

An Analysis of The Biomedical Sectors in Australia and Canada in a National Innovation Systems Context

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Introduction¹²

The previous paper³ provided a comparison of the biomedical sectors in Australia and Canada based heavily on an analysis of biomedical alliances as well as a broader range of indicators. The analysis suggested that the industry in Canada is much larger and more substantially integrated into the global biomedical industry than is simply explained by the relative size of the two countries. While there were significant issues of data definition in comparing the size of the industries in the two countries, the differences across the range of indicators are sufficient to suggest that the industry in Canada is 3 to 4 times the size of its Australian counterpart.

This was supported by the data on alliances, which indicated that the degree of global integration of Canadian companies is substantially greater than is reflected in the differences of size between the two national industries. It showed significant differences in alliance patterns between the two countries. In particular Canadian biotechs had much greater success in forming high value later stage alliances with large pharma than Australian biotechs.

In discussing a framework to explore the reasons for these differences it was agreed that a national innovation systems approach might be helpful. It would provide a framework within which to compare the essential features of the sectors in the two countries and identify the role of policy in these differences.

While the framework provided by national innovation systems has been used to research a range of industries, it is of particular relevance to R&D intensive sectors such as the biomedical industry (Lundvall 1992; Nelson 1988; Bartholomew 1997).

This paper will firstly provide an outline of the major theoretical concepts discussed in the literature on national innovation systems, secondly review related empirical work on biomedical sector and finally begin to develop some explanations for the differences between Australia and Canada.

National Innovation Systems

Edquist and Lundvall (1993) have defined national innovation systems in terms of 'the institutions and economic structure affecting the rate and direction of technological change in the society.' Metcalfe (1995) extends this definition to explicitly include a role for government by describing it as the framework 'within which governments form and implement policies to influence the innovation process'. Niosi (2002) among others, places emphasis on the importance of interactions (linkages and flows) that occur between government and private organisations. These include financial, human resource, and knowledge flows. Following a multi country survey of innovation systems, Nelson (1993, 1996) suggested that differences in innovation systems arise from the large differences in national economic and political

¹ This paper is one of a series of papers comparing the performance of the Australian and Canadian biomedical industries. Over this period new data sources have emerged and where relevant have been incorporated into subsequent analysis.

² The enthusiastic research assistance of Alison Welsh is gratefully acknowledged.

³ See Pharmaceutical Industry Project Working Paper No. 20.

circumstances – levels of affluence, resource endowment, education and attitudes to new technology.

Consideration of innovation systems clearly requires better definition of both innovation and systems. The application of complex systems concepts to economics has a long history, particularly in spatial economics (see for instance, Forrester 1969) in which the many independencies of economic activity, communication and transport costs were modelled in complex systems of non-linear differential equations. Forrester became widely known following the publication of the Club of Rome report, *Limits to Growth*, for which his model, published in *World Dynamics* (Forrester 1971), predicted world catastrophe due to resource depletion and environmental degradation. Such models have been useful in helping to explain the rapid rise and fall of variables such as population, urban and regional areas, but have tended to be discredited by economists (Forrester was an engineer) for oversimplifying underlying economic relations (see for instance Cole et al. 1973⁴).

Nonetheless the lessons learned from these models proved useful in developing systems concepts and formal methodologies that could be married with the emerging evolutionary economics, which developed from organic/biological analogies (Clark, Perez-Trejo and Allen 1995, 1998). These focused on such issues as perpetual novelty (innovation in new markets, technologies, behaviours and institutions), interdependencies and tangled interactions, adaptation and learning and out of equilibrium dynamics (Rosser 1999).

Of particular relevance was the idea, from systems dynamics, of feedback or self reinforcing mechanisms in socio economic systems (Radzicki 1988, Arthur 1990). In particular Arthur (1988, 1989) demonstrated that under certain conditions one technology would dominate to the exclusion of other competing technologies. The particular conditions he identified were those of increasing returns, arguably the case, given high sunk costs, for most high tech products (Sutton 1999). His analysis showed that once a dominant technology began to emerge, small historical events would act in a self reinforcing manner to ensure that it would assume dominance over technologies sharing the market, even though it was not possible to predict in advance which of two technologies might prevail. In particular, technical excellence was no guarantee of adoption. Examples of inferior technologies prevailing include VHS over Beta in the VCR market (Arthur 1990) and perhaps Microsoft Windows over the Apple Macintosh operating system.

Formal systems are characterised by many feedback loops defined as the transmission and return of information. Agents within systems are assumed to follow goal-seeking behaviour reacting to information and other flows positively or negatively depending on their goals. The self-reinforcing nature of positive feedback loops produce exponential change in systems, while negative loops tend to be stabilising (Radzicki 1988). This suggests that systems have a trajectory of their own, which is not easily shifted. However one difference between the dynamics systems modelled in the computer, and real world socio economic systems, is the capacity of the latter to learn from experience and evolve over time. (Radzicki 1988 quoting Perelman 1980). This

⁴ Interestingly this particular critique also involved Chris Freeman and KLR Pavitt both to become prominent evolutionary economists and proponents of 'national innovation systems'.

notion has its corollary in evolutionary economics in the concept of 'path dependence'.

