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GUEST EDITORIAL

# From research to engagement to translation: words are cheap. Part 1 – research funding and its consequences

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## The virtuous circle

Throughout the scientific disciplines in academia, there are two paramount indicators that are used as proxies for the quality of researchers: publishing peer-reviewed journal papers, and winning research funding. Provided the quality of journal/funder meets appropriate standards, a higher volume of both, in general, brings greater prestige.

Yet both represent an enormous cost to the public purse. In 2016 the UK Government allocated Research Councils UK (RCUK) a total investment of £26.3 billion (between the 2016/17 and 2020/21 financial years) for research projects and research infrastructure[1] (including for most of the UK's more than 20 university research departments working on various aspects of metal finishing and surface treatment). Such support of research is unquestionably a good thing, but how do we make it sustainable, when it contains inbuilt drivers that reduce its sustainability? One commonly-used indicator of a successful funded research project is that it leads to further, larger, successful research applications. This ever-increasing demand on the public purse by a researcher with a string of such projects is unsustainable, unless it is so pivotal to increasing tax income that those extra tax revenues would not have occurred if that research had not been funded (a higher bar than researchers usually set themselves when claiming the benefits of their research).

Another commonly-used indicator is that the research leads to journal publications – but publishing information in a journal paper gives away Intellectual Property Rights (IPR) to everyone, and when everyone has IPR, no-one has. Without the protection of IPR, no manufacturer will invest the ~£20–50 M needed to take an idea for hardware innovation through to a consumer product (paying out to conduct research and development, hiring staff, building manufacturing plants, marketing, setting up servicing facilitates etc.; see Table 1). This is because their first products must be sold at a higher price to recoup the debt they must incur for perhaps 10 years before ever making income from a sale, and if they do not have IPR then a competitor can buy their first product, copy it and, because they are not paying off the R&D debt, sell at a much lower price. Premature publishing can prevent new products, new businesses, and new jobs, which would ultimately lead to new tax income to the Treasury. Keeping money flowing in this 'virtuous circle' matters, because the vast majority of academic research is funded by the Treasury.

Without doubt, research investment brings societal benefit. In 2008, Buxton *et al.*[2] surveyed the time it takes from the initial innovation to wealth creation through innovation. The report records a one-year study into the economic benefits of the UK's public and charitable investment in medical research. It found the benefits to be high: a £1.00 investment in public/charitable cardiovascular disease (CVD) research produced a stream of benefits equivalent to earning £0.39 per year in perpetuity. However, it also records that the time lag between research expenditure and eventual health benefits is around 17 years: it infers

> a mean lag between research and impact for CVD treatments of between 10 and 25 years, with a central estimate of 17 years.

This lag, if replicated across all disciplines, means that for every £1M research grant awarded, there needs to be many tens of millions of pounds generated to the Treasury by research, in order to:

- support this 'float' without an unsustainable dependence on legacy income from prior research;
- adequately ensure that the projects that eventually generate Treasury income also pay the share of those that do not. It is vital to factor this in, or research sponsors will undervalue research that provides no obvious commercial end-point or does not inform policy (but might instead enrich society in non-monetary ways, or provide fundamental research on which later commercial successes are built);
- ensure funders do not become risk-averse. Although most funders say they champion 'high-risk, high-reward' research, few actually do for fear of supporting failures. An unspoken risk-averse attitude leads to funding more obvious income generation through incremental research than high-risk game-changers. It also funds research that duplicates the approaches taken by well-funded labs overseas, an attractive option for researchers and universities alike (on the basis that because these overseas researchers are successful at generating grant income for their universities, that income-generation can be replicated for universities whose researchers propose very similar projects); consequently, when the sponsors take guidance from the researchers and universities they fund most as to the priorities for future funding, the 'hot topics (and approaches)' list becomes uniform worldwide.

As an example of the afore-mentioned lag, it is a common

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**Table 1.** Approximate schedule of costs to take a hardware innovation from the point where it leaves a University and moves into a start-up company, prior to selling the first consumer device (2 rounds of specialist versions of the device are developed first to reduce risk by providing user feedback and allow staged scale-up).

| | Period: | | | |
|---|---|---|---|---|
| | Years 1–3 | Years 4–5 | Years 6–7 | Years 8–9 |
| Activity | R&D | 1st specialist product + continued R&D | Expand specialist product range + support 1st product + continued R&D | Prepare for 1st consumer product + support previous products + continued R&D |
| Staff/year incl. overheads & pension | 20 staff at £80k/year | 30 staff at £80k/year | 60 staff at £80k/year | 130 staff at £70k/year |
| £1000/year for staff including overheads & pension | 1600 | 2400 | 4800 | 9100 |
| £1000/year for consumables, equipment & subcontracting | 200 | 300 | 800 | 1000 |
| £1000/year for space & facilities | 100 | 200 | 300 | 500 |
| £1000/year for market, certification, technical, legal, HR specialities (consultancy in early years) | 70 | 150 | 300 | 300 |
| £1000/year for distribution & servicing | 0 | 50 | 200 | 500 |
| Total per year (£1000/year) | 1970 | 3100 | 6400 | 11400 |
| Total for the period (x £1000) | 5910 | 6200 | 12800 | 22800 |
| Cumulative cost (x 1000) | 5910 | 12110 | 24910 | 47710 |
| Income from sales as product from previous period is released (x £1000) | 0 | 0 | 500 | 5000 |

