The First Globelics Conference on Innovation Systems and Development Strategies for the Third Millennium

Rio de Janeiro, November 2003

Return on Investment in Innovation: Implications for Institutions and National Agencies

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Abstract

The likely economic returns to higher education institutions, and a country, from investing in technology transfer can be forecast using international benchmarks of innovation performance. This forecast uses a combination of an institutional return on investment model, and a simple national economic model. The model is generic and can be adapted for use in any institution and country. As more data becomes available from local sources, the model can be refined to give better estimates based on both local and international data.

The model is dynamic and shows, quantitatively, why it can take up to 10 years for an institution, and 20 years nationally, to attain a steady state rate of return. This enables the long-term impact of policy decisions, in an institution and nationally, to be examined and alternative scenarios explored.

The performance of individual institutions is, however, highly variable and unpredictable. This is even for those institutions that are comparable in size and maturity. A large portfolio of patents and licences is required to give a reasonable probability of positive returns. This may be possible at a national level, but is problematic in all but the largest institutions. Because the benefits of the innovation system are captured largely at national level, with institutions having a high uncertainty, public sector support to reduce the institutional risk is justified, and required, to ensure institutions make the necessary investments.

Various scenarios illustrate the magnitude of these effects and their causes. There is a need for more thorough analysis to improve the model so that it can be used to inform decision-making at institutional and national levels. One of the applications of the model, for example, is to quantify the impact on an institution, and nationally, of various levels of support for training, patent expenses and office costs.

Attainment of even the average returns assumes that appropriate technology transfer mechanisms are in place. Structured capacity building programmes to improve the performance of technology transfer offices are required to ensure that these norms (or better) are attained. The model can also be used to quantitatively illustrate the impact of professional staff on the magnitude of the returns and time to break-even.

The cost of an effective technology transfer system is of the order of 1% of the expenditure on R&D so there is no significant cost impediment to establishing this capability. Institutional understanding and capacity, as well as the wider innovation support environment, are more difficult impediments, but an understanding of the dynamics, costs and economic returns can help overcome these constraints.

Research & Innovation Value Chain Benchmark Data

Universities and research institutions have been benchmarking the research & innovation value chain for a number of years. This data covers each step in the value chain including expenditure on research, number of invention disclosures, patents, licences, spin-out companies, income from licencing, expenditure on IP protection, etc. An example of the type of data that is collected is illustrated in Table 1 from the Association of University of Technology Managers (AUTM) FY 2000 survey. The AUTM survey includes both the USA and Canada, but only data from the USA is reported in Table 1. The AUTM survey has been performed since 1991 so over 10 years of data is available. (The FY 2002 survey is expected to be released shortly.)

A number of other countries have licenced or emulated the AUTM survey including the UK, Australia and Europe, with others proposing to do so. A summary comparing data from the USA, Canada, UK, Europe and Australia is shown in Table 2. The data from other countries is generally not reported in the same detail and in all other cases, except Canada, the institutional detail is hidden or kept anonymous. There are also problems of definition with specific entries as well as the usual currency equivalent difficulties; so direct comparisons between countries are difficult. This is in addition to the cautions noted in the AUTM survey:

> *"The statistics provided in this Survey are not directly comparable from one institution to another, in light of the autonomous stature of each institution, and the significant variables between institutions. Some institutions are land grant universities with unique missions; some institutions have teaching/research hospitals while others do not; and some institutions are located in rural communities with little entrepreneurial infrastructure.*
>
> *Note also that some survey respondents are reporting the results of mature programs, while others are reporting the results of new programs. Since the technology transfer process takes place over many years, data from programs at different points in the process are not readily comparable, and the aggregation of such data will result in lumpy or skewed distributions."* (AUTM 2000)

Table 2 - Abstracted data for a few countries with SA projections

		Disclosures		Licences/Patents			Spin-outs		Licence + Spin-out
	$Research	No	$Research /disclosure	#Licences/ disclosures	$Research /Licence	Income as % research	#Spin-outs/ disclosure	$Research /spin-out	
USA[1]	$29b	13,032	$2.3m	33%	$6m	4.5%	3.5%	$66m	37%
UK[2]	$2.6b	1,402	$1.8m	20%	$9m	1%	12%	$14m	32%
Canada[1]	$1.4b	875	$1.6m	15%	$10m	2%		$38m	
Australia[3]	$510m	274	$1.9m	23%	$8m		4%	$31m	27%
Scotland[4]	$347m	216	$1.6m	17%	$8m		5%	$17.6	
Europe[5]	$3.5b	1,522	$2.3m	16%	$14m	1.4%	17%	$13.2	33%
USA mid-50[6]	$4.5b	2,073	$2.2m	33%	$6m	1.7%	4%		37%

Projections to SA if operating at international norms (high/low ratios used)

		# disclosures	# patents/licences	Income	# Spin-outs
S Africa	$500m (ppp adjusted)	250 - 300	50 - 80	$3-$10m	10 - 50

1. Association of Unversity Technoloy Managers (AUTM) FY 2000 survey
2. UNICO-NUBS Survey on University Commercialisation 2001
3. Australasian Tertiary Institutions Commercial Companies Association Inc (ATICCA) 1988
4. Edinburgh University Research and Innovation Office (for 1999/2000)
5. The Association of European Science and Technology Transfer Professionals (ASTP) Feb 2001
6. AUTM survey mid-50% ($15m to $100m research expenditure universties & ignoring outliers)

