



Forward Together

Complementarity of public and charitable research
with respect to private research spending September 2009



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Foreword



Over recent years the case for government and charitable medical research funding has strengthened. Yet some areas, like dementia research, remain severely underfunded.

At a time when public finances are under immense pressure, calls for an increase in dementia - and other kinds of medical research - funding are sometimes met with critical questions like “why should taxpayers’ money be squandered by scientists?” and “can’t the private sector do it?” This report provides an answer.

Government and charitable spending on medical research, as this OHE analysis shows, actually encourages, rather than squeezes out, private investment in medical research. This effect is particularly acute when investment is directed at basic science, as with most dementia research in the UK. One US study analysed in the report suggests a £1 investment in basic research leads to £8.38 of further investment over eight years.

But we may be missing out on these economic - not to mention medical - benefits. In April 2009, the government conceded that “both UK-based businesses and the Government itself continue to invest less in R&D as a percentage of GDP than other comparator economies.” Moreover, in November 2008, the Prime Minister admitted to the Alzheimer’s Research Trust that dementia research has been “neglected for too long”.

Basic research may be riskier, and ostensibly less likely to produce quick pay-offs than some clinical trials. Yet basic science is precisely what we need if we are to develop new treatments for this currently incurable condition that afflicts 700,000 people in the UK.

Basic, translational and clinical research into dementia must receive much more support if we are to defeat dementia once and for all.

Professor Julie Williams

Chief Scientific Adviser, Alzheimer’s Research Trust



This absorbing study highlights the potential merit of research charities, public funders and private R&D organisations working more closely together. Charities and their public and private sector colleagues should talk early and often to identify those areas of science where their respective funding has the potential to drive forward research of patient benefit. Government and policy-makers should also take heed. Given the complementary nature of research funding, sector specific policies could have adverse knock-on effects for other partners. It is therefore vital that they keep the bigger and longer-term picture in mind at all times.

Simon Denegri

Chief Executive, Association of Medical Research Charities

1 Summary and Key Points

- There is an ongoing debate as to whether public and charitable funded research replaces private (commercial) research that would otherwise have taken place or stimulates additional private research to take place or does neither. This debate is not exclusive to the biomedical sector; indeed since April 2009 grant applications to all UK research councils are required to set out the economic impact of the proposed research. But given the extent of public and charitable biomedical research, the debate in this sector is even more intense.

- The literature looking at whether public and charitable research substitutes private research or complements it (i.e. not specific to the biomedical sector) tends to support the result that public research is complementary to private sector research and development (R&D) activity. That is, public and charitable research stimulates additional private R&D that would otherwise not have been carried out.

- There are certain characteristics of R&D for health care technologies, including high uncertainty, high risks of failure and high R&D costs, that reinforce the complementarity argument between publicly/charitable funded medical and private investment on R&D in the pharmaceutical and biotech sectors.

- The literature highlights a number of mechanisms facilitating the transmission of knowledge from the public to the private sector, including universities (taken to represent publicly funded research), networking and social interactions and 'absorptive capacity' (the possibility for firms to assimilate and exploit existing information to create new knowledge). These different channels through which public research can affect (positively) industrial R&D are even more important in the biomedical sector than in other sectors.





- For the biomedical sector estimates of the size of this stimulus in practice are based on two US studies. They demonstrate that public medical research is complementary to private pharmaceutical R&D investment. The studies imply that a £1 increase in extra public medical research can lead to an increase in private pharmaceutical industry R&D spending in the range of £2.20-£5.10.

- One of the studies measured separately the impact of public basic and public clinical research and found differences both in the duration of the effect and its magnitude. Changes in private pharmaceutical R&D investment follow a ‘U-shaped’ pattern of response as a result of public basic research. Firms will react quickly to new information generated from public basic medical research, then hold their level of investment constant for a period before increasing it again later. This sequence of reactions lasts for eight years. Private pharmaceutical R&D investment expenditure also responds to public clinical research, but this response is shorter in duration (three years) and smaller in magnitude. Thus public and charitable basic research appears to stimulate more private research than does public and charitable clinical research. About 80% of neurological research spending in the UK by public and charitable research bodies is on “underpinning” or “aetiology” research.

- The literature does not provide any evidence at a disaggregated level by therapy area. Thus, we cannot conclude whether the response of private pharmaceutical R&D in neuroscience or mental health is different from total research, or indeed, different from research in other disease areas.

2 Introduction

2.1 Policy Question

Policy makers and other stakeholders are engaged in an ongoing debate about what the role of the government should be in the development of scientific and technological knowledge. The debate affects all areas of research and one of the largest is biomedical research. A number of major issues are being discussed: how much public money should be spent on scientific research, which areas should receive funding and what is the relationship between the public and the private sectors. The same questions apply to charitable funding: charities are responsible for a substantial portion of biomedical research. This note focuses on the last issue, and in particular, whether public and charitable biomedical research complements or substitutes for private R&D.

Broadly speaking there are two main views regarding the issue. On the one hand, there are those who support public (and charitable) funding of research not only for the direct value it creates, but also because it creates knowledge that complements private industry investment in R&D. On the other hand, those advocating to reduce (and in the extreme discontinue) publicly-funded research believe that public research substitutes for, or ‘crowds out’, private investment.

