and greater efficiency. And they help spread knowledge and raise capacities across the EU, creating new networks. EU-funded evaluations estimated between a five- and 10-fold economic return, though some methodologies have been questioned.

- There are many **market failures** which require publicly funded R&I to correct: a need to translate the growing amount of knowledge towards tackling societal challenges, uncertainty over returns on investment of (basic) research, as well as the unmet need for cross-sectoral multi-stakeholder involvement in R&I at all levels. Carefully designed public R&I programmes can bridge, or minimise, such market failures whilst channelling knowledge to tackle societal challenges. Moreover, publically funded R&I does not just paper over market failures but is entrepreneurial in nature — enabling disruptive market creation, for example creating much of the technology behind the iPhone.

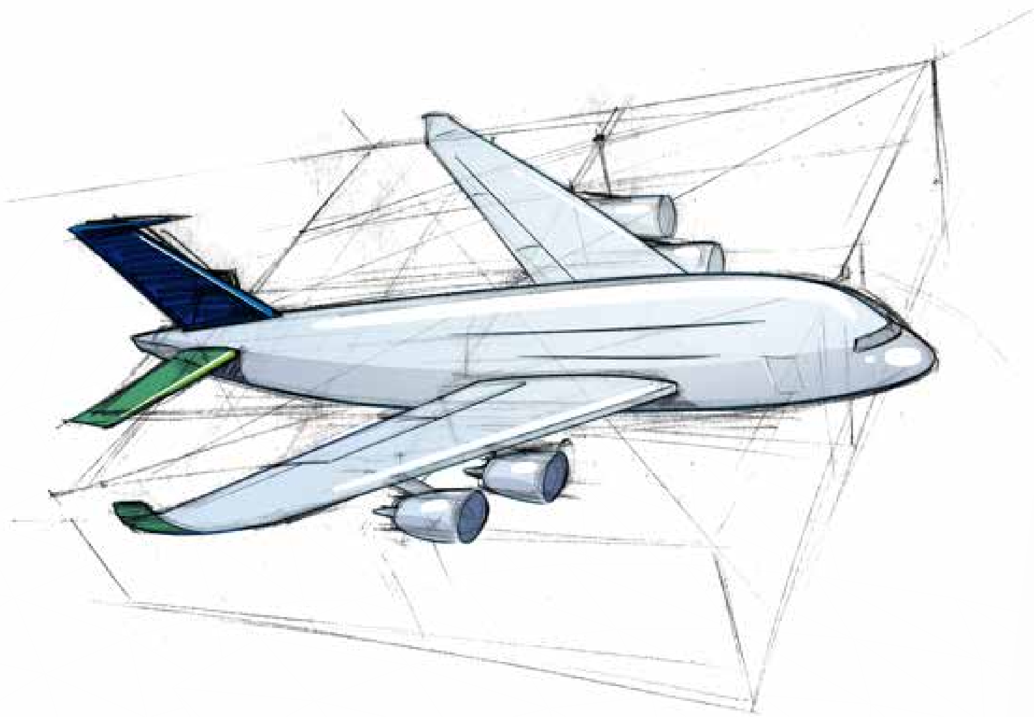
- There are several **mechanisms behind the economic benefits** of publicly funded R&I. Direct benefits come from the employees hired for the conduct of the R&I itself, the services used by them, the licensing revenues and spin-out company formation, and sales and tax revenue from new products and services. Indirect benefits come from increasing and spreading useful instruments, methods and knowledge, training a larger, more-capable workforce, and increasing productivity among companies that adopt the new technologies. And R&I helps reorganise society – creating network linkages between industry and academia, stimulating new multilateral supply chains and creating new markets.

- Publicly funded R&I also promotes several desirable, if less quantifiable, goals for Europe. It enables structural changes towards **a more knowledge-intensive economy and society**, raising international competitiveness, boosting productivity growth and generating high-quality jobs. This promotes higher standards of living and contributes to the progress of democratic and open societies. It fosters **international cooperation** to pool resources, connect and align action towards the EU's goals. It enhances **global resilience and sustainability**, providing new tools to protect the environment, improve health and promote social welfare at home and abroad.

- Against all these potential benefits, however great, comes a frequent criticism of EU-funded R&I: many now argue that the competition has grown too intense, with barely one in 10 applicants getting the money. These programmes carry **a heavy administrative cost** – mainly, in time wasted on rejected applications, for which estimates start at €500 million a year. The Commission has been attempting to simplify the programmes, but so far has achieved little in addressing this problem of opportunity-cost.

Of course, we have seen how many of our fellow-citizens now fear innovation. The fact is that, around the world, new technologies – from the Green Revolution to smartphones – have helped raise standards of living, abated hunger and extended lifespans. But these benefits can be dwarfed politically by more-immediate fears of losing jobs or cultural identities in a global, tech-powered network of trade, migration and information. It is difficult to counter-act these fears – to communicate the real and broad benefits of research and innovation, and the danger of not conducting them.

In such circumstances, we must remind all that research and innovation are more than tools to find the truth – however important that may be. They are tools to find and harness truth to serve society.



2. The economic case

Science and technology are perceived as major expenditures. Annual research and development spending world-wide is running at around $1.9 trillion – or, put another way, accounts for about 2 per cent of the world's gross domestic product (GDP), with the vast majority being spent by the private sector (R&D Magazine, 2016; WorldBank, 2013; Figure 2). On average, countries within the EU also spend around 2 per cent of their GDP on R&I (Eurostat, 2014) – though the range is huge, from barely 0.2 per cent in Romania to more than 3 per cent in Finland. Throughout Europe, however, it's the private rather than public sector that has the biggest budgets - skewed towards close-to-market product development rather than frontier research (Figure 2.)

Business rules the R&D world

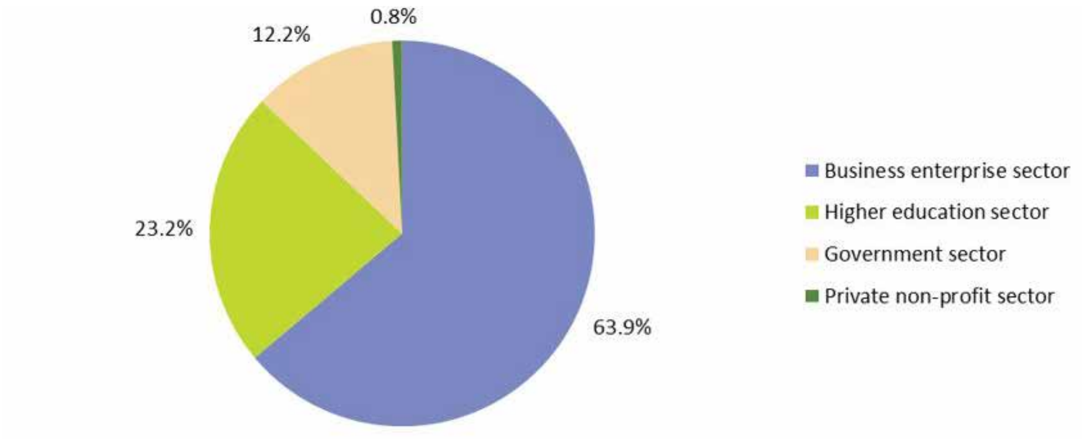


Figure 2. EU member states' R&I expenditure, by sectors of performance (2014).
Notes: Provisional data.
Source: Eurostat, 2016. http://ec.europa.eu/eurostat/statistics-explained/index.php/File:R%26D_expenditure,_by_sectors_of_performance,_EU-28.png

The Lisbon Agenda, the EU's millennial blueprint for growth, set an objective of devoting 3 per cent of EU GDP to research and development activities by 2010. The target was not reached, but the 3 per cent ambition has been maintained, forming one of five key parameters within the EU's overarching 2020 strategy (European Commission, 2010).

But why 3 per cent? And why should we strive to spend so much on research and development?

This argument predominately boils down to the economics of it – for which, read on. But another way to look at it is that societal progress in everything, from the economy to health care, has been driven partly by a combination of scientific advancement and political governance. Energy consumption and efficiency, online commerce and media, cancer and antibiotic therapies, globalisation and (un) sustainability – for good and for bad, these have all been shaped in the past few generations by R&D. And this has been funded by a complex mix of public and private interests.

What are research & innovation worth?

There are many figures bandied about to proclaim the economic importance of R&I. But as in many fields of policy, analysing impact is far from easy. The conclusions vary wildly, with different methodologies, assumptions and ideologies. But here, we provide a summary of economic arguments relevant to EU R&I expenditure.

At the lower end of the scale is one of the earliest and most influential studies. In 1991, Edwin Mansfield of the University of Pennsylvania published a survey of 76 companies in seven manufacturing industries in the US: information processing, electrical equipment, chemicals, instruments, drugs, metals and oil (Mansfield, 1991). He found that 11 per cent of new products and 9 per cent of new processes could not have been developed (or not without a substantial delay) in the absence of academic research. Based on this observation, Mansfield estimated the rate of return from public money invested in academic research to be 28 per cent. He noted later that the trend was accelerating—the success of US companies was becoming unceasingly dependent on science. In a follow-up study published in 1998, Mansfield noted that the impact had indeed risen: 15 per cent of new products and 11 per cent of new processes had been significantly aided by academic research (Mansfield, 1998). In total, he said, innovations that could not have been developed without academic research accounted for 5 per cent of total sales for the firms.

