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Value of Research

Policy Paper by the Research, Innovation, and Science Policy Experts (RISE)

Luke Georghiou
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Directorate-General for Research and Innovation
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Contents

1. INTRODUCTION 4
2. THERE ARE MULTIPLE PATHWAYS TO GENERATING VALUE 4
3. ECONOMIC BENEFITS OF RESEARCH REACH FAR BEYOND THE ORGANISATIONS THAT PERFORM IT 5
4. PUBLIC SUPPORT FOR THE RESEARCH AND INNOVATION ECOSYSTEM IS ESSENTIAL TO REALISATION OF ITS VALUE 5
5. RESEARCH IS BECOMING MORE PRODUCTIVE 6
6. HIGH RATES OF RETURN ON RESEARCH ARE SHOWN BY STUDIES OF INNOVATIONS 6
7. MACRO-ECONOMIC STUDIES CONFIRM THAT PUBLIC SECTOR RESEARCH HAS A SIGNIFICANT POSITIVE EFFECT ON PRODUCTIVITY 6
8. PUBLIC R&D INVESTMENT STIMULATES PRIVATE SECTOR R&D 7
9. NATIONAL, REGIONAL AND SECTORAL ASSESSMENTS OF IMPACT AND VALUE CONFIRM BROADER FINDINGS 7
10. EUROPEAN NEEDS TO PROVIDE THE FRAMEWORK CONDITIONS TO REALISE VALUE 9
11. CONCLUSIONS AND RECOMMENDATIONS 10

ANNEX 1. ESTIMATES OF THE IMPACT OF PUBLIC INVESTMENT IN RESEARCH 11

REFERENCES 13

INTRODUCTION

Research and innovation lie at the heart of Europe's economic strategy and make a critical contribution to the development of its society and cultures. They are a key source of new jobs, growth and competitiveness and underpin a wide range of policy priorities including digital Europe, energy efficiency and sustainability. The aim of this brief is to synthesise and summarise the overall evidence for investment in research in Europe and to indicate ways in which the return on this investment can be increased. The brief addresses the value of all forms of R&D including academic, government and business R&D but will focus on the role of public support. Our focus is on research as an investment and hence the economic dimension but we also address returns which materialise as social benefit in health, environment and other grand challenge areas. It is also important to acknowledge the value of research as consumption through its intrinsic value as a cultural good and symbol of human achievement.

In reviewing the evidence on the value of science a committee established by the Royal Netherlands Academy of Arts and Sciences concluded that conceptualisations of the value of research in general and econometric models in particular neglected the positive long effects of research and publicly funded R&D by analysing only short term budgetary effects. While it is undoubtedly true that some of the economically transformative effects of research take a considerable time to achieve their full economic weight (common examples cited are lasers and transistors), there are many pathways by which research knowledge drives value on much shorter timescales (Alexy and Slater, 2014; Haskel et al, 2014). In this brief we review those pathways and what is known about the value of research and draw conclusions on the implications for EU policy.

THERE ARE MULTIPLE PATHWAYS TO GENERATING VALUE

There are multiple ways in which research achieves impact and creates value (Salter and Martin, 2001). Common misunderstandings such as the linear or sequential model of innovation can lead to significant underestimation of the value of research. The public research base is engaged in a continuous process of knowledge exchange with users in business, the public sector and social organisations. Key pathways include:

1. *Increasing the stock of useful knowledge.* This is primarily achieved by publication but also operates through the creation of secured intellectual property. The codified knowledge secured in this way forms the basis for one channel of realising value, the commercialisation of research through licensing and creation of spin-out companies. However, formal commercialisation remains a relatively small part of the value created. As one indicator, while the number of patents produced by HEIs grew by a factor of five in the decade to 2006, they still accounted for less than 2.0% of EPO applications. The use of codified knowledge is widely thought to require substantial capacity in R&D to understand and apply it.

2. *Training skilled people*. This is a critical means for the transfer of knowledge from research to companies and other organisations that apply it. The benefits of developing human capital go well beyond formal education – those who perform research acquire substantial tacit knowledge of how to make innovations work in reality. Tacit knowledge by its nature can only be transferred through direct contact or mobility of people (Zellner, 2003).

3. *Creating new scientific instrumentation and methodologies* and collaborating with users in the use of such facilities or processes. Many key technologies used widely in the economy have their foundations in research instruments and the relationship continues over time as the demands of leading-edge research stretch requirements and lead to solutions. Celebrated examples include the origins of the World Wide Web at CERN and the spread of Nuclear Magnetic Resonance extended it from being a tool for analytical chemistry to form the basis of non-invasive medical diagnostic instruments.

