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Making a Difference:
Canada's influence on globalising science

by

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Prologue

In December, I was asked by the Canada Foundation for Innovation (CFI) to address the topic of Canada's influence on international science. I presume it was intended that I reflect on whether or not Canadian science policy is so structured as to allow Canadian scientists to make a difference; not only by bringing their insights to the substance of the research being undertaken but also by playing a part in setting the research agenda and, so, affecting the direction of research in the various international programmes in which they participate. For this presentation, I have changed the title only slightly and will speak about Canada's influence on globalising science.

Let me explain the reasons for this shift of emphasis. First, science is an international activity in two senses: in the sense that the community of its practitioners are, and indeed have always been, linked internationally by informal communicative links. Second, with the growing capital intensity of research, scientists have found it necessary, in certain cases, to set up large projects based around a common facility. The costs of these facilities have been so large as to require special funding arrangements, often involving treaty-like agreements between governments. It is the requirement for inter-governmental agreement that makes these projects joint ones between nations – hence the appropriateness of the term international science to describe them.

But in both cases the term "international" no longer captures what is going on in research. In the case of informal communications it does not begin to grasp the spontaneous increase in the density of communication that operates currently throughout the scientific community; in the case of projects based on inter-governmental agreements, the term does not capture the spectacular growth of partnerships, alliances and networks that link researchers across national borders but which emerge almost independently of any formal relationship with governments. It is to catch the dynamics of these changes that I have coined the term globalising science. I want to suggest that if Canada intends to make a difference "internationally" it will need to look more closely at the extent of its participation in globalising science.

Globalising science may be thought of as a mode intermediate between the spontaneous forms of communication and collaboration that have always existed between members of the scientific community and the rather more heavily bureaucratised forms of international science that are normally associated with "big science" and that often involve treaty- like arrangements between countries. This mode is "globalising" in the sense:-

- that the problems that make up the research agenda arise in a variety of different contexts; some, well beyond either any national policy framework or, indeed, the disciplinary structure of science; many of these problems are multidisciplinary in nature;

- that their solutions are pursued through collaborations between researchers that can be based in any country in the world and be drawn from any of the vast number of organisations in which research is carried out competently;
- that the composition of any research group is determined by the nature of the problem and may change as the problem develops;
- that the forms of organisation in which the research is pursued are more open, flexible and sometimes rather transient, and which may embody a range of organisational arrangements and modes of working, often involving specialised forms of infrastructure, customised to the problems to be addressed;
- that financial support for the research flows in from a range of sources.

Globalising science is an outcome of the new context in which governments, corporations and universities currently find themselves. This new context comprises four principal elements: a rightward shift in political thinking, an intensification of competition that is often associated with globalisation, a new, more central role for knowledge-based innovations, and the emergence of a socially distributed knowledge production system which is increasingly acquiring a global dimension.

Within the new context change is being driven by a range of factors but perhaps most obviously by the intensification of competition, not only between firms but also among universities and government research establishments. As I will explain, it is the intensification of a specific form of competition that is driving the research agenda of globalising science. The way this works can be seen most clearly in terms of the distinction between static and dynamic competition as they work themselves out in the process of innovation in industry. In the new context, I will argue, universities face similar problems that firms do as competition intensifies in the higher education sector. I will conclude by arguing that “making a difference” implies that Canada strengthen its participation in the agendas of globalising science.

1. The new context

Rightward shift in political thinking

In all jurisdictions, both public and private institutions are having to learn to engage with a new context. As I have indicated, there are several elements to this but they all seem to be related to a profound shift in our political thinking. A case for this change has been cogently argued recently by the eminent political scientist, John Dunn who has observed that “across the nations the balance of beliefs and sentiments of a given population, the institutional forms through which that population can act, and the cumulative consequences of the actions which members of those populations choose to perform, have all shifted in the direction of one particular kind of order - that is, to the values, institutions and modes of organisation of a capitalist political economy.” (Dunn, 2000) This complex of

changes, which I will summarily refer to as the “rightward” shift, is not primarily about which of the various models of capitalism – whether the Anglo-Saxon, the German, or the Japanese form – will come to dominate the global economy. Rather, it describes changes in the ways in which individuals want to organise their lives and the institutions in which they choose to place their trust in achieving their personal and communal objectives.

