The Impact of Basic Research on the Economy
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It is an honour to have been asked to speak to the Canadian Club today. In doing so, I am aware of the long list of University of Toronto Presidents who have preceded me at this podium each of whom discussed issues of the day of great interest to the University and the community. So it is today. Above all, I welcome the opportunity to speak to you on a topic that I view with passion – the impact of basic research on the economy.

I speak to you as a physicist, researcher, teacher and academic administrator, and as one who has been intimately involved over the last three and a half decades in the unprecedented revolution in research in the United States in industry, the national laboratories and, most especially, universities. I have been witness to, and a beneficiary of, the enormous impact that scientific research has had on the US and Canadian economies.

My own experience, and all the empirical evidence, both national and international, reveal that major investment in university-based research including especially basic science, has a direct payoff for the economic success and strategic interests of the political jurisdictions that support research universities. Research universities are also the prime source of the qualified researchers and teachers who people our nation's research, educational and industrial enterprise.

Before elaborating on the main theme of my address, I wish to clarify what I mean by a research university, and its centrality to my argument. Let me illustrate this by talking about my own university, the University of Toronto.

I. THE UNIVERSITY OF TORONTO AS A MAJOR RESEARCH UNIVERSITY

Virtually all great cities have at their core a great university. The University of Toronto holds that privileged position in our community. The University of Toronto is the largest university in Canada, and one of the world's major public research universities. We are immensely proud of our status as a research university, since we understand that the research university is the optimal environment in which new knowledge is created. In a research university, professional school education, graduate arts and science education, undergraduate education, research and teaching are joined together synergistically and harmoniously like the sections of a great symphony orchestra. In my view, the research university offers the best possible education that one can obtain as an undergraduate, graduate, or professional student. There is nothing more exciting than sitting in a classroom being taught by a professor who, one week earlier, has made some discovery that promises to change the paradigm in her field.

The University of Toronto contains enormous resources and plays a special role among Canada's research universities by virtue of its size and the amazing breadth and

quality of its programs. There is an expert on campus in almost everything that can be imagined. Further, our human resources are in many cases backed up by outstanding research facilities, including the Library--one of the best research libraries anywhere--which is a great resource not just for Toronto but for Ontario and all of Canada. The humanities and social sciences play a vital role at the core of our enterprise by addressing the central questions of the human condition, and by helping us to understand how we live our lives across time and culture. Of course, science plays a significant part in the universality of knowledge as well. Indeed, we can not separate the sciences from the humanities and social sciences, for they are all part of the human continuum. This goes to the heart of a well- structured liberal arts curriculum that must be the foundation of every university of standing. In such an environment, the added element of leading edge research informs teaching to the benefit of both scholars and students. That is the unique role of a major research university such as the University of Toronto.

Another important function of the University of Toronto as a prime centre for research and scholarship is the education of a significant portion of the faculty for the rest of the country. Fully 3,600 professors in Canada, that is, 15 percent of the professoriat, have a U of T degree, and, most importantly, U of T graduates are overwhelmingly represented in the faculties of our nation's leading research universities.

The University of Toronto educates a significant percentage of the best students from our surrounding communities. Our primary obligation as a university is to educate to the highest standards the finest undergraduate students from the Greater Toronto Area (GTA). The University now welcomes more that 8,000 students from the GTA into a first-year class numbering over 10,000 in its direct-entry programs in arts and science, engineering, music and physical education. To all of these students, we offer a truly outstanding education. I speak from first hand experience when I say that we deliver an Ivy League quality education at one tenth of the price.

About 40 percent of our undergraduate students were born outside Canada – a reflection of the rich diversity of this metropolitan area. International students, that is, students who come directly to the University from abroad, make up about 6 percent of this first-year class. At the graduate level, about 20 percent of our students come from abroad. There are more than 350,000 living graduates of the University of Toronto, over 31,000 of whom live outside of Canada.

Because we draw most of our undergraduates from the Greater Toronto Area, with its incomparable diversity, we benefit from one of the most multidimensional student populations of any university in the world. In this diversity, I see the potential for greatness and a cause for celebration. Our multicultural make up provides us with a unique learning environment, and it presents us with an important foundation for a truly excellent education. In fact, the University of Toronto draws much of its strength as a centre for innovative and creative thought from the unique intercultural competence of its student body.