Innovation systems are typically characterised by path dependence and 'lock-in'. That is to say, the characteristics of national innovation systems are in part determined by an accumulation of historical decisions, skills and knowledge that is likely to be difficult to depart from (Bartholomew 1997). Noisi (2002) suggests path dependence can be explained by such factors as sunk costs, network externalities and increasing returns, which may lock-in the institutions of an innovation system to a particular development path that is difficult or costly to change. This may extend to levels of specialisation and expertise in the knowledge base, for example in biomedical sciences, choice of a pro private capital market regulatory environment which may favour the availability of venture capital. To the extent that these are deeply ingrained in the institutional structure, they may be difficult to change even if a superior strategy is identified.

As with the profession more generally, those economists who support the innovation systems approach to analysing these problems are divided about the ability of government to usefully intervene in the innovation process. Some would suggest that because systems are resilient, self sustaining, indeed path dependent, the action of government can only have, at best, a temporary effect. Rather like the construction of a major freeway that temporarily reduces congestion but is soon clogged by additional traffic. (Radzicki 1988) Similarly Arthur doubts that policy incentives would be effective in changing the choice of dominant technology (Arthur 1989). This view is supported by the power of the stochastic process. That is that systems are driven along by a series of chance and random events over which no government can prevail.

On the other hand, those who are optimistic about the ability of governments to effectively intervene in the innovation process, point to other behavioural characteristics of systems such as positive feedback mechanisms, which can result in small system changes having dramatic compounding or exponential effects (see for instance Niosi and Bas 2004, Kaiser 2003). An aspect of this view is that it is essential to properly understand the innovation system so that policy can be directed at points in the system where it is most likely to have greatest effect. Such interventions may range from modifying a fully functioning system to make it more effective to helping construct an effective system from a partial set of components.

Such a policy intervention might be to encourage the development of a cluster of firms, in which the interaction of interdependent firms produced a better outcome, than their independent and isolated operation. Cooke (2004) suggests that biotechnology has created 'mega centres' which are 'science driven, public and privately funded institutional complexes that in biosciences have as their ultimate goal the production of patient health care' p164. Cooke suggests that there are perhaps 5 mega centres in North America and 3 in Europe. However much regional policy is directed toward creating such centres in other regions (Cooke 2004).

That intervention might be successful also follows from the importance accorded to institutional factors in structuring innovation systems. In particular those seeking to explain the vast differences in the performance of national economies point to the significant differences in national institutional structures. Britain's 19th century

economic dominance, for instance, is seen to be in large part the result of institutional leadership, such as the support for science as a 'national institution', laissez faire economic policies both in relation to domestic markets and international trade, and the development of capital markets to invest in factory production (Freeman and Soete 1997). The identification of the importance of technical education and training systems by Germany in the mid 19th century is seen by many historians as one of the main factors in Germany overtaking Britain towards the end of the century (Freeman and Soete (1997). Thus intervention by government in this case was not only significant, but had an enduring effect on the national innovation system.

It is beyond the scope of this paper to define and discuss in detail the notion of innovation. Economists such as Nelson and Winter (1982), Dosi (1988), Freeman and Perez (1988) have described and categorised various aspects of innovation. Implicitly Dosi (1988) defines innovation as the 'exploration and development of new products and new techniques of production'. Freeman and Perez (1988) distinguish between incremental and radical innovations, changes to the 'technology system' and changes to the 'techno-economic paradigm'. 'Incremental' innovations are of a type that produce improvements in production routines or product quality, while 'radical' innovations are those that produce a major new product, process or organisational change. Changes to the 'technology system' may affect several branches of the economy, while a change to the 'paradigm' follows from an innovation that is all pervasive.

It follows from this dichotomy that biotechnology is clearly an example of a change to the 'technology system' since it has had an impact on several sectors of the economy – health, pharmaceuticals, agriculture etc. While biotechnology may not be as economically ubiquitous as the recent innovations in ICT, Noisi (2003) deems it to be one of three generic technologies to have emerged in the post war period (along with ICT and advanced materials) and accordingly could be considered as a 'technology paradigm' shift. It has certainly resulted in the production of many new products and processes both of a radical and incremental nature.

Components of National Biomedical Innovation Systems

In older industries the source of innovation is linked to such factors as exploiting economies of scale or incremental improvements arising from new capital goods, but biomedical innovation is directly linked to the new biotechnologies based on molecular biology, genetics and biochemistry. The technological opportunity is very high and appropriability mechanisms ranging from patents to significant lead times are available (Dosi 1988). The system dynamics are driven by the high returns available for successfully transforming a discovery into a valued product in the market place.