This ongoing debate is not exclusive to the biomedical sector. Indeed since April 2009 grant applications to all UK research councils are required to set out the economic impact of the proposed research (BERR, 2009). Although the main focus here is on the biomedical sector, the literature looking at this issue for other sectors is also relevant and is discussed here. As pointed out by a number of researchers on the topic, the pharmaceutical sector in particular has some distinctive characteristics that suggest that the public-private interactions are more important here than in other sectors. But exploring what the literature has to say about the complementarity/substitute issue in other sectors offers important messages for the biomedical sector.

In the recent report “Medical Research. What’s it Worth?” (HERG et al., 2008) we and our co-authors argued that “the literature, especially that looking at the medical and biotechnology sectors, almost without exception takes the view that public research and private R&D are complements, not substitutes. Public research stimulates private, and vice versa” (page 6). Note, however, that the remit of that report was wider than the discussion in this paper, in that the ultimate objective of the previous work was to estimate the economic returns to public/charitable medical research. The private R&D generated as a result of public/charitable research spending is only one element of that overall return.

2.2 Method

Our starting point for this paper was the literature review we carried out and which is reported in HERG et al. (2008). For that report, we adopted a selective approach for the literature search, mainly driven by:

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- *our accumulated knowledge and experience on the topic;*
 - *core references from past reviews of the value of the pharmaceutical industry, that also helped us in identifying key authors in the fields.*
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This is a strategy suitable for methodological reviews where conventional keyword based search strategy (such as R&D) may result in a very large number of references.

We nevertheless searched the following databases: British Library Integrated catalogue – search on Serials/Periodicals; Economic working papers database (EconPapers); EconLit; and PubMed. We looked for papers that combined the following keywords (or nearest equivalents): “Medical”; “research” (or R&D” or “research and development” or “medical research”); “spillovers” (or “externalities or “synergies”); “social rate of return” (or “rate of return”). In addition, we were interested in exploring the factors attracting private R&D to the UK, including public medical research, so we carried out a literature review combining the following keywords: “location”; “research” (or “R&D” or “research and development” or “medical research”); “companies” (or “firms” or “enterprises” or “business” or “economic activity” or “manufacturing” or “clinical trials”); “productivity”; “competitiveness”; “nations” (or “countries” or “regions”). As an illustration of the large number of hits obtained with the different databases, the search criteria (“medical” and “research” and “spillovers” or “externalities” or “synergies”) yielded 100, 829 and 345 hits in the Economic working papers database (EconPapers), PubMed and the British Library Integrated Catalogue respectively.

The references listed in previously known and identified literature also provided an additional indirect route to the “grey literature”, which is information produced at all levels of government, academia, business and industry in formats not controlled by formal publishing, monographs and books. Overall, we identified and reviewed 139 papers and reports for HERG et al. (2008), of which 20 looked specifically at the complementarity issue.

This paper focuses exclusively on the complementarity/substitute issue between public/charitable research and private R&D. For this purpose, we have updated the literature review carried out for HERG et al. (2008), and used additional criteria to identify relevant papers. In particular, we have used the additional key words “substitutes” and “complements” (and variants) in our search criteria. We identified and reviewed eight additional papers.

The structure of the paper is as follows. Section 3 summarises the results of the published evidence. For the purpose of this paper, the literature has been divided into two main strands: the literature exploring (mostly empirically using econometric methods) how public/charitable medical research affects private R&D, and the literature exploring how new firm start-ups and the location decisions of new firms are affected by university and other public/charitable research. The presumption is then that these new firms will invest in R&D. Sections 3.1 and 3.2 concentrate on the first strand of literature, distinguishing between biomedical/pharmaceutical research (Section 3.1) and non-medical research (3.2). Note that in some instances, some wider industry studies also include the pharmaceutical sector, so where relevant, some studies are cited in both subsections. Section 3.3 discusses the literature looking at the second strand of the literature. Section 4 concludes.

3 Summary of the Published Evidence

Policy makers may want to stimulate R&D performed by business, either to reduce the private costs of R&D (e.g. by giving grants) or by generating knowledge to help firms understand the technological opportunities that are available, thereby reducing the cost and uncertainty of research. Although the literature is generally expressed in terms of public/governmental research activity, the same arguments apply to charitable sector research support and research activity. When these policies are effective, public and private funding will be complementary and increasing the former will increase the latter. According to Guellec and van Pottelsberghe (2003), there are three challenges to this idea.

First, public research spending may crowd out private spending, by increasing the demand for R&D and hence its price. As argued by Golsbee (1998) and David and Hall (2000) one of the main effects of government funding is to increase the wages of researchers. When firms face higher research costs, firms may shift their funding to alternative investments. If this is the case, then even though the total amount of R&D is higher due to government funding, the real amount, when adjusted for the higher cost of research, may be lower.

Second, public money may directly displace private funding, as firms may simply substitute public support for their own. In this case, government will support R&D that would have been performed anyway, so there is no additionality.