4. *Collaborating in research projects and networks with users.* This leads to coproduction of knowledge and may address directly problems or challenges posed by users from both economic and social domains. An extensive review of academic engagement concluded that the increasing importance accorded to achieving societal impact when allocating or evaluating research funding meant that a much better understanding of the relationship between excellence and impact is needed (Perkmann et al, 2013).

Other approaches highlight processes which lead to changes in behaviours or organisational structures, development and delivery of services and supporting regulatory, standards or ethical frameworks.

ECONOMIC BENEFITS OF RESEARCH REACH FAR BEYOND THE ORGANISATIONS THAT PERFORM IT

Economic value can also be understood in terms of 'spillover' or externalities frameworks. The US economist Adam Jaffe distinguished three kinds of ways in which actors other than those performing research or owning its results may benefit:

- *Knowledge spillovers* - Knowledge created by one agent can be used by another without financial compensation, or with compensation less than the value of the knowledge. This can take place against the will of the originator, for example through reverse engineering or imitation, but it may also result from deliberate disclosure through publication or patenting. Open access and open data help to accelerate this process for publicly funded research.
- *Market spillovers* - Market forces cause buyers of new product or products made with new processes to get some of the benefit because not all of the product's superiority or price reduction is captured in price (also described as the consumer surplus).
- *Network spillovers* – These arise when the commercial or economic value of a new technology is dependent upon developments in related areas, for example communication systems. Firms may fail to coordinate their activities without intervention. This is particularly important when trying to establish a new standard or ecosystem, for example the Future Internet.

The existence of spillovers also places a focus on the importance of *absorptive capacity* – the ability of a firm to recognise, assimilate and apply new information. The originators of the concept, Cohen and Levinthal (1990), stress the importance of a firm performing R&D as the principal means of developing this capacity. This observation has important implications for flows of knowledge in the European Research Area. It also emphasises the need for high quality human capital as essential to having the capacity to absorb and make use of advanced knowledge. This is as true for a region as it is for an individual organisation.

PUBLIC SUPPORT FOR THE RESEARCH AND INNOVATION ECOSYSTEM IS ESSENTIAL TO REALISATION OF ITS VALUE

These arguments help to underpin the core rationale for public support for R&D, that the social rate of return exceeds the private rate of return. In consequence, without government intervention, market and system failures would mean that valuable research would not be performed by companies. Asymmetric information and uncertainty underpin the reluctance to invest. Systemic perspectives also recognise the problem of 'bounded vision' (Fransman, 1990,3) whereby firms focus on their existing businesses and knowledge bases and have difficulty in recognising or reacting to technologies which fall outside but which may be disruptive to their business. External linkages with universities and others mitigate this risk.

More broadly innovation is today recognised as taking place within an 'ecosystem', an extension of the earlier concept of 'systems of innovation' (Soete et al, 2010, Coombs and Georghiou, 2001). This perspective has wide implications for the institutional and regulatory environment in which research and innovation take place but also stresses:

- the need for public research to overcome 'lock-ins' to existing solutions;
- the importance of coordinated approaches, particularly towards societal challenges and complex systems; and
- the importance of infrastructures and the value of foresight as a means of countering bounded vision.

RESEARCH IS BECOMING MORE PRODUCTIVE

An important driver of increasing rates of return on research is the increasing productivity of the research system. This can be assessed in a macro-sense by comparing numbers of scientific articles per unit of GERD in the EU27. In the period 2008-12, articles/GERD grew at 2.02% pa. Moving to a more quality-oriented indicator, citations/GERD, the annual growth rate from 2004-2008 to 2008-2012 is 3.19%[1]. Productivity in research is also evidenced at the micro-level. For example the productivity of DNA sequencing technologies has increased more than 500-fold (1997-2007) 5 and continues to increase.[2] The opportunity to carry out experiments *in silico* via simulation, and to take advantage of big data are further emphasising this trend. These productivity gains also highlight the importance of investing in research infrastructures.

HIGH RATES OF RETURN ON RESEARCH ARE SHOWN BY STUDIES OF INNOVATIONS

Numerous studies have addressed the rate of return on public investment in research by tracing the linkages between research and innovations in the market across a variety of industries (see Annex 1). The methodologies individually raise some questions but the strong consensus is that the rate of return is high. According to most studies, the overall value generated by public research is between three and eight times the initial investment over the entire life cycle of the effects. When calculated in terms of annual rates of return, the median values are in the range between 20% and 50%. Other studies have investigated the proportion of innovations which could not have been introduced without the contribution of public research and again have found a high share, typically between 20% and 75%.

