Economic Impact Indicators for Academic Research: Spin-Off Companies and Licensing[1]

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Abstract
The importance of academic research ('AR') to economic growth is widely accepted, although attribution of impacts to any one country's expenditures is difficult. Governments, however, seek quantitative impact indicators to justify their research expenditures. We are therefore trying to quantify various intra-country, incremental economic impacts of AR that can be directly attributed to a government's outlays. Such impacts, while only a fraction of the long-term benefits, justify the investment if they significantly exceed the outlays. We focus here on the impacts and funding of AR in the non-medical natural sciences and engineering (NSExm) in a whole country (Canada) since the 1950s, and specifically investigate spin-off companies and other licensing. 'Applied' disciplines are sometimes assumed to be the most 'commercializable', so we compare a very 'basic' science (physics) with the NSExm as a whole. With very conservative assumptions, the discounted impact of spin-offs is about three times the discounted government funding; physics actually fares 25% better than the NSExm combined. Licensing to existing companies appears much less important.
The favourable results, and the comparison of a very basic science with the overall NSExm, suggests that calls for more commercialization of AR should not be answered by less emphasis on basic work.

Introduction
Few would question the importance of academic research ('AR') to long-term economic growth. However, while national governments seek quantitative impact indicators to justify their basic research expenditures, science itself is international: attributing impacts to any one country's expenditures is difficult. Demonstrating causal connections and incrementality is also challenging. The often long delays between basic research and large-scale commercialization aggravate the problems, making econometric correlation studies difficult and requiring studies covering many decades.

Rather than investigating all the impacts of AR, we therefore seek indicators that quantify some important intra-country economic impacts that can be directly, incrementally and causally attributed to a government's funding of AR ('attributable impacts'). By summing impacts and funding over many decades and converting to present values, we compare the impacts on an 'apples-to-apples' basis with the funding. This is important from a policy standpoint, since it directly addresses the cause and effect relationship between a single-country's support of science and its medium-term benefits to that same country. Our impacts represent only a fraction of the total long-term benefits, but we shall see that they alone justify the investment.

We apply this approach to AR in the non-medical natural sciences and engineering (NSExm) of a whole country (Canada) since the 1950s. (We exclude the medical and health sciences, as their support is organized separately in Canada. Life sciences are included in NSExm.) We are not aware of any previous effort to quantify the impacts and cost of such an extensive, long-term program in any country. While we focus on one country, our techniques should be applicable to most.
Calls for more 'commercialization' of AR tend to implicitly assume that this will come from the more 'applied' disciplines, so we focus particularly on one very 'basic' science (physics) and compare it with estimates for the NSExm as a whole. Our ongoing work addresses a number of attributable impacts, but here we focus on two: companies spun-off since the second world war to exploit university-created IP, and licensing to existing companies.

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Despite the substantial lags between research and major exploitation, the discounted impacts of spin-offs alone exceed the government funding by a factor of around three. The impact-to-funding ratio is actually larger for physics than for the whole NSExm, even including subatomic physics (SAP), a capital-intensive sub-discipline. Without SAP, the physics impact-to-funding ratio is more than double that of the NSExm as a whole. Licensing to existing companies appears to be, surprisingly, a much smaller impact at present.

Impacts, Costs and Incrementality

We must (i) compare government expenditures with economic impacts on an equivalent basis, and (ii) ensure that the impacts are incremental. The direct impacts of new technologies are often measured by the sales of the companies exploiting them, yet the net benefit to the economy may be far less than this if, for example, a new product simply substitutes for another. Moreover, is it valid to directly compare government research expenditures with the net impacts? These points are often overlooked.

We believe that comparing the sales of science-based spin-offs directly with the associated government research expenditures can be an 'apples-to-apples' comparison, for most (but not all) countries. This is so if (i) we wish to consider the benefit to a country's economy as a whole and not merely the 'private' benefit to the company or to governments (via taxes), (ii) the country represents only a fairly small part of the world's technology industry, and (iii) there is a highly dynamic world market for the products, which is usually true for research-based products.