But there have been many bigger estimates. Luke Georghiou (2015) of the University of Manchester reported that typically between 20 per cent and 75 per cent of innovations could not have been introduced without publicly funded R&I. Right at the far end of the scale, a prodigious 2011 report "Economic Impact of the Human Genome Project" from Battelle Memorial Institute found that the US government's $3.8 billion investment in the sequencing of the human genome in the 1990s drove $796 billion in economic impact, personal income exceeding $244 billion and 3.8 million job-years of employment. The report states: Every $1 of federal investment contributed to the generation of $141 in the economy. In 2010 alone, the genomics-enabled industry generated over $3.7 billion in federal taxes and $2.3 billion in US state and local taxes; revenues returned to government nearly equalled the entire 13-year investment, says the report. The $3.8 billion investment could be the "best single investment ever made in science," it boldly concludes (Tripp and Grueber, 2011). A postscript, however: Much of the calculated returns were only possible because the government made the data and results freely available – "open science"- for others to generate added value out of the research. A more closed approach might have diminished the impact – highlighting the importance of the policy framework in which R&I operate.

The return from Framework

According to an ex-post evaluation performed for the European Commission, the €55 billion EU Framework Programme 7 had a disproportionate impact on Europe's economy, with each euro spent generating an estimated €11 in return (Fresco, Martinuzzi, and Wiman, 2016). The evaluation pooled the methodologies of existing studies, but pooling methodologies is a risky business, and it is impossible to calculate this accurately so recently after the programme has finished.

There are many other studies. A dig through the published literature on the topic reveals "returns" on investment covering all the ground between two extremes — from useless (0 per cent) to omnipotent (14,000 per cent) — see Table 1.

Table 1. Keeping score: Key studies into the economic value of public research

Description	
Annual rate of return	**Average amount gained per year, as a percentage of the original investment**
20%	Three separate studies investigating the annual rate of return from public investment in R&I came up with the same number: 20%. If economics can be voted on, this number seems to win the election in Europe (European Commission, 2017a; Frontier Economics, 2014; Georghiou, 2015).
28%	Surveys on the impact of public research on innovation in the US and Germany. The three studies back 28% as being a likely annual rate of return (Mansfield, 1991;1998; Beise and Stahl, 1999).
30-37%	Estimate of the financial impact of biomedical research in mental health and cardiovascular diseases in the UK; translating reduction of mortality/morbidity into GDP gains (Buxton, et al., 2008).
By comparison in another sector…	
3.1%	10 year Euro Area (19 countries) Government Bonds (OECD, 2017).
6.8%	Past 10 years of the US stock market (S&P 500)
Cumulative return on investment	**Total amount gained or lost from the investment**
6-8.5x	The interim evaluation by the European Commission estimated that, by 2030, Horizon2020 will have generated €6-8.5 for every €1 invested (European Commission, 2017e).
10x	The €55 billion EU Framework Programme 7 had a disproportionate impact on Europe's economy, with each euro spent generating an estimated €11 in return (Fresco, Martinuzzi and Wiman, 2016).
14x	Research conducted by the US National Institutes of Health ($16 billion) led to reductions in illness calculated to save the economy $240 billion (Murphy and Topel; 2006 OECD, 2008).
44x	Over a 10-year period, the $335 million invested in clinical trials carried out by the US National Institutes of Health generated $15.2 billion (2004 value). This is a gross return, excluding costs and depreciation (Johnston, et al., 2006).
140x	Every $1 of US federal investment into the Human Genome Project contributed to the generation of $141 in the economy (Tripp, and Grueber, 2011).
By comparison in another sector…	
<1x (0.4:1)	The effects of the EU's Common Agricultural Policy (CAP) are reviewed by the Australian government. They look at its protectionist effects, and the opportunity costs of CAP expenditure (Costa, et al., 2009).
Percentage of innovations dependent on public research	**Innovations which could not have occurred (or would have been substantially delayed) without underlying public research**
9-11%	Looking at seven manufacturing industries in the US: information processing, electrical equipment, chemicals, instruments, drugs, metals and oil (Mansfield, 1991).
20%	Mail survey of inventors, to discover how dependent private sector innovations (patents) are on public sector research across the Netherlands (Tijssen, 2002).

The range of different figures within Table 1 raises the question: how can they vary so much? The answer lies in their different methodologies, from those that look at the direct outcomes of the original investment, such as profits generated from patents, to those that look at the indirect outcomes, such as the profits from all proceeding technologies incorporating the initial innovation. For example, imagine the returns on investment from an early microchip. It may not have had many applications initially, providing limited returns on investment; but now we rely upon it in a vast array of day-to-day technologies and tasks — bringing huge value. Another source of variance in the results: Different studies often look at different areas of R&I, on a large or small scale, using different timeframes which may not account for the substantial time lag that occurs between basic research and the innovation itself — sometimes up to 20 years.

In the face of divergence there are other variables beside returns on investment which we can look at to try to find where reality is — such as productivity. At the macro level, the European Commission (2017a) uses existing research to estimate that an increase of 10 per cent in R&D is associated with gains in productivity between 1.1 per cent and 1.4 per cent. Applied to Europe, that formula suggests that an increase in R&D of 0.2 per cent of GDP would produce 1.1 per cent more GDP. Although, as might be expected, this has also been found to be far lower in other research (Comin, 2004).

Consider another outcome, employment within science and technology. It demonstrated a remarkable resilience during the financial crisis (2008-2013), with the number of researchers increasing by 2.1 per cent per year against a backdrop of reduced employment (-0.7 per cent) across Europe (European Commission, 2016a). Of course, that may have been simply because some member-states – notably Germany, the UK, and the Nordics – didn't slash their R&I spending. And, after an initial hiccup, private sector R&D spending continued its long-term rise. So, from one pocket or another, the money kept flowing in parts of Europe to keep scientists at their lab benches.

So what's the answer? The preponderance of the research so far points to a fairly simple conclusion. As Georgiou (2015) puts it, there is "overwhelming evidence from multiple sources to justify research as one of the best investments that can be made with public (and private) funds. [annual] Rates of return are of the order of 20-50 per cent" (European Commission, 2017a; Frontier Economics, 2014). This can be considered far higher than long-term Euro area government bonds at 3.1 per cent, or the past 10 years of the US stock market (S&P 500) 6.8 per cent annual return (OECD, 2017; Damodaran, 2016).

If R&I is so economically brilliant, why can't we leave it to private enterprise?

The economic benefits of R&I don't happen by magic; they often have to start with basic research – fundamental, exploratory, high-risk science with surprising results that open new markets. In the words of Rolf Heuer, former director-general of CERN: "Take the example of electric lighting. A mere 150 years ago the candle was the main source of artificial light. By then, it had already been developed to a very sophisticated degree. But no amount of research on the candle would have given us the electric light bulb. For that, you need basic science to prepare the way" (Science Business Publishing, 2015).

Yet, basic research occurs at a distance from the market, which makes it unappealing to private investors who often operate with short- to medium-term timeframes. The benefits of basic research can take up to 20 years to translate into innovations and generate a positive rate of return (Heher, 2006). Such a timescale means that, assuming a societal discount rate of 4 per cent per annum (and discounting inflation), in order to break even on a €100 investment which reaches the market 20 years later, the investment would have to generate at least €226 in overall returns.

Science, and particularly basic science, is also inherently unpredictable. Failure is common. "Science cannot be driven like a bus," as one scientist, Dirk Helbing from ETH-Zurich, once put it. This high risk makes basic research, along with the more ambitious innovation projects, unattractive as investment prospects for private enterprise. Furthermore, the knowledge generated through basic research often disperses into the wider economy as a shared public good and so makes its benefits harder to track and demand revenue for. This is unlike in business where, for example, patent protections allow one easily to measure and recoup the revenues from an innovation. This same high risk applies to market-creating innovations, making them less attractive to prospective investors.

What's more, this dispersion of knowledge (or leakage, as economists call it) often benefits sectors which themselves have a largely indirect, but fundamental, relationship with economic growth, such as education and healthcare. These sectors may have reciprocal relationships with R&I, with their benefit in turn benefitting R&I (Maradana, et al., 2017). Knowledge leakage also means that publicly funded basic research intrinsically cuts across silos, as solutions can arise from research fields that industry would not normally fund. Consider, for instance, research into lasers that ended up leading to compact discs and profits for the music industry. No recording studio would have funded that basic, essential laser research. Also, R&I done in the private sector tends to depreciate quickly — around 20 per cent per year. For example, product innovations often have lifespans in the order of 10 years before obsolescence. But public investments, because of their more fundamental nature, tend to depreciate at a much lower rate (Frontier Economics, 2014).

This uncertainty over returns to investment, the timeframe required to receive returns, and their leakage, are all examples of market failures that require publicly funded R&I to correct. These market failures are widened by the rapid pace of global development accelerating the complexity of knowledge, further increasing the need for public funds to keep apace and fill in gaps in translating this knowledge into marketable innovations.

But basic science is not enough. Applied science, private enterprise, social sciences and humanities (SSH) are also important for the innovation process to grow benefits for society out of basic science. So, whilst the benefits of public spending on R&I may be difficult to calculate precisely, without it costly market failures would remain.