The belief that the institutions of a liberal political economy - essentially those that promote markets – are the ones most likely to provide the framework within which to make our life-choices constitutes a revision of our expectations concerning the ability of our public institutions to provide “goods” we desire. How far this will go, and for how long this belief will be sustained, we cannot know but such a profound change is bound to touch those institutions, which, heretofore, have been responsible for delivering education. Universities, in particular, cannot expect to be exempt from them. To the extent that universities are drawn into the rightward shift, they enter more intensely into competition with one another, not only nationally, but also internationally. Universities now view one another with a wary eye, for they compete against each other for students, staff, and, increasingly, for resources of all kinds.

Globalisation and competition

Globalisation is an admittedly ambiguous term. For our purposes it can be viewed as the outcome of the processes of imitation, adaptation and diffusion of innovations as they are taken up by one country, firm or institution after another. From this perspective, globalisation is simply a consequence of the spread of industrialisation from one country to another. Here, innovations are “solutions” to problems of many different kinds - whether they are new technologies, organisational forms, or modes of working. As innovations these “solutions” offer different ways of doing things and as such they can pose a threat to established routines.

Innovation always provokes a competitive response in so far as it induces other participants in the market to seek to protect themselves from a possible threat to their position. The appropriate and indeed most common, competitive response is more innovation. Under globalisation this threat can now arise anywhere in the world. Thus, globalisation enhances competition and stimulates innovation but the particulars of any innovation - the ways in which it can be imitated or adapted - depend critically on local circumstances. Not only firms but also countries differ in their abilities to imitate, and adapt solutions produced elsewhere. Globalisation, then, turns on differences in the processes of imitation, adaptation and diffusion between one locality and another. Globalisation processes do not operate to produce the homogenisation of institutions, corporations and products, as is so often asserted. In fact, the overall effect of the diffusion of innovation is to increase diversity and to produce not uniform but different forms of indigenous capitalisms with different scientific, technological and industrial characteristics.

Was this not the case, globalisation as a phenomenon would be undermined at its roots and atrophy.

Knowledge-based Innovation

The sources of innovation, it appears, increasingly lie in knowledge and this underpins the belief that we now live in a knowledge economy. But note that the vitality of the knowledge economy does not necessarily imply a simple dependence on the flow of scientific discoveries but rather it relies on the ingenuity with which individuals, groups and organisations are able to imitate, adapt and diffuse solutions using knowledge that has been in all probability, generated by others. Unfortunately, this cannot be done unless potential innovators possess at least some formal knowledge. That is why universities are so crucial to this type of economy. If they do nothing else, university education generates in its graduates the ability to access knowledge. Whether they can then do anything with this knowledge depends upon their creativity and the resourcefulness of national and regional innovation systems.

Socially distributed knowledge production

The fourth element which contributes to the new context concerns the spread of research as a recognisably competent activity that is practised well beyond the walls of academe. The past fifty or so years have seen the emergence of a socially distributed knowledge production system. Though this system is acquiring a global dimension it is not its geographical reach which is of greatest significance. Rather, socially distributed knowledge production is meant to refer to the fact that research is now carried out in many different types of organisation; in universities, industrial laboratories, and government research establishments to be sure, but also in a vast numbers of private foundations, research institutes, think tanks, and consultancies. This system comprises the reservoir of skills and expertise which are available to enter into a variety of problem contexts. In the maintenance of this reservoir, the universities play an important part by providing a supply of trained researchers, but as research has become a more socially distributed activity so the universities have become only one player amongst many.

Socially distributed knowledge production has five principal characteristics: -

* There are an increasing number of places where recognisably competent research is being carried out. This can be easily demonstrated by consulting the addresses of the authors of scientific publications, though change, here, is taking place so rapidly that the full extent of the social distribution of knowledge production is probably no longer fully captured by the printed word.

* These sites communicate with one another and, thereby, broaden the base of effective interaction. Thus, contributions to the stock of knowledge are derived from an increasing number of tributarial flows from various types of institutions that both contribute to, and draw from, the stock of knowledge.