Under these conditions, a new world-class product, even if it replaces an existing one, will very likely be replacing one produced in another country, and will generally be sold primarily abroad; if sold at home, it will likely replace or pre-empt an import. Even if the product merely replaced a less sophisticated one already made in its home country, rapid technical advance ensures that similar R&D elsewhere (probably in another country) would otherwise have soon displaced the old product. Thus, spin-off revenues will be very largely an injection of 'new' (incremental) money into the country, or money prevented from flowing out. In this sense, they are analogous to new government spending in the same region of the country, although governments (if they maintain a constant overall budget) would have to reduce spending elsewhere.

New money from governments or from a spin-off will be largely spent in the country and will re-circulate to produce normal economic 'multiplier' effects. Apart from timing differences and any differences in multipliers, both types of new money are directly analogous. If a government spends \$Y on research, this will ultimately cause \$X of spin-off sales (with multiplier M_X), plus the impact of the spending of the initial investment (\$Y with multiplier M_Y). If the government had spent the money on some more typical (non-capital) investment, the impact would simply have been \$Y with multiplier M_Z. <u>If</u> the multipliers are similar, and if we express Y and X in present value terms at some particular time, the proportionate advantage of research spending over some other (non-capital) use of the government money is $(M_X X + M_Y Y)/ M_Z Y$, or approximately $1+(X/Y)$. We set out to measure the indicator X/Y.

Assuming roughly equal multipliers is reasonable and perhaps conservative. PriceWaterhouseCoopers (2001) studied the University of Waterloo's impacts using detailed input-output models. They found similar multipliers (differing by a maximum of only 15%) for the impacts of items as different as spin-offs' operations, the expenditures of high-earners (alumni) and low-earners (students), and the operating expenses of the university itself.[2] The technology transfer office of TRIUMF, a Canadian national laboratory, actually uses a higher multiplier for the expenditures of its high-tech licensees than for any other impact, including salaries, purchasing, and services (Gardner 2004).

The validity of comparing spin-offs' sales directly with the related government spending is often implicit in impact studies, and our analysis suggests that it will likely be true for research-based spin-offs in most countries. However, it might well not apply to the U.S., for example: the U.S.

2 These would be reasonable surrogates for government expenditures as different as high-tech procurement, tax cuts, pensions, research grants, education, income support and many other social programs, etc.

already generates a large fraction of the world's high tech products, so a new spin-off's sales might well not be incremental exports.

If a spin-off's sales are incremental, one can also recognize its full sales as impacts of the original research (as is done for example by NSERC (1995, 1999, 2002)), even when they may come from later R&D or from new business areas. Others might have developed the later areas absent the company in question, but they would very likely have done so in another country. [3]

Definitions

Our benchmark year is 1998: we count government spending, and companies spun-off, prior to then. One reason for choosing this year is an independent 1998 listing of Canadian academic spin-offs by the Natural Sciences and Engineering Research Council of Canada: *Research Means Business* (NSERC 1999). We do, however, use sales up to 2003 to help our projections of the future impacts of existing companies. NSERC (1999) attempts to identify all significant for-profit spin-offs founded to exploit university IP created by an individual who received research funding from NSERC, in any NSExm discipline. The limitation to NSERC-supported researchers makes our analysis somewhat more conservative.

For physics, most NSERC researchers received their principal funding from NSERC's core Discovery Grants program or its precursors; to include a company as a physics spin-off, we require that such a researcher's funding came from one of these programs' four physics Grant Selection Committees (GSCs)[4]. Where it was not obvious, the GSC was verified with NSERC or the researcher. Such individuals' core work has to be considered by physicist peers to be primarily heartland physics, so we are generally classifying companies via the nature of the researcher's work, rather than by his/her disciplinary background or department. In estimating government funding, we do not limit ourselves to NSERC-funded individuals.

All dollars herein are Canadian. In late 2004, C$1 = US$0.82.