The underlying benefits

In their 1996 seminal work on the topic, "The Relationship Between Publicly Funded Basic Research and Economic Performance", Ben Martin and Ammon Salter of the University of Sussex saw the benefits of basic research as: "Increasing the stock of information, the development of new instrumentation and methodologies, the creation of skilled graduates and of professional networks, the solving of complex technological problems and the creation of new firms (Martin, Hicks and Salter, 1996). Building on these relationships, below are the main mechanisms through which public R&I benefits the economy (BiGGAR Economics, 2015; European Commission, 2016a):

1. ***Core economic contribution***
   Based on wages and supply chains (as well as student expenditure and employment).
2. ***Consultancy services and staff volunteering***
3. ***Direct technology licensing, spin-outs and start-ups***
   This commercialisation remains a small part of the value created. For instance, while the number of patents produced by higher education institutes grew by a factor of five from 1996 to 2006, it still accounted for under 2.0 per cent of European Patent Office applications.
4. ***Increasing the knowledge base***
   Allowing industry to use this knowledge in R&I close to the market —complementing rather than competing with private R&I.
5. ***Increasing human capital***
   Training skilled graduates, the workforce which drives knowledge-intensive industry.
6. ***Absorptive and adaptive capacity***
   The improved ability of a research-intensive firm to recognise and apply new research or innovations, as well as solve problems (Cohen and Levinthal, 1990; Georghiou, 2015). This occurs even when no innovations are produced (European Commission, 2017a).
7. ***Developing instruments, infrastructure and methodologies***
   These can have applications in industry.
8. ***Network linkages between industry and academia***
   Catalysing regional R&I hubs and improving the translation of research into innovations.
9. ***Crowding-in effect of R&I***
   Attracting human capital, foreign direct investment or the (re)location of R&D intensive industries, as well as leveraging private R&I itself. This crowding-in effect also carries across borders according to geographical proximity (Haskel, Hughes and Bascavusoglu-Moreau, 2014; Park, W.G., 1995).
10. ***Market creation and supply chain fostering***

What's a university graduate worth?

A report entitled "Entrepreneurial Impact: The Role of MIT" looked at the economic contribution of alumni of the Massachusetts Institute of Technology. It found that at the end of 2006, there were 25,600 active companies founded by living MIT alumni, employing 3.3 million people and generating annual world revenues of nearly $2 trillion. This group of companies, if it were its own nation, would be the 11th-largest economy in the world (Roberts and Eesley, 2011).

Publicly funded R&I embeds new actors – entrepreneurs, customers, intermediaries - in markets and supply chains (Heles, 2017). It also helps reduce entry barriers to market creation through, for example, investing in new infrastructures such as adaptable electricity grids for renewable energy. Moreover, R&I is increasingly global and requires access to new markets in order to gain new knowledge, skills and partners. One example is public R&I's importance for the creation of the iPhone and the associated smartphone market (Mazzucato, 2015).

Why not just leave it to national research and innovation bodies?

The arguments for the added value of the EU in R&I are manifold. In the recent stakeholder consultation on Horizon 2020, there was a consistent majority rating Horizon 2020 as having higher added value than national/regional R&I programmes (European Commission, 2017d; 2017e). These are the main mechanisms behind this EU added value:

1. ***Generating a critical mass***
   Pooling resources, for instance, to build research infrastructures or to tackle societal challenges — generating a larger crowding-in effect. Advancing (single) market access and supply chain integration.
2. ***Fostering human capital***
   Free movement in R&I allows personal development and the associated increase in diversity and networks.
3. ***International network linkages between industry, academia and users***
   Catalysing participatory R&I through open, interdisciplinary and international cooperation. This internationalisation raises R&I intensity through exposure to new ideas and competition, and in turn this R&D intensity drives further internationalisation — a virtuous cycle (UK - Department for Business Innovation and Skills, 2011).
4. ***Coordinating national research and innovation programmes***
   Preventing duplication among similar national programmes. The Commission once calculated, for instance, more than 100 different projects underway around the EU on the same topic.
5. ***Advancing science policy and 'Open Science'***
   National R&I policy can look to the EU's example (or not as the case may be). The EU also offers consultation to improve national R&I policy. The EU's open science model, which extracts added value out of research through opening up the results so others can participate and learn, may catalyse this as best practice.
6. ***The 'Champions League' argument***
   Raising the quality of grant applications, by enlarging the competition beyond the national level. This in turn improves the quality of research and innovation outcomes; the share of publications in high-impact research journals is higher for research funded by the EU than the European/US average.
7. ***Spreading knowledge and raising capacities***
   Positive externalities produced by cooperation between the north-south, east-west, rich-poor, centre-periphery divides.
8. ***Economic efficiency***

It is difficult to compare the EU's publicly funded research with that in the member-states, but in theory it is logical to think that better quality research should yield higher societal returns.

These theoretical examples of the EU's added value, however, don't take into account the added costs. For instance, because of the high standards, the application process for many of the mechanisms is extremely slow and bureaucratic. These high standards, combined with high demand, also mean that Horizon 2020 has an overall success rate of only 12 per cent, compared to much higher numbers in some national funding bodies (Else, 2014; European Commission, 2017c). Because of these low success rates, novel, high-risk research is reputedly being discouraged in favour of more established R&I. Moreover, the existence of this EU pot of money has been viewed by some as a disincentive for national expenditure on R&I, substituting rather than complementing it. It also has a cost in terms of inequality, with research-intensive countries taking the lion's share of the money available, reducing the value for some of the less research-intensive member states.

But, to put this in perspective: “Sources of evidence point to a central contribution from research to economic growth. However, they also emphasise that this contribution only is realised when certain framework conditions apply. Excellence in research is one such condition, the existence of effective channels for knowledge flows and mobility of people is a second and a high absorptive capacity in industry (or other users) is a third” (Georghiou, 2015). The EU utilises its size to improve these conditions, along with the mechanisms above, in a manner which national research budgets alone cannot. It is this kind of argument that lies behind the 11-to-1 rate of return from EU research reported by some.

Whilst there is agreement that public R&D provides returns, there is no such consensus when it comes to deciding the optimum level of public expenditure on R&I as a per cent of GDP. It is difficult to estimate the trade-off between diminishing rates of returns for increasing expenditure on R&I (and the growing opportunity cost of allocating resources to R&I) against the increased benefits to the economy. The UK, for instance, spends less on R&I than France – yet its economy has generally performed better in the past generation (more on this paradox below). Nevertheless, the 3 per cent benchmark has been adopted, or at least recognised as important, across a good deal of the developed world. In sum, 3 per cent seems to be what scientists euphemistically call heuristics (or, a rule of thumb.)

Much of the literature stresses, however, that whilst publicly funded R&I is needed throughout the innovation cycle, it should be focussed on areas where there are market failures and barriers - for example, basic or SSH research - and where it serves to attract rather than drive out private investment. Further, the market failures which prevent bringing basic research to market also need addressing: for example, dismantling barriers to scaling up innovative ideas across the whole of the EU. In short, the policy details matter.

Case Study: Stacking shelves
The importance of public funding for innovation

RELEX Solutions is seeking to help reduce the magnitude of the pressing, global food wastage problem. It has written software to eliminate excess in-store inventory and ensure the right amount of stock at exactly the right time through demand forecasting and automated replenishment.

The company, started in Finland, received money from the SME instrument of Horizon 2020, which consists of several phases of funding, the first of which tests for its market feasibility. This phase-1 funding allowed it to see where the gaps in the markets lie through the conduct of market research which was then used to define the R&I priorities of the company and the best markets to target. It steered them to focus on the societal challenge of waste in the food sector.

This Horizon2020 grant was complemented by funding from the Finnish Funding Agency for Innovation, Tekes, which facilitated the commercialisation of the software and expedited the company’s expansion into neighbouring Nordic countries. As a result of this early success in scaling up, RELEX has now attracted substantial private growth equity and employs 160 people across 17 countries (Relex, 2016).

Public funds do more than ensuring innovations with societal impact, like RELEXs’, reach the market. They also leverage greater R&I intensity of these firms; Tekes estimates that for every euro invested by Tekes, companies increase their R&D investments by €2. (Tekes, 2015).

3. Counting the un-countable

There are, of course, many more reasons to invest in R&I that go beyond the EU's current mantra of "jobs and growth".

The most obvious is the promotion of knowledge. Science seeks truth – about how nature works, how society functions, how the mind operates. Historically, truth-seekers required leisure and wealthy patrons (think of Aristotle's students, royal and non-royal, or the Royal Society's rich gentlemen-members). But for at least the past century, the role of government in basic research funding has inexorably risen. Applied research, goes the theory, is then also worthy of funding because it fills in the knowledge gaps that the scientific pioneers leave unanswered and translates this knowledge into useful applications (innovations). All mankind benefits – whether through the medicines or foods that result, or simply through finally knowing why the sky is dark at night (because the universe is expanding).

There are many other "spill-overs" from R&I – and economists have done their best to categorise them (BiGGAR Economics, 2015; European Commission, 2016a; Joly, et al., 2015; Georghiou, 2015):

- ***Environmental effects***
  Better awareness and management of natural resources (Bach and Georghiou, 1998; Hermann, et al., 2007; Walker, et al., 2008)
- ***Social, cultural and (geo-)political effects***
  Greater understanding of society can increase the effectiveness of governance and civil society. This knowledge allows for evidenced-based action to be taken, improving the resilience and credibility of society. (Bornmann, 2013; Bozeman, 2003; Donovan, 2011; Godin and Doré, 2004; Molas-Gallart, et al., 2002)
- ***Organisational effects***
  Workforces with greater knowledge are better able to innovate. Improved resilience and management through evidence-based administration of organisations (Godin and Doré, 2005).
- ***Health effects***
  Wider societal impacts of improved health from medical technologies and the protective health effects of better education (Bozeman, 2003; Cutler, et al., 2015).

Publically funded R&I seeks to maximise these spill-overs, investing in areas which tend to have high social returns but are subject to market failures that limit the returns of private investment in R&I. The sections below combine these qualitative effects with economic effects to highlight four dimensions that are enhanced by publicly funded R&I: International competitiveness, international cooperation, global resilience and sustainability, and standard of living.

International competitiveness

"With an ageing population and strong competition from emerging economies, Europe's future economic growth and job creation must come from innovation in products, services and business models including public sector innovation." - European Commission, 2014.