Table 1 - AUTM Survey Data Fields+, totals, some averages and ratios			
Field description	**Totals**	**Averages and ratios**	
(all data for FY 2000 except where agregated)	(all $ in $ millions)		
Name of the Institution	190	Number in survey	
Year which Institution started	1987	13	Average office age
Licensing FTEs Technology Transfer Office	634	3.3	Professional staff
Other FTEs Technology Transfer Office	669	3.5	Support staff
Research Expenditures: Industrial Sources	$2,729	9.3%	% industrial
Research Expenditures: Federal Govt. Sources	$18,076	61.3%	% federal
Total Research Expenditures	$29,492		
Licenses/Options Executed	4,362	$6.76	$m research/licence
		33%	of disclosures
Licenses Executed with Equity	372	9%	of total
Cumulative Active Licenses though FY 2000	20,968	21%	in current year
Licenses Executed on Exclusive Basis*	2,161	50%	of total
Licenses Executed on Non-Exclusive Basis*	2,136	49%	of total
Licenses Executed to Start-Up Companies*	626	14%	of total
Licenses Executed to Small Companies (Excl. Start-ups)*	2,009	46%	of total
Licenses Executed to Large Companies*	1,359	31%	of total
Licenses/Options to Start-Up Companies: Exclusive*	558	89%	of start-ups
Licenses/Options to Start-Up Companies: Non-Exclusive*	60	10%	of start-ups
Licenses/Options to Small Companies: Exclusive*	846		
Licenses/Options to Small Companies: Non-Exclusive*	1,156		
Licenses/Options to Large Companies: Exclusive*	497		
Licenses/Options to Large Companies: Non-Exclusive*	849		
Research Funding Related to Licenses/Options	$236		
License Income Received	$1,335	4.5%	of total expend
Licenses/Options Generating License Income	9,059	$0.15	Av income
		43%	Licences active
License Income Rec'd Paid to Other Institutions	$72		
License Income Rec'd : Running Royalties*	$751		
Licenses/Options Generating Running Royalties	4,581		
License Income Rec'd : Other Income*	$391		
Licenses/Options Generating More Than $1M	125	0.6%	
Legal Fees Expended	$141	11%	of licence income
Legal Fees Reimbursed	$63	5%	of licence income
Invention Disclosures Received	13,032	$2.3	$m per disclosure
Total Patent Applications Filed	9,925	76%	of disclosures
New Patent Applications Filed	6,375	49%	of disclosures
U.S. Patents Issued (per Survey)	3,764	29%	of disclosures
Start-ups Initiated	454	$65.0	$m per startup
		3.5%	of disclosures
Start-ups Initiated Operating Home State	364	80%	
Start-ups That Became Non-Operational	59	3%	
Cumulative Operational Start-ups as of the end of 2000	2,309		
Start-ups Formed which the Institution Holds Equity	252	56%	

* Not all participants were able to provide this detailed information; thus, the sums of the related fields may not equal to the total aggregate data reported.

+ Most but not all fields listed (**AUTM 2000**)

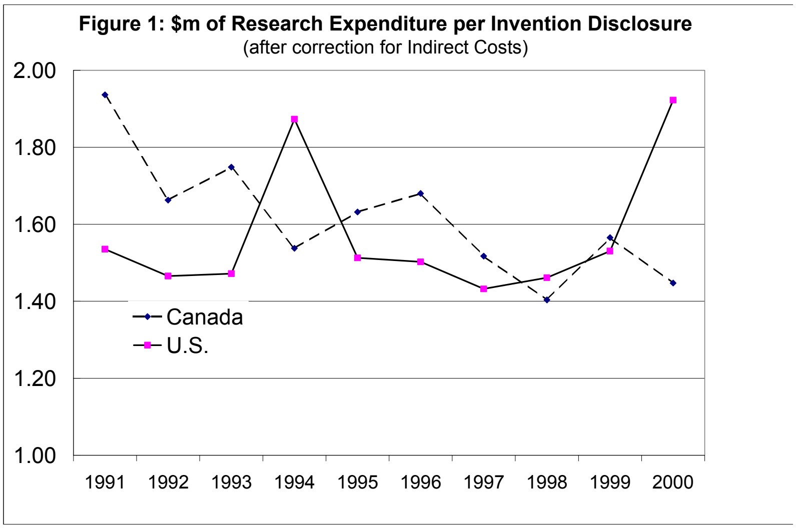
Both the AUTM data, and data from other countries, have been widely used (and abused) by politicians, university presidents and many others. For example, it has been claimed that the UK is "more efficient" with respect to spin-out company formation because the UK spins out an average of one company for every $14m of research versus $66m in the USA. Even a cursory look at the more detailed data shows the fallacy of making such claims because of the evident differences in policy approach. (The USA emphasises licencing rather than spin-out company formation.)

Nevertheless, the country average data is useful for making high-level comparisons at an aggregate level and for making projections to other countries. A projection for South Africa is shown in Table 2, based on high and low scenarios from different countries. These projections must of course be treated with caution and are subject to a number of caveats which are detailed below.

An important aspect of undertaking benchmarking is the understanding and insight that the process fosters. This is a learning-by-comparing approach that is advocated (**Lundvall 2001**). The inherently long time delays make innovation system benchmark data particularly difficult to collect and interpret. In depth understanding is necessary to avoid misuse of the data that is all too prevalent. The models that are proposed can assist with this interpretation and with fleshing out the raw benchmark data.

Some observations with respect to the country average data are relevant:

- The invention disclosure rate of approximately $2m of research per invention disclosure is remarkably consistent across countries and, if previous years are compared, is consistent over time. (See for example Figure 1 comparing the US and Canada over 1991 to 2000. The absolute values are lower than the figures in Table 2 because of an adjustment for indirect costs – an example of problems of definition even between close neighbours!) (**Clayman 2002**)



- The "conversion" rate of disclosures into a patent or licence varies from 15% to 30%. This is a relatively close correspondence with differences explainable by different national policies and support measures.
- The spin-out company rate shows a similar range, explainable by the greater emphasis on company formation vs licencing in Europe and the UK versus the USA. What is

noteworthy, is the similarity in the total of invention disclosures that result in either a licence or a spin-out. This is around 30-35% in all the countries examined.