It should be noted that rates of return vary considerably between industries, between types of innovations, and by type of sponsor.

MACRO-ECONOMIC STUDIES CONFIRM THAT PUBLIC SECTOR RESEARCH HAS A SIGNIFICANT POSITIVE EFFECT ON PRODUCTIVITY

A well-known study estimated of the contribution of technical change to Multifactor Productivity (MFP) growth in major OECD countries over the 1980-98 period (Guellec and van Pottelsberghe de la Potterie, 2001). The study found a long-term elasticity of MFP with respect to business R&D was 13%, a result consistent with other studies, and that this had been increasing over time. In a finding of potential significance for the EU, the impact of cross-border spillovers is higher for smaller countries than for larger ones, reflecting the higher shares of international co-publication and co-patenting of smaller nations. To achieve such a benefit, though, the smaller country needs to be more R&D intensive and more specialised. The greater the effectiveness of the ERA, the more such effects are mitigated.

Concerning the contribution of public research, the study found that the long-term elasticity of government and university-performed research on productivity is around 17%. Within that, the effect of universities was higher, possibly because government laboratories often have non-economic objectives such as supporting defence. Haskel and Wallis (2103) confirm these findings with a robust correlation between UK public-sector financed R&D disbursed via research councils and market sector total factor productivity growth.

Recent work by Bart Verspagen with the CPB Netherlands Bureau for Economic Policy analysis set out to estimate the rate of return (or elasticity) of public R&D through a broad survey of the topic by estimating a range of available models a broad sample of countries, using data going back into time (1963)and applying different definitions of public R&D (funded or performed?). It concluded that estimating the rate of return to public R&D by macro-econometric models is a heroic task and that this can be completed only if heterogeneity of those rates of return between countries is accounted for and explicitly modelled. With the preferred specification used in the study the results suggest scale effects in public R&D itself, i.e., countries that are public R&D-intensive tend to have higher rates of return.

[1] International Comparative Performance of the UK Research Base – 2013, A report prepared by Elsevier for the UK's Department of Business, Innovation and Skills (BIS) Page 82
[2] Genome Synthesis and Design Futures; Implications for the US Economy, BioEconomic Research Associates, 2007

RISE believes that it is a matter of concern that econometric models used to support economic policy at both national and EU level do not take appropriate account of the positive effects of R&D on growth and employment. A review by JRC (Di Comite and Kancs, 2015) of four models used by the European Commission concluded:

> *"While being very useful tools for the ex-post evaluation of R&D effects, econometric models cannot be employed for ex-ante impact assessment of innovation policies. Instead, macroeconomic models need to be used for simulation of R&D and innovation policies, and comparing the results to the baseline (without policy)."*

Following the Commission Communication "R&I as sources of renewed growth", RISE notes that DG R&I is building up better decision making tools, including tools that can properly measure and forecast the full impacts of R&I policies and reforms. DG RTD is building up its macro-economic modelling capacity. It is aiming in 2015 to explore ways to update and improve the existing parameters of macroeconomic models, such as QUEST III, and to propose new parameters to take into account R&D reforms. In addition, in 2017-2018, further work will be carried out to calculate and measure new parameters that can take better account of R&D investments and reforms that can enhance the results of these investments.

PUBLIC R&D INVESTMENT STIMULATES PRIVATE SECTOR R&D

Studies confirm the complementarity between public and private R&D. Jeaumotte and Pain (2005a, 2005b) analyse 20 OECD countries over a 20 year period to 2001 and find clear complementarity between public sector R&D and business sector R&D, with public sector R&D influencing business R&D at the level of the economy as well as being reflected in patenting. They consider that this more than offsets any negative effect from public sector R&D pushing up labour costs in the business sector. Specifically they find that: "an increase of one standard deviation in the share of non-business R&D in GDP (an increase of 0.06 percentage points for the average economy) raises business sector R&D by over 7% and total patenting by close to 4%." (Jeaumotte and Pain, 2005b, p.38). This finding emphasises the importance of public sector investment in gearing the EU 3% target for R&D/GDP. In a recent ERAC peer review of the Spanish research and innovation system (Georghiou et al, 2014) a clear investment path was recommended with a phased increase in public investment being used in tandem with reforms to initiate a growth path for business R&D spend.