There is stock of knowledge substantially but not exclusively held by universities and research institutes. Specialist biotechnology companies are involved in the development and transformation of this knowledge into an array of final and intermediate products and services. A range of financial institutions, most notably venture companies, but also pension funds and wealthy individuals are involved in financing this transformation. Pharmaceutical companies are both directly involved in the development process and in supporting the efforts of biomedical specialists

through collaborations and other alliances. They also have a critical role in bringing the final product to market. Government agencies have a central role as a regulator of the development process and provide final product approval for all of the drugs and most other devices produced by the biomedical companies. An array of specialist biotech companies provide vital platform technologies to increase the efficiency of the drug development process. Various contract service organisations are available to conduct trials, manufacture and distribute drugs developed by biomedical companies.

The information, financial and human resource flows between the participants in this highly complex system are central to its functioning (Niosi 2002). The flows are necessary not only to link the specialist participants of the system but also to provide both positive and negative feedback. In an industry in which it is just as important to know about dead end investments, as great successes, feedback is essential for system viability. Scientists need information about medical needs, venture capitalists need to keep abreast of pharmaceutical company priorities and investors need information about financial returns. Finally policy analysts need to understand the reasons for system dysfunction or underperformance and the points of greatest leverage so that government intervention can be most effective.

Empirical research on key success factors of the biomedical industry

The growth of the biomedical industry is typically ascribed to five broad factors (see for instance Zucker et al. 1998a, Hall et al. 2002, Bartholomew 1997, Government of Canada 2001). These are:

- Excellence of the life science base
- Generous government funding of health and biotech related R&D
- Availability of finance - government start up grants, venture capital or other risk capital
- Strategic alliances that provide technology access and product development support
- Favourable regulatory regime (or absence of an unfavourable one)

Each of these factors has its place in any conception of the biomedical innovation system, although their proponents do not always evaluate them in a systems context. For each factor, there are many subsidiary factors and issues of measurement and emphasis. Niosi (2002) provides a table of indicators to measure the effectiveness and efficiency of an innovation system, the quality of its outputs and volume of flows and synergy levels. The empirical research also provides an important perspective on the appropriateness of these indicators as well as the relative importance of the various factors.

Three contributions to the empirical research are reviewed here – the role of firm linked star scientists in increasing the value of those firms (Zucker et al. 1998a); the importance to the commercialisation process of biotech venture capital clustering; (Powell, Koput, Bowie and Smith-Doerr 2002) and finally the significance of in-house capabilities in determining the financial fate of the biotech company (Bagchi-Sen, Lawton Smith and Hall 2004).

One of the reasons given for the successful development of biotechnology in the leading clusters of Boston Mass. and the San Francisco Bay area is the proximity of

leading research institutions – Harvard and MIT in Boston, Stanford in San Francisco (see for instance Swann 1998 (check); Casper and Karamanos 2003 comparing Cambridge and Boston; Kaufman et al. 2003). Zucker et al. (1998a) have explored one of the mechanisms by which this association benefits biotech firms. They examine the role of Californian star scientists affiliated with nearby biotech firms. The nature of the affiliation may range from part ownership, to consulting contracts or membership of scientific advisory boards. Most star scientists continue to maintain their university positions while being affiliated with a biotech firm. The research showed that firms, with which such scientists were affiliated, increased their employment by four times as much over a five-year period and introduced many more products to the market over this period, compared with those without such affiliations. The affiliation had generally been formed prior to the period reviewed.

The relative absence of such a strong role of the star scientist may provide part of the explanation for the poor performance of the Cambridge, UK biotech cluster when compared with its US namesake. Casper and Karamanos (2003) show the relatively low level of association between Cambridge University and biotechs in the region across a range of measures – location of academic collaborators, scientific advisory board membership and prior employment. Most glaring was the failure of the world class Sanger Centre (headed by a Nobel Prize winner in gene sequencing) and the European Bioinformatics Institute to participate in commercialisation activity. No scientist from either body was employed on the scientific advisory board of any firm.

Biotechs supported by VC firms tend to have higher productivity levels, eg generate a higher number of patents than those that don't have that support. In the United States the leading centres of biotechnology, Boston, Massachusetts and the San Francisco Bay Area are co-located with venture capital (VC) firms. Powell et al (2002) show the important role played by local VC firms in the development of biotechs in these two centres, particularly in their early stages. About 58% of firms in these centres received funding from local firms. New York VC firms were most likely to support non-local firms. The study showed that locally supported firms had, on average, a shorter time to IPO than 'externally' supported firms. The study appears to support the proposition that the close involvement of nearby VC's in the management and guidance of biotechs promotes their early development. It also suggests that the VC's knowledge of suitable investment bankers to conduct the IPO is also likely to be important.

The importance of alliances in the development of the biotechnology is well supported by the literature (see for instance Arora et al. 2001; Powell et al. 1996; Baum et al. 2000; Hagedoorn 1995, Lerner and Merges 1997; Rasmussen 2004c; Rothaermel 2001) each of which discusses various aspects of alliances. As has been argued in the previous paper, alliances provide often essential later stage financing and expertise. Niosi (2003) suggests that the role of alliances in biotechnology has been overemphasised, although the conclusion of his study is to provide caution about the significance of properly timing alliance formation to maximise its benefit, rather than to discount its importance altogether.