* The dynamics of socially distributed knowledge production lie in the flows of knowledge and in the shifting patterns of connectivity amongst these flows. The connections may appear to be random but they move with the problem context rather than according either to disciplinary structures of science and scholarship or the dictates of national science policy.

* The number of inter-connections is accelerating, so far apparently unchanneled by existing institutional structures, perhaps for the reason that these connections are intended to be functional and to survive only as long as they are useful. The ebb and flow of connections follow the paths of problem interest, and the paths of problem interest are no longer determined by the disciplinary structure of science.

* Knowledge production, thus, exhibits heterogeneous, rather than homogeneous, growth. New sites of knowledge production are continually emerging which, in their turn, provide intellectual points of departure for further combinations or configurations of researchers. In this sense, the socially distributed knowledge production system exhibits some of the properties that are often associated with self-organising systems in which the communication density is increasing rapidly.

The distributed character of knowledge production constitutes a fundamental change both in terms of the numbers of possible sites of expertise and in their degree of connectivity. Crucially, it also provides a significant fraction of the human resources upon which globalising science depends.

These four elements, then, the rightward shift, globalisation and intensifying competition, knowledge-based innovation and socially distributed knowledge production are linked and, together, constitute a new context in which all our institutions are immersed and with which they are trying to come to terms. One effect of the new context has been to increase greatly competition between the institutions and organisations that make up society, whether they be governments, corporations or universities. To this intensifying competition firms, in particular, have responded by forming alliances and partnerships with researchers located not only in universities but throughout the socially distributed knowledge production system. Globalising science, then, can be seen as one response to the uncertainties generated by competition in the new context.

2. Competition as a discovery process

Though others might express it differently, perhaps by laying more stressing one or other element, the overall shape of the new context that I have adumbrated is probably uncontroversial. Nonetheless, it may seem surprising, perhaps even paradoxical, that in the new context intensifying competition is associated (1) with a virtual explosion in the numbers of collaborative ventures and (2) the fact that

these ventures often involve collaboration with competitors. After all, is it not the case that competition, together with the institutions of the market, are meant to weed out the inefficient? Why then, as international competitiveness intensifies, do we see collaboration amongst competitors?

The paradox is removed once it is realised that in market-type economies there are, at any given time, two modes of competition at work simultaneously. These modes are sometimes referred to as static and dynamic competition.

One way to get at the differences between static and dynamic competition is take on board the notion that any change in the intensity of competition always launches a discovery process. Discovery processes differ in their modes of organisation and search behaviours, depending on the goals that are being sought. Accordingly, static and dynamic competition stimulate two fundamentally different types of search behaviour: one, largely internal to an organisation, deals with the issues of resource allocation and the efficiency of their use. With this, most will be familiar. It underlies the notion of efficiency gains that has dominated the minds of the senior management of most universities and government research establishments for more than a decade. The second mode of search behaviour involves what is sometimes called, environmental scanning. It looks outwards, beyond the walls of an organisation, and with the characteristics of this mode of search behaviour we are, by and large, unfamiliar. Yet, it is this externally-oriented search behaviour that moves organisational thinking beyond the need for efficiency gains toward the pursuit of those innovations which may be necessary to stave off a major threat from a competitor.

Firms, know very well, and fear greatly, a challenge to their existing ways of doing business arising from an innovation that they cannot meet through a simple change in product performance. Environmental scanning, however, involves much more than talking to colleagues, going to conferences, reading the scientific and technological literature, or surfing the web. Environmental scanning is not an armchair activity. In order to mitigate the risk that their business might be rendered obsolete firms scan the environment by doing something; principally, they join networks, make strategic alliances and form partnerships that carry out research. These inter-firm collaborations often involve competitors, in part because they are intended not to make improvements to existing products and processes but to search for new ideas, technologies, organisational forms and modes of working that might allow them to withstand a major competitive threat, and in part because design configurations tend to be complex entities and, therefore, require ranges of skills and knowledge which few, if any, organisations possess in-house. Dynamic competition generates what could be called competition-induced collaborations. Dynamic competition lies at the root of the current explosion of research partnerships and alliances between firms and resolves the paradox that these collaborations can also involve competitors.