Third, governments are presumed to be less likely to allocate resources efficiently than market forces would, which may generate distortions in the allocation of resources between fields of research. It may also distort competition between firms by supporting some at the expense of others.

There are different ways of exploring whether indeed public/charitable research substitutes, or complements, private R&D. The literature referred to in Sections 3.1 and 3.2 below share the same methodology, in that, based on econometric studies, it explores the effect on some measure of private R&D of changes in government R&D, along with some other control variables. A positive coefficient is then interpreted as predominance of complementarity while a negative one is used as evidence of public and private investments being substitutes. Several studies then use these coefficients to estimate the effect that “a one dollar increase in public R&D funding leads to an X dollar increase (decrease) in private R&D”.

The literature referred to in Section 3.3 below takes a different approach: it looks at the public-private relationship by exploring how new firm start-ups and the location decisions of new firms are affected by the presence of university research (taken to represent publicly funded research).

Before going into the details, it is important to outline how the innovation model has been described in the literature to understand the potential interactions between the public and the private sector along the different steps of the innovation process. The “linear model” of innovation was originally conceived as industrial innovation proceeding from basic research to applied research and then to development and commercialisation. Under this traditional model, public/charitable research would take place upstream of private R&D. However, during the last two decades, a richer characterisation of the innovation process has been developed,

where the process is better characterised as a more interactive relationship between the public/charitable and the private elements of research (Cohen et al., 2002).

The newer and richer innovation model characterises well the innovation process in the biomedical sector. Without doubt, public and charitable research plays an important role in the discovery of new drugs and other healthcare technologies. However, the interaction between the public/charitable and the private sectors is certainly much more complex than a simple basic/applied dichotomy would suggest. For instance, Reichert and Milne (2002) and several articles by Cockburn and Henderson (1996, 1998, 2000), illustrate that the private sector does invest heavily in basic research, viewing it as fundamental to the maintenance of a productive research effort. The work carried out by Cockburn and Henderson, for example, shows that co-authoring of research papers between the public and private sectors is extensive – and these authors conclude that the private sector results can have importance for public research.

3.1 Medical Research and Pharmaceutical R&D

3.1.1 Theory and Intuition

It is important to understand why an increase in public/charitable expenditure on research has a positive effect on private R&D in the biopharmaceutical sector – and indeed, why this effect has been characterised by a number of researchers as significantly more important than in other sectors. For this purpose, we discuss now the key characteristics of R&D for health care technologies that make it so important for the public sector to intervene through specific policy mechanisms as well as the role of public funding supporting biomedical basic research.

Two main factors characterise the development of innovative technology in the pharmaceutical and biotech sector. First, there is a high level of uncertainty due to a significant scientific challenge at early stage (basic research and pre-clinical) and recurrent risk of failure at clinical phases. And second, the cost of bringing new drugs to the market is significantly higher compared to other sectors. Di Masi et al. (2003) estimate that the average out-of-pocket costs of a new product approval is \$400 million (Di Masi et al., 2003), whilst in other highly innovative sectors, such as IT and communications technologies, the cost of bringing new products to the market is around £4 million (Cooksey, 2006).

Shareholders and venture capitalists are the main investors in the pharmaceutical and biotech sectors. They need to assess the expected returns on their investments – and this is particularly problematic at the basic research stage, given the uncertainty around the early stages discussed in the previous paragraph. However, these investors are keen to generate returns as quickly as possible. As argued by Pisano (2006) there is an important mismatch between time horizons for venture capitalists (who are key funders of early-stage biotech firms), which is three years, and the time required for companies to develop and market successful health care products – which is around 10-12 years.

Against this background, various reports have been commissioned by government authorities to illustrate and explain why publicly funded medical research can stimulate and complement private investment on R&D in the pharmaceutical and biotech sectors. Factors cited as important to private companies include:

- potential collaborations with research centres and universities supported by government funding. These are associated with “cost-sharing and risk reduction opportunities” (NERA, 2007; CRA, 2004). For example, public resources can be used to finance fixed capital costs (e.g. laboratories and other infrastructures) and private funds can cover variable costs of research projects (Crespi and Geuna, 2004);
- returns may be subsidised by public investment on research and clinical trials. The National Institutes of Health (NIH) in the US is often cited as an example of government funds effectively complementing venture capitalists investments in the biotech sector.

The literature highlights a number of mechanisms and channels facilitating the transmission of knowledge from the public to the private sector. These mechanisms relate to all sectors generally, but as discussed below, some are particularly important for the biopharmaceutical sector. First, universities (taken to represent publicly funded research) via their pool of talented graduates, the ideas generated by faculty, their high quality libraries and other facilities of research universities and their publications facilitate this transmission.

Second, networking and social interactions are also deemed to be important mechanisms. These include formal and informal ways of interaction; for the former, technology transfer programmes, such as licensing from universities to firm can be important. The literature also suggests that both means of interaction are relatively important for the pharmaceutical and biotech market.