A survey of US biotechnology firms by Bagchi-Sen, Lawton Smith and Hall (2004), while confirming the importance for business success of various proximity factors – research institutions, venture capital firms and other specialist services, found that the largest scores explaining business performance, were received for in-house

capabilities – managerial skills, ability to recognise commercial applications and quality of product. This indicates that at least from the point of view of biotech managers, their greatest challenge is to overcome their own perceived shortcomings.

The empirical literature appears to broadly support most of the five factors proposed above as the essential features of the biomedical innovation system. For instance the importance of the knowledge base, venture capital and alliances are each confirmed. However the actual process of commercialisation of scientific knowledge is clearly important, with Zucker et al. (1998a) drawing attention to the critical role of the star scientist.

It is beyond the scope of this paper to provide a detailed evaluation of each of these factors for Australia and Canada. Clearly the previous paper provides a strong basis for consideration of the influence of strategic alliances, but the other factors can at best be sketched out at this stage.

The Life Science Base

Both countries would claim that their science base is a competitive advantage in establishing a biomedical industry. A recent analysis of the comparative positions of the two countries appears in the Third European Report on S&T Indicators (European Commission 2003) for the period 1995-99. This suggests that both countries have a relatively powerful life science base. Canada is ranked 6th in the world with 25,039 publications while Australia is ranked 11th with 13,200 (about equal on a population adjusted basis). However Canadian research is cited more frequently, 8.9 times compared with 6.9 for Australia. This puts Canada up to 3rd in the world, while Australia remains 11th ranked. The mean field citation score in basic life sciences, considered the most accurate in levelling out various country size distortions, still has Canada ranked ahead of Australia, 6th vs 14th. A number of smaller European countries improve their positions, as does Singapore, based on this measure.

Table 1 in the earlier paper showed that the number of biotech patents issued by the US Patent Office over the period 2000-03 totalled 305 for Australia compared with 913 for Canada. An analysis of patents prepared by CHI (ARC 2000) shows, for the period 1994-98, a similar pattern to that of scientific papers. Canadian patents in the pharmaceutical and biotechnology sectors tend to be cited more frequently than Australian ones. It is this citation by subsequent patents that has been found to correlate closely to the value of the technological advance made by that prior patent (ARC 2000, p. 24). To measure this, CHI constructed a 'current impact index'. For the biotechnology sector it was 1.02 for Canada and 0.88 for Australia. For the pharmaceutical sector it was 1.12 and 0.84 for Canada and Australia respectively. Each of these indices was relatively high in terms of country rankings – Canada was second, behind the US, in both the biotechnology and pharmaceutical sectors, amongst a group of 10 selected competitor countries listed in the report. Australia ranked 5th and 4th in the biotechnology and pharmaceutical sectors respectively.

This analysis suggests that while Australian science is certainly world class, it does not have the equivalent impact of the Canadian life sciences.

Both Federal and state government have instituted various programs to bring back Australian scientists from overseas. The work of Zucker et al. indicates that the presence of the star scientist is not sufficient. It is necessary for them to be actively involved in the commercialisation process through links with local biotechs for these programs to be effective.

Public Spending on Life Sciences R&D

Table 1 in the previous paper⁵ provided a number of indicators of public expenditure on life sciences related R&D. The most comparable measure between the two countries is public expenditure on health R&D. This showed for 2001, that Canada's expenditure was substantially higher, C\$2.8b compared with Australia's of A\$1.3b. This issue will be discussed further in the section on 'Innovation Policy Settings.'

Availability of Finance

Comparative measures of sources of finance for the biomedical sector are at best patchy. For instance a survey of Australian venture capitalists (AVCAL) indicates that venture capital investment in Australian biotechs was A\$257m in 2001, while the Canada Statistics survey of Canadian biotechs suggested that the Canadian figure was C\$363m. Such figures are however subject to considerable year-by-year variation. The Australian figures for 2000 and 2002 are A\$41m and A\$53m. Comparable data are not available since the Canadian survey was not conducted for those years.

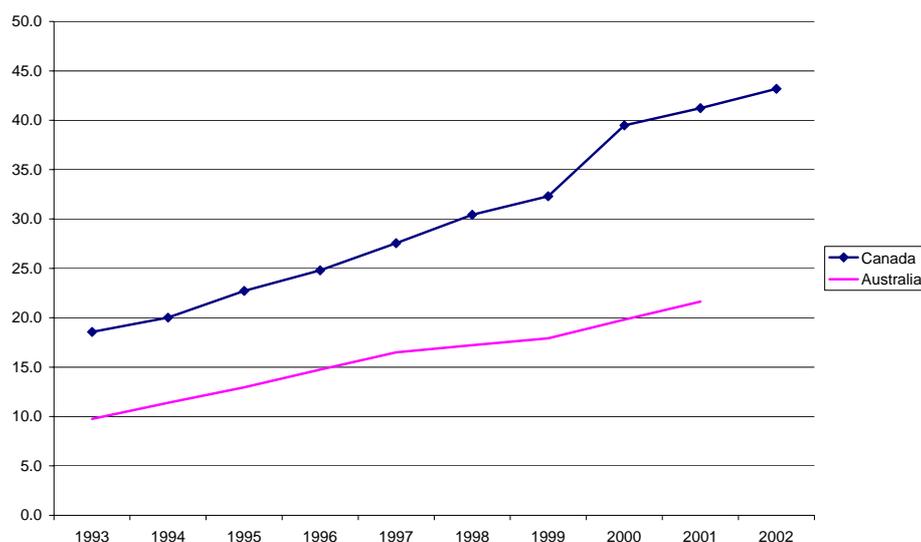
An alternative view of private sector funding is provided by business expenditure on R&D. While this will include some expenditure provided by government sources, at least for Canada, this appears to be less than 3% of the total (Statistics Canada 2003d). Again comparability of coverage is an issue, however biotech-related business R&D expenditure was \$C2241m for Canada compared with A\$647m for Australia in 2001.