There are several important differences between static and dynamic competition:

1. Static competition drives the search for efficiency gains within an established design configuration (way of doing things); dynamic competition drives the search for new design configurations (novel ways of doing the same things, ways to do different things, etc.);

2. Static competition tends to rely on more efficient use of existing resources that are internal to an organisation; dynamic competition draws upon resources that are more widely distributed, beyond the organisation's boundaries.

3. Static competition tends to favour incremental innovation within the framework of an established design configuration; dynamic competition, by contrast, seeks to find ways to change the established design configuration and so can be said, provide the basis for radical innovation;

A simple example of the role of design configurations in the innovation process can be seen in cases where an existing way of doing things is threatened by a new technology. Think of the dilemma that faces firms devoted to delivering classical music. Historically, the sequence of delivery systems extends from vinyl records to tapes to CDs to MP3 systems to whatever next. They all deliver Beethoven's Ninth Symphony but each uses different and sometimes superior technologies; physical groves in the case of vinyl records, magnetic films in tapes, lasers in CDs, and microprocessors in MP3 systems. Each of these technological solutions constitutes a distinct design configuration. Each uses a different nest of technologies and requires a different configuration of knowledge and skills.

4. Such sequences of new design configurations are common throughout industry; but what is not often realised is that strategic alliances, networks and partnerships are among the principal ways that firms search for them.

5. Perhaps the least understood difference between static and dynamic competition lies in the fact that whereas in static competition markets select amongst products, in dynamic competition markets also exist but in this case they operate to select those research groups which appear at a given time to be making most progress towards the solution of some problem or other. As with other types of markets, so too, here, information concerning progress and performance of research groups circulates in the relevant selection environments; participants use this information to determine whether to continue in a given collaboration or to move on; funders use it as a basis for moving their resources differentially from one group to another. Over time, hierarchies emerge as intelligence reports circulate about the relative progress being made, or otherwise, of different groups. In such a market, there will be winners as well as losers because research groups differ in their creativity. Inevitably, some will succeed while other will fail. To join an ineffective collaboration can be disastrous

for a firm and, therefore, choice of which groups to join, and for how long to remain, are amongst the most important decisions that it ever makes.

Dynamic competition drives radical innovation; that is, the search for new design configurations. Amongst firms, as we have seen, dynamic competition works through networks, alliances and partnerships to promote the establishment of groups of researchers and through circulating information about performance of different groups, set up markets which will select the most creative amongst them. This mode of searching and the research collaborations to which it gives rise gives rise, to one part of the research agenda of globalising science that I have already outlined at the beginning.

But it should be noted these these sites of collaborative research – spawned, as they are, by firms in search of alternative design configurations - also act as "attractors" for academics; in part, because they involve research at the leading edge of a disciplinary field, but also because, for many academics, the opportunity to work in these problems solving groups provides an important way for them to utilise and develop their specialist skills. Into this process are being drawn an increasing number of members of the university community. In fact, the numbers of academics participating in this type of industry-oriented research are already large enough for the experience to begin to "feedback" into, and so is beginning to affect, the ways in which research is pursued in universities. These competition-induced collaborations contribute significantly to the development of globalising science.

3. Impact of dynamic competition on universities

Of course, universities are not businesses, at least not yet, but perhaps I have said enough to indicate that, in the new context, both types of organisation are in a similar position. In the new context, universities too are being buffeted by the rightward shift in political thinking; are being subjected to intensifying competition both from within and from outside the higher education sector, have begun to recognise the need to find innovative ways to maintain their positions through collaboration in the research market place and, increasingly, in the teaching market place as well. Unsurprisingly, they, too, are forming networks, alliances and partnerships with other universities as well as others in the socially distributed knowledge production system.

But, if talk about intensifying competition in higher education is more than rhetoric, then one should be able to discern the effects of both static and dynamic competition on them. Let me being first with static competition. In terms of the language I have developed, universities have embraced what amounts to a global design configuration. It is known as the disciplinary structure of science and scholarship and this structure organises both teaching and research in almost every university. The disciplinary structure determines not only what "good science" but also what it is that students must be taught. When league

tables are produced university departments can be ranked in terms of "excellence" because they all have departmental structures which reflect the disciplinary structure of science and scholarship. Because of this, across the higher education system, the similarities between departments of physics, chemistry, biology, economics or sociology are greater than their differences. Were it otherwise it would not be possible to draw up league tables in the first place. Static competition dominates here, and, for example, when governments impose cost reductions on universities they meet the challenge by searching for efficiency gains within disciplinary structure. In terms of static competition, the similarities between universities and firms in this respect are clear. Both are working within the confines of their chosen design configuration and to the extent that circumstances induce a search for changes, they will be limited to those that are possible within the existing design configuration. As is always the case in the regime of static competition, innovation is incremental.