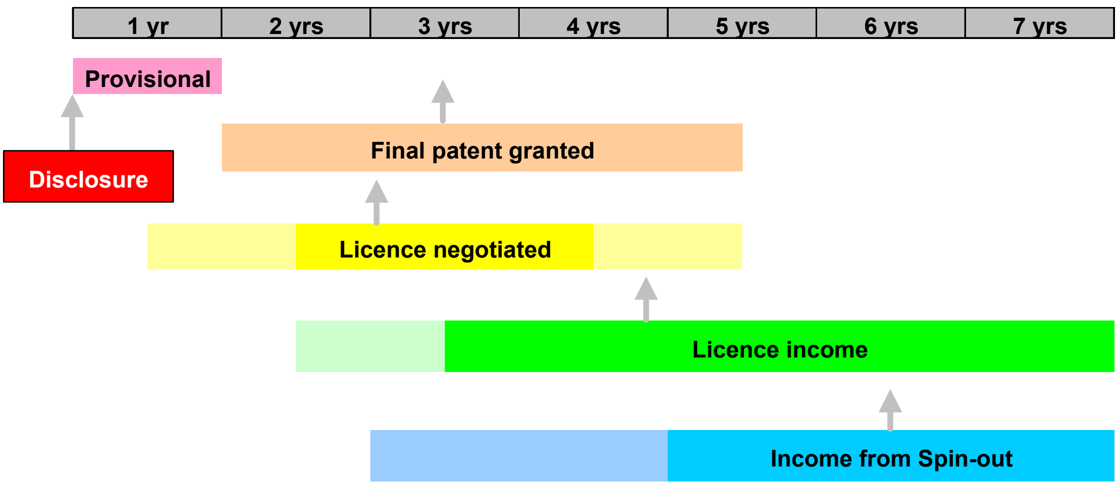
- More substantive variations are notable in the income generated from commercialisation activities. Income varies from 1% to 4% of research expenditure. However, if the mid-50% of AUTM universities are examined (excluding the bottom 20% and top 30%) then the US average of 1.7% is similar to that in most other countries i.e. it is a few large outliers which distort the US figures.
- The cost of operating a technology transfer office varies from 0.5% of research expenditure in a large university to around 1% in smaller institutions. The AUTM data for individual institutions shows that approximately 40% of institutions (75 out of 190 in the survey) operate at a net loss. In the UK, figures for individual institutions are not available, but the lower total revenue indicates that a greater proportion run at a loss, confirmed by anecdotal evidence from practitioners who claim that "75% of the 120 universities with Tech transfer offices in the UK run at a loss".

Key Conclusion: The strong similarities in performance between countries with different innovation systems and cultures, indicates that the creative innovation process is inherently similar whatever the environment. The single biggest factor that dwarfs all others is the expenditure on research and it appears unlikely that any one innovation system makes any significant difference to the 'efficiency' with which ideas are generated and transformed.

This is not to imply that active innovation support systems are not required. All the countries listed above have such strong systems of support and are actively involved in training and developing capacity to manage the research & innovation process. Without such strong support it is highly unlikely that the performance of any institution, region or country will come even close to matching the average benchmarks.

Phasing of Innovation Value Chain

The benchmark data is masked by the long delays inherent in the technology transfer process. Each step in the value chain takes a few years, with typically 6 to 10 years elapsing from invention disclosure to significant income from a licence. These delays are depicted in Figure 3:



This phasing makes interpretation of the benchmark data difficult because the benchmark data for a particular year is dependent on activities that happened many years previously. The total licence income in any one year, for example, depends on the accumulated sum of invention disclosure and patenting activities from prior years and is independent of the disclosure rate in that particular year. But for ease of analysis and reporting ratios are used to measure the relationship between variables that may in fact be years apart. In a steady state environment, these ratios are correct, but the dynamic relationship must be understood.

The data presented in Table 2 is therefore primarily useful as a steady state approximation, particularly when used to make projections for a new institution or country establishing an innovation system. The danger of not understanding these dynamics is contributing to false expectations of returns based on observations of essentially steady state data from mature systems.

A model which deals with these issues is presented in the next session.

Innovation System Dynamic Model

The dynamic model combines knowledge of the phasing of the value chain, and the time duration of the various steps, with the steady-state benchmark data in Table 2. The primary purpose of the model is to provide estimates of the likely rate of return and cash-flow forecasts (institutional and national) of alternative innovation system scenarios. As the parameters of any particular innovation system are not known in advance (and are difficult to measure even in retrospect) the main use of the model is as a 'what-if' tool to explore alternative approaches and predict likely bounds on performance.

Table 3 illustrates one possible model based on a hypothetical institution investing R100m pa for 20 years. The model has also been used for actual institutions where the past and future research expenditure is known or can be forecast. Any available data on past invention disclosures, patents or licences can also be used as 'initial conditions' as the model can incorporate as much past data as is available to support the future forecasts.