Another view of the availability of finance, comes from private expenditure on health R&D – largely expenditure on pharmaceuticals and medicines which may exclude some relevant biotech R&D. For a number of years, comparable data for the two countries dating back to 1993. This data on a per capita basis are shown in the table above.

Canada's private expenditure on health R&D on a per capita basis has been consistently above Australia's, although over the decade 1993 to 2002 shown in the chart above, the growth rates of the two countries have been much the same. Per capita expenditure in 1993 was C\$19 for Canada compared with A\$10 for Australia and by 2001 it had grown to C\$41 for Canada and A\$22 for Australia. While coverage by this data series of the total biomedical sector is an issue, this pronounced and persistent difference has doubtless had a significant impact on the relative development of the biomedical industry in the two countries.

⁵ See Pharmaceutical Industry Project Working Paper No. 20.

Chart 1. Private Per Capita Expenditure on Health R&D in Canada and Australia (\$)*



Source: Access Economics 2003, Statistics Canada.

*Australia in A\$, Canada in C\$.

Strategic Alliances

The analysis of strategic alliances presented in the previous paper indicates a considerable gap between Canada and Australia. This is particularly the case for drug development alliances, but also applies to technology alliances. Canada's close proximity to the United States might be expected to give it a particular advantage. Certainly Canada represents a close-by, lower cost source of biomedical research expertise, than many companies in the United States (KPMG 2002). However it is only a partial explanation. Canadian alliances with European companies seem to be of at least equal breadth and depth.

One particular advantage apparent from the analysis is that there is a greater number of later stage drug development alliances formed by Canadian companies. Presumably this reflects a more advanced drug development pipeline than Australia's. However whether the existence of high value, later stage alliances is a cause or effect is more difficult to judge. The broad based participation by both European and US large pharma, capable of large investments, is certainly a feature of the Canadian alliances.

Relatively speaking, Australia's strength is in platform technologies, diagnostics and devices, but even in these, compared with Canada, Australia 'punches well below its weight'.

Regulatory Environment

As is widely recognised, the regulatory environment for the biomedical sector is fundamental to the conduct of the industry. This covers patent protection, product approval and sales approval by national and provincial agencies. Both Canada and Australia offer similar levels of IP protection and this should be competitively neutral between the two countries. The key regulatory authority for product approval is the

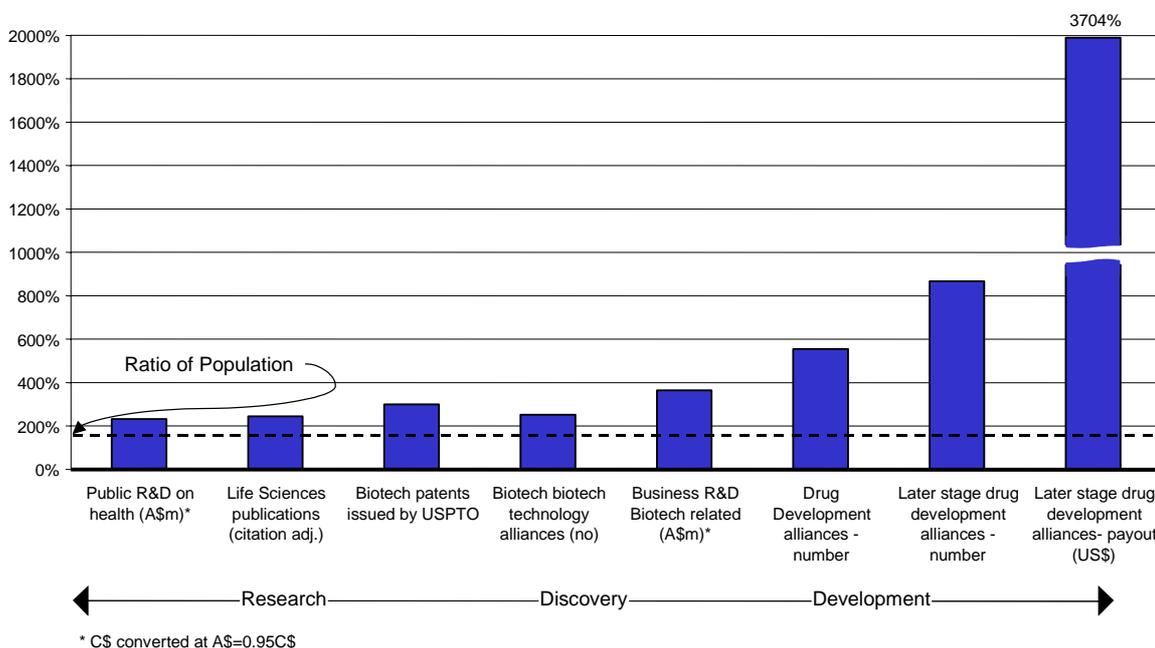
US FDA, which stands guard over the world’s largest market. Companies in both countries therefore, seek approval through much the same process.