The third transmission mechanism discussed in the literature relates to ‘absorptive capacity’, i.e. the ability of economic agents to recognise, assimilate and apply new scientific knowledge – and thereby to appropriate some of the returns accruing to investments in new knowledge made by others (Cohen and Levinthal, 1989). The conventional wisdom, as argued by these authors, was that R&D generated only one product – new information. However, the possibility for firms to assimilate and exploit existing information – the firm’s ‘learning’ or ‘absorptive’ capacity – represent an important element of a firm’s ability to create new knowledge.

Cohen et al. (2002) argue that many of these different channels through which public research can affect (positively) industrial R&D are even more important in the pharmaceutical sector relative to other sectors.

3.1.2 Empirical Estimates

In terms of the empirical estimates of the relationship between publicly funded and privately funded R&D in the pharmaceutical industry, two particularly relevant published empirical studies have been identified: Ward and Dranove (1995) and Toole (2007). Both studies refer to publicly funded medical research in the US, by the NIH, and to the impact on the sum of R&D expenditure in the US by all companies and R&D expenditure by US-based companies worldwide. When thinking about applying these results directly to the UK, a great deal of caution must be exercised. In particular, the scales of activity are several times greater in the US than in the UK – and thus, the opportunities for interactions between the public and the private sector are much greater in the US than in the UK. We were unable to find empirical data on the public/private R&D linkages for the UK or for an economy closer to it in scale.

To our knowledge, Ward and Dranove (1995) was the first paper to examine directly the relationship between basic and applied pharmaceutical research. These authors investigate the process of pharmaceutical research by focusing on three distinct stages of the research process: (1) government funded basic research; (2) publication of the results in medical journals; and (3) industry-funded applied R&D. One key objective of this analysis was to determine the magnitude of the vertical information flows between each stage of the research process.

Data on government funded research comes from the NIH Data Book, which provides detailed information on National Institutes' funding for each year since 1962. The authors use R&D expenditures aggregated into medical conditions based on the actual institute. The second step in the R&D process, publication of results, is estimated by a simple count of medical journal articles in the MEDLINE computerised data base supported by the National Library of Medicine. The third step examined is the development for specific therapeutic use. Most drug development in the US is done by members of the Pharmaceutical Manufacturers of America, PMA (now named Pharmaceutical Research and Manufacturers of America, PhRMA). The PMA Annual Survey Report groups total member sales and R&D expenditures into the following broad categories: Infectious; Neurology; Cardiovascular; Cancer; Gastrointestinal; Dermatology; Respiratory. Data was available from 1966-1988.

The first relation these authors estimate is the effect of NIH funding on medical journal articles – and results suggest that NIH funding is a positive predictor of medical journal articles. The total effect of a 1% increase in National Institutes funding is to increase journal articles output by 0.95 per cent. The second relation explored shows that a permanent 1% increase in journal articles results in a permanent 0.22-0.26% increase in industry development funding within the same category.

Overall, the cumulative effect of a 1% increase in publicly (NIH) funded basic research expenditure in the US in a particular therapeutic category will be to increase, over seven years, industry (private) R&D expenditures in that category by 0.57-0.76 percent. In addition, this 1% increase in publicly funded research will cause a 1.26-1.71% increase in industry R&D expenditures in other categories, so that in total a 1% increase in public basic research will generate a 2.5% increase in total private pharmaceutical R&D spend by members of the US trade association.

One of the improvements of Toole's analysis over Ward and Dranove's is that this author uses comprehensive grant and contract award data covering all NIH funding. Ward and Dranove used total financial obligations by NIH institute but this includes other financial commitments other than basic and clinical research, such as administrative, training and demonstration activities. Toole can therefore measure more accurately public research investment by medical class. Moreover, he is able to disaggregate public medical research between basic laboratory research and clinical human research. This is an important distinction, as the nature and objectives of both types of research can be significantly different. Toole, among others, suggests that pharmaceutical companies will react differently to either basic or clinical research.

In Toole's analysis, basic or fundamental research is broadly defined as bench-level laboratory research directed at the discovery and characterisation of physiologically active substances. Public clinical biomedical research is patient-oriented research involving human subjects,

and obviously includes investments in carrying out clinical trials. Public basic research is characterised by a high degree of uncertainty in both its scientific maturity and its potential market applicability.

Toole used data for the period 1981-1997 for NIH spend disaggregated into the following seven therapeutic categories: endocrine/neoplasm (cancer), central nervous system, cardiovascular, anti-infective, gastrointestinal/genitourinary, dermatologic and respiratory. Data on pharmaceutical industry investment correspond to US pharmaceutical industry R&D spend defined as US and worldwide spending by US companies and spending in the US by non-US companies (i.e. the same definition used by Ward and Dranove, and again from the trade association of the pharmaceutical industry in the US, now named PhRMA).

The analysis carried out by Toole is based on an empirical model where the level of private R&D is a function of public basic and clinical research, as well as other control variables, such as regulatory stringency (proxied as FDA regulatory delay) and industry sales. Moreover, the model is dynamic, given the long timeframes involved in developing new drugs (between 10 to 12 years). In econometrics, this implies that the explanatory variables are included with lags.