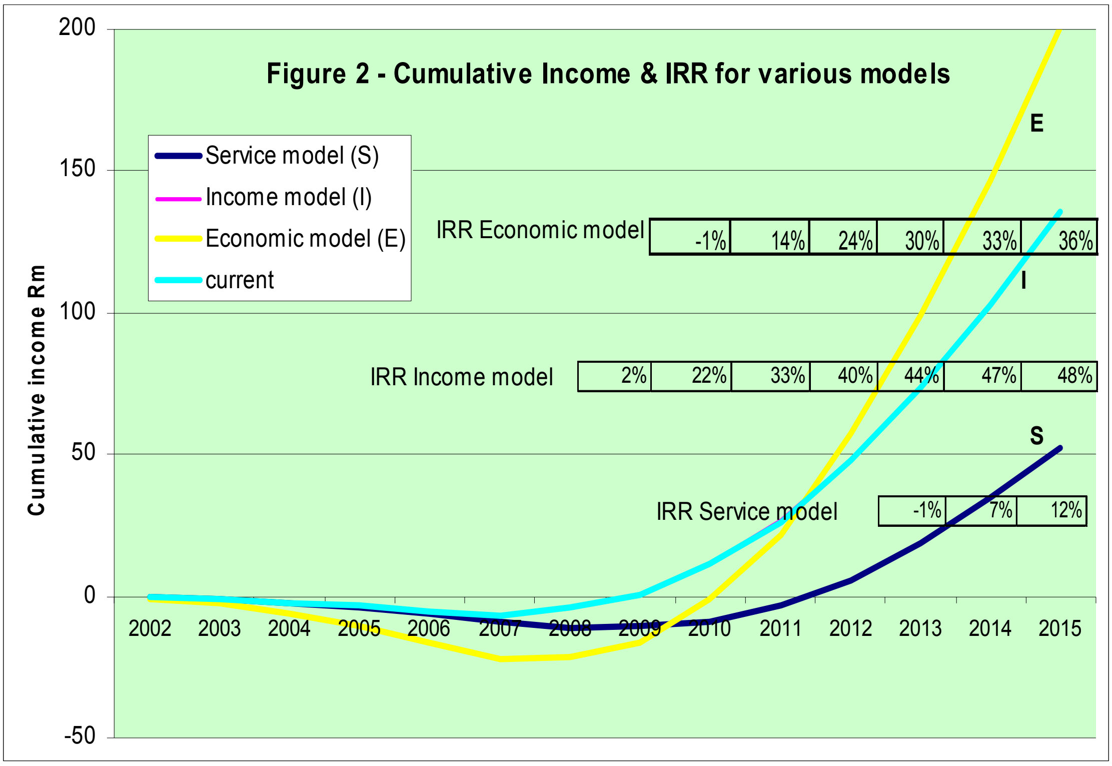
The use of the model for providing estimates of the GDP impact of an innovation system is described below.

Table 3: Technology Transfer Model - Institutional and national effects

	Param eter	Years lag	Year																			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Research Rm			100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Disclosures	R 8.0		13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Patents	50%	1		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Average patent cost Rm	R 0.2	0		R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3
Licences	20%	2			3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Licences lapsing		7										3	3	3	3	3	3	3	3	3	3	3
Licences cumulative	#	0	1	1	4	6	9	11	14	16	19	19	19	19	19	19	19	19	19	19	19	19
Royalties Rm	R 0.2	3				R 0.2	R 0.2	R 0.7	R 1.2	R 1.7	R 2.2	R 2.7	R 3.2	R 3.7	R 3.7	R 3.7	R 3.7	R 3.7	R 3.7	R 3.7	R 3.7	R 3.7
Spin-outs	10%	4					1.3	1.3	1.3	1.3	1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3
Income from sale of spinout Rm	R 3.0	5										R 3.8	R 3.8	R 3.8	R 3.8	R 3.8	R 3.8	R 3.8	R 3.8	R 3.8	R 3.8	R 3.8
Total income	Rm					R 0.2	R 0.2	R 0.7	R 1.2	R 1.7	R 2.2	R 6.5	R 7.0	R 7.5	R 7.5	R 7.5	R 7.5	R 7.5	R 7.5	R 7.5	R 7.5	R 7.5
Office costs (salaries & overhead	R 0.3	15%	R 0.3	R 0.3	R 0.3	R 0.3	R 0.3	R 0.4	R 0.5	R 0.6	R 0.6	R 1.3	R 1.3	R 1.4	R 1.4	R 1.4	R 1.4	R 1.4	R 1.4	R 1.4	R 1.4	R 1.4
IP costs	Rm			R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3	R 1.3
Net income	Rm		0	-R 1.6	-R 1.6	-R 1.4	-R 1.4	-R 1.0	-R 0.5	-R 0.1	R 0.3	R 3.9	R 4.4	R 4.8	R 4.8	R 4.8	R 4.8	R 4.8	R 4.8	R 4.8	R 4.8	R 4.8
Cumulative income			0	-R 1.6	-R 3.1	-R 4.5	-R 5.9	-R 6.8	-R 7.3	-R 7.5	-R 7.1	-R 3.2	R 1.2	R 5.9	R 10.7	R 15.5	R 20.3	R 25.1	R 29.9	R 34.6	R 39.4	R 44.2
IRR to institution							0%	0%	0%	0%	0%	-9%	2%	9%	13%	15%	17%	18%	19%	20%	20%	21%
Income as % Research					-1.6%	-1.4%	-1.4%	-1.0%	-0.5%	-0.1%	0.3%	3.9%	4.4%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
Economic impact estimates																						
Turnover at average royalty rate	3%		0.0	0.0	0.0	6.7	6.7	23.3	40.0	56.7	73.3	215.0	231.7	248.3	248.3	248.3	248.3	248.3	248.3	248.3	248.3	248.3
GDP Multiplier	1.5		0.0	0.0	0.0	10.0	10.0	35.0	60.0	85.0	110.0	322.5	347.5	372.5	372.5	372.5	372.5	372.5	372.5	372.5	372.5	372.5
Tax revenue direct	30%		0.0	0.0	0.0	3.0	3.0	10.5	18.0	25.5	33.0	96.8	104.3	111.8	111.8	111.8	111.8	111.8	111.8	111.8	111.8	111.8
Indirect mulitplier	4		0.0	0.0	0.0	40.0	40.0	140.0	240.0	340.0	440.0	#####	#####	#####	#####	1490.0	1490.0	1490.0	1490.0	1490.0	1490.0	1490.0
Tax revenue indirect	25%		0.0	0.0	0.0	10.0	10.0	35.0	60.0	85.0	110.0	322.5	347.5	372.5	372.5	372.5	372.5	372.5	372.5	372.5	372.5	372.5
Net income			-100.0	-100.0	-100.0	-90.0	-90.0	-65.0	-40.0	-15.0	10.0	222.5	247.5	272.5	272.5	272.5	272.5	272.5	272.5	272.5	272.5	272.5
IRR - national									-	-	-	-	-3%	3%	7%	10%	11%	13%	14%	14%	15%	16%