If firms realise the dangers of being committed to a single design configuration - to one way of doing things – so, too, do academics and university presidents. And, it is dynamic competition that creates the need to search for new design configurations in universities. Here, the pressures exerted by the new context on academics has launched the search for ways of carrying out research that promises some protection against the possibility that the peer review system will announce that their specialism is no longer of the first rank, or perhaps even moribund. As with firms, academics have extended their expertise into other problem contexts by forming networks, alliances and partnerships in both research and teaching, some of which overlap with industry-led searches for new design configurations.

The effects of dynamic competition are evident. In addition to research organised according to the dictates of the disciplinary structure of science and scholarship, universities now house a vast array of units, centres, institutes, think tanks and consultancies. Not infrequently, these organisations are staffed with experts drawn from somewhere in the socially distributed knowledge production system. Academics choose to enter these collaborative arrangements for both personal and professional reasons: for example, working on complex problems provides opportunities for them to develop their skills which they might not otherwise have; may give them access to a broader base of research funding; and allows them to add another string to their bow, against an uncertain future. In this sense, the collaborations that academic enter into are competition-induced; they are undertaken in anticipation that a threat to their professional livelihood might arise from discoveries made elsewhere. Working with others to develop new research paradigms that lie out with the disciplinary structure, provides ways for academics to develop alternate research strategies because in the new context it is prudent to do so.

So it is that contemporary universities are differentiated not only in terms of research excellence within the disciplinary structure but also by the creativity and

resourcefulness of faculty and administration in configuring establishing research and teaching partnerships to address a wide range of problem contexts some of which lie out with the disciplinary structure. If the excellence of a university is still largely determined by its ranking within the disciplinary structure, its vitality and robustness against competition on this front from others, is perhaps more accurately measured by the range of units, centres, institutes, think tanks and consultancies that are housed within its walls.

As ever, here, too, with universities, dynamic competition is a source of radical innovation; that is innovations undertaken to meet the possibility that the established way of doing things might be about to change. Through these collaboration-based innovations, university faculty engage with a much broader range of problem contexts than they would encounter within the disciplinary structure. In a word, by forming these partnerships and alliances, universities link their faculty to the agendas of globalising science.

4. Making a difference

The distinction between static and dynamic competition makes it possible to address the question of where, and how Canada could make a difference, where the difference in questions is determined in terms of its impact on what I have termed globalising science.

Canada may have a small economy but its science policy is very bullish. Currently, the Federal Government is committed to increasing the percentage of GNP devoted to research and to improving its position in the OECD's GDP-Research league table; has established a research chairs programme which is the envy – not to say the fear - certainly of every Commonwealth country; has gone some way to meeting the indirect costs of research. Likewise, the Canadian research council system has for many years been in the lead in terms of establishing multidisciplinary research programmes in universities; and has contributed to the strengthening of Canadian research capabilities through a variety of schemes, including the Network Centres of Excellence Programme. More radically, the CFI has been invented and supports, among other things, infrastructure development in Canadian universities, nationally and internationally. In the current, sometimes depressing, funding climate, Canada stands out, perhaps uniquely at the present time, in terms of its Government's firm financial commitment to excellence in research in universities, and its determination to utilise the results of this research to promote international competitiveness in industry and improve the quality of life of Canadian citizens.

It is to be expected that most of the funds expended under these various headings will be aimed at developing Canada's research capability, nationally, and will be spent at home, so to speak. And perhaps that is as it should be. But, in some fields, national research capability can only be maintained by providing access to large international programmes; say, in radio astronomy or nuclear

science. NRC, for example, supports Canada's presence in many large international science projects.