The University of Toronto has long made major contributions to the Canadian economy and society through its research. Under research-minded President Falconer in the first decades of the twentieth century, the University of Toronto invested in research, particularly in the health sciences. The most dramatic payoff was the discovery of insulin in 1921-22 that netted Banting and Macleod their Nobel Prizes and created a whole pharmaceutical industry around the Connaught Laboratories. The University, in

conjunction with its affiliated teaching hospitals, has continued to play a central role in health research ever since. And so it has been in other fields of research in the sciences, applied sciences, and in the humanities and social sciences.

Our own experience at the University of Toronto, and the overwhelming evidence from the United States, illustrate the central role that research universities have in assisting economic growth. This has been abundantly clear since the end of the Second World War.

II. IMPACT OF RESEARCH ON THE ECONOMY

Near the end of World War II, in a study entitled: "The Endless Frontier", Vannevar Bush, the true progenitor of the modern research university, stated that "new products and new processes do not appear full-grown. They are founded on new principles and new conceptions which in turn are painstakingly developed by research in the purest realms of science." With that historic statement, Vannevar Bush provided the rationale for large scale investment by governments in basic research in universities and the concomitant responsibilities that this implied. What followed was decades of accelerated government investment in US research universities, and in basic science.

Why do governments invest in these areas? Recent experience, and the dramatic success of the United States' economy over the past many years point to the answer. Major investment in university-based research has a direct payoff for the economy. Dr. Allan Bromley, a Queen's University graduate and a former employee of Atomic Energy of Canada at Chalk River has enjoyed an illustrious career in the United States. He was formerly presidential science advisor to George Bush Sr., and Sterling Professor of Sciences and Dean of Engineering at Yale University. In a recent op-ed piece in the Washington Post, he wrote of the unprecedented boom in the American economy and the great federal budget surplus. He stated that this success had little to do with new approaches to fiscal management, and all to do with "past investments in science." He observed that "federal investments in science ... produce cutting-edge ideas and a highly skilled work force. Government makes the [venturesome] investments in university-based research that ensures long-term competitiveness." He noted that economists, including Alan Greenspan, "attribute much of America's 1990s boom to increased productivity stemming, in large part, from scientific research. Two simple discoveries –the transistor and the fibre optic cable—are at the root of it." I should point out that both the transistor and the fibre optic cable were developed in industry. However, these technological developments were only possible because of two decades of basic research in universities on the electronic and optical properties of materials. Bromley added that anyone skeptical of the importance of the transistor and the fibre optic cable " should turn off the computer for a day and see how much work gets done." His message was simple and clear: "No science, no surplus."

In modern societies, research universities are the principal sources for the creation of new knowledge and the new economies and as such, they have a disproportionate impact on the economy. It must be emphasized that the return on investment in basic research is not often immediate. However, over the long term, it can impact significantly, and often as least expected. Indeed, investment in basic research produces a multifold payback.

To their credit, Canada's Provincial and Federal Governments have responded to the call for increased attention to research activities. Ontario committed itself to invest $1.5 billion in new research programs: the Ontario Research and Development Challenge Fund (ORDCF), the Premier's Research Excellence Awards (PREA), the SuperBuild Growth Fund, the Ontario Innovation Trust (OIT) and tax incentives for research and development. The Government of Canada has invested in research through the 21st Century Chairs for research Excellence, the Canadian Institutes for Health Research (CIHR), the Canada Foundation for Innovation (CFI), new resources for the granting councils, expanded Networks of Centres of Excellence, and tax incentives. The recent Speech from the Throne in Ottawa underlined the current federal government's intention to commit to doubling its spending on research and development by 2010. This is welcome news. Indeed, in a recent speech, Federal Finance Minister Paul Martin stated that he expects Canada's research universities to be the primary mechanism for carrying out the research that will enable Canada to compete effectively in the 21st century. On another level, last week's Provincial Budget announcement promises assistance that will enable us to address the looming challenges inherent in enrolment growth and faculty renewal, both of which threaten the positive gains that have been made in recent years. The return on such an investment will be immediate.

Let me now return to the US scene and the lessons that we Canadians can learn from the US experience. Certainly one important development that enhanced the impact of basic research on the economy in the US was the Bayh-Dole Act in 1980. Through Bayh-Dole, universities obtained ownership of the intellectual property that came out of the research that was being done by their faculty and students. Recently, two people at the University of Pennsylvania did a study of the effect of the Bayh-Dole Act on both Stanford and the University of California, and their conclusions are very interesting. They demonstrated that once the university has ownership of intellectual property, this has a tremendously positive impact on the transfer of basic science and technology from universities to the private sector and thence to the economy, thereby creating a marvellous number of jobs.