Figure 2 shows the results of using a range of parameters which represent the three main Technology Transfer Office operating models, called the income, service or economic models[1]. The choice of office operating model depends on institutional and national policy, capabilities and resources. Each model can be defined by a set of innovation value chain operating parameters. Using these parameters enables future performance of an office (or country) to be calculated, including investment outlay required, patent prosecution costs, time to break-even and potential Internal Rate of Return (IRR).

The importance of the model is not the accuracy of the predictions, which can of course be no better than the underlying parameters and assumptions underpinning their use. The primary benefit is understanding the dynamics and the relatively long time scales. This can help avoid unrealistic expectations and also provides the basis for a series of intermediate benchmarks to provide confidence that the innovation system is moving in the right direction. Invention Disclosure, for example, is clearly an important early indicator that measures both the health and vibrancy of the research system as well as the likely future innovation performance.



Economic impact estimation

> *"The economic impact of the licensing of technologies developed at academic institutions is remarkable. The responses from member institutions estimate that the licensing of innovations made at academic institutions contributed over $40 billion in economic activity and supported more than 270,000 jobs in Fiscal Year 1999. In addition, business activity associated with sales of products is estimated to generate $5 billion in U.S. tax revenues at the federal, state, and local levels." **(AUTM 1999**)*

[1] A description of these models is beyond the scope of this paper. The AUTM Directors Toolkit has a good overview. (**AUTM 2002**)

The calculation or even estimation of the economic impact of technology transfer activities has been actively debated for a number of years. The statement above in the AUTM 1999 licence survey has been disputed and in subsequent years AUTM has refrained from making claims in the survey, but have identified the need for ongoing research on this.

Despite the contention over specific claims of economic impact, in all countries that have active innovation systems and promote university technology transfer, it is widely recognised that the process is of economic benefit. The many countries that are investing resources in technology transfer development confirm that there is widespread confidence that the investment is worthwhile and generates a positive return. (Whether this confidence will continue in the face of slower and lower than hoped for returns is another matter.)

The overriding argument that is used with considerable justification in developed countries, is that the research is being undertaken in any event and that for a small additional cost (around 0.5 to 1%) significant additional benefits can be realised.

In developing countries with smaller economies, less developed innovation systems, and many competing demands for resources, the situation is not quite as clear. What is clear from the benchmark data is that the volume of innovation activities arising from research is directly proportional to the volume of research i.e. research funding. If additional investment in research is therefore proposed on the basis that it supports economic growth, some justification for this needs to be shown i.e. that there is a positive return from that investment.

As the return to the institution performing the research is small (1% to 4% of research expenditure), income generation for the institution from licence and spin-outs is clearly not the reason for investing in research. The benefits are captured primarily at the national economic level, through business creation, with national returns arising from the direct and indirect economic impacts.

Even assuming the investment in public sector funds in research is made (whether for economic development reason or otherwise), a further difficulty is the magnitude of the investment required over an extended period (8 to 10 years) by the research institution before a positive return is likely. The highly uncertain and variable nature of the returns, discussed below, compounds these difficulties for the institution and makes a compelling case for institutional support from public funds for the technology transfer process over and above the support for research per se.

Measuring the national economic impact is difficult and has been the subject of intense discussion and debate. The following is proposed as a highly simplistic model to illustrate the concepts and motivate for additional research into the development of more comprehensive models.

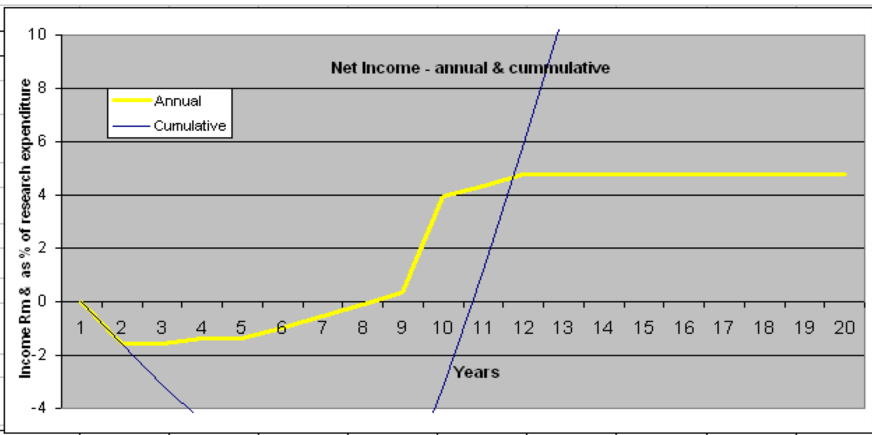
Assuming an average royalty rate in the range of 2 to 4%, and a direct GDP multiplier of 2 (reasonable for high value added technology intensive business) then the impact on GDP will be between 2 to 4 times the investment in research – after a 10 year lag.

This GDP return is the direct return from the activities measured and managed by the institutional technology transfer offices. There is strong evidence, that the entrepreneurial culture resulting from the focus on technology transfer results in many more benefits which are neither captured nor measured by the institution. These benefits can only be estimated by examination of regional developments such as Silicon Valley or Route 28. These benefits are estimated to be an order of magnitude more than the direct benefits. Whether similar benefits will accrue in less concentrated regions of technological development is difficult to say, as the more dispersed and the smaller the contribution, relative to the local economy, the harder it is to measure.