The sale of drugs is controlled, in both Canada and Australia, by governmental bodies and the key issues are delays in the approval of drugs available for sale and the price of those drugs. The price of drugs for the Australian market is set under the Pharmaceutical Benefits Scheme and Canadian prices are set by the Patented Medicine Prices Review Board. Sweeny (2003) shows that Australian prices are 30-40 %, and Canadian prices are some 50-60%, respectively of US levels. Canadian prices are however above those generally prevailing in Europe. It has been suggested that the low level of Australian prices acts as a disincentive for pharmaceutical companies to support Australian biomedical research and product development. Certainly the higher relative prices in Canada may act to its advantage.

Policy Implications

Canada appears to be ahead of Australia across a broad range of measures from public support for health R&D to the number and value of drug development alliances. The relatively high drug prices also helps to support an industry, which is significantly larger than Australia’s. Chart 2 draws together the key indicators used through the course of this paper to measure the relative size of particular aspects of the sector in the two countries.

Chart 2. Ratio of Key Canadian to Australian Indicators for the Biomedical Sectors



See Appendix A for details of measures used.

The indicators are presented according to their approximate position in the value chain, from the level of public investment in health sciences, to measures of research outputs and business inputs and finally, the value of alliances, at the later stages of the

drug development pipeline. The reservations and qualifications that pertain to each of the indicators were discussed in the previous paper⁶.

However what is striking about the ratio of Canada to Australia for each indicator is how a relatively modest difference between the two at the beginning of the pipeline, develops to be of such a magnitude towards the end. The benchmark could be considered to be the difference in population between the two countries (163%). The additional investment made by Canadian government agencies is reasonably significant at 232%, but the indicators of research output is higher, 245% for publications and 299% for patents issued. Technology alliances typically focus on the discovery or early development stage of the drug pipeline and is an area where Australia is not so weak, with the ratio of the number of alliances being 252%. The majority of business R&D, which in Australia and Canada tends to be invested early in the development stage, has a ratio of 365%. Drug development alliances provide support for biotechs over each of stage of the pipeline, but most of the differences emerge in the later stages (phase 3 and approved) when the ratio in the number of alliances increases to over 8 times and that for total payout value to 37 times.

This suggests that compared with Australia, Canada's biomedical sector enjoys a virtuous circle in which a relatively small but significant difference in public sector investment appears to produce a very substantial difference in industry performance in the later stages of the drug development pipeline. At each stage the differences between the two countries are magnified.

This would be consistent with an innovation system that is characterised by a series of positive feedback loops. Relatively higher levels of public R&D expenditure in Canada produces a greater number of drug candidates, which encourages relatively higher levels of venture and other private capital, which finances drug projects to an advanced stage attractive to a well funded pharmaceutical alliance. Relative success at each stage appears to be self-reinforcing. Compared with Australia, the magnitude of pharmaceutical alliance commitments would provide domestic capital participants with confidence that exit opportunities were available reinforcing the inclination of venture capitalists and others to invest in the industry.

This would of course be only possible if there were suitable projects to support. Although we lack comparable figures of the complete product pipelines in each country, the Canadian pipeline appears to be significantly larger. Ernst and Young suggests that there were more than 30 products in Phase 3 and 60 in Phase 2 in Canada in 2003. Our own estimates of the Australian pipeline for 2002 indicated that there were about 5 at Phase 3 and over 20 at Phase 2 (Rasmussen and Sweeny 2002). Again the differential is much larger than explained by population or GDP differences, suggesting a more productive research and commercialisation process than Australia.

Innovation Policy Settings

An overall appreciation of Australia's long-term policy commitments to science and innovation is shown in the chart below. This shows Commonwealth support for

⁶ See Pharmaceutical Industry Working Paper No. 20.