The overall result obtained by Toole is that public research is complementary to private pharmaceutical R&D investment. However, there are important differences in terms of the effects generated by either basic or clinical research. First, changes in pharmaceutical R&D investment follow a 'U-shaped' pattern of response as a result of public basic research. Firms will react quickly to new information generated from public basic research (years 1 and 2), then hold their level of investment constant for a period (years 3-6) to increase it again in years 7 and 8. The long-term elasticity of private R&D to public basic research is 1.69 – thus, a \$1 increase in public basic research stimulates an additional \$8.38 of industry R&D investment after eight years.

Second, pharmaceutical R&D investment also responds to public clinical research, but this response is shorter in duration and smaller in magnitude. Pharmaceutical firms will increase private R&D investment as a result of public clinical research within the first three years and thereafter there is no significant impact. The long-term elasticity of private R&D to public clinical research is smaller, 0.4, suggesting that a \$1 increase in public clinical research stimulates an additional \$2.35 of industry R&D investment after three years.

We note that a large majority of neurological research (which includes dementia research) in the UK is basic research. According to the UK Clinical Research Collaboration's analysis of the 11 largest government and charity funders of health related research, about 80% of neurological research spending in the UK (in 2004/05 financial year) was on "underpinning" or "aetiology" research (UKCRC (2006) – Figure 6).

Neither Ward and Dranove (1995) nor Toole (2007) estimate the response of pharmaceutical R&D investment by therapy area. Thus, the literature does not provide any evidence at a disaggregated level and we cannot conclude whether the response of private pharmaceutical R&D in neuroscience or mental health is different from total research, or indeed, different from research in other disease areas. This issue is picked up by Ward and Dranove (1995), as they argue that some firms and therapeutic categories might be more responsive to government-sponsored R&D and published results than others – but their data do not allow them to estimate these differences.

A recent article by Cohen et al. (2002) also explores the extent and nature of the contributions of university and government research labs – public research – to industrial innovation. Their focus is however not exclusive to the pharmaceutical industry, but they comment throughout the paper that the results seem to suggest that the pharmaceutical sector stands out as an anomaly along many dimensions. Their results are based from a survey to R&D managers (administered in 1994) in R&D units located in the US conducting R&D in manufacturing industries as part of a manufacturing firm.

In particular, the authors assess the four following issues: (1) how public research stands relative to other sources of information affecting industrial R&D; (2) consider the overall importance of public research; (3) consider the importance of the different pathways through which public research may impact industrial R&D, including publications, informal interactions, consulting and the hiring of university graduates; and (4) consider what roles different kinds of firms play in bridging public research and industrial R&D.

Their main result, based on the data collected, is that public research has a substantial impact on industrial R&D in a few industries and is generally important across a broad segment of the manufacturing sector. This impact is primarily through public and personal channels and university research contributes to project completion as well as suggesting new projects. What is directly relevant to our work is that this impact is particularly important for the pharmaceutical sector.

The authors observe that the pharmaceutical industry stands out in the degree to which public research both suggests new R&D projects and contributed to R&D project completion. Indeed, they argue that there is no other industry when public research – and particularly a basic science (i.e. biology) – is thought to be so relevant.

The authors also explore the importance to recently completed major R&D projects of different sources or channels of information. For all the sectors included in the analysis, publications/reports are the dominant channels; informal information exchange, public meetings or conferences and consulting follow in importance. Licences or cooperative ventures seem to be the least important. For drugs in particular, these rank in similar order, although patents and licenses are relatively more important than in other industries. But it is also true that all channels tend to be more important for pharmaceutical companies. Another issue explored by these authors is whether there are differences across firms of different size and whether they are new firm start-ups. Overall, they find that larger firms are more likely to make greater use of public research, though start-up firms also benefit from public research especially in pharmaceuticals.

A recent US Congressional Budget Office (CBO, 2006) report summarises the public-private relationship in biopharmaceutical R&D along the same lines expressed here: “It is seldom possible to identify particular cases in which the private sector would have performed research if the government had not. Thus, most of the available empirical evidence is based on aggregate studies. On balance, that evidence suggests a positive relationship between public and private pharmaceutical R&D” [p31].

3.2 Other Sectors

A number of articles over the last few decades have explored the issue of complementarity/substitutes in public-private research for other, non-medical, sectors. A literature review of the econometric evidence was published some years ago (David et al., 2000). While this paper, as argued by the authors, did not have the ultimate objective of coming up with a definitive answer regarding the sign and magnitude of the relationship between public and private R&D, they comment that “at this time, the econometric results obtained from careful studies at both the micro-and macro levels tend to be running in favour of findings of complementarity between public and private R&D investments” (page 500). Moreover, to our knowledge, only Kealey and Al-Ubaydli, (2000) have gone so far as to contend that government funding of science cannot be justified on economic grounds.

David et al. (2000) classify the published studies into four main groups, depending on the ‘type’ of observational units: line-of-business or laboratory, firm, industry and national (or domestic) economy. Table 1 summarises the different tables provided therein.