Funding of the NSExm by Canadian Governments, 1955 to the Present

Core funding for Canadian NSExm AR comes from NSERC (prior to 1978 from the National Research Council of Canada); we refer to all these grants as 'NSERC'. Critical to Canadian AR is NSERC's Discovery Grants program (its largest, $244M in 1997-98); this is for long-term programs of curiosity-driven work, rather than specific projects. Selection criteria are based on excellence, rather than 'relevance.' Other programs include targeted 'Research Partnerships' and 'NCEs' ($117M in 1997-98), and postgraduate training ('HQP') grants to students, PDFs etc. ($54M). Smaller programs, plus administration, brought the 1997-98 NSERC total to $436M.

There is additional Federal funding, and many significant Provincial government programs. Beyond direct government funding, 'indirect costs' must be defrayed: for research space (capital and maintenance), functions reporting to VPs Research, technical services, university libraries, IT services, etc. Until recently, these were paid largely from universities' general Provincial operating funds, which thus constituted indirect research funding.

We compiled annual data on all these funding elements from 1955 to 1998. (Funding before 1955 was very small.) This is highly complex, because of the wide and ever-changing array of programs, the many years covered, and the need to estimate funding for physics as well as for the total NSExm. Sources used were mainly annual reports, with data often reviewed at the level of individual grants lists. Details will be published elsewhere.

All expenditures, and all impact estimates (past and future), were converted to their 1998 present values ('PV's), using a discount rate of 3% plus inflation. With the timescales involved, the PV factors can be large: $1 spent in 1960, for example, has a 1998 PV of $18.

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3 This may be questionable if a spin-off acquires another company and combines their revenues, since the reported combined revenues may then not be fully incremental. We reviewed this for all the physics companies, and applied a correction in one small case.

4 For the Space and Astronomy GSC, we restrict ourselves to its non-astronomy portion. In the few cases where a researcher did not hold Discovery Grants, we considered his research area and university department. NSERC is now also known as Science and Engineering Research Canada.

IP used to found a spin-off reflects research going on for some time before then: we assume a period of up to 10 years. The first physics company started in 1970, so we count government funding from 1960. The same assumption implies that work in the 10 years before 1998 may lead to companies founded after 1998 and thus not counted here. We therefore apply a 10-year ramp-down on the funding, counting 90% of the 1989-90 funding, down to 10% for 1997-98. If the 10-year assumption is varied between 3 and 15 years, our funding numbers generally drop by a few percent.
The grand total 1998 present value of NSExm government AR funding, direct and indirect, up to 1997-98 is thus estimated as $31.4B, with physics representing $4.3B of this, or 13.8%. Excluding SAP, physics consumed $2.4B, or 7.6% of the total. As to annual funding, physics as a whole accounted for about 9.1% in the years immediately preceding 1998.

The Past and Future Impact of Spin-Off Companies Established After the Second World War and Before 1998

The Companies
Our starting point is the previously mentioned *Research Means Business* (NSERC 1995, 1999, 2002). The three editions list spin-off revenues as of (primarily) 1994, 1998, and 2002; we refer to them as RMB94, RMB98 and RMB02. [5]

RMB98 and RMB02 identify 111 and 134 companies respectively. Their number, revenues and employees are rather consistent with Statistics Canada's 680 companies (Read 2003), if one adjusts the latter for very small or closed companies, those in the health field, etc. Another database (Cooper 2004a, b) has more companies, with higher total revenues than Statistics Canada or RMB02. We cannot use Cooper's database, however, since confidentiality prevents the release to us of key details. Many of its differences may be a question of timing, and some companies (e.g. non-NSExm spin-offs) do not meet our criteria, but some no doubt do. Not counting them represents a further source of conservatism.

The RMB98 physics companies are listed in the endnote[6], with their 1998 sales. The total sales are not unduly driven by any one large company. Total 1998 physics-related sales were $214.9M, or 16.8% of the all-discipline sales of $1,281.5M. The physics percentage of 1998 sales was 1.8 times higher than its share of recent annual funding (16.8% / 9.1%). Excluding SAP, the ratio rises to 3.3.