Europe is an excellent generator of knowledge. This is something the EU is rightly aiming to maintain. Europe's advantage lies in its marriage of diversity and cohesion, and in its governance and institutions, and in its willingness (most of the time) to invest. But much is required to maintain its position as a world leader in R&I: This goes above and beyond the money and includes better framework conditions and incentives for cooperation between industry and academia.

In the report 'Science, Research and Innovation Performance of the EU' (European Commission, 2016a), European Commissioner for Research, Science and Innovation Carlos Moedas says Europe faces "three major challenges." The first is the need to improve the translation of research into marketable innovations: innovations developed in Europe are often commercialised elsewhere. The second is that, despite a world-leading quantity of scientific output, Europe sometimes lags global rivals in the quality of science (Figure 3). The final challenge laid out is that Europe doesn't foster enough international science cooperation and science diplomacy: "Europe is a world leader in science, and this should translate into a leading voice in global debates".

EU research: Good in parts

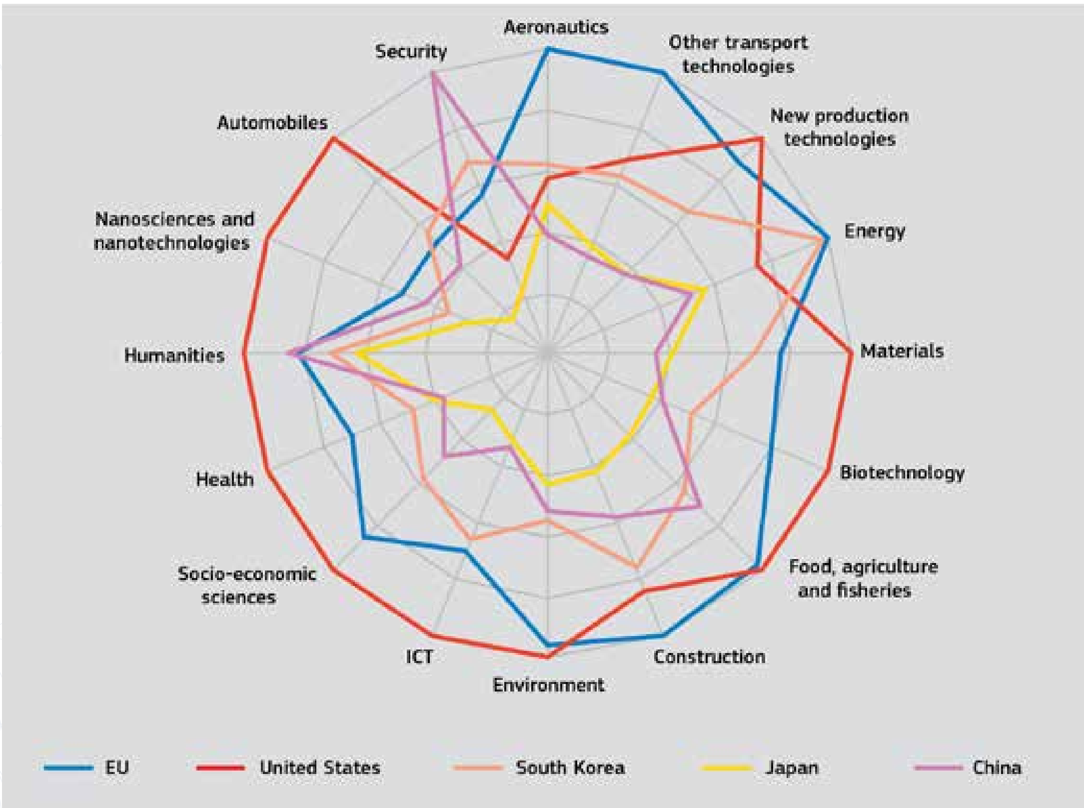
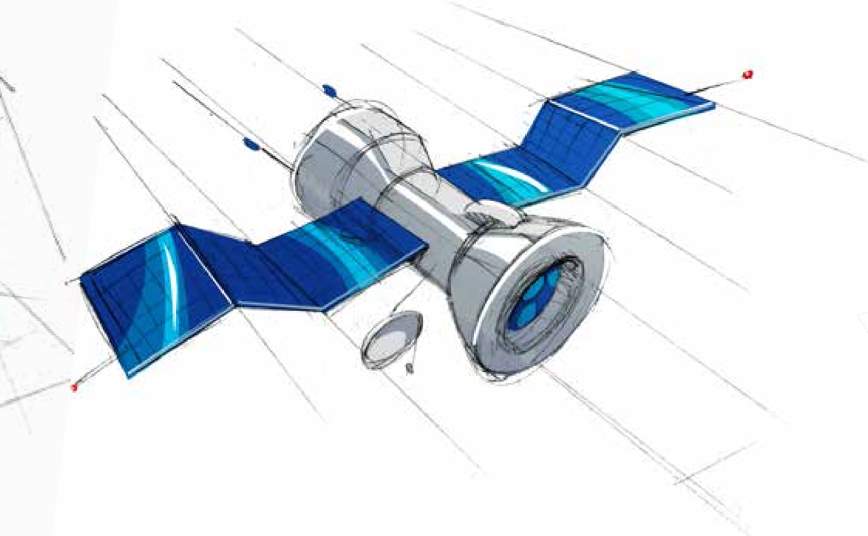


Figure 3. Highly cited scientific publications by sector, 2010.
Scientific publications within the 10 per cent most-cited scientific publications worldwide as a per cent of total scientific publications. Fractional counting method; scientific publication window 2010-2013.
Source: European Commission, 2016a; DG Research and Innovation – Unit for the Analysis and Monitoring of National Research Policies. Data: Science-Metrix (Canada), based on Scopus database.

So what does the EU do, anyway?

Examples of EU research and innovation projects that make a difference

Over 33 years of funding collaborative research, the European Commission has supported thousands of projects – both in its flagship Framework research programme, and in other areas. Here are just a few that capture our imagination. For more, see the Annex of this report.

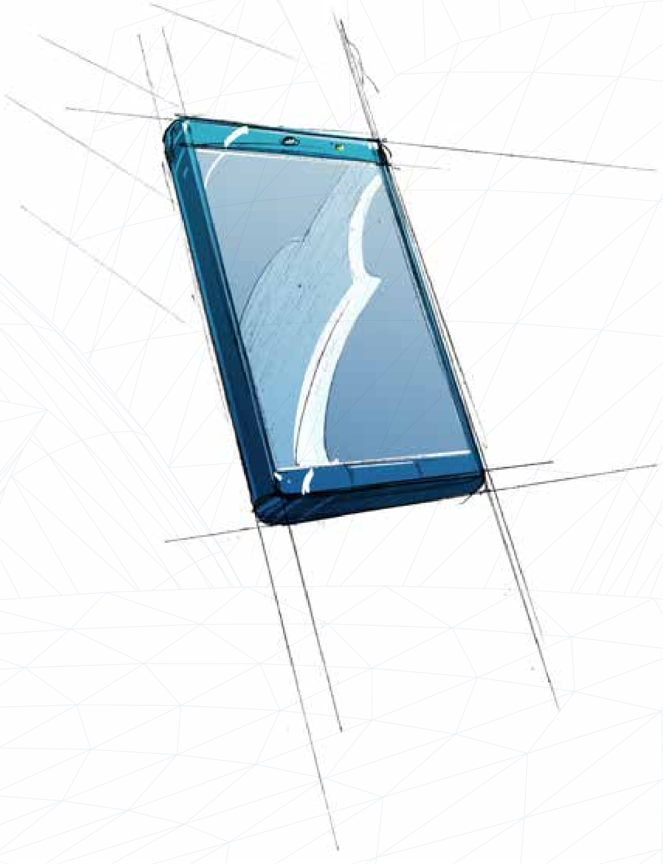


Eyes in the sky

Copernicus is the most ambitious earth observation project to date — with 30 satellites circling the earth, in a joint effort between the EU and the European Space Agency. It tracks crops to predict yield, monitors air pollution and climate, and watches ocean currents and ice floes to aid shipping – and all this data is provided free, to anyone, around the world. Copernicus data has been essential in confirming the risk of climate change, building pressure for the 2015 global climate agreement in Paris. Its data on air pollution are being used now to reduce the risk of 400,000 premature deaths a year in Europe. Next up: Monitoring nations' compliance with the Paris accord.

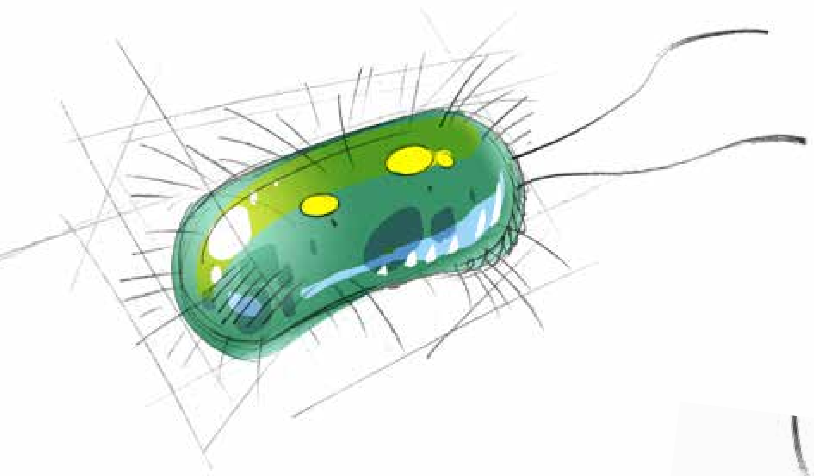
Hate mobile phones? Blame the EU

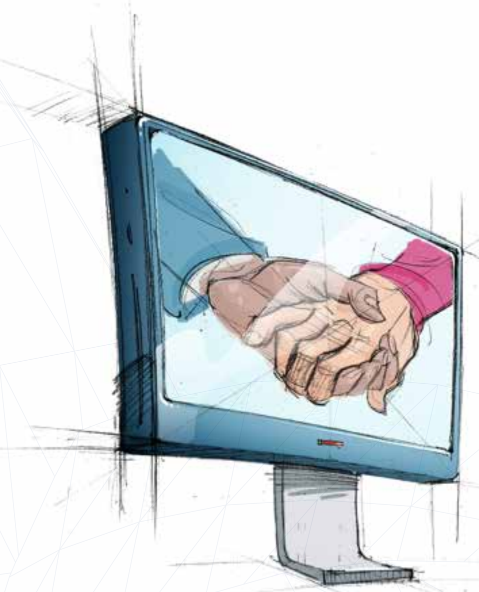
If there is one technology for which the EU can claim a lion's share of credit, it's the mobile phone. It started as a Nordic experiment in the 1970s, but by the 1980s the European Commission was pushing to make it an EU-wide network, and dragging the major ICT companies to the negotiating table to agree on technical standards. Though European companies no longer dominate the world market, the EU has continued to advance research on new mobile technologies. From 1990 to 2013, it funded 380 different research projects. Its long push to eliminate EU roaming charges just took effect. And next: Connecting machines as well people, with so-called 5G, or fifth-generation, networks linking billions of wireless sensors for the "Internet of Things."