On the surface of it, it would seem unlikely that a country with a relatively small economy could be expected to make significant impact on international science, as conventionally defined. International science, in the sense in which I have used it here, tends to be dominated by big players, primarily the USA, who have successfully transformed scientific research in these fields into a capital intensive activity, effectively open only to those that can invest at appropriate levels.

Consider, for example, the "big science" installations in radio astronomy, nuclear science, geophysical explorations, which are organised through governmental institutions. Countries pay an "access fee" which allows them to use common facilities and to have a say in the shaping the research programme. For the most part these international collaborations are enormous enterprises and the research programmes are determined by those who pay most. It is probably not too unrealistic to suggest that the scientific impact of Canadian investments in these types of programmes is, natural Canadian genius apart, somewhat limited because of the relatively small size of their financial commitments.

But investments in international science, as important as they are, deal with only part of the question of Canada's influence on international science. The other part has to do with establishing a determining Canadian presence in the new regime of globalising science. Here, CFI currently is playing an important role through its international infrastructure programme. Here, it is important to draw a distinction between access funds and funds for infrastructure. The former concerns Canada's participation in international science and has already been dealt with. The latter aims to support infrastructure projects that are managed the universities themselves; that encourage multidisciplinary research; that are linked to provincial priorities; that are funded from several sources; and that are related to each university's research strategy. Perhaps uniquely, it allows Canadian dollars to be spent outside of Canada if the infrastructure project requires it.

The idea here is to use "state of the art" infrastructure as an "attractor" to draw into collaborative activity the "best researchers world wide to work with the best Canadians". If this should involve building facilities in another country, then so be it. For the most part, inter-governmental agreements are unnecessary.

By using infrastructure as an "attractor", CFI has already facilitated the establishments of a number of world class research groups. By allowing universities to choose the partners they want to work with, by funding infrastructures that will facilitate collaboration, and requiring universities to assume responsibility for managing the project, CFI is promoting dynamic competition and drawing Canadian universities into the regime of globalising science. Through its various administrative innovations, CFI has ramped up the numbers of collaborative partnerships in which Canada can have a *determining*

presence and, therefore, may be expected to give more Canadians the opportunity to have a major influence on the shape of globalising science.

Although CFI has been extremely innovative in its programmes, it remains a relatively small organisation and, its long term future is by no means assured. A crucial question is whether, and for how long CFI can continue its record of innovation. It must be “oh so tempting” to try to draw it into the bureaucracy of the Canadian science system. In my view, this is the very opposite of what is required in the new context. Globalising science requires more open, flexible approaches to research; to its organisation and funding as well as the modes in which researchers work.

Let me give two examples where Canadian scientists, possibly with the assistance of CFI, could make even more of a difference in terms of impact on globalising science. The first concerns a new nexus between teaching and research, and the second an extension of CFI’s current practice to encourage job sharing.

Teaching and dynamic competition

You may be feeling that I have made rather a lot of fuss about design configurations and that, while they may be important in industry, their relevance for universities are somewhat limited. Let me then illustrate an area where I believe dynamic competition is at work in universities, where new design configurations are being sought, where competition-induced collaboration is taking place, and where the outcome will radically change the ways that universities do business. I refer here to a new nexus between teaching and research.

Traditionally, university professors have been both researchers and teachers. But while as researchers they have been “committed” publishers, as teachers they have been little more than “occasional” publishers. For most academics, there has been little incentive to raid their grey filing cabinets for the lecture notes that have formed the basis of the courses that they have taught over a lifetime with the aim of publication in mind. These filing cabinets doubtless contain much insightful material, but in many ways they are personal accumulations of knowledge. The materials in them have been modified, year after year, to meet what it was thought students needed to know. In this process, it was the academics themselves that largely decided how they would structure their courses. They constructed reading lists, set essays and examination papers, and determined the level of mastery of the subject that each student achieved. At the end of each course, the lecture notes were then put back in the grey filing cabinets to await the next crop of eager students hungry for the knowledge contained in them.

