Research Policy 39 (2010) 736–747

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

The economic impacts of academic spin-off companies, and their implications for public policy

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ARTICLE INFO

Article history:
Received 8 February 2007
Received in revised form 1 February 2010
Accepted 2 February 2010
Available online 31 March 2010

Keywords:
Technology transfer
Economic impact
Government funding
Academic entrepreneurship
Spin-off company

ABSTRACT

The importance of academic research ("AR") to economic growth is widely accepted but quantification of incremental impacts, and their attribution to any one country's expenditures, is difficult. Yet quantitative justification of government AR funding is highly desirable. We therefore attempt to quantify one impact which *can* be directly and causally attributed to one country's funding: spin-off companies. We focus on AR in the non-medical natural sciences and engineering (NSExm) in a whole country, Canada. 'Applied' disciplines are sometimes assumed to be the most commercializable, so we also separately investigate an especially 'basic' science, physics. Using a novel methodology, we estimate the lifetime impacts of companies spun-off directly from AR performed in 1960–1998, and compare the impacts with all government funding, direct and indirect, over the same period. This picks up virtually all funding and most company-formation since WWII, up to 1998. Such long-term studies are rare but essential, since we show that successful spin-offs grow (often exponentially) over several decades.

With very conservative assumptions, and allowing for the time value of money, the impacts exceed government funding by a substantial margin. Physics actually fares 30–60% better than the combined NSExm; this reflects more successful companies, rather than greater numbers, and therefore does not seem inconsistent with earlier studies on company numbers. Firm lifetimes are long, with Canadian impacts truncated primarily by some foreign acquisitions.

We argue that the spin-off impacts represent incremental contributions to GDP, much larger (even on a time-discounted basis) than the government funding and directly attributable to it; governments will also receive more in additional tax than they spent. The impacts therefore provide a quantitative justification for the public investment, allowing the much more important (but less quantifiable) long-term benefits to be regarded as a 'free' bonus. The very good showing of physics also suggests that reduced emphasis on basic work or on the basic disciplines could actually weaken the commercialization of AR.

1. Introduction

1.1. Background

The importance of academic research ("AR") to long-term economic growth is widely accepted but difficult to quantify. Demonstrating causal connections and incrementality is challenging, and the often-long delays between basic research and substantial commercialization exacerbate the problems.

Viewed globally, AR has been enormously important to economic growth: discoveries and methodologies underlying the computer and communications revolutions, and the WWW,[1] are just a few examples. But major advances like these do not come from scientific investments by a single country, and governments increasingly want to know the incremental impacts of *their own* investments in science in *their own* country.

AR creates other very important but usually less spectacular impacts that do clearly require *national* investments in AR, and go to the heart of critically important *national* capabilities: to absorb outside knowledge, to inspire and educate the next generation, to benefit from technological spillovers (Salter and Martin, 2001), to encourage private R&D (Jaffe, 1989), and to create new companies and vibrant intellectual and economic communities. These imply strongly that basic research is crucial for the strategic position of a nation in the world economy and that "no nation can free ride on the world scientific system". Nonetheless, while these benefits are almost certainly very large, it is usually very hard to say how large. For policy-makers, such statements leave much to be desired.

Some attempts have been made to quantify the impact of national efforts. Martin (1998) estimated that Canadian AR contributed ~2% of Canadian GDP in 1993. However, he assumed that AR has the same medium-term 'cost-effectiveness' as industrial

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[1] An outgrowth of subatomic physics.

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doi:10.1016/j.respol.2010.02.001

and other R&D. This is far from obvious, since AR's relative 'cost-effectiveness' is a key part of what governments want to know. Moreover, Martin was not concerned with the costs to governments or the time value of money.

In the U.S., AUTM (1999) briefly reported impact calculations based on estimates of sales arising from licensed academic Intellectual Property (IP). The estimates have been disputed and it is not at all clear how much of these impacts would be incremental, rather than a replacement of one U.S. product by a better one. Furthermore, as we shall see, one or a few years' sales do not give a fair indication of overall impact-to-funding ratios.

Most other attempts to measure the returns to publicly funded R&D are cost-benefit studies on limited programs of targeted *government* research, and there are significant methodological concerns. For example, reported benefit-to-cost ratios of mission-oriented R&D programs may be drastically reduced if selection bias is allowed for (APC, 2006). The limited evidence on *academic* work does suggest that *international* AR has a large payoff. Mansfield's (1991, 1998) 10–28% rate of return on worldwide AR is well-known, although his rather large assumptions have been criticized. Mansfield's methodology would be hard to apply to single-countries (respondents would generally not know the IP's true country of origin), and it also focuses on fairly short-term impacts: recent AR, and industrial product introductions that otherwise could merely have been somewhat delayed.