Past and Future Impacts of the Spin-Offs
The preceding numbers do not take account of timing effects: (i) the typically long delay between research and major sales and (ii) the past and future impacts of companies that existed in 1998. A cross-sectional analysis, using RMB98 data, suggests that the average company's 1998 sales increase exponentially as a function of its age, until the company is at least 30 years old, which is the limit of the data. We also obtained longitudinal data on the past annual sales of the individual larger physics companies, from the literature, the company, or the founder. Those for which we have the best data were founded in the 1970s and early 1980s and are still growing exponentially (as of 2003) at rates ranging from 7 to 27% p.a. (Figure 1). There is no sign of 'saturation' after 20-30 years, even during the high-tech meltdown of the early 2000s. This reflects healthy, world-leading companies that may well continue to grow rapidly into the future, but it emphasizes the need for discounting techniques in comparing impacts and funding.

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5 We utilize RMB02 sparingly, since it appears to have some data problems.

6 The physics companies considered are: CTF ($10.3M*), NEC Moli Energy ($60.3M*), Quantum Technology ($1.0M), TIR ($4.0M), Vortek ($4.3M*), ITRES ($3.5M), SED ($40.0M), Optech ($15.5M*), MDS-Sciex (50% x $81.0M), Philips Waterloo Scientific ($5.3M*), E-Tek Electrophotonics ($8.8M*), Wi-LAN (50% x $5.3M), Brooks Automation Software ($14.6M), Millenium Biologix (50% x $1.3M), and Cosma Powerlasers (50% x $6.9M*). Total: $214.9M. An asterisk means that confidential sales were estimated based on number of employees; there should be little error in this, as we have rough verifications for the larger companies. Sales shown as 50% of another number relate to work funded by two GSCs or work which straddles physics and astronomy.

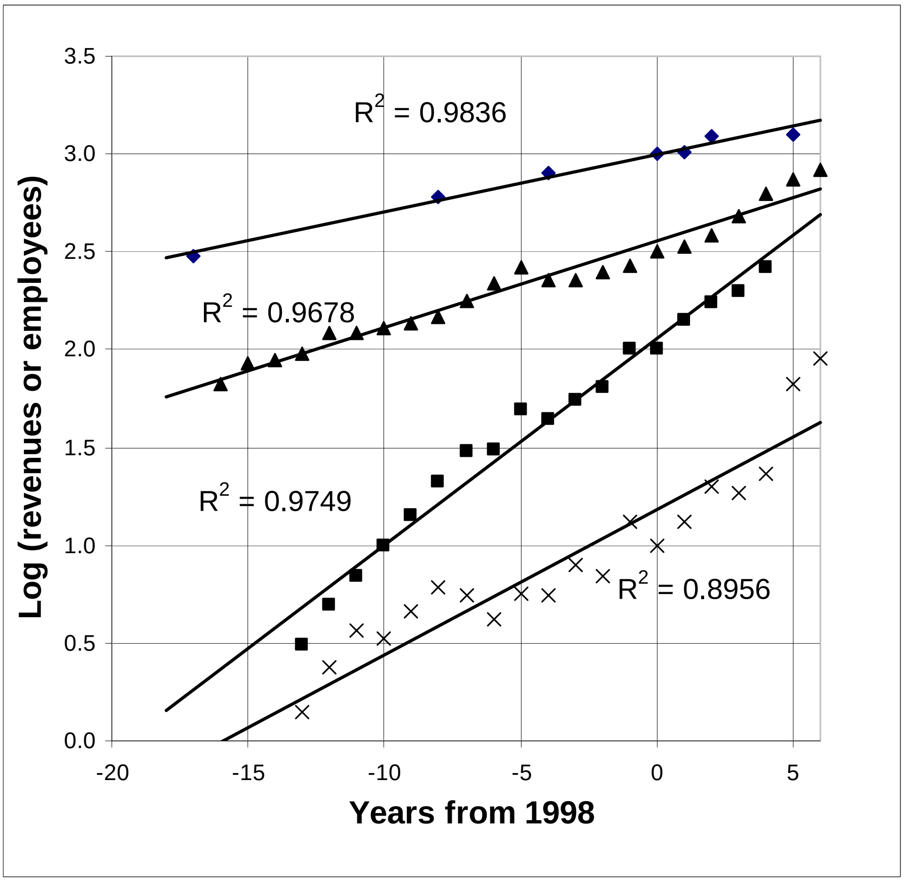

Figure 1. Revenues (in one case Employees) as a Function of Year for Some Physics Spin-Offs (plots are offset by arbitrary amounts)

For the future growth of physics companies, we assumed conservatively that the current (1998-2003) growth rate (averaging about 15% p.a.) does not continue, but that each company's 1998-2003 rate decreases linearly over the next 4 years to only 2% above inflation, where it stays. Where the 1998-2003 real growth rate was less than 2%, we assumed it merely continues. This procedure implies that high growth rates in force for a couple of decades will very soon stop and that none of the spin-offs will continue growing into a major company, a highly conservative assumption.