Table 1 Summary of the evidence provided by David et al. (2000)

Study type	Complementarity	Substitutes	Insignificant	Subtotal
Line-of-business and laboratory studies	2	0	2	4
Firm level studies	7	7	1	15*
Industry level studies	5	0	1	6
Aggregate studies	6	0	1	7
Total	20 (63%)	7 (22%)	5 (16%)	32

* Note: one study was treated as two different studies as the authors used two different methodologies arriving at a different result.

Source: Adapted from David et al. (2000)

As illustrated in Table 1, nearly two thirds of the studies included in their review support the notion that public research and private R&D are complementary, rather than substitutes.

A more recent study for the OECD has been published assessing this relationship using new data (Guellec and van Pottelsberghe, 2003). This paper assesses the effect of government spending on R&D that is funded and performed by business. It addresses the following questions: do public performed research, direct funding and fiscal incentives stimulate business-funded R&D? Does the stimulation effect dominate the crowding effect? How do the policy instruments interact with each other? Are they complement or substitute?

The authors break down public research into two components: government research and university research. Government funding of business R&D is composed of procurement and grants or subsidies. Their empirical analysis relies on a simple R&D investment model: business-funded R&D is a function of output, the policy instruments (government funding of R&D performed by business, tax incentives, government intramural expenditure of R&D, research performed by universities), time dummies and country-specific fixed effects. They use a dynamic specification to distinguish between short-run and long-run elasticities. In total, data for the period 1983-1996 for 17 OECD countries are included in the analysis.

One of the main results of this paper is that one dollar of direct government funding to business generates a 0.70 dollars marginal increase in business funded R&D i.e. 1.70 dollars in total R&D. On the other hand, one dollar from government leads to a 0.44 dollars marginal reduction when spent on government research. But as commented by the authors, this reduction is less than the original one dollar increase, as total R&D (public plus business) will increase after government has increased its spending. In other words, the crowding effect of the research performed in public laboratories is only partial.

The authors also decompose government performed research into defence and civilian research. When the analysis is replicated using this distinction, results change: the impact of higher education R&D becomes positive and significant and the effect of government research changes to zero (negative before) when the defence component is netted out. This implies that non-defence government intramural research (public labs or academic), which is the bulk of government intramural R&D in most OECD countries, has no negative effect on business R&D.

These authors conclude that two major instruments of government policy, fiscal incentives and direct funding, stimulate business-funded R&D. When research performed by government is not differentiated between defence and civilian, it seems that this research appears to have a crowding out effect - but a more detailed analysis shows that only the defence component of government-performed research has a negative impact on business funded R&D.

3.3 New Firm Start-ups and Location Decisions

The second strand of the literature that explores the public-private relationship looks at how new firm start-ups and the location decisions of new firms are affected by university and other public research. This literature does not focus exclusively on the biopharmaceutical industry – although this industry is included in many of the studies.

The literature unanimously agrees that traditional regional characteristics, such as size of cities and population, influence the decision of new firm start-ups where to locate. But other factors are also important too: in particular, the possibility of accessing the knowledge generated by universities and other public institutions. For example, Jommi and Paruzzolo (2007) argue that there is empirical evidence showing that the formation of new start-ups is strongly correlated with the strength of universities and public research institutes.

Two main results can be drawn from this work (see, for instance, Audretsch and Lehmann (2004) and Audretsch et al. (2003)). First, regions with a greater presence of knowledge inputs enjoy a greater number of entrepreneurial start-ups. Second, a distinction needs to be made in terms of the 'type' of knowledge generated. For those university outputs and mechanisms transmitting the knowledge across different stakeholders that are more tacit (i.e. knowledge that can be difficult to write down in such a way that is meaningful and readily understood) in nature (social sciences and human capital), geographic proximity plays a greater role in accessing and absorbing university knowledge.

The recent study by Abramovski and colleagues (Abramovski et al. (2007)) focuses on the links between university research and business innovation in the UK for a number of sectors, including pharmaceuticals. They find a positive correlation between the location of R&D-performing establishments and the presence of high quality relevant university research departments. Moreover, private-sector R&D labs are disproportionately clustered around

highly-rated university research departments in some industries – and this is particularly strong in the pharmaceuticals and chemicals sectors.

The quantitative analysis presented in Furman (2003) is based on panel data reflecting activities of more than 30 pharmaceutical firms over the period 1984-1994. Again, this author argues, based on the results found therein, that regions offering extensive scientific resources, such as universities, government laboratories, or collection of private, science-oriented firms, will be more likely to generate science-oriented firms than will those with more limited scientific assets.

4 Conclusions

The literature that addresses the issue of complementarity/substitutes between public and charitable research and private R&D generally supports the notion that public/charitable funded research generates private R&D. However, the literature is less clear what the exact quantitative impact is. The estimates of the effect vary considerably, depending on the sector analysed and the methodology used.

“the complementarity effect seems to be particularly important in the biomedical sector”.

The literature that explores this issue in the biomedical sector tends to support to a greater extent the complementarity result. Indeed, and based on a number of papers published over recent years, the complementarity effect seems to be particularly important in the biomedical sector.