Various other methodologies show substantial impacts of academic/public research on industry, typically in the U.S. (Cohen et al., 2002; Stephan, 1996; Zucker et al., 2002; Adams, 1990; Baldwin and Da Pont, 1996). These studies, however, do not quantitatively estimate incremental impacts, or compare them with the underlying funding. Also, while national science may be important in spillovers of this kind, international science often plays a key role (Narin et al., 1997).

A few investigations (e.g. Mansfield, 1995; Cohen et al., 2002) attempt to obtain information on individual disciplines' impacts. However, respondents tend strongly to recall more recent, downstream parts of the R&D chain, which usually involve the less basic sciences. Basic efforts may also be hidden in categories like materials science. Their impact is therefore probably severely underestimated.

In short, AR's benefits, while almost certainly very large, are hard to quantify and to attribute to any one nation's or discipline's efforts. Yet governments increasingly question their AR funding, particularly of basic work. Our limited ability to provide quantitative estimates of even a few of the long-term national benefits flowing from such funding (much less to properly *compare* them with the funding) is a potentially serious danger to AR, and to the resulting economic benefits.

1.2. Objectives

Rather than studying AR's largest impacts, we investigate an impact that *can* be attributed to a single country, is quantifiable, has a clear causal connection to AR, and which can be argued to be incremental: companies spun-off to directly exploit university-created IP based on science or technology. Such impacts represent only a fraction of AR's benefits but, if they significantly exceed the government funding, they may single-handedly justify it.

While all research builds on earlier international work, the immediate precursor of research-based academic spin-off companies ("RASOCs") is almost always research in their home country. Thus, the benefits accruing to that country would not have occurred absent that country's funding of AR. We specifically focus on Canadian AR in the "NSExm": the NSE e̲x̲cluding the m̲edical and health sciences, but including life-sciences and engineering.

Successful RASOCs typically grow rapidly for decades (Section 5.1), so short-term impact-to-funding ratios are not meaningful. We therefore integrate funding and impacts over very long periods, and 'discount' them to Present Values to provide a proper comparison.

We estimate (i) all the government funding, direct and indirect, of the entire Canadian NSExm AR effort since the 1950s, up to 1998, and (ii) the past and future impacts of all companies spun-off directly from NSExm AR *in this period* and known to the Natural Sciences and Engineering Research Council of Canada ("NSERC"), Canada's NSExm AR funding agency. We know of no previous cost-benefit analysis covering such a long-term, wide-ranging program in any country. Our techniques should be applicable to most countries, and our conclusions may be widely applicable.

Many calls for 'commercialization' of AR implicitly assume that this will come largely from more 'applied' disciplines. Therefore, contrarily, we also focus particularly on physics, as an especially 'basic' science, and compare it with the NSExm as a whole.

2. Overall methodology

2.1. What do we measure?

The direct impacts of new technologies are often measured by the sales of the associated products and services (hereafter 'products'). Yet, since we seek the benefit to the home country's whole economy and not simply the 'private' benefit to a particular company, the net direct benefit to the economy could be much less than the sales if, for example, a new product is a substitute for an older one.

However, in most countries, a new world-class research-based product from a RASOC, even if it displaces another company's existing product, will very likely be displacing one produced abroad,[2] and will generally be sold primarily abroad (RASOCs' sales are typically overwhelmingly exports); when the new product is sold at home, it will usually displace or pre-empt an import.[3] Thus, we argue that RASOCs' sales are very largely an injection of incremental foreign money into the home country (increasing the country's GDP), or money prevented from flowing out.

RASOCs' sales (essentially a net injection of foreign money) are therefore analogous to new government spending in the same region of the home country, although governments (if they maintain a constant overall budget) would have to reduce spending elsewhere. The impacts of government research spending are thus those flowing immediately from the spending itself, plus those from the spending of the later RASOC revenues.[4] We compare these impacts with the government's opportunity cost: the impacts of the money that it would otherwise have spent on more typical expenditures. (An alternative would be to compare the impacts with those of the tax cuts that might otherwise have occurred. We express

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[2] RASOCs are typically world-leaders in a very specific technological niche: it would be very unusual for two companies in the same country to operate in exactly the same niche, unless the country (e.g. the U.S.) was home to a large fraction of the world's research-based industry. Our analysis would therefore need modification if applied to the U.S.

[3] Even if it merely displaces a less sophisticated product already made in its home country (perhaps by the same company), rapid technical advance and dynamic markets (which usually characterize research-based products) ensure that R&D elsewhere, very probably in another country, would otherwise soon have displaced the old product.

[4] One referee points out that, while this economic activity metric is valid from governments' point of view (which is our focus), social welfare benefits could be less if our firms were unprofitable for long periods, as is frequently the case for biotech companies. This is true, but in our case the impacts come almost entirely from larger companies, which in general are profitable. Moreover, our metric actually understates many social benefits of our companies (Section 2.2).