Of course, what troubles people is that this growth in technology, or emphasis on technology transfer, can have a negative effect on universities. Some of you may have seen me quoted as saying that we do not want universities to become "jobshops" for industry. In fact, the overwhelming evidence in the research-intensive universities in both Canada and the US is that this has not happened. Indeed, if you look at the pattern of basic research in the US before 1980, and the pattern of basic research after 1980, it has not changed one iota. So the process of technology transfer has in no way blemished the purity of basic research, at least in the leading institutions.

Another notable finding of the study was that though the Bayh-Dole Act gave ownership of intellectual property to universities, it did not change the character of university-industry relationships. It just added to the richness and fullness of their impact on the economy.

A little over a year ago I had the good fortune to have lunch with James Sensenbrenner, who up until January, 2001 was Chairman of the House Science and Technology Committee. He was a key figure making decisions about the growth of US research funding, especially university research funding. Sensenbrenner, who comes from rural Wisconsin and is a conservative Republican, said that "in Congress,

Republicans and Democrats believe deeply that the current economic boom in the US rests completely and entirely on the investment in basic research made in universities in the US in the 1980s." This illustrates that the current political leadership in the United States in both parties understands that there is a 20-year time lag, or thereabouts, between the original investment in research and the economic benefits that accrue from that investment. Moreover, they see the fact that the US economic boom has been a very direct result of long term, sustained investment in universities by federal and state governments. To quote Alan Bromley again: No Science, no Surplus.

Manifestly, here in Canada we are already seeing tremendous progress. Now that we are well along in our transition to a knowledge-based economy, our governments will have to respond in exactly the same way that the American governments did twenty years ago if we are going to be able to compete effectively in what is now demonstrably an international marketplace.

III. CASE STUDIES:

It is often a long road from the laboratory to the marketplace, with many stops along the way. From basic research in the lab, to economic impact, a phenomenal technological development is also required, and that is how it always is. You can not have an impact on the economy unless you have the basic research, but you need basic research, and technology, and venture capital all coupled together. These are the necessary ingredients that ultimately will provide an economic impact.

Alan Bromley has already given us the example of the transitor and the fibre optic cable. Let me now cite three more examples with which I have some special personal knowledge to demonstrate my point.

1/WORLD WIDE WEB

My first example comes directly out of the nature of international, basic research. Experimenters carrying out fundamental research in elementary particle physics at the European nuclear accelerator centre known as CERN needed to find a way to share their data internationally so that, for example, physicists at universities in Canada and the U.S. could analyze the results in real time. To accomplish this, the CERN scientists and, specifically, Tim Berners-Lee invented the World Wide Web. Roughly a decade later, the result is an entirely new economy-the dotcom universe. I suspect that this was the furthest thing from the minds of the Web's creators. But this kind of serendipity can only result from research investment that does not have a narrow commercial focus.

2/BIOTECH

My second example concerns Biotechnology. In March of last year, the *Atlantic Monthly* published an interesting article entitled, "The Kept University". It is important because it deals in a rather sophisticated way with relationships between

universities and the private sector. This article references Professor Paul Berg and his pioneering work.

Berg, who is at Stanford, is the one who did the basic work on gene splicing for DNA, which was the immediate predecessor to the work done by Stanley Cohen at Berkeley and Herb Boyers at UC San Francisco. Their work led to the first recombinant DNA clone, and it marked the beginning of the biotech revolution.

Berg tells an interesting story about how after he made his discovery, he went and visited Merck & Company Incorporated –a pharmaceutical company which has a long history of supporting basic research, and one with a wonderful research lab in Montreal. It turns out that there was a scientist at Merck Research Labs who was following exactly the same track as Berg, and was in position to start the biotechnology revolution himself. The trouble was that he ran into a technical difficulty; something you just had to get over when doing this kind of research. But Merck, in spite of being a great corporation and being committed to research, nevertheless had a time horizon of between 12 and 18 months on its research projects. As it turned out, that was not enough, and the scientist who might well have created the new field of biotechnology at Merck & Company was ordered to stop, and was switched to a project with a shorter time horizon.