In the report “Medical Research. What’s it worth?” (HERG et al., 2008), which we co-authored, we calculated, based on Ward and Dranove (1995) and Toole (2007), the (potential) impact of increasing public medical research in the UK: a £1 increase in extra public medical research can lead to an increase in private pharmaceutical industry R&D spending in the range of £2.20 and £5.10.

These calculations are based on US estimates, so caution needs to be exercised when applying the results directly to measuring the impact of UK public and charitable research on the UK private sector. First, the scale of public and private R&D in the US is several times greater than in the UK, so there is scope for the within-country impact in the US to be higher. Second, the marginal impact calculated depends on the estimated levels of R&D spend.

According to Toole (2007), the complementarity effect as a result of public basic medical research is different in nature and magnitude to the effect generated by public clinical research. In particular, and while both effects are positive and significant, he estimates that the effect on private pharmaceutical R&D is greater and lasts longer with public basic research than with public clinical research.

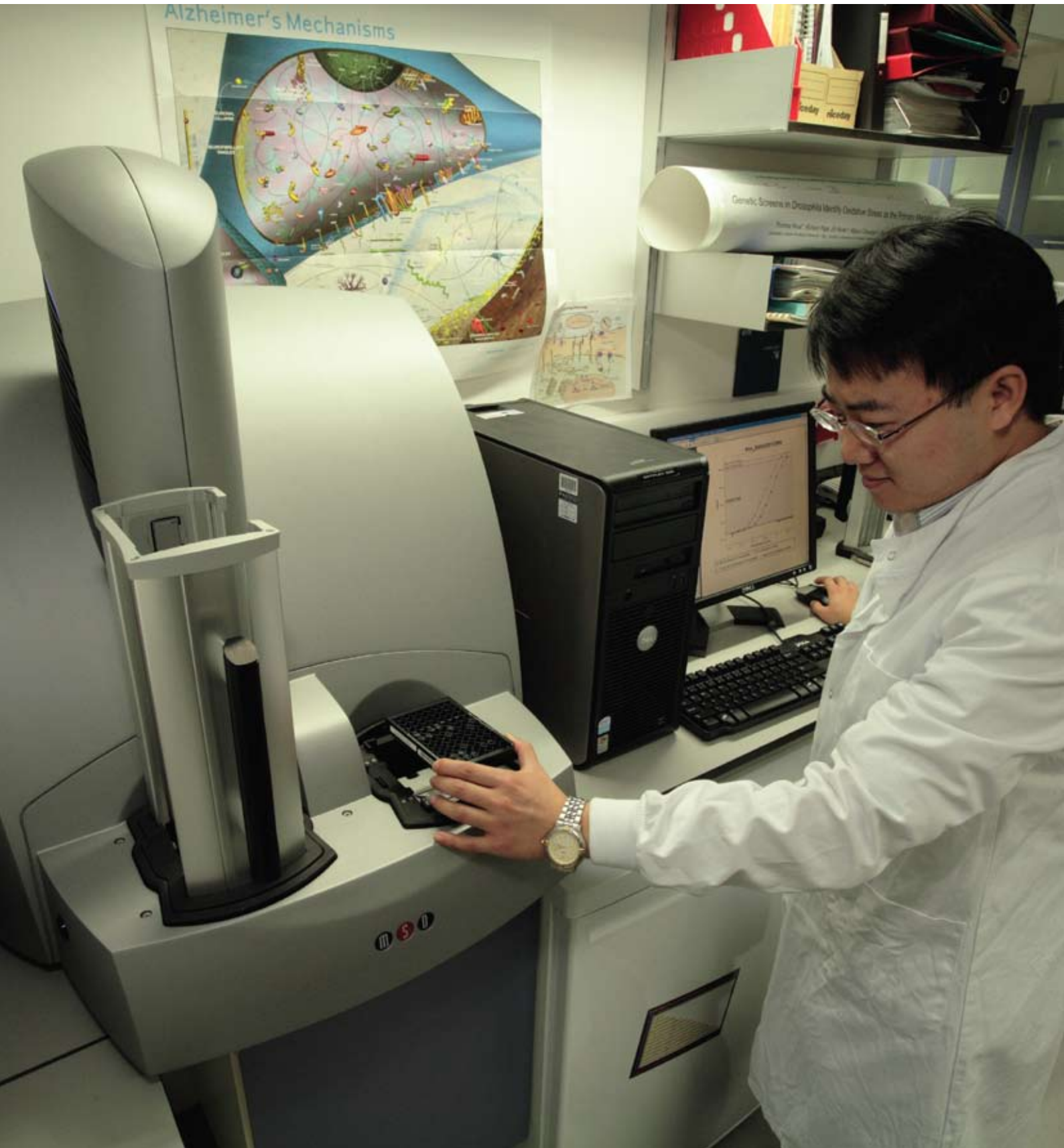
“a £1 increase in extra public medical research can lead to an increase in private pharmaceutical industry R&D spending in the range of £2.20 and £5.10”.

The empirical studies reviewed do not provide any evidence at a disaggregated level by therapy area. Thus, we cannot conclude whether the response of private pharmaceutical R&D in neuroscience or mental health is different from total research, or indeed, different from research in other disease areas.