Stopping "superbugs"

Since the discovery of penicillin 89 years ago, antibiotics have been a miracle success story. But now we use too many of them too carelessly – and the bugs have caught up, mutating to build resistance. A World Health Organisation official, Keiji Fukuda, recently warned that without action, "the world is headed for a post-antibiotic era, in which common infections and minor injuries which have been treatable for decades can once again kill." The EU has been a leader in generating knowledge and awareness. Its Innovative Medicines Initiative (IMI), for example, funds several research projects attempting to combat antimicrobial resistance.



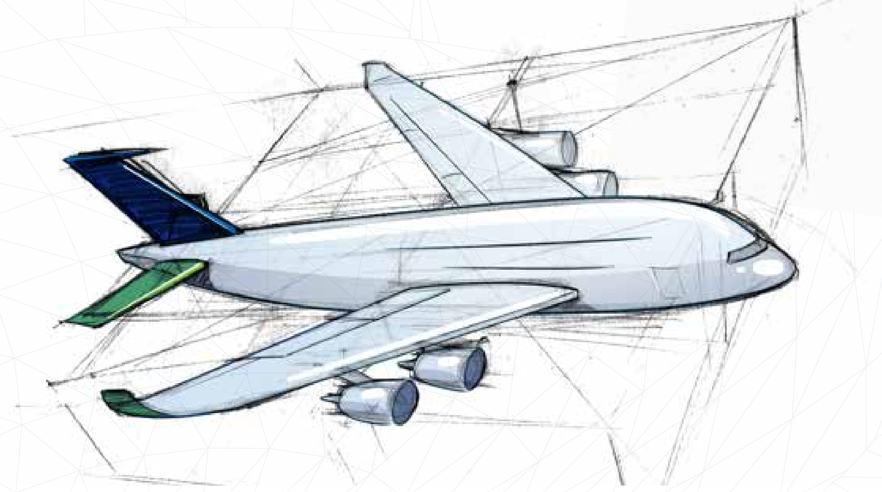


Check your e-mail, save the world

The EU also promotes social research. One such project, Charity Engine, lets people use the idle time on their personal computers to make money for charities. Here's how it works: You download the free software that connects your PC into a network of thousands of other volunteers – today, more than 550,000 and growing at 20,000 a week. The resultant "grid" of PCs is then used as a massive, distributed supercomputer to perform calculations for customers. Then the revenues are split three ways – a third to run the system, a third in prizes as an incentive to volunteer, and a third to charities such as CARE and Amnesty International.
The slogan: "Changing the world one bit at a time."
(www.charityengine.com)

The quiet, clean plane

Last year, people flew nearly 360 billion kilometres around the globe – in unpleasant tin cans that are noisy, polluting, uncomfortable and sometimes vulnerable to terrorist attack. So the EU is working on "nicer" planes. Its European Clean Sky project is developing technologies to cut by 2050 the CO_2 emissions of planes by 75 per cent, NOx pollution by 90 per cent, and noise by 65 per cent. The Diamonds project is working to protect transport networks from cyber attack. And in the hold, one project, Fly-Bag2, is developing bomb-proof cargo containers while another, AISHA II, is already deploying sensors in Lufthansa planes to detect any leakage of corrosive liquids in the cargo bay.



But beyond research, as Europe emerges from the economic crisis, it faces a fundamental labour productivity gap with the US of around 15 per cent (European Commission, 2017a; Figure 4). It is also losing ground economically to Asian countries such as South Korea and China (Figure 6). Part of the reason for this gap lies in the EU's specialisation in medium-high tech sectors such as automobiles and machine tools, rather than high-tech industries such as ICT which has a higher productivity (Figure 5). Closing this gap will require increased multifactor productivity (MFP), two key components of which are R&I and human capital (van Pottelsberghe de la Potterie and Guellec, 2001). But perhaps more importantly, Europe's commitments to the Sustainable Development Goals (SDGs) and the COP21 Paris agreement, as well as Europe's largely stagnant economy, require raising its productivity.

The lag in labour productivity

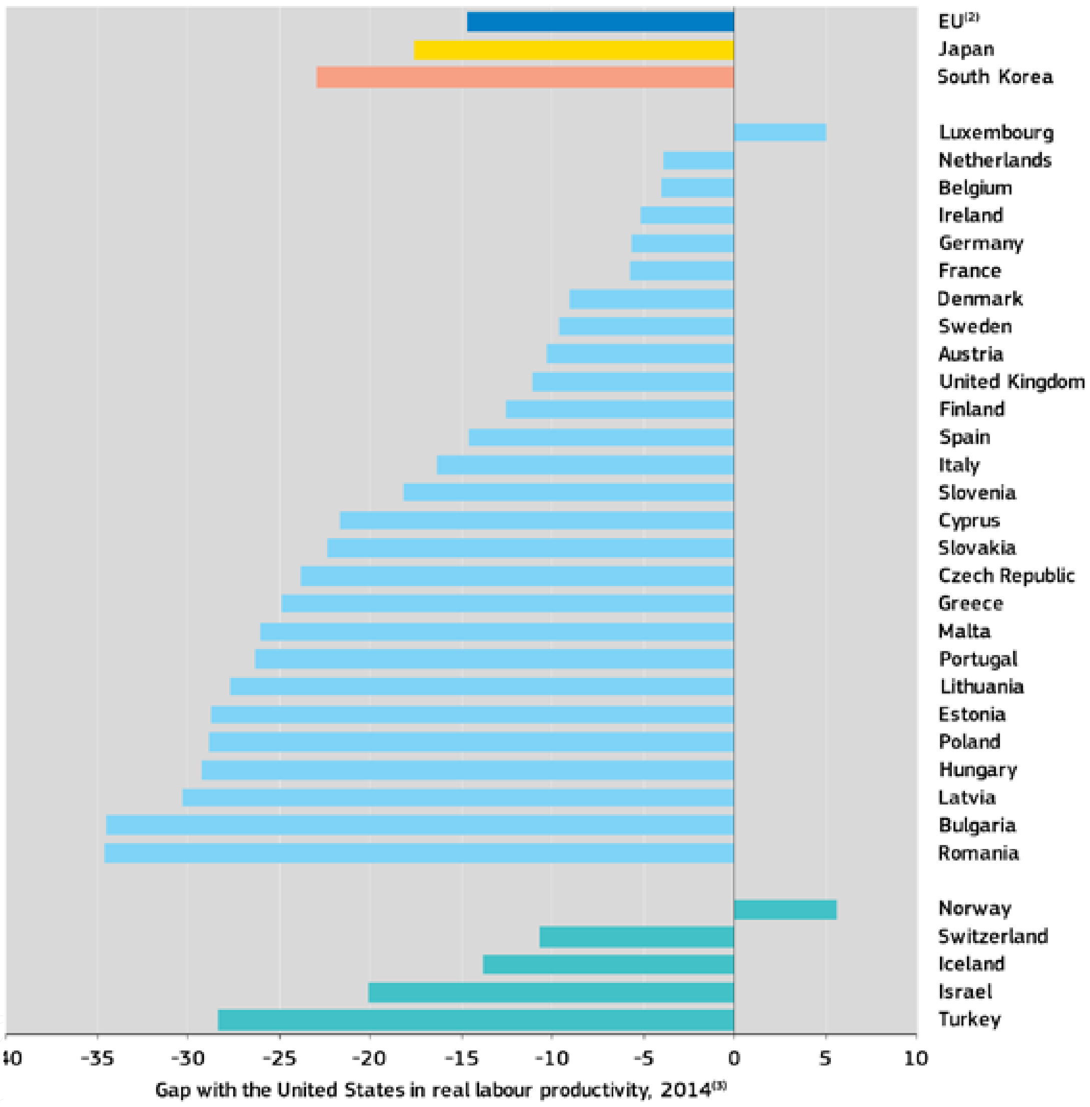


Figure 4: Difference between real labour productivities (GDP per hour worked) across select countries and the United States. GDP per hour worked in purchasing power parity of the euro at 2010 prices and exchange rates.
3IS, NO, CH, TR, IL, JP, KR: 2013 data.
Source: European Commission, 2016a; DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies. Data: Eurostat, DG Economic and Financial Affairs.

Are member states betting on the wrong horses?