Now all this is changing. It is my contention that in universities, teaching is going to become a research-based activity and that academics will have to move from

being occasional publishers of their privately held teaching materials in books to committed publishers of their innovative approaches to specific teaching and learning in a variety of contexts. Indeed, with the increasing use of the Internet in both course design and delivery, academics will find that they will be submitting ideas for course designs to a peer review process similar but more open than the one which they are familiar when they publish research papers; more open because, in large part, peers will be evaluating work in progress.

The drivers of this change in university teaching the same elements of the new context that I described earlier: the rightward shift in our political thinking, the intensification of competition brought about by globalisation and the search for knowledge-based innovation and the emergence of a socially distributed knowledge production system. Let me illustrate:-

The *rightward shift in political thinking* has transformed students, if not into consumers, into aware individuals who have ideas about what they want to learn, expectations of the skills they want to acquire from pursuing a given course, how it will be delivered and assessed, and how, if they take it, they can extend their knowledge further by taking other, more advanced, courses. Parents make use of university league tables and scan the higher education market for the best university that they can afford for their offspring. They also have expectations of what they want from the university in return for their investment. Finally, governments and industry have encouraged universities to reach out to disadvantaged sections of the community, to take the lead in developing life long learning respectively and to structure their courses offerings accordingly. All of this argues for much greater attention to the details of course design and delivery.

The *intensification of competition* being brought about by the rightward shift puts pressure on individual institutions to develop a much broader range of courses that meet the requirements of a diverse set of students, each with a particular level of ability, interests and academic/career intentions. The increase in competition in course provision, here, is in no small part due to the entry of private sector firms as players in the delivery of course materials.

Knowledge-based innovations are the solutions being sought, but the inputs extend far beyond the grey filing cabinet. Required now are the development of subtle learning methodologies for teaching students more or less complex ideas, the use of accredited psychological techniques to structure learning experiences for different formats – whether class room teaching, small group work or distance learning - in which a degree of self assessment allows students to move at a speed appropriate to their abilities and previous history - and the development of methods for more or less continuous assessment. In this, each knowledge “knowledge element” must be integrated into larger packages that will allow the student to move from, say, elementary algebra to set theory, and beyond with some mixture of independent study and group tuition.

The point of all this is that each stage of the learning process – course design, modes of delivery, evaluations, etc. - involves the generation of knowledge by established researchers from many different areas. This knowledge will emerge from research traditions in their own right but most of this knowledge will not be possessed by the average mathematician, physicist, economist, or historian, as such. To illustrate using the language that I have developed in this paper, one could ask what are the most effective design configurations for teaching physics, or chemistry, to post 25 year old students who know no mathematics and want to study part time? No one knows the answers to these questions, but in future such courses will have be designed with methodological rigour to reach a much broader range of students. Exploratory behaviour is necessary and will involve drawing the appropriate expertise from the socially distributed knowledge production system. We are here in the regime of dynamic competition. To compete, universities will need to join collaborative ventures in the search for those design configurations that show at least some prospect of being applied to the objectives in teaching and learning that the particular university wants to achieve. As I have already indicated, finding the right group is crucial for institutions individually and making the right choice is among the most important decisions that any academic senior management team will ever make.

Further, course design in the sense that I am using that term here will, in all likelihood, be developed using electronic forms of communication, and that products at various stages of development will be shared on the Internet with other members of the collaborative team. As a consequence, academics – whether their discipline be economics, educational psychology or methodologies for self assessment - will be exposing to one another their ideas in both their strengths and weaknesses. Peer review systems will emerge spontaneously and will make judgments as to quality and robustness of each element in the course design a matter of public knowledge – at least among the groups of specialists involved. And finally if, as seem likely, the final product - the single course or the cluster of courses – adopted by a particular institution is readily available on the Net, students will be able to compare the relative approaches and evaluate the costs and benefits of different institutional offerings.

As Alan Jenkins has suggested in a recent article in *The Times Higher Education Supplement*, the new nexus between teaching and research then lies in teaching becoming a more professionalised, research-based activity. It is well known that universities differ in their ability to do good research. Now, they will be subjected to external peer judgments about the quality of their teaching, as well. But it is not simply as another university research activity that the new nexus derives its importance, but, rather, in the innovations - the designs for new teaching and learning experiences - that this research makes possible. No university will be able to hold, in-house, all the knowledge required to produce these innovations. And, if industry has anything to teach us it is that if one fears that one's way of doing business might be undermined by an innovation from an unknown quarter,

then the intelligent way to proceed is to form partnerships with others wherever, even if some of them happen to be competitors.