References

- Abramovski, L, Harrison, R, and Simpson, H, 2007, "University research and the location of business R&D", *Economic Journal*, Vol. 117 Issue 519, 114-141
- Audretsch, D, Lehmann, E and Warning, S, 2003, "University Spillovers: Strategic Location and New Firm Performance", DP3837
- Audretsch, D and Lehmann, E, 2004, "University Spillovers and New Firm Location", Discussion Papers on Entrepreneurship, Growth and Public Policy
- BERR, 2009, "Building Britain's Future: New Industry, New Jobs", Department for Business, Enterprise and Regulatory Reform
- CBO Study, October 2006, Research and Development in the Pharmaceutical Industry
- Cohen, W and Levinthal, D, 1989, "Innovation and Learning: the two faces of R&D", *Economic Journal*, 99, 569-596
- Cockburn, I and Henderson, R, 2000, "Publicly funded science and the productivity of the pharmaceutical industry", NBER conference on science and public policy
- Cockburn, I and Henderson, R, 1998, "Absorptive capacity, coauthoring behaviour and the organization of research in drug discovery", *The Journal of Industrial Economics*, 66 (2), 157-182
- Cockburn, I and Henderson, R, 1996, "Public - private interaction in pharmaceutical research", *Proc. Natl. Acad. Sci. U*, Vol. 93, pp. 12725-12730, Colloquium Paper. This paper was presented at a colloquium entitled "Science, Technology, and the Economy," organized by Ariel Pakes and Kenneth L. Sokoloff, held October 20-22, 1995, at the National Academy of Sciences in Irvine, CA
- Cohen, W, Nelson, R, and Walsh, P, 2002, "Links and Impacts: The Influence of Public Research on Industrial R&D", *Management Science* 48, 1-23
- Cooksey, D, 2006, "A review of UK health research funding", HM Treasury.
http://www.hm-treasury.gov.uk/media/4/A/pbr06_cooksey_final_report_636.pdf (accessed December 2007)
- CRA Charles River Associates, 2004, "Innovation in the pharmaceutical sector". A study undertaken for the European Commission. http://www.crai.co.uk/pubs/pub_4510.pdf (accessed December 2007)

- Crespi, G and Geuna, A, 2004, "The productivity of science", SPRU – University of Sussex. Report prepared for the Office of Science and Technology, Department of Trade and Industry. <http://www.sussex.ac.uk/spru/documents/crespiost2.pdf> (accessed December 2007)
- David, P and Hall, B, 2000, "Heart of Darkness: Modelling Public-Private Funding Interactions inside the R&D Black Box", *Research Policy* 29, 1165–83
- David, P, Hall, B and Toole, A, 2000, "Is public R&D a complement or substitute for private R&D? A review of the Econometric Evidence", *Research Policy* 29, 497-529
- DiMasi, J, Hansen, R and Grabowski, H, 2003, "The price of innovation: new estimates of drug development costs", *Journal of Health Economics* 22, 151-185.
- Furman, J, 2003, "Location and organising strategy: exploring the influence of location on the organisation of pharmaceutical research", in Baum and Sorenson (eds.), *Advances in Strategic Management Geography and Strategy*, Vol. 20, JAI Press: Greenwich CT
- Golsbee, A, 1998, "Does government R&D policy mainly benefit scientists and engineers?", *American Economic Review*, 88(2), 298-302.
- Guellec, D and van Pottelsberghe, B, 2003, "The Impact of Public R&D Expenditure on Business R&D", *Economics of Innovation and New Technology*, 12(3), 225–24
- Health Economics Research Group, Office of Health Economics, RAND Europe, 2000, "Medical Research: What's it worth? Estimating the economic benefits from medical research in the UK", London: UK Evaluation Forum.
- Jommi, C and Paruzzolo, S, 2007, "Public administration and R&D localisation by pharmaceutical and biotech companies: a theoretical framework and the Italian case-study", *Health Policy*, 81(1), 117-30
- Kealey, T and Al-Ubaydli, O, 2000, "Should governments fund science?", Institute of Economic Affairs, Oxford
- Nera Economic Consulting, 2007, "Key factors in attracting internationally mobile investments by the research-based pharmaceutical industry". A report prepared for the UK Trade and Investment and the Association of the British Pharmaceutical Industry. http://www.nera.com/image/PUB_MobileInvestments_Sep2007.pdf (accessed December 2007)
- Pisano, G, 2006, "Can science be a business? Lessons from Biotech", *Harvard Business Review*
- Reichert, J and Milne, CP, 2002, "Public and Private Sector Contributions to the Discovery and Development of 'Impact' Drugs", *American Journal of Therapeutics* 9, 943–55
- Toole, A, 2007, "Does public scientific research complement private investment in research and development in the pharmaceutical industry?", *Journal of Law and Economics*, Vol. 50, 81 - 104
- UK Clinical Research Collaboration, 2006, "UK Health Research Analysis", London: UKCRC
- Ward M.R. and Dranove D, 1995, "The vertical chain of research and development in the pharmaceutical industry", *Economic Inquiry* Vol. XXXIII, pp.70-87



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