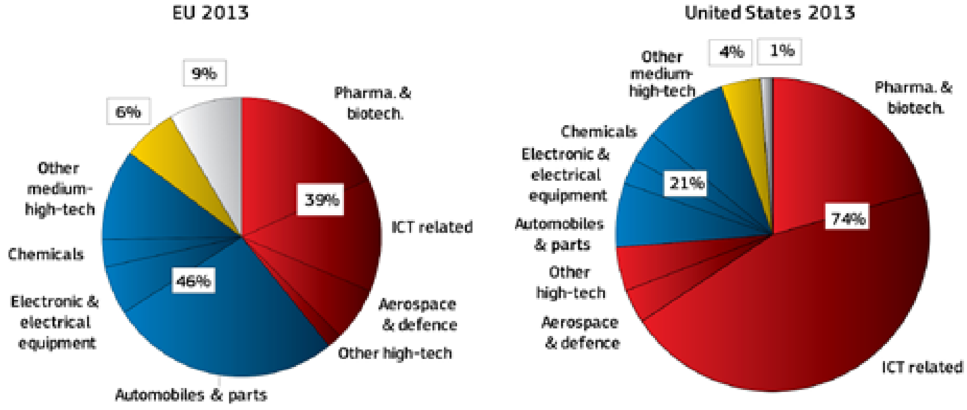


Figure 5. R&D-intensive sectors of the EU and US economies 2013.
Source: European Commission, 2016a; DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies. Data: EU Industrial R&D Scoreboard, 2014.

Yet, calls for more investment in R&I have come up against an inconvenient paradox in recent years: despite technological innovation, Europe's productivity has stagnated. This productivity paradox contradicts the literature outlined above. So what's going on? Several clues have been suggested. There may be a general failure to take up innovations, partly caused by the increasing complexity and pace of innovation which is prohibiting all but a few companies from reaping the benefits, and partly caused by the limited co-creation of innovations with users and civil society (European Commission 2017e). Macroeconomic policies which fail to pick up slack in the economy could have counterbalanced the positive effects of innovation on productivity. A fragmented single market with differing labour market rules and the limited availability of venture capital could also have limited the translation and spread of research into innovation (European Commission, 2017a).

GDP growth: the EU tortoise and the hares?

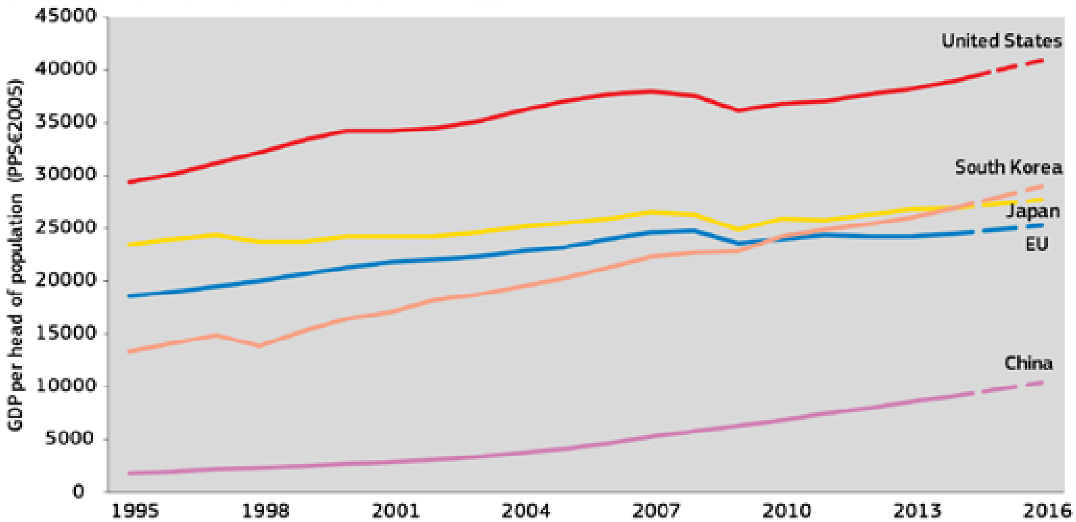


Figure 6. GDP per capita in real terms, 1995-2016.
Source: European Commission, 2016a; DG Research and Innovation - Unit for the Analysis and Monitoring of National Research Policies. Data: Eurostat, DG Economic and Financial Affairs Note: (1) PPS€ at 2005 prices and exchange rates.

To overcome these difficulties, the EU is making greater efforts to finance innovation and its internationalisation. This reflects a global trend amongst a number of its competitors (OECD, 2016). And proponents of R&I investment argue, a structural change towards a more knowledge-intensive economy in Europe is crucial for productivity growth and competitiveness, and for fostering high-quality jobs.

International cooperation

Big science projects—such as CERN, the Human Genome Project and the International Space Station—provide vivid demonstrations that mankind is able to achieve the most complex of things when it cooperates. And so to look at R&I solely through the prism of competition is to belittle this, especially when viewing a union founded on cooperation. But international competition is undeniable, and so compete the EU must.

In R&I, as in other areas, the EU has sought to sell cooperation as a means to boost competition, and competition as a means to sell further cooperation. In striking a balance between these two, the EU has developed its European Research Area (ERA), a common area for research. The ERA aims to align national research agendas to further both cooperation and the competitiveness of EU R&I. The ERA has strived to reduce duplication and generate critical mass in key research areas. It has also facilitated movement for researchers, improved labour standards, advanced gender equality and built networks between researchers and institutions. But there remains a persistent divide in R&I, with the newer member-states performing at lower levels. It is hoped that the collaborative relationships built through EU R&I funding can help to reduce this, but to date this has been slow to occur.

The ERA is designed, at least in part, to make the EU fit enough to cope with the increasingly rapid pace of change, combined with the size of the challenges it faces. Its success has attracted a growing list of non-EU associated countries. These 16 countries get equal access to parts of the Framework Programme, with financial contributions negotiated based on the size of their GDP.

In the ERA and beyond, international cooperation is useful in improving research excellence — benefiting all parties through shared access to world class research institutions, funding mechanisms, research and innovation networks, and markets. It generates critical mass in an era where research infrastructures are increasingly costly, aligning national R&I policy agendas to tackle common challenges which alone would be unsolvable. Cooperation outside of the ERA also supports the EU's external and development policies (science diplomacy) whilst increasing the attractiveness of Europe itself (European Commission, 2017a).

Nevertheless, when it comes to cooperation with non-EU countries that don't have associated country status, the EU is lagging behind. The Commission states that "only 11.7 per cent of Horizon 2020 grant agreements include one or more partners from outside the EU Member States (MS) and the Horizon 2020 Associated Countries (AC), compared to 20.5 per cent under FP7" (European Commission, 2016b). Whilst some of this may be down to countries shifting to associated country status, and wider geo-political changes, it is undoubtedly a worry. Of course, there are also concerns about the leakage of innovations or their intellectual property rights to non-EU partners, be it research institutes or companies. These are often addressed case by case, consortia by consortia, but they are a barrier to cooperation.

Global resilience and sustainability

"Although the chance of a disaster to planet Earth in a given year may be quite low, it adds up over time, and… we will not establish self-sustaining colonies in space for at least the next hundred years, so we have to be very careful in this period."

Stephen Hawking, 2016.

There are many moral arguments for R&I. One is our responsibility to the planet: climate change, resource management, biodiversity and the like. Europe has long been a leader in these fields of research. But, it's worth noting, there are also quite selfish reasons to remain so. For example, mobilising resources to tackle climate change early, and in an era of cheap capital, is easier and cheaper in the long run than waiting until drastic adaptation is required. Further, entering early into new markets can build market share (Green New Deal Group, 2013; Stern, 2007). Investments in climate adaption and clean tech can have advantages beyond the economic; for example, electric cars could reduce the burden of disease in cities, through a reduction in air pollution (Woodcock, et al., 2009).

Another moral responsibility is inter-generational. Our research today produces inventions and ideas that help our children and grandchildren even more than they do us. Another moral consideration, inter-societal responsibility, is a foundation of the European project. Whilst the cause of the Syrian conflict itself is undoubtedly complex, several observers have pointed to water shortages as sparking the civil war and subsequent asylum seeking (Gleick, 2014; Hammer, 2013). Such shortages are a very real threat, with the World Economic Forum (2017) consistently rating water shortages as a top-five global risk. International cooperation in R&I, it's argued, can help. For example, the EU's MADFORWATER project will be involved in developing wastewater treatment and efficient reuse in agriculture in North Africa. The new technologies developed will produce irrigation-quality water from municipal and industrial wastewaters, as well as from drainage canals.

Then there is our moral responsibility to one another, inside Europe. Income inequality is one of our most pressing problems. With returns from capital outstripping wage growth (Piketty and Ganser, 2014), R&I could play a key role in reducing inequality and improving social cohesion, resilience and sustainability. R&I can help in both understanding the drivers of inequality, and in redistributing human capital. That's just as well, as a more-populist theory would blame R&I for creating the inequality in the first place, as new technologies create new castes of wealth.

Standards of living

How long can you live?