Another dimension of complementarity between investment in research and private sector R&D arises from the attraction it exerts for internationally mobile R&D, a 'crowding-in" effect. Factors such as the prospect of high quality collaborators, recruitment opportunities and technology transfer infrastructure feature variously in such studies. It should be noted that locational decisions also give considerable weight to other factors such as proximity to markets. From an EU perspective the overall message is that a high quality research base will attract international R&D (and the same factors will encourage European companies to retain and expand their R&D investments). However, this will also create an incentive for relocation within the EU and emphasises the need for countries and regions to support R&D to maintain their presence in key sectors.

NATIONAL, REGIONAL AND SECTORAL ASSESSMENTS OF IMPACT AND VALUE CONFIRM BROADER FINDINGS

The value of research has been explored in several ways at the national level. Two studies already mentioned are the Netherlands Academy review of Value of Science (Soete et al) and the UK report on the Economic Significance of the Science base (Haskell et al). As well as reviewing evidence, the latter presents a regression analysis of the impact of public R&D on sectoral TFP. A cautious conclusion is that the rate of return on public spending on R&D is 20% and that in turn this would lever further private R&D. Obtaining this benefit is crucially dependent on cooperation of the university sector with industry and derives from increasing the usable knowledge stock for industry and the absorptive capacity of industry.

In Sweden, a study on the relationships between publicly funded research and economic growth (Broström and Lööf, 2008) sought to draw lessons for national policy from a review of the relationship between publicly funded research and economic growth. They confirmed many of the findings listed here and concluded that R & D personnel and human capital constituted the most important single factor.

In recent years the main approach in the US has been Star Metrics, a federal and research institution collaboration to create a repository of data and tools that will be useful to assess the impact of federal R&D investments. Initial efforts focussed on developing uniform, auditable and standardized measures of the impact of science spending on job creation, using data from research institutions' existing database records. A second level is developing "an open and automated data infrastructure that will enable the documentation and analysis of a subset of the inputs, outputs, and outcomes resulting from federal investments in science". StarMetrics has a particular role in reporting on the effects of the American Recovery and Reinvestment Act. Progress has been mainly methodological to date but lessons can be taken about the need to build an infrastructure for consistent data collection.

In the United Kingdom the largest effort to measure the value of research recently took place as a part of the Research Excellence Framework, the evaluation of research performance which drives the allocation of block funding for research in universities. For the first time impact of research was included as a separate criterion and allocated a 20% weighting in the final profile awarded to each Unit of Assessment (subject area) at each university. The approach taken was to require case studies in a specified format to be submitted for review and rating by a mixed panel of academics and users. The requirement was two case studies for the first 15 researchers submitted and one more for every further ten plus an 'impact template' which described out the structures and processes for supporting and enabling impact from research conducted within the unit. The criteria applied were reach and significance. A high standard of evidence was generally applied, with data needing to be sourced and claims corroborated by beneficiaries. The REF approach was useful in eliciting a clearer understanding of what is meant by impact of research and hence its value. A strict criterion was that the impact had to result from research above a quality threshold as represented by specified outputs or peer reviewed grants (for example excluding consultancy activities which had not advanced knowledge). The research in scope could be from 1993 but the impact had to take place in a window from 2008 – 2013. A series of studies have followed or are in progress carrying out meta-analyses on the 6,975 case studies (eg Technopolis, 2015) and are being used by funding bodies to support their cases for government finance. Impact was not restricted to the economy, although economically-oriented cases are more likely to be used in the advocacy referred to above. The formal definition of impact was:

"an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia"

Panels sought to elucidate this definition and reflect in for the disciplines covered. Hence the panel responsible for social sciences and related disciplines identified the following areas:

- Impacts on creativity, culture and society
- Economic, commercial, organisational impacts
- Impacts on the environment
- Health and welfare impacts
- Impacts on practitioners and professional services
- Impacts on public policy, law and services

As with all areas of research this list demonstrates the impact of research is also upon societal challenges and the development of culture. Box 1 shows the types of impact that social sciences might have in the economic category indicated above.