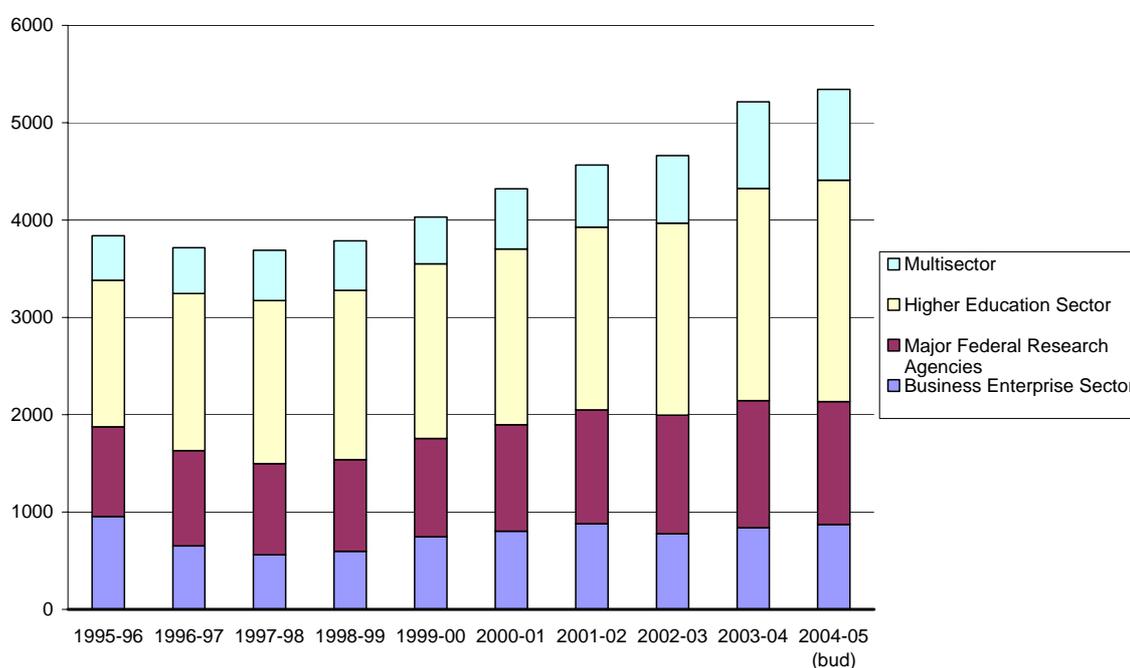
science and innovation through the Budget and other appropriations over the ten-year period to the 2004-05 Budget. Commonwealth government support falls into four broad sectors – one targeted at business and the other three covering funding to various public sector institutions.

Overall support for innovation fell in current dollar terms for the first four years of the decade as funding for business through the R&D tax concessions was drastically cut. A switch to funded programs such as R&D Start was insufficient to make up the difference. Expenditure on the business sector fell from \$954.4m in 1995-96 to \$560.4m in 1997-98. Support for business innovation under various programs recovered somewhat in the second half of the decade to reach \$872.6m budgeted for 2004-05, still lower in dollar terms (approximately 40% lower in real terms) than in 1995-96.

Funding to the public sector, the higher education sector (up 51%) and major Federal research agencies such as CSIRO (up 37%) all received additional funding. In recent years funding to the NH&MRC, part of the so-called ‘multisector’ group has increased substantially from \$163.9m in 1995-96 to \$428.3m promised in the 2004-05 Budget.

Chart 3 overall is of a substantial shift in resources from business support to funding public sector research.

Chart 3. Commonwealth Support for Science and Innovation 1995-96 to 2004-05



Source: 2004 Budget Papers.

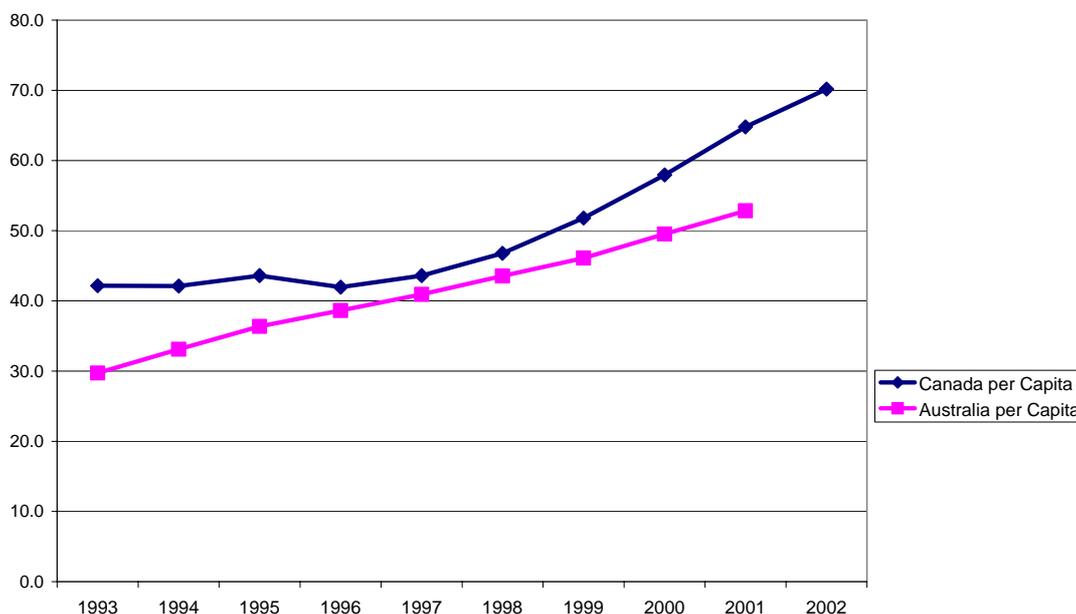
Regrettably we lack comparable data for Canada. However most of the Australian science and innovation programs have their counterparts in Canada. Since bringing its Budget into balance in 1997-98, the Canadian Federal Government has made a significant commitment to science and innovation. It has established and funded large new research bodies such as Genome Canada, restructured its health research funding