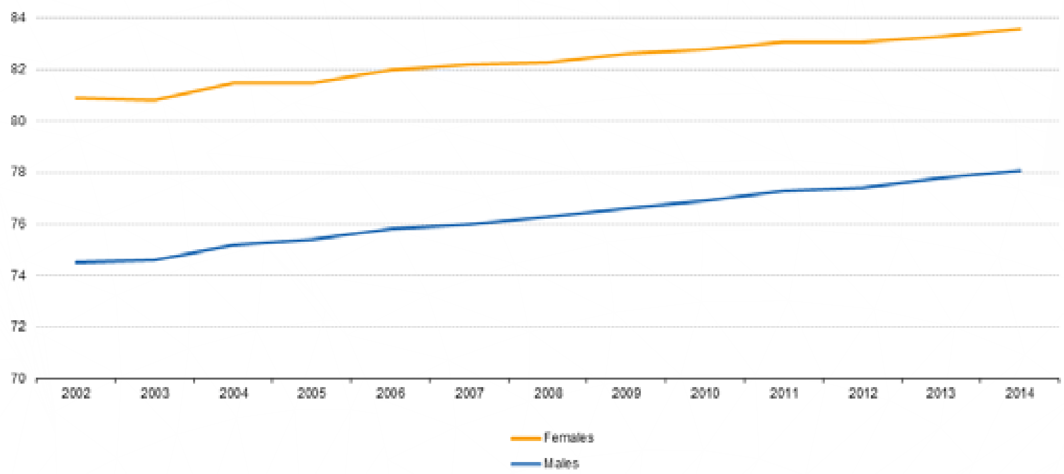
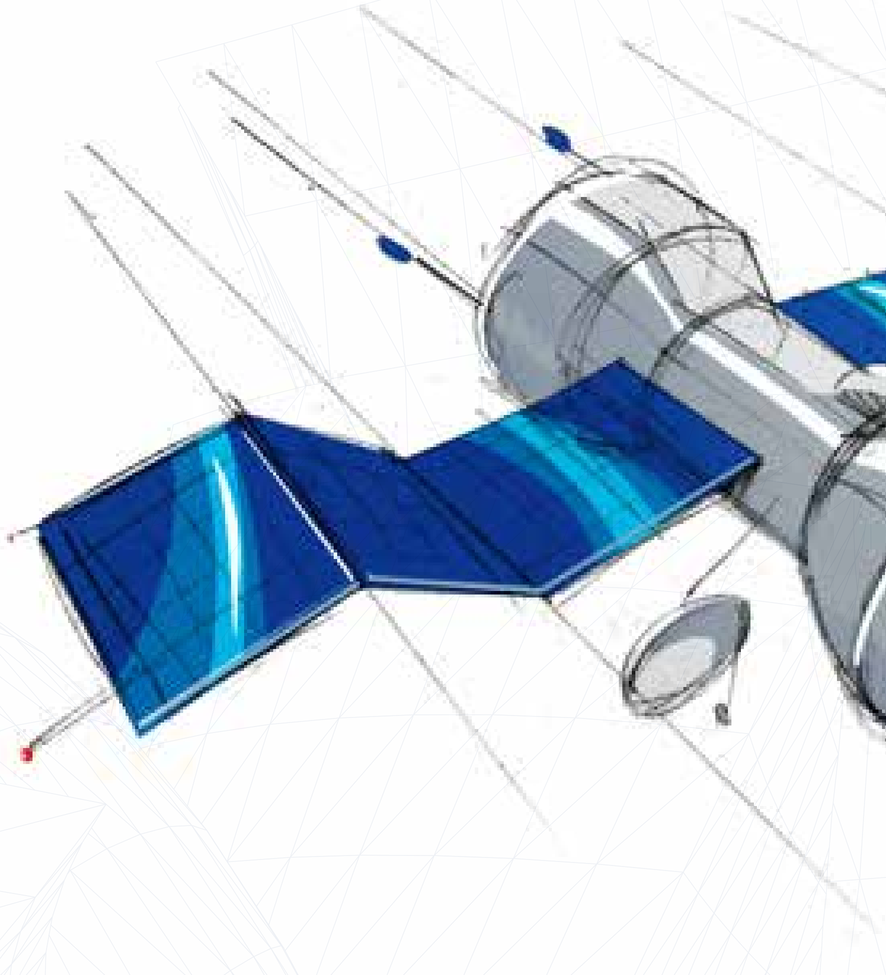


Figure 7. Life expectancy at birth, EU-28, 2002–14.
2009, 2011, 2012 and 2014: breaks in the series. Note: the y-axis is broken. 2013 and 2014 are provisional.
Source: Eurostat (data code: demo_mlexpec)

Last, but far from least, is the most obvious argument for R&I: It improves people's lives.

Consider life expectancy: It has been rising, across the EU and the rest of the world, since industrialisation, and continues to do so (Figure 7). There are many reasons – chief among them a historic reduction in hunger and disease. Both are down, in large measure, to R&I: the 'green revolution' that fed billions since World War II, the development of antibiotics and other medicines (up to about 70% of the increase in average life expectancies from 2000 to 2009 may be due to new medicines (Lichtenberg, F.R., 2014), and the rising volume of technology-enabled trade that helped poor nations raise their living standards. Of course life expectancy only captures some of the benefits, and as this report has stated and re-stated, many of the things relied upon in day-to-day life, from the use of mobile phones, to the quality of universal healthcare, have progressed through R&I — much of it public. Whilst many citizens fear the pace of innovation is moving too fast, there is in fact an urgent need for change and a real cost of not doing so - both of which are difficult to communicate (Edelman, 2017).

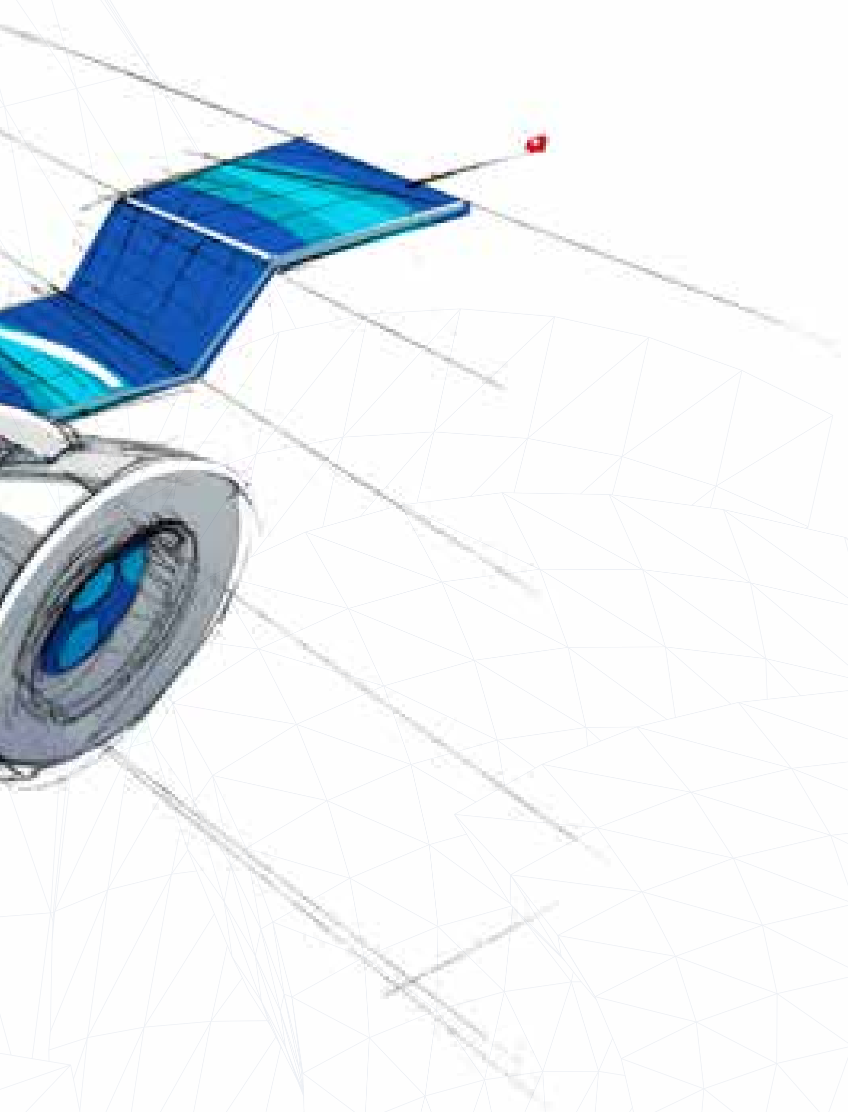


4. Conclusion

Research and innovation are more than tools to find the truth; they are tools to harness truth to serve society.

How much we invest is a political question. But as far as track records in investment go, our current standard of living serves as testament to its success so far. Its cross-sectoral nature also provides a buffer from diminishing returns on investment, with the oversubscription seen in applications to Horizon 2020 funding demonstrating the ample areas of opportunity for R&I investment. It also has a positive, reciprocal relationship across many sectors (Maradana, et al., 2017). Yet the opportunity cost of funnelling resources from other important sectors such as infrastructure spending, international aid and even agriculture is substantial.

So whilst R&I investment should not be undertaken lightly, and the economic and societal case must be compelling – we believe the research to date clearly demonstrates its value. Although some may see R&I as a luxury item, it is in fact the opposite — laying the foundation for the prosperity many of us enjoy today and the only hope for tackling the challenges we face, today and tomorrow.



Annex: Examples of EU-funded R&I projects

So what does the EU do with all that research money? Science|Business has compiled this teaser list. We thank our members for their suggestions (and note that, in some cases, we have opted to quote directly from project Web sites.)

Health

The **Innovative Medicines Initiative** (IMI) is Europe's largest public-private initiative in health, aiming to speed up the development of better and safer medicines for patients.

One of its activities is the IMI Ebola+ programme, which was launched in response to the Ebola virus disease (EVD) outbreak that started in western Africa in 2014. The comprehensive programme contributes to efforts to tackle a wide range of challenges in Ebola research, including vaccines development, clinical trials, storage and transport, as well as diagnostics and treatments.

When IMI's **EBODAC** project started in late 2014, Ebola had already killed over 8,000 people in just a few short months, most of them in the western African nations of Liberia, Guinea and Sierra Leone. With the outbreak continuing to devastate lives across the region, fear and anxiety were rife, and rumours spread rapidly through local communities. It was against this backdrop that IMI's EBODAC project successfully developed a community engagement strategy to enable a clinical trial of a promising new Ebola vaccine candidate.