In sum, international competitiveness in higher education is beginning to manifest itself in teaching and is driving what I have called research-based teaching. If universities are to meet the challenge of wider access and life long learning, innovations in teaching will be necessary. In this, major investments in infrastructure will be necessary. Could an infrastructure programme to support the development research-based teaching in Canadian higher education be configured so that it can maintain its competitiveness in the emerging global markets for higher education services? Research-based teaching is surely an idea whose time has surely come but as with most research-based activities, it won't come cheaply.

Job sharing

The second example concerns what is sometimes called the greying of the professoriate. We know, indeed we have known for a long time, that all universities are going to experience massive retirements as the current generation of academics hired for the most part in the 60s and 70s reach retirement age. What is not so well known is that the supply of new academics available to replace them has reached dangerously low levels. In Canada, in particular, the Association of Universities and Colleges of Canada (AUCC) has calculated that in the next decade or so Canadian universities will need to recruit about 2500 academic per year for about a decade, to replace the cohort that is going to retire over that period. Unfortunately, the PhD programmes of Canadian universities will be turning out, in total, only about 1000 PhD graduates per year. Assuming that all of these will want to go into academic life – a most unrealistic assumption, based on current behaviour patterns - there will be an annual short fall of about 1500 academic recruits for about a decade. From where will these young academics be found?

Well, in the time-honored fashion, I suppose that universities will pinch young staff from one another. The problem is that across the Commonwealth most universities are in the same boat. The proximate reason is easy to determine: in many Commonwealth countries the numbers of students presenting themselves for postgraduate work has all but collapsed. As a result, there are simply not going to be enough young PhDs graduating to meet demand. This a serious matter for which there is no easy, comprehensive solution. In my view, something amounting to a global war on highly qualified personnel is erupting as universities try to recruit the best young staff that they can. As a consequence, we are likely to experience intellectual asset stripping on a global scale which will undoubtedly benefit a few universities but which can only leave the higher education system as a whole seriously weakened, if not undermined.

Yet, what other choices are there? If one recalls that it takes about 7-10 years after first a degree to train someone for an academic career, attempting to increase the supply in this way will not remedy the situation quickly enough.

One possibility would be to explore the whole question of job sharing as an interim way to maintain a university's teaching resources, at least in the short term. For example, if Canadian universities used one third of the salary of one retiree they could pay the salary of a visiting university professor from the developing world for, say, an academic semester. This would attract the needed teaching resources -- teaching resources --, bring instant improvement to the financial position of the professor from the developing world while creating a job there, and reduce the pressure of having to make a large number of appointments quickly which on the current AUCC scenario might mean having to take on as university teachers, staff without a PhD.

On the basis of the model I have outlined here, universities might be able to attract one or two part time high quality professors, not all necessarily from the developing world, for the price of one retiree while not stripping the home country of its, always scarce, intellectual resources. Could CFI help here by adding to proposals for international research infrastructure an incentive to recruit partners who, in addition to participating in research, would be agreeable to undertake a semester's teaching in a Canadian university? The groundwork for such a scheme has already been prepared by CFI. In its international infrastructure it has assembled research partnerships amongst the best the world has to offer. To me it is inconceivable that these individuals would not also be competent teachers, because if they weren't, they would hardly be credible as scientific partners. Such a development would allow the current crop of retirees to be replaced in a rational fashion, while meeting the need to teach the current cohort of students.

5. Concluding summary

To conclude: Globalising science may be thought of as a mode intermediate between the spontaneous forms of communication and collaboration that have always existed between members of the scientific community and the rather more heavily bureaucratised forms of international science that are normally associated with "big science" and that often involve treaty-like arrangements between countries. Globalising science is a mode that is well adapted to address the kind of research problems that may be expected to arise from the new more open context generated by the rightward shift, intensifying competition and globalisation. In CFI, Canada has invented precisely the type of organisation that, through its modes of infrastructure investment, can make it possible, for a more diverse set of Canadian scientists to have a determining presence in the shaping of the scientific agenda in years to come.

END