Box 1 Categories of economic impact for social sciences

- Changed approach to management of resources has resulted in improved service delivery
- Development of new or improved materials, products or processes
- Improved support for the development of 'small scale' technologies
- Improved effectiveness of workplace practices
- Improvements in legal frameworks, regulatory environment or governance of business entities
- Better access to finance opportunities
- Contribution to improved social, cultural and environmental sustainability

- Enhanced corporate social responsibility policies
- More effective dispute resolution
- Understanding, developing and adopting alternative economic models (such as fair trade)

Source: Main Panel C Guidelines UK Research Excellence Framework

This list is useful in emphasising that economic benefits flow from the whole range of research not only from physical sciences, engineering or biomedical research. Similar arguments can be made (and were demonstrated) for arts and humanities research.

Another approach to assessing the value of research is at institutional level. Universities UK commissioned an economic analysis of the impact of universities on the UK economy (Kelly et al, 2014). The approach was to treat universities as a conventional industry and to assess a series of their economic characteristics sources of revenue, employment created, output generated and export earnings attracted. Modelled estimates were made of the economic activity generated in other sectors of the economy through multiplier effects of expenditure by universities and their staff, international students and visitors. Additional analyses addressed the overall contribution of the sector to GDP. At the core of the methodology was a 'type II' input-output model based on data derived from the UK Office for National Statistics' input-output tables. The context is that less than half of revenue came from public sources. While research was not separated out in the study it accounted for 16% of revenue and this it could have attributed to it a comparable share of the headline effects – that direct and secondary or multiplier effects caused the sector to generate over £73.11 billion of output and 757,268 full-time equivalent (FTE) jobs throughout the economy. The total employment generated was equivalent to around 2.7% of all UK employment in 2011. The figures did not include the effects of knowledge generated on innovation as discussed in this document. Many individual institutions in Europe and North America have carried out studies using similar methodologies.

EUROPEAN NEEDS TO PROVIDE THE FRAMEWORK CONDITIONS TO REALISE VALUE

All 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. It is apparent that such conditions do not occur equally across Europe and that as a result the ability to benefit from the value of research is also highly differentiated. A formalisation of that disparity can be found in the Innovation Scoreboard.

This puts the focus on identifying the necessary framework conditions needed to realise value. There has been a growing realisation within the ERA that increased R&D expenditure may be a necessary condition to drive forward knowledge based economies but it is by no means a sufficient condition. Parallel actions are needed on key aspects such as breaking down institutional and legal barriers to intersectoral mobility (for example civil service regulations) and in addressing core deficiencies in industrial characteristics such as a lack of large firms engagement in ecosystem roles or insufficient highly qualified personnel in SMEs to enable better absorptive capacity.

In terms of policy implications this suggests that recent moves towards better coordination across research, innovation and economic policy need to be further strengthened. The conditionality terms attached to European Structural and Investment Funds have been a positive step in this direction but need continuing reinforcement.

CONCLUSIONS AND RECOMMENDATIONS

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. Rates of return are of the order of 20-50% and there are few innovations that do not have at least a proportion of their realisation rooted in publicly funded research. Economic evidence also indicates that public sector R&D does not crowd out private investment but rather is complementary and a driver of business investment.

In these circumstances it is at first sight difficult to explain why resources for research have been constrained or even cut back as a consequence of austerity. The answer almost certainly lies in two beliefs among policymakers:

- The benefits of research are perceived to be long term and hence expenditure here is less likely to have effects on jobs and growth in the current political cycle; and
- While global benefits of R&D are not disputed these accrue to the leading performers and are not of the same order for followers, thus reducing the argument for investment.

Each of these suppositions can be countered. To the first, there is ample evidence that the benefits of research go well beyond the radical paradigm-setting innovations that define long-term economic cycles. They come from the daily interactions of researchers with current business and societal challenges, from the trained people and tacit knowledge that engaging in these produces and from the ground they prepare for absorption and adaptation to disruptive innovations. To those who believe that their economies or regions are excluded from the benefits of research the riposte also lies principally in the concept of absorptive capacity. There is no sector that can survive in the long run without innovation and access to new knowledge. Performing research is the most effective way to ensure that local economies can stay in touch. The more peripheral is the region the stronger is this imperative. The argument is both for institutions which can act as a window on the world and for training that can populate firms and other actors with these capabilities. The neglected concept of adaptive R&D is also relevant here and can also be a pathway to joining the general advancement of the sector.

The consequences of undervaluing research in budget allocation decisions are similar in the micro environment of the firm and the macro environment of national accounts. In both cases a short-term improvement in performance indicators (earnings per share or deficit reduction) is at the cost of long term reduction in the capacity to remain in the market.