EU funding for rare diseases: **The International Rare Diseases Research Consortium** (IRDIRC), launched with the European Commission and the US National Institutes of Health, has over 40 members from four continents. It is seeking to deliver 200 new therapies by 2020 for diseases which are often currently untreatable.

CureVac is pioneering the use of unmodified messenger RNA (mRNA) to instruct the human body to produce its own proteins capable of fighting a wide range of diseases. CureVac (now a >€1 billion "Unicorn") began with EU Framework Programme grants. Bill Gates, co-chair of the Bill & Melinda Gates Foundation, said: "If we can teach the body to create its own natural defenses, we can revolutionise the way we treat and prevent diseases. Technologies like mRNA give us confidence to place big bets for the future. We are pleased to partner with CureVac who has been pioneering this technology".

At present, bone replacement surgery involves transplants from other parts of the body, usually from the hip or shinbone. Other techniques involve using the ground bone from donors or even ground or heat-treated bone from cattle. The complexity of the surgery often increases the risk of complications. The **NewBone** project has invented a new porous ceramic material that can be inserted into the affected area as artificial scaffolding to allow the bone to repair itself, removing the need for transplants.

Anyone who has ever had a blood test knows that the process takes time. You go to the doctors, they take a blood sample which they send to the hospital where it is analysed for infection. A patient could be waiting days, or even weeks, before the results return. For someone in urgent need of a diagnosis, such delays can be quite serious. The **SPINIT instrument** can help prevent this. This instrument allows doctors to run quick blood tests at the point of care, which until now could only be done in hospital, speeding up diagnosis.

The European Innovation Partnership on Active and Healthy Ageing is a collaborative partnership with EU countries, regions, industry and professionals aiming to improve older people's healthy lives. Working together in six thematic Action Groups, the partners are committing themselves to find and implement innovative solutions that meet the needs of the ageing population. The ultimate aim is to increase the average healthy lifespan of EU citizens by 2 years by 2020.

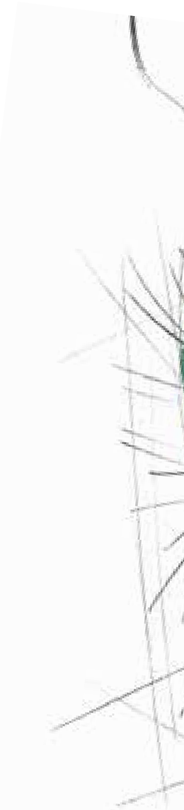
Construction

The **HINDCON** project aims to adapt 3D printing manufacturing technologies to the construction sector. Paving the way for printable constructions e.g. houses. It will develop and demonstrate a hybrid 3D printing machine to deliver an innovative technology to the construction industry that reduces environmental impact and economic costs.

Agriculture

REFRESH is an EU research project taking action against food waste. 26 partners from 12 European countries and China work towards the project's goal to contribute towards Sustainable Development Goal 12.3. This entails the halving of per capita food waste at the retail and consumer level and reducing food losses along production and supply chains, reducing waste management costs, and maximizing the value from un-avoidable food waste and packaging materials.

PRACE Research Infrastructure provides world-class high performance computing service for scientists and researchers from academia and industry in Europe. One example of a project using PRACE is CybeleTech, which seeks to compute the interaction between plant genetics and the environment in order to predict the best-performing breeds of crop.



Environment

The beginning of the conflict in Syria has been linked to water shortage. Such shortages are a very real threat, with the World Economic Forum consistently rating water shortages a top five global risk. The **MADFORWATER** project will be developing wastewater treatment and efficient reuse in agriculture in North Africa. The new technologies developed will be able to produce irrigation-quality water from municipal and industrial wastewaters, as well as from drainage canals. They will be adapted to the social and technical context of the three countries involved, decreasing exploitation of water reserves and water pollution.

Transport

The European Clean Sky initiatives are developing innovative, cutting-edge technologies aimed at reducing emissions and noise levels produced by aircraft. Its 2050 targets are to achieve a 75% cut in CO_2, a 90% reduction in NO_x and a 65% reduction in noise.

Everything from entire governments and cities through to individual cars and smartphones are increasingly connected and in continuous communication with each other - and us. This brings huge benefits, but also challenges and risks: these complex systems are vulnerable to attack, potentially endangering human lives and undermining entire business sectors.
The **DIAMONDS** project developed a new security testing paradigm and methodology, and successfully demonstrated and evaluated it in eight industrial settings and continues to influence international standards.

Similarly, Rapita Systems has developed a new tool, RapiTask, to test safety-critical software in aircraft, space vehicles and cars.

The FLY-BAG2 project has invented, developed and fully tested a 'bomb-proof bag'. This light but resistant bag limits the impact of an explosion on-board an airplane. The FLY-BAG2 consortium has patented and certified a series of products for airplane luggage holds and passenger cabins.

Similarly, in aircrafts, aqueous liquids arising from spillage, condensation or rainfall during boarding can result in heavy corrosion of structural parts. This is especially the case for the floor structures in the passenger cabin. A reliable sensor for detecting aqueous liquids helps to reduce repair and maintenance costs considerably, since the aircraft does not need to be fully dismantled. No on-board electronics are required and the signal detecting the presence of liquids is electrical resistance data that are easy to interpret. In the meantime, operational Boeing aircrafts of Lufthansa are equipped with the sensor networks.

Cyclists suffer a disproportionate share of serious injuries and fatalities, and indeed in recent years that disadvantage has been growing. At the same time, they often are not treated equally by traffic systems.

The **XCYCLE** Project will develop technologies aimed at improving the active and passive detection of cyclists, systems informing both drivers and cyclists of a hazard at junctions, effective methods of presenting information in vehicles, and control systems aimed at reducing collisions with cyclists.

Communication

The **5G public-private partnership** has been conducting research on the next (fifth) generation mobile phone networks. It is intended to secure European leadership in a field where there is potential for creating new markets in smart cities, e-health, intelligent transport, education or entertainment & media.

We now have the opportunity to access information directly from primary sources, through social media. A key problem, however, is that it takes a lot of effort to distinguish useful information from the 'noise' (e.g. useless or misleading information). **REVEAL** aims to provide (and integrate) tools for social media content mining and verification.

Content verification tools and metrics offered by REVEAL help address the problem of fake news online. REVEAL provided a variety of content verification tools which examine different modalities of a story. For example, the image forensics tools (e.g. the Image Verification Assistant) help spot manipulated content. Other modules (e.g. Truthnest) allow for the assessment of the reputation of the author or truthfulness of a particular post, thereby facilitating the discovery of "original" fake content, i.e. content that has been created "from scratch".

Energy

The European Strategic Energy Technology Plan (SET-Plan) aims to accelerate the development and deployment of the most impactful low-carbon technologies. It seeks to improve new technologies and bring down costs by coordinating national research efforts and helping to finance projects. One resultant project is ECCSEL which is building to a top quality European research infrastructure devoted to second and third generation carbon capture and storage technologies, enabling low to zero CO2 emissions from industry and power generation.

The **CarbFix** project aims to provide a complete carbon capture, transport and storage (CCS) solution at a single operating power-plant. Second, in contrast to most projects, CarbFix aims at storing carbon by accelerating the transformation of CO_2 into stable carbonate minerals (e.g. calcite) as rapidly as possible. Because calcite is stable over millions of years, once CO_2 is transformed into carbonate minerals, there is little need for further monitoring. One can 'walk away' from the storage site.

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A brief history of EU research and innovation policy

1950s: Provisions for research are included in the European Coal and Steel Community (ECSC, 1951) and European Atomic Energy Community (Euratom, 1957) treaties.

1957: The treaty setting up the European Economic Community (the EEC or 'common market') leads to a number of research programmes in areas considered priorities at the time, such as energy, the environment and biotechnology.

1983: The European strategic programme on research in information technology (Esprit) launches a series of integrated programmes in information technology research, as well as development projects and industrial technology transfer measures.

1984: The first 'framework programme (FP)' for research is launched. These programmes will become the EU's main funding instrument for research. FP1 focuses on research in biotechnology, telecommunications and industrial technology.

1986: Research becomes a formal Community policy, with a specific chapter in the Single European Act. The objective is to 'strengthen the scientific and technological basis of European industry and to encourage it to become more competitive at international level'.

2000: The EU agrees to work towards a European research area (ERA): a unified research area open to the world and based on the internal market, in which researchers, scientific knowledge and technology can circulate freely.

2007: The European Research Council (ERC) is created as part of the seventh framework programme (FP7). Its mission is the support of frontier research across all fields, on the basis of scientific excellence.

2008: The Budapest-based European Institute of Innovation and Technology is created: the first EU initiative to fully integrate all three sides of the 'knowledge triangle' (higher education, research and business) through support for knowledge and innovation communities. It becomes operational in 2010.

2010: The EU launches the Innovation Union, an initiative consisting of more than 30 action points aimed at improving conditions and access to finance for research and innovation in Europe. The Innovation Union is placed at the heart of the Europe 2020 Strategy to ensure that innovative ideas can be turned into products and services creating growth and jobs.

2014: Horizon 2020, the biggest EU research and innovation framework programme ever, is launched. A major financial instrument for implementing the innovation union, it will run from 2014 to 2020 with a budget of almost €80 billion (later reduced slightly). Horizon 2020 is part of the drive to create new growth and jobs in Europe.

Source: Directorate-General for Communication, 2014. Research and Innovation - Pushing boundaries and improving the quality of life. Brussels: European Commission. https://europa.eu/european-union/sites/europaeu/files/research_en.pdf (Accessed 24/04/2017)

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