Figure 3 illustrates these concepts in an example projecting the international benchmark figures to South Africa. These projections are of course sensitive to the assumptions made. The model indicates for example, that a positive IRR can only be achieved if the secondary effects are at least 3 to 4 times more than the direct effects. This reinforces the need for a more in-depth understanding of innovation system dynamics so that these effects can be understood and measured.

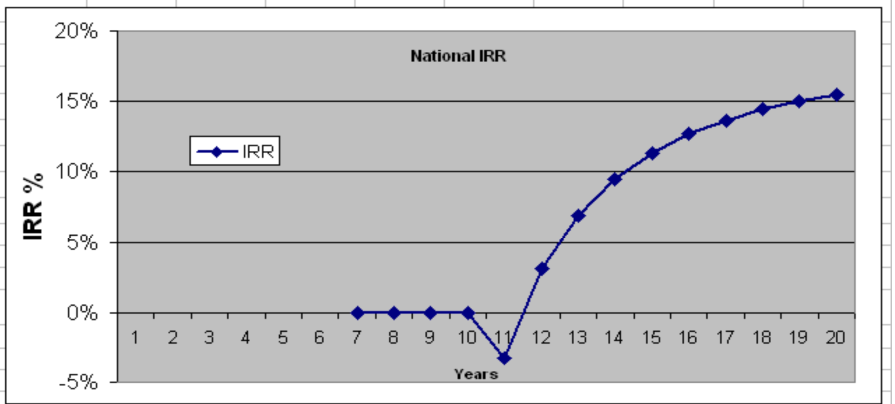
Figure 3: Projection from institutional to national internal rate of return (IRR)

	Parameter	Years lag
Disclosure Rm	R 8.0	
Patents	50%	1
Average patent cost Rm	R 0.20	
Licences	20%	2
Licence period		7
	#	
Royalties Rm	R 0.20	3
Spin-outs	10%	4
Income from spinout Rm	R 3.0	5
Office costs (salaries & o/hs)	R 0.3	15%



Year	9	10	11	12	13	14	15	16	17	18
IRR (institution)	0%	-9%	2%	9%	13%	15%	17%	18%	19%	20%

Parameters:	
Average royalty rate	3%
GDP Multiplier	1.5
Tax revenue direct	30%
Indirect mulitplier	4
Tax revenue indirect	25%

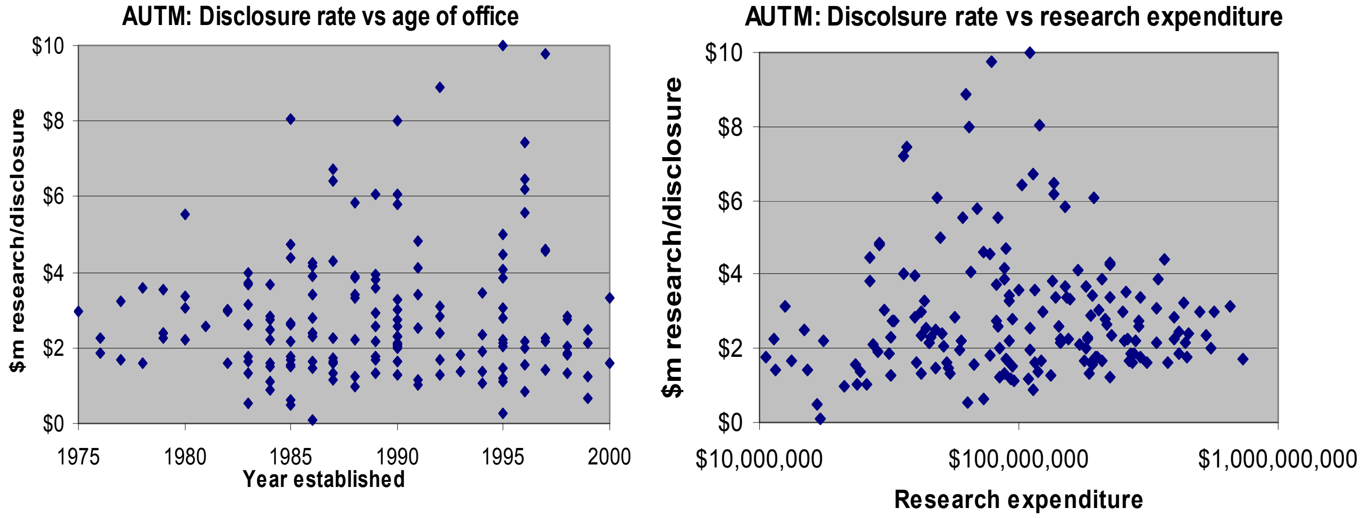


Variability of benchmarks and returns

The benchmark data from all countries and many hundreds of institutions shows a very high variability from year to year and institution to institution. This variability is observed on all measures in the value chain: invention disclosures, patents, licences, spin-out companies, and income. The variations are up to two orders of magnitude, even for institutions that in other respects are similar. Analysis of this data by income, size of the institution, maturity or size of the technology transfer office indicates that none of these variables are strongly correlated with the efficiency or performance measures. The only figure that shows any significant correlation is that the innovation output measures are proportional to the volume of research, as measured by expenditure on research. Even this figure is proportional only in aggregate over a large portfolio, with strong institutional variations.