institutes by establishing the Canadian Institutes for Health Research and increased the attractiveness of its R&D tax concession scheme. The scheme includes an investment tax credit of between 20% and 35%, which may be used to reduce federal income taxes otherwise payable. The larger provinces also have their own R&D tax concession schemes, (Niosi 2004) all of which leads Canada to claim to have the most favourable tax regime for R&D amongst the G7 countries (ref).

It has also provided assistance and incentives to venture capitalists, reducing the corporate tax rate from 28% to 21%, phasing out federal capital tax and allocating C\$270m from the 2004 Budget and a further C\$400m through the Business Development Bank of Canada and Farm Credit Canada to establish a range of venture capital funds. (Canada 2004).

Comparable time series data are available for expenditure on health R&D for Australia and Canada. Chart 4 shows, on a per capita basis, the quite different trends in public R&D expenditure in health for the two countries. Australia's public investment in health R&D has been increasing steadily over the period for which comparable data are available 1993 to 2001, while Canada's expenditure was flat until 1997 when it began to increase sharply. In 1997 the difference in per capita expenditure was relatively small A\$41 and C\$44. However by 2001 the gap had opened up. Canada's per capita expenditure was \$65 and Australia \$53.

Chart 4. Public Per Capita Expenditure on Health R&D in Canada and Australia (\$)*



Source: Access Economics 2003, Statistics Canada.
Australia in A\$, Canada in C\$.

An Assessment of the Two Biomedical Innovation Systems

Within the constraints of the data limitations a number of observations can be made about the two innovation systems. Canada's biomedical innovation system has enjoyed a much higher level of commercial success than Australia's. Even based on the partial data we have, the number of drug candidates in Phase 3 is many times that

of Australia. The relative level of private sector funding, whether by venture capital or in later stage alliances, is indicative of greater commercial success.

The Australian innovation system seems to be characterised by long-term systemic failure in private sector support for the biomedical industry compared with Canada. Is this a supply or demand side problem? Australia is proud of its science base, which does appear to be world class, but is nonetheless shaded by Canada's as measured by citation adjusted publications and patents. So is there a sufficient supply of 'investable' projects? Australia's per capita public expenditure on health R&D is lower than Canada although the difference is not as large as for other innovation system indicators.

Is Australia lacking effective linkages between science and industry? Do Australia's scientists play the same role of star scientists in the commercialisation process, as Zucker et al have identified as a critical success factor for US biotechs?

Compared with Canada, Australia has significantly under-invested in private R&D in health and while the growth rates for the last decade have been about the same, the gap has remained large. Over this period the Commonwealth has significantly wound back its business innovation support schemes, in particular, the R&D tax concession arrangements, while Canada has made its more attractive. Funding for the pharmaceutical industry through the Factor (f) scheme has been replaced at a much lower level by P3.

Its objectives are laudable. It focuses 'on the develop[ment] of medicines for global markets and [to] encourage multinational firms to foster partnerships with local players' (DITR 2004). It has available \$150m over 5years to support expenditure on R&D. First round offers have been made, to both large pharma and Australian biotech, for amounts up to \$10m. Its objective is to encourage the formation of partnerships, but whether its scale is of sufficient size too to have a serious impact remains to be seen.

Australia's policy initiatives appear faint hearted by international standards. Both countries have intense competition from US states outside the dominant clusters, seeking some share of the biotech 'boom'. Most US states have attractive tax related incentive schemes and a myriad of other initiatives aimed at achieving commercial returns from biotechnology. Florida recently committed US\$500m to recruit the Scripps Florida Biotechnology Research Institute (Battelle 2004).

If Australia's biomedical innovation system was to match the performance Canada's, this analysis suggests that industry policy could usefully focus on three aspects:

- Public expenditure on health and biotech related R&D
- Funding to complement private financing of commercial development
- Policies designed to attract large pharmaceutical companies to partner biotechs

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Appendix A

Table A1: Key Indicators for the Canadian and Australian Biomedical Sectors

Indicator	Year	Australia	Canada	Canada % Aus
Population	2003	19.7	32.2	163%
Public R&D on health (A\$m)*	2000/01	1284	2984	232%
Life Sciences publications (citation adj.)	1995-99	91080	222847	245%
Biotech patents issued by USPTO	2000-03	305	913	299%
Biotech biotech technology alliances (no)	2000-03	121	305	252%
Business R&D biotech related (A\$m)*	2001	647	2359	365%
Drug development alliances				
- number	2000-03	31	172	555%
- payout (US\$)	2000-03	273	2209	809%
Later stage drug development alliances				
- number	2000-03	9	78	867%
- payout (US\$)	2000-03	51	1889	3704%