However, companies may fail, or be acquired and have their operations moved outside Canada, thus reducing or eliminating the benefit to Canada. While many authors have commented on the longevity of academic spin-offs, none has apparently estimated quantitative per-annum data or the probability of loss to a foreign acquirer. In late 2004, we therefore investigated the fate of the companies in RMB94 in all disciplines; the details will be published elsewhere. We excluded companies under $1M in 1994 sales to avoid infant mortality effects and 'one-man shows', leaving 53 companies. The 1994-2004 timescale may be pessimistic, as it straddles the technology bubble/collapse.

We estimate that companies corresponding to 18% of the 1994 revenues were lost to Canada over nearly 10 years (primarily via acquisitions), about 2% per year. Physics-related losses were much less, but we use the broader 2% p.a. average in our calculations. When projecting future sales of current companies, we therefore proceeded as described above, but then applied a 'mortality' multiplier of about 2% per year to each successive year's discounted income, in addition to the normal 3% p.a. discount factor.

We do not have accurate recent growth data for the other disciplines. However, based on the four-year period between RMB94 and RMB98, we estimate that the total (all-discipline) companies may have been growing roughly 2.6% p.a. faster than physics companies. We therefore assumed they start with a 2.6% higher growth rate, then applied the same methodology as above.

Based on these calculations, the 1998 present value of all physics sales (past and future) is estimated as $14.5B, 17.3% of our slightly less certain all-discipline estimate of $84.0B.

Table 1. Present Value of Past & Future Spin-Off Sales as a Multiple of Past Gov't Funding

Types of Government Funding Included in the Calculation	All Physics (A)	Physics excl. SAP* (B)	All NSExm Disciplines (C)	Ratios: (Phys. / All –Discs.) A / C	B/C
NSERC Discovery Grants only	5.7	11.4	6.2	0.92	1.83
All NSERC, incl. Discovery Grants, HQP and Partnerships	4.9	9.3	4.7	1.03	1.97
All Direct Federal and Provincial Grants, including all NSERC	4.6	8.3	3.6	1.26	2.29
All Gov't Funding, Direct & Indirect	3.4	6.1	2.7	1.26	2.29

*SAP = Subatomic Physics

Table 1 shows the ratios of
- the preceding spin-off present values, to
- the 1998 present value of past government funding

for increasingly more comprehensive categories of funding. For example, the bottom left number (3.4) is the above $14.5B physics impact divided by the $4.3B total physics funding shown at the end of the Canadian Funding section.

The impact-to-total-funding ratio (the bottom line) is obviously the key indicator, but comparison with Discovery Grants alone is also important, since without this core program there would be little effective NSExm AR in Canada.

For physics as a whole, the impact is nearly six times the Discovery Grant funding, and 3.4 times the total funding by all governments, direct and indirect. The numbers for physics excluding the capital-intensive sub-field of SAP are nearly twice this. For the NSExm disciplines as a whole, the impacts are 6.2 times the Discovery Grants, and nearly three times the total funding, direct and indirect.

The final two columns show the Impact-to-Funding ratio for physics, divided by the same ratio for the whole NSExm. For example, the bottom right-hand cell is 6.1/2.7. The left column (A/C) shows that physics has a 25% better impact-to-total-funding ratio if we count all government funding. The ratio is 2.3 if SAP is excluded.

Licensing to Existing Companies

IP not spun-off to a new company may be licensed to an existing organization. The consideration is usually (i) a 'running royalty' equal to a percentage of the company's sales from exploiting the technology, (ii) other fees, and/or (iii) an equity position in the licensee.