Figure 4 for example shows the variation in invention disclosure rate in terms of $m or research per invention disclosure. Although in aggregate over time and across countries

Figure 4: Invention disclosure rate as a function of age or size of institution

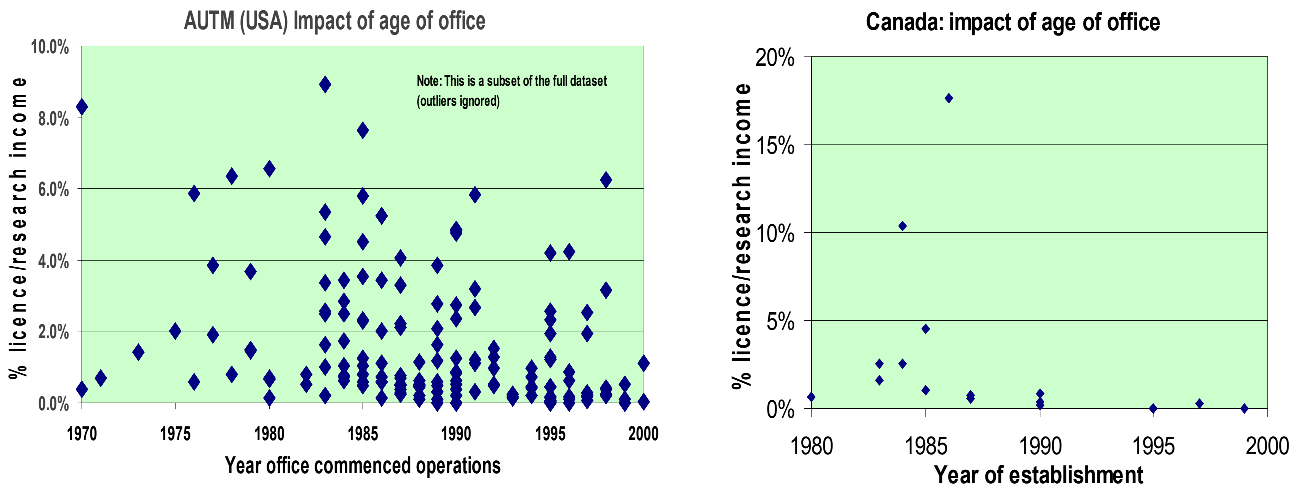


the figure is relatively constant, at institutional level very strong variations occur, irrespective of the size or maturity of the institution. Data from the European ASTP survey shows a similar distribution and this wide distribution is not unique to the USA.

Figure 5 shows the variation in licence income (as a % of research expenditure) for US and Canadian institutions. The Canadian institutions demonstrate the 10-year start-up lag before significant revenue is generated, confirmed by experience reported in the literature (**Clayman 2002**). But even after this portfolio-establishing period, returns to offices of similar size and experience vary greatly.

The US data shows even higher variability, with both young and old offices exhibiting low and high returns, with an order of magnitude common. (Outliers of those few offices reporting greater than 10% income are omitted.) Noteworthy also is the large number of offices 10 to 20 years old which earn less than 1%, and many which are under 0.5%. Most of these offices will be running at a net loss, with the cost of patent protection and office costs exceeding income received. The UK data (UNICO 2001) exhibits similar trends, with even more offices running at a loss.

Figure 5:Licence Income (as % of research expenditure) vs age of office



This high variability in returns, and in the intermediate benchmarks, has been noted and studied. (**AUTM 1999, 2000, 2001**), (**Sherer 2000**) and (**Marsili**). While the variability in innovation returns appears to be inherent to the nature of innovation, the variation in returns in early intermediate benchmarks e.g. invention disclosure rate, is not affected by the same factors. While variable, this variability is less inherent and more manageable. Economic returns are determined by an unpredictable set of market factors, whereas the intermediate benchmarks are more controllable by the technology transfer offices. Skilled, experienced staff can make a significant contribution to generating & motivating invention disclosure – and of course the subsequent steps in the value chain.

Evidence of this can be found in Figure 6 which shows the invention disclosure rate vs size of office. As the office size increases, there is a converging trend towards the world norm of $2m of research per disclosure. While aggregation over a larger number of disclosures will be a contributory factor in the larger offices, it is likely the bigger offices are staffed by more skilled and experienced practitioners, with more opportunities for peer learning than is possible in smaller offices.

Figure 6: Invention disclosure vs number of staff

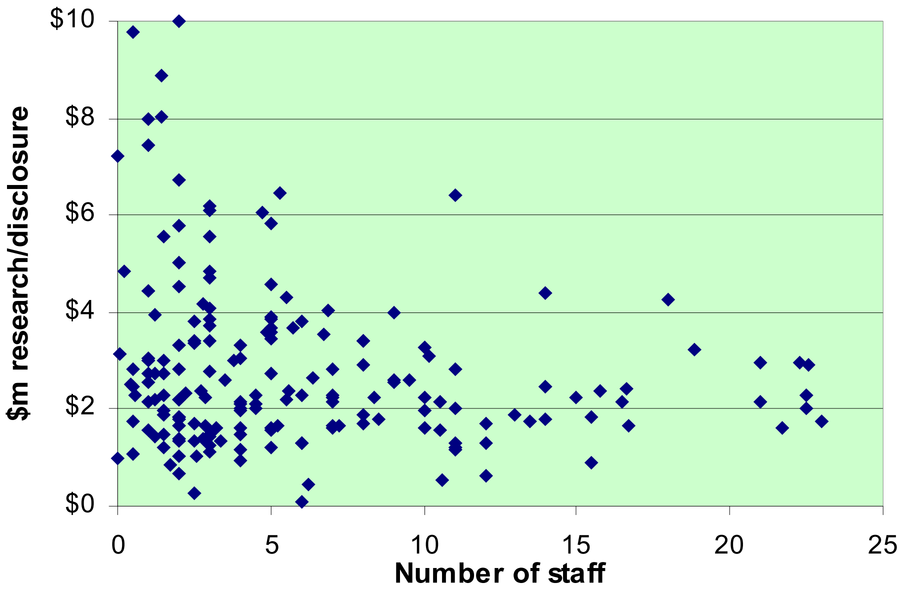


Figure 4, relating office age to disclosure rate, could be expected to show a similar trend, but as the average tenure of technology transfer professionals is reported to be around 3 years[2], age of office is not a good indicator of accumulated expertise. With the average office size of 3 professionals (Table 1) this implies that there will be only one person in the average office with 2 or more years of experience. In smaller offices knowledge retention will be an even bigger problem.