Costs could be ±50% (e.g. a reduction of one of the later years can save £10M; a larger build run for the consumer market launch to avoid risk of losing reputation by failing to build enough units to meet orders, can cost £10M extra).

misconception that warnings of climate change from burning fossil fuels began in the early 1990s, and the pace of change to effect control of this, and the nurturing of a viable alternative energy economy, have been too slow. In fact, early warnings of climate change came from Svante August Arrhenius (who won the Nobel prize for Chemistry in 1903) in 1896,[3] and through the spare-time hobby[4] of Guy Stewart Callendar, a steam engineer, who in 1938 stated[5] that

> By fuel combustion man has added about 150 000 million tons of carbon dioxide to the air during the past half century … approximately three quarters of this has remained in the atmosphere … the increase in mean temperature, due to the artificial production of carbon dioxide, is estimated to be at the rate of 0.003° C per year at the present time.

This work came from multidisciplinary mavericks, not dedicated climate centres, and its importance was overlooked by policymakers: the overwhelming argument for research funding should not be the ease with which the public can be convinced that the funds are well spent.

It is vital not to undervalue, and still support, research that enriches us in non-monetary ways. It is therefore important to recognise that the research that leads to Treasury income must pay, not only its own way, but also support a virtuous circle that both repays the original investment, and in addition supports the research that did not.

A £1M research project might include a £50k funded engagement programme to communicate the results of the research, but as the future possible outcomes of the research are predicted, at some range from the original research the benefits are described with the word 'might' (e.g. 'this research might solve the 'leaves-on-the-line' crisis' or 'who knows what engaging with a schoolchild on science might produce?') as opposed to 'did' (e.g. 'tax revenues from this new company did indeed exceed £1M this year'). How should this £50k of engagement be viewed? Certainly, it falls short of the ~£10M needed to place a disruptive hardware technology in a small number of pilot hospitals, and the further ~£40M required before the first public product is sold (Table 1), and so return income directly to the Treasury – but that is not its role. Outreach is crucial, and the issue is not whether we do it, but how we avoid squandering resources on tokenism: if a researcher spends an hour at a science festival, how do we distinguish between an hour of an academic talking jargon at the public, and an hour of two-way dialogue where both sides learn and come away wanting to know more? Whether research projects are used as the foundation for other researchers, or produce successful outreach, they are sustainable so long as some research projects produce a return to the Treasury that greatly outweighs the investment. How do we ensure that we do not fail to realise the potential of research breakthroughs that offer the possibility of increasing Treasury income (and by doing so, fund more research and translation, and support projects that do not contribute directly to the Treasury)? This hazard can be reduced by implementing dedicated measures to translate research outcomes, above and beyond simply publishing them.

## Ensuring today's research changes lives 10 years hence

Research is fraught with the potential to go nowhere. A conference session where all the presenters tackle the same problem, the same way, is likely to be one where the citation rates of the subsequent papers are high, but the research is incremental and unlikely to change society or their country's tax revenue. At the other extreme, a proportion of a truly adventurous research portfolio will lead to dead-ends: if the result were guaranteed, it would not be research. Indeed, if research is about discovering the unknown, then it is about trying to challenge received wisdom. On the one hand, it should not be blind to the possibility that accepted norms are wrong; on the other hand, if those norms are correct, then a challenge to them (whilst adding to the knowledge base) can be perceived as being 'research that went nowhere'. If a proportion of our research does not fall in that class, we are either very lucky, or inadequately adventurous.

Yet the slippery slope to nowhere also derives from the fact that the publication of a high-quality journal paper is seen by many in academia as the pinnacle of success of a project. The messy and slow business of ensuring that a particular research brings about effective societal change is unfamiliar to most academics, and the activity

would take time away from winning more research funds and writing more papers. Furthermore, 'societal change' is a far more risky end-point to stake one's reputation on, compared to 'publish a paper somewhere': failure is easier. Low/Middle Income Countries (LMICs) have been presented with many 'solutions' from research by G8 nations that cannot be practically implemented. Yet even if we, for the moment, discount any failures of research to produce societal change, and accept for the moment that publication is the pinnacle achievement of research, then the performance metrics of researchers worldwide are not overwhelming. In 2009, Larivière *et al.*[6] conducted a census of papers using Thomson Reuters' Web of Science.

Figure 1(a) shows a retrospective from 2007. The black columns show the proportion of papers published in 2005 that had received no citations in the 2 years since their publication; and the grey columns show the percentage of papers published in 2002 that had received no citations in the 5 years since their publication. The percentages were smallest in the Medical fields (~10%–20%). Larger values were seen in Social Sciences, and Natural Sciences and Engineering (~25%–45%). The greatest proportions were in Humanities (~80%–90%, though the tendency to publish long single-author books means that with Humanities one is not comparing like with like).