For FY99, largely corresponding to calendar year 1998, AUTM (Pressman, 2000) reports total running royalties for Canadian universities of $10.9M, after removing double-counts. As well as the NSExm, AUTM figures include licenses associated with the health, medical and social sciences; no breakdown by individual discipline is available (Stevens, 2004).

To estimate the corporate sales underlying the running royalties, we first subtract royalties received from start-ups, whose sales are already counted above, as spin-offs. AUTM reports the numbers of licenses executed annually with startups (28% and 19% in FY98 and FY99: Massing 1999, Pressman 2000), but not their royalties. One major Canadian university, however, reports (Livingstone, 1997, 1998) that in 1994/95 to 1997/98, 34% of its royalties were from spin-offs; over longer timescales, they were about 45%.

Revenues of foreign licensees must also be subtracted in calculating Canadian impacts, although the royalties should be included. Read (2000) reports that 1999 royalties were 31.5% Canadian-source and 47.0% foreign-source, with 21.4% unspecified. Assuming that the unspecified royalties split in the same proportion as the others, and that running royalties split the same as total royalties, the total foreign portion is 59.9%.

Finally, we need the royalty rate. AUTM (Pressman, 2000, p.7) used an average rate of 2% of sales. This is low in our experience, although it may reflect other considerations, such as equity. The average rate reported in a small Canadian study that we did[7] was just over 4%. Stevens (2003a) suggests 2 to 5%. Since we are subtracting start-ups, which are the licensees most likely to receive a low royalty rate in return for equity, we assume a likely range of 3 - 4% for the remainder.

If spin-offs account for say 25% to 45% (or more) of all royalties, which will be almost all (say 95%) Canadian-source, Table 2 shows a Canadian all-discipline impact of $7M - $66M. It could be somewhat higher if spin-off payments came preferentially from flat licensing fees, rather than from running royalties. However, even if running royalties were only 10% from spin-offs, Table 2 still shows an impact of only $90-120M. [8] By comparison, the RMB98 spin-off revenues for the NSExm were $1,281M; the licensing numbers also include the medical, health and social sciences.

Even guessing that only one-third of licensing revenues came from health, medicine, etc., the impact of NSExm spin-offs seems to be at least 15 times higher than that of licensing, and probably much more. Nor has this changed much recently. AUTM (Stevens, 2003b) shows Canadian running royalties roughly tripling between FY99 and FY2002, but RMB02 reports nearly doubled spin-off revenues in roughly the same period.

Licensing to existing companies is an important way of commercializing some products, but its current Canadian impact appears to be very small compared with spin-offs. We consider it no further.

Table 2. Licensing Impact for Various Assumptions

Assumed Percent of Royalties from Spin-Offs		45%		25%		10%	
Total Running Royalties ($)	A	$10.9M		$10.9M		$10.9M	
% of Royalties from Canadian Spin-Offs	B	42.8%		23.8%		9.5%	
% of Royalties from Foreign Companies	C	59.9%		59.9%		59.9%	
Hence % of Royalties from Existing Canadian Companies (100-B-C)	D	0 *		16.4%		30.6%	
Assumed Royalty Rate	E	4%	3%	4%	3%	4%	3%
Revenues of Existing Canadian Companies (A*D/E)	F	0	0	$45M	$60M	$83M	$111
Royalties Paid by Foreign Companies (A*C)	G	$7M	$7M	$7M	$7M	$7M	$7M
Total Canadian Impact (F+G)		$7M	$7M	$52M	$66M	$91M	$118M

* = Calculation gives less than zero.

7 This was performed with the kind help of Phil Gardner and Ann Fong of the TRIUMF Ventures Office.

8 Our small study (footnote 6) suggests that the physics licensing impact may be in the $0.5M to $2.5M range, but this is exceedingly rough.