The impact that skilled staff could have on the overall innovation process and the benchmark figures is a topic for further research that could have the potential to increase innovation returns substantially if best practice could be identified and disseminated. This is particularly relevant to smaller, more isolated offices and offices in developing countries where the peer learning is absent. Strong professional networks are critical and need to promoted and developed.

Sherer and Harhoff performed an in-depth study on returns from innovation (**Sherer 2000**). Based on their analysis of 8 large patent portfolios in both USA and Germany, they conclude:

[2] Techno-L discussion list communication May 2003

*"Our empirical research reveals at a high level of confidence that the size distribution of private value returns from individual technological innovations is quite skew — most likely adhering to a log normal law. A small minority of innovations yield the lion's share of all innovations' total economic value. This implies difficulty in averting risk through portfolio strategies and in assessing individual organizations' innovative track records. Assuming similar degrees of skewness in the returns from projects undertaken under government sponsorship, public sector programs seeking to support major technological advances must strive to let many flowers bloom. The skewness of innovative returns almost surely persists to add instability to the profit returns of whole industries and may extend even up to the macroeconomic level. Although much remains to be learned, some important lessons for technology policy have begun to emerge" (***Sherer 2000***)"*

The AUTM data confirms this skewness is even more apparent in university portfolios with an average of only 1 in 200 licenses generating more than $1m in revenue (**AUTM 2001**). This concurs with Sherer's data where of the 8 portfolios he analyzed, the 3 from universities all had higher levels of skewness than the industry portfolios. This skewness is of particular relevance to smaller institutions and countries.

Projections for South Africa

If South Africa were to attain an innovation performance similar to comparable institutions elsewhere, the benchmarks in Table 2 indicate that the entire South African higher education research system could be expected to generate 250 to 300 invention disclosures per annum – when operating at international norms of efficiency i.e. trained staff are in place. After 7 to 10 years this should lead to a portfolio of around 500 active licences, 2 of which would be likely to be generating revenue of greater than $1m pa, and with total revenue of between $5m and $10m pa.

Furthermore, the distribution of returns will almost certainly be skewed, even amongst the 5 or 6 major research universities, let alone the 15 smaller institutions. A few institutions are likely to perform relatively well, while the majority are likely to operate at a net loss, even after 10 or 15 years. Furthermore, the skewness and variability of returns means that it is not possible to predict who is likely to succeed and who will "fail".[3] Given the financial constraints that exist in higher education institutions, the continuation of institutional support for technology transfer is unlikely, unless external support or stimulus is provided.

In the USA the Bayh-Dole act has provided a major stimulus, but the difficulty of using a similar measure in South Africa is illustrated by the differences in funding. In the USA federal funding is 61%, industry 9% of total research funding (**AUTM 2001**). In South Africa, industry funding is 58% and government funding 28% of total research funding (**CENIS 2002**). This funding pattern also implications for IP generation and ownership and is an example of the differences that need to be considered when making projections based on international benchmarks.

Whether the benchmarks from large well-developed countries will scale to small countries is at present not known. Much more detailed analysis and measurement is required to

[3] This disparity in outcome, which can occur even between institutions of similar size, capability and investment, is causing problems. Without an in depth understanding, the benchmarks can easily be misused to penalise offices whose performance may in fact be entirely adequate. In the USA it is reported that some universities are even considering withdrawing from participation in the AUTM survey because the benchmark data has been used, by their own management, to berate institutions whose performance is perceived to be less than that of their peers.

determine appropriate benchmarks, and to construct more accurate and pertinent models, of both the innovation value chain and the economic impact parameters.

If the parameters that have been used in the model above are within the ballpark, or are attainable over time, then there is a net positive economic benefit to the country from an investment in research in higher education institutions. But given the constraints and difficulties, it is unlikely these will be realized without substantial public sector support for research and for appropriate technology transfer activities.

Conclusions

Key conclusions and recommendations for further research are:

- Unrealistic expectations of the benefits from technology transfer in smaller countries and institutions can damage the innovation process and lead to withdrawal of support – at the time when success may be just 'around the corner'.
- Effective models of the innovation system based as much as possible on local data, can help predict budget requirements, the possible return on investment and the time scales to attain these goals.
- Measurement of the local innovation system should commence at the earliest possible stage as early indicators, such as invention disclosure rate, can provide insight into how the remainder of the value chain is likely to develop.
- Well-trained technology transfer professionals are an essential requirement if institutions, and countries, are to have any possibility of attaining international norms of performance.
- Even more important is the need to have a strong research system and a strong research culture. Without that base, there will be insufficient 'deal flow' into the innovation system. Without this flow, no innovation office can perform, no matter how professional they are.
- The economic dynamics of innovation systems in developing countries is likely to be significantly different from that of developed countries. This needs study and determination of the structure and parameters.
- The skewness of returns needs to be understood and evaluation of institutions and innovation systems needs to be nuanced. More emphasis will need to be placed on intermediate benchmark measures and less on traditional performance measures such as licence revenues and spin-out company formation.
- Appropriate national support measures need to be introduced to encourage innovation development and overcome institutional resistance in resource-constrained environments. Research is needed to determine what the most effective support measures are, using an innovation system model where appropriate to evaluate and quantify alternatives.

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