In the 2-year window for papers published in 2005, the proportion of papers that were responsible for 80% of all citations in the discipline category in the 2 years after publication (Figure 1(b)) was 7% in Humanities, 28% in Social Sciences, 28% in Natural Sciences and Engineering, and 33% for Medical fields. Is the competitive nature of Medicine healthy? A discipline that has long author lists (who then cite the work in their later papers) and which has topics that dominate funding (such as cancer), and in which there is a tendency for short papers and reviews, will of course appear to fare better in citation statistics than a discipline that does not. More to the point, what do we mean by 'healthy'? Whilst peer-review publication is undoubtedly the bedrock of academic research, this editorial is concerned with the financial sustainability of the public funding of research, and from this perspective the twin pillars of academic assessment (journal papers and research income) are double-edged swords: whilst a University perceives an Academic who has a career of winning multi-million pound grants every year (each grant producing only papers and further grant applications) to be an income-generator (for it), the Treasury could see this as parasitic on the public purse, ameliorated only by appreciation of the young people that such research trains – at the public's expense – for future jobs. This dichotomy is resolved if genuine links can be made between what was taken from the Treasury, and what returns to it.

The publication of quality peer-reviewed articles is undoubtedly a critical component of research, in archiving perspective, methods and results, and in subjecting these to peer review. However, bar the work of a tiny minority of researchers, it is delusional to believe that the papers of a given researcher uniquely contribute to changing society and affect the lives of millions for the better, as they struggle even to achieve recognition for influencing other academics interested in the subject (Figure 1). Most individual contributions are unrecognised for the small part they might play in the incremental grind to new knowledge: supporting that grind is worthwhile and what most researchers do.

Ensuring a good idea makes it through to Treasury income and societal benefit some years later, takes far more than publishing. The words 'This could cure … ' are some of the least convincing words one can see in a grant proposal, or the press release of a research breakthrough: they raise the possibility that the researcher treats their findings like a ball, thrown into the air, with the expectation someone will catch it, and put in the £20–50 M and a decade or more of insight and understanding needed to turn a journal paper into societal benefit. What is needed is a careful selection by the researcher of the appropriate partner to make impact, and dedication and ingenuity by both over many years to bring it to societal benefit and Treasury income.

This is in no way a call to abolish blue-skies research, nor to denigrate outreach, public engagement and publication: these things should be rightly held in high esteem. The problem is that the worthy and unworthy can cite these in equal measure as badges of esteem, because their value to society is so difficult to quantify reliably for an individual research project.

The second part[7] of this editorial therefore focuses on a measure more easily quantifiable, and more difficult to fake: the ratio of the direct revenue back to the Treasury for every pound paid out to a research programme and, more particularly, the time taken to do this (since longer times require greater payback to support a larger 'float').

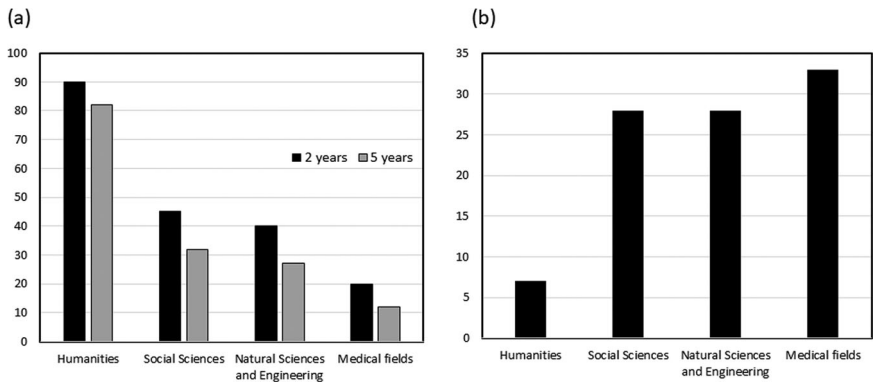


**Figure 1.** From a census of papers on the Thomson Reuters' Web of Science up to 2002, the figure shows: (a) the percentage of papers that have received no citations within 2 or 5 years of publications; and (b) The percentage of papers that were responsible for 80% of all citations in the discipline category in the 2 years after publication. Data are taken from Larivière *et al.*[6].

## Conclusions

A society that bases the success of its academics on their ability to publish papers of high impact factor, does not have a sustainable funding stream if enough of that activity does not in turn generate tax revenues. Worse, a badge of success that is based on the winning of previous grants, used as a marker to win future grants, is a positive drain on the Treasury, if it does not increase tax revenues. In both cases, the tax income generated by those projects that do achieve this, must far outweigh the funds allocated to them in

research grants, because of two factors: first, the delay between the award of the grant and the generation of tax revenue, which can be decades; second, the fact that a genuine game-changing research portfolio must contain a large proportion of high-risk projects, and by their nature many of these will fail to deliver the promised societal benefits.

The first part of these paired editorials has focused on this problem, and on one aspect of assessing research within 5 years of its conduct, namely through publications. The second part of this pair of editorials will consider other indicators, specifically the generation of patents and spinout companies.

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