Limitations of the Study – Sources of Conservatism

Our spin-off calculations are highly conservative. Regarding the companies studied, we exclude the following: (i) Second-order spin-offs (spin-offs from a spin-off). These can exceed the revenues of the original spin-off, and can eventually give rise to major high-tech clusters, like Silicon Valley or Waterloo. (ii) The 'social' returns of new companies: improved products improve the economic performance of companies which purchase or imitate the innovator's products, and reduce costs to consumers. (iii) Any of Cooper's (2004a) companies that may meet our criteria and which are not in RMB98; the latter is based on university reports and is limited to NSERC-funded researchers. (iv) Companies started by former graduate students based on their general research training, rather than their specific graduate research. (v) Any companies that disappeared prior to 1994.

Timing matters cause further conservatism. (i) Surviving academic spin-offs appear to grow exponentially over long periods, on average for at least 30 years. Thus, while we have counted most government research funding since the 1950s, we have almost certainly not yet seen the full growth of the companies founded after the early 1970s. Our projections are very conservative and assume that none of the companies becomes a major corporation. (ii) Given the long growth periods, we are largely studying the fruits of a period long before the application of university IP became a major issue. Current technology transfer should be much more efficient.

Since we seek impacts that are clearly attributable to one country's research efforts, the enormous long-term impacts of international science are ignored. For physics, examples are the transistor, the laser and the World Wide Web, and in earlier days X-rays, cathode ray tubes, and the exploitation of electromagnetism . Also ignored are (i) many impacts on existing companies (including those from collaborative research), such as those studied by Mansfield (1991), (ii) most impacts of techniques and instruments arising from research (where physics is particularly rich), and (iii) the impact of basic research upon the ability of a country to absorb foreign knowledge.

Conclusions

Despite these major sources of conservatism, we estimate that direct spin-offs from Canadian physics AR, founded since the second world war and prior to 1998, will produce discounted economic impacts of about 3.4 times the associated government funding. No multipliers related to re-circulation of money in the economy are included in this statement. Since the initial outlay itself causes impacts, as discussed previously, <u>the total discounted impact is about 4.4 times what a more conventional outlay would have produced</u>. Preliminary indications are that companies founded by graduate students (using their general training) will add 40-80% to this. Licensing to existing companies, however, seems to add comparatively little impact at present.

Our estimate measures the incremental benefit to the country as a whole, rather than simply the 'private' benefits accruing to the companies themselves or to governments. However, using the Waterloo input-output study (PriceWaterhouseCoopers 2001), we can also estimate the discounted 'private' return to governments themselves, via increased tax revenues. PriceWaterhouseCoopers showed that \$1 of spin-off operating expenditures, \$1 of spin-off capital expenditures and \$1 of university operating expenditures respectively produce about \$0.39, \$0.31 and \$0.41 of incremental tax to the Federal and Provincial governments. Unlike our other calculations, these numbers <u>do</u> include multiplier effects; they will be conservative, since they do not consider money spent outside Ontario but within Canada. The spin-offs' capital outlays were roughly 13% of their total expenditures. Assuming that any distributed profit gives rise to comparable levels of tax, we then calculate discounted <u>incremental tax of about \$1.70 for every \$1 of discounted physics research funding</u>. This will increase substantially when we include other direct impacts, such as graduate student spin-offs.

In addition, and crucially, we find that people judged by their peers to be working in heartland physics have been roughly 25% more effective at producing impact than the whole NSExm. (We estimate the impact for the whole NSExm, including the impact of the original investment, to be about 3.7 times that investment; incremental tax to senior governments is estimated as about \$1.40 for each \$1 invested.) If the capital intensive field of subatomic physics is removed, physics is more than twice as effective as the overall NSExm.

Most of the currently projectable impacts are from companies founded before the 1980s, i.e. before the current emphasis on commercialization. They therefore reflect grants that were almost entirely for basic research; furthermore, given the core nature of NSERC funding, little effective NSExm AR would have occurred without these grants. In short, we are measuring the fruits of basic research funding without which few, if any, spin-offs would have occurred: the causal connection is clear. This investment has been shown to produce a very good incremental, directly attributable return to governments and to the economy generally, even without its much more important but less easily quantified impacts.

The excellent returns of companies spun-off from basic NSExm research, and the success of a particularly basic discipline, suggest strongly that the widespread calls for more commercialization of university research should not be answered by less emphasis on the basic disciplines or on basic work, quite apart from the serious long-term indirect consequences that such a strategy could entail.

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