The lesson of this story is that in most cases, this kind of research can only happen in a university. Accordingly, if we are really going to produce radically new technologies on which new economies are based, it will almost certainly happen in universities. Specifically, universities are the only places that have long enough time horizons to allow researchers to do the kind of research that is revolutionary, rather than evolutionary. Beyond this is the obvious fact that you can not make an impact on the economy with just the discovery; you also need technologists and business people with foresight.

An important aspect of the example of biotech is that it reveals dramatically the long times involved in the transition from basic research to a new industry. There was about a thirty-year delay between the establishment of basic research programs in molecular biology in the mid-fifties in some lead universities, to the creation of industries such as Amgen and Biogen in the mid-eighties.

3/INFORMATION TECHNOLOGY

I would now like to give you a very recent example, this time in information technology. This involves a friend of mine, Tom Leighton, who is an applied mathematician at MIT specializing in theoretical computer science.

Several years ago, Tom assigned a problem to a graduate student named Dan Lewin: how to move information around more efficiently on the World Wide Web. It was essentially an operations research problem. If you personally had ever tried to order something from a popular website three, or four years ago, you know that it often took five minutes before you would get an answer back from the site. By then, in all likelihood, you would have lost interest, and the business would have lost you as a potential customer. Therefore it is fundamental for all web-based businesses that they be able to respond to queries as quickly as possible. At the heart of this issue is a very interesting information routing problem.

The student that Tom had assigned to the problem found a clever mathematical solution based on maximally intelligent routing through distributed servers - a marvellous achievement worthy of some recognition. I am told that a venture capitalist heard a presentation at MIT by the student of a business plan based on this concept, liked the idea and gave him $500,000 to develop the plan further. The student then convinced his mentor, Tom Leighton, to become directly involved. Seeing this positive turn of events, the venture capitalist came back with another $5.5 million. They used this venture capital to rent space at Tech Square on the fringes of the MIT campus. They hired nineteen MIT undergraduates and began paying them in stocks. They then were very fortunate to attract George Conrades to develop and execute the business strategy. Shortly after this, Cisco Systems, Apple Computer and Microsoft became involved in the company, now called Akamai. So to make a long story short, Akamai, which came straight out of MIT's Department of Mathematics, went public in October of 1999 and at the end of the day, had passed Sears Roebuck in its capitalization. In June, 2000, MIT had close to 20 undergraduates receive their bachelor degrees, each of whom was worth more than $10 million due to his or her Akamai stock options.

You might wonder at this point why I have been using examples that have come from the United States and Western Europe and not Japan. In fact, the Japanese situation is very instructive. During the 1980s and 1990s, Japan failed to make major investments in university research. They now believe that this was a major contributor to the downturn in their economy. Accordingly, to compensate for this they are presently making mammoth investments in their research universities to guarantee the long term economic health of their country.

IV. CANADA'S RESEARCH UNIVERSITY FUTURE

As Canadians, it is paramount that we emulate and, if possible, surpass the Americans, the Japanese and the Europeans in recognizing the importance of basic research and the vital role that research universities play in promoting economic growth. We must, therefore, invest in our universities to allow them to be internationally competitive. I would like to see us develop a national pride in our top-ranked universities here in Canada that sets our standard of excellence at a global level. This is not just about the University of Toronto, it is about creating an environment that is larger than any one institution, an environment in which our best young minds will be able to flourish, and our country prosper. We need to cultivate the generous expectation that top research universities will achieve a level of greatness for which Canada will be known, and to recognize that this both sets the bar higher for everyone, and brings honour to us all.

Over the next ten years, it is estimated that enrolment growth and faculty renewal will require Canada to hire about 26,000 new faculty, as many as half of these in Ontario. This will be a singular opportunity to affect the way in which we develop our university sector; indeed, it will determine the future of Canadian post-secondary education for decades to come. These represent long-term investments, both in the professors who join us, and in the students whom they will teach. By hiring the very best faculty that we can

find, and by creating the kind of environment to which other great minds will be drawn, we will reap the benefits for a generation.

It is our decision to make together. If Canada is going to compete in the global marketplace in the 21st century, it must have research universities that rank among the best in the world. We can accomplish this through the dedication of dramatically increased resources from the private sector and, more importantly, from the public sector – for salaries, research, infrastructure, and graduate student support. Your support means a great deal to us, and I look forward to engaging you in the challenges that face all of us as a nation.

I thank you.