As noted in the previous section the conditions to drive value from research do not necessarily lie within decisions made about the direction of research funding. Here a balance is needed between investigator-driven research from which breakthrough ideas may emerge and strategic applied research which allows large scale coordinated efforts to be applied to economic and societal challenges. The real issue may lie in the framework conditions for innovation in which R&D capacity is just one factor – extending to regulation and deregulation, fiscal policy, investment capacity including venture capital, education and training, public procurement and the European Single Market. These require coordination at European, Members State and regional levels.

Despite the findings which have been referred to in this review, there is still insufficient evidence on the value of research. Many of the studies referred to are carried out in one, or a few, countries and many originate from the USA. Some of the classic studies are now some decades old and require revisiting in the 21st century environment. On the positive side data are now far more powerful and the opening of innovation also creates opportunities for observation and measurement. The need is both for methodological development and systematic collection of information to reinforce what is known about the value of research and how to increase it across the variety of situations found in Europe.

Finally, to reiterate once more, the value of research is not only economic. There is a direct contribution to societal challenges (which itself requires better measurement through understanding impacts on human behaviour in general and on policy in particular). Beyond that research is a part of the culture of Europe and should be valued for its role in creating a critical and reflexive society.

Annex 1. Estimates of the impact of public investment in research

Source	Overall economic value	Share of innovations that would not have been possible without public research	Annual rate of return of public research	Notes
Dalton and Guei (2003)	Many times the initial investment			Return of research on new genetic varieties of rice
Grant et al. (2000) Hanney et al. (2003; 2004) Buxton et al. (2004)	4 categories of positive economic impact			Studies on the impact of basic biomedical research on health and clinical outcomes
Lasker Foundation (2000) Access Economics (2003) Murphy (2003) Murphy and Topel (2003)	300-800% of initial investment			Survey of several studies on the impact of biomedical research in the USA
Silverstein (2005)	300% of initial investment in cost savings for health			Impact of biomedical research in USA
Johnston et al. (2006)	More than 45 times the initial investment over 10 years			Clinical trials carried out by the National Institute of Health in the USA
Access Economics (2008)	217% of investment			Estimate of the impact of biomedical research in Australia
Tjissen (2002)		20%		More than 20% of industrial innovations depend on public research
McMillan and Hamilton (2002)		75% (patents)		75% of patents cited in patent citations come from public research
Grant et al. (2003)		2-21%		Study of five important clinical innovations
Arundel et al. (1995)		High		Large European firms make intense use of scientific publications
Narin et al. (1997)		High		Increase in the share of citations to scientific

				papers in US patents
Office of Technology Assessment (1986)			20-50%	Survey of studies in the previous 30 years.
Griliches (1986; 1995)				Rate of return higher in basic research
Mansfield (1991; 1995; 1998)			28%	Survey on the impact of public research on innovation in the USA
Beise e Stahl (2002)				Confirmation of results from Mansfield in Germany
Toole (1999)			12-41%	+ 1% stock of public research in the biomedical sector produces + 2.1- 2.4 % new commercial principles
HERG- OHE- Rand (2008)			37-39%	Estimate of the impact of biomedical research in the biomedical sector in mental health and cardiovascula diseases in UK on reducton of mortality/morbility and on GDP
ISFRI (2000)			100% (mean) 48% (median)	Survey of 292 studies on agricultural research, one third of which published in peer-reviewed journals

Source: compiled by A. Bonaccorsi from Martin and Tang (2007); Access Economics (2008); HERG-OHE-Rand (2008); Jones and Williams (1997); Hall, Mairesse and Mohnen (2009); ISFRI (2000)

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This paper summarises the evidence for investment in research in Europe. The continuous exchange of knowledge between the public research base and users takes place via multiple pathways. Spill-overs ensure that the benefits of research reach far beyond the organisations that perform it. Absorptive capacity is key to gaining from these. Public support helps to overcome market and system failures and nurtures innovation ecosystems. Numerous studies of innovations, using different methodologies, show high rates of return on research. Macro-economic studies confirm that public sector research investment has significant positive effects on productivity and that it stimulates private sector R&D. National, regional and sectoral assessments of impact and value confirm these broader findings. It is concluded that Europe needs to provide the framework conditions to realise value including reinforcing recent moves to coordinate research, innovation and economic policy. Underinvestment in research may be founded on misperceptions of the timings of benefits and of who benefits. Benefits are immediate as well as longer term. Performing research is necessary for all regions in order to foster the capacity to absorb the knowledge needed for innovation. Research also has value through its contribution to societal challenges and as part of Europe’s culture.

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