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Good evening. It's a very great pleasure to be here this evening although I feel as though I have gone through a bit of a time warp back about 20 years, which would be the last time that I stood in a university lecture theatre giving a talk like this. I would have been talking about the subject on the left hand side of that screen [Slide 1 - From Science to Investment] – Quantum Fields in Curved Space – a very different subject from what I'm involved in now, which is represented by the publication over on the other side of the screen. I think the main difference between the two for me is that if I made mistake in the one on the left I'd get academically ridiculed; if I make mistake in the one on the right I can go to jail as a director. So I don't know if it's a very good progress that I've made. Those publications pretty well capture my career and I'll be touching on elements from each of them this evening.

As we move towards the 21st century what are going to be the big structural changes that affect the economy and society, and in particular science, universities and Australia generally. And from answering those questions we then get answers to questions related to investments.

I'll start off talking a bit about investment and this idea of structural change in investment. Structural change is really important for making any decisions, be they in politics, in investment or in business. Structural changes are changes of typically epic proportions that represent changes from one era to another. To make that abstract concept a bit more concrete I'll throw up a typical investment type chart. [Slide 2 - Dow Jones Industrial Index] This is a graph of the Dow Jones industrial average, which measures essentially the wealth of the US stock market. It's from 1940 – 1994. The period that I want to concentrate on is the flat period starting in about 1966. In 1966 the Dow Jones industrial average hit 1000, bounced off, hit 1000 again, bounced off, hit 1000 again, bounced off and kept on doing that for 17 years only to go through the 1000 level in about 1982. That was a period of very high inflation in the United States, which meant that in real terms, adjusting for changes in price, the Dow Jones really declined. In fact it declined by 71%. For people who had started saving for retirement in about 1966, investing in the stock market, and retired around 17 years later, that's really pretty devastating. They had their wealth destroyed over that period and that happened because of structural change that occurred in the world and US economy.

 

In the first period on the chart, post-war, the US economy was booming. It was moving at above trend growth rates, a reflection of post-war prosperity. A whole series of change occurred in the mid 60s – the baby boomers hit the labour market and started going to university, the civil rights movement went into full swing and Japan and Europe, the conquered in the war, began to overtake the US in industrial competence. The share markets missed this structural change. They thought the post-war boom would just keep on going and they extrapolated. They bid the Dow Jones up to 1000 – it was far too high and it took another 17 years to get through that level. So that's the sort of investment consequences of missing a structural change. It can devastate a complete generation of savers.

There has been a whole range of major structural changes taking place over the last century and they have had quite an impact on the sectoral composition of the world's economy. I've used US data to illustrate the effect but the similar trends are apparent everywhere. [Slide 3 - Economic Structural Change] What we've got here is a time-line from the beginning of the last century and we've got the percentage composition of US employment broken up into 3 sectors – industry, agriculture and services. What you see of course is that post the industrial revolution employment in the agricultural sector declined and just kept on declining while manufacturing or industry took off and then the services sector grew with it and has kept on trending up, while the industrial sector has turned over.

Australia's prime competitive advantage occurred in that post-industrial revolution era, taking advantage of our agricultural and mineral resource endowments. Ever since that time Australia's competitive position has decreased and as the industrial revolution moved onto the information technology revolution then subsequently the biotech revolution, which I'll spend a bit of time talking about in a minute, we haven't kept up. This not keeping up is evident in our wealth per head as measured in this table by GDP, – Gross Domestic Product, per head. [Slide 4 - GDP/Head] Back in 1870 Australia was the wealthiest country in the world in terms of GDP per head. In 1992 we declined to 13$^{th}$ and the trend is generally being for that slide to continue. The big question we need to ask ourselves is whether that is going to turn around as a result of subsequent revolutions and structural changes. And that very much is the question for the rest of my talk.

So what then are the sources of wealth generation? The industrial revolution back at the beginning of this slide was driven by inventions such as the steam engine. The information technology revolution was driven by the microprocessor, or more precisely the digital binary circuit. Both of these technologies are very general purpose in nature. A couple of people - Besnahan and Tajtenberg have defined in some detail the concept of general purpose technologies as major causes of structural change. They have concentrated on three properties of technologies that make them general purpose. [Slide 5 - General Purpose Technology] The first is general purposeness, that is that the technology has a generic function that's vital to the functioning of a large element of existing or potential products and production systems. This property is very clear in the microprocessor for example.

The second one, technological dynamism, means that continuous innovation efforts and learning increase over time the efficiency with which the generic functions of the technology are performed. This is also very evident with the microprocessor. You might be familiar with Moore's law that the power of microprocessors double every 18 months – this is very typical of general-purpose technology.

The final characteristic of innovational complementarities is that there is a spill-over effect with other application sectors in that sense that technical advances in the general purpose technology make it more profitable for users to innovate and vice versa. This is really clearly seen in the Internet. The Internet has been enabled by, amongst other things, microprocessors, and developments in microprocessors have led the Internet to develop and developments in the Internet have led companies like Intel to develop their processors more.

The general-purpose technology of information technology has very clearly generated enormous wealth. We've seen Microsoft grow from nothing 23 years ago to being a giant corporation now valued at more than $530 billion Australian dollars. Silicon Valley, the home of the information technology, has a population of around 2 million; it has 7,000 electronics and software companies; creates about 11 start-ups in those fields every week; between 1992 and 1996 it developed 125,000 new jobs; and in 1996 created 62 new millionaires every day and wages grew by 5 times the national average. This exemplifies enormous wealth creation out of that general-purpose technology of information technology.

The previous slide showed at the end of my time-line, the revolution that I believe is going to be most consequential in the next millennium, namely the biotechnology revolution. And the reason for that is that I see biotechnology as being a general purpose technology, satisfying those definitions that are on the screen. Further there are many similarities between information technology and biotechnology that lead me to believe it will be an enormous wealth creator in the next century.

The easiest way to see this given that we're familiar with information technology is to look at those similarities between information technology and biotechnology. The general-purpose technology of IT comes from the flexible encoding of programs in binary digits, ones and zeros representing ons and offs in Random Access Memory. Programming tools configure these bits as instructions which are then executed by the processor to carry out a whole range of general-purpose tasks from navigating to the moon to preparing your tax return. [Slide 6 - Information Technology]

The similarity with biotechnology comes from DNA, the heart of biotechnology, being very much like a computer program. [Slide 7 - DNA at Work] The sequences of bits of a computer program become the base pairs of the double helix structure of DNA. The genetic code relating triplets of bases to amino acids is like the programming language. Genes are like sub-programs. These are collections of base pairs ranging from 1000 or so to maybe 100,000 or millions of base pairs. They're the computer programs that affect things like the colour of your eyes, your intelligence, and your susceptibility to disease.

I think of the total human genome as being like a big computer program. Interestingly, it's got about as much information in it as some versions of the Windows operating system. The revolution that arises in biotechnology comes about not from the fact that this program exists, but that we've got the technology now to reprogram it. This capability exists from back in 1973 with the invention of recombinant DNA technology, which effectively gives us the ability to cut and paste bits of DNA and thus reprogram that programming language.

The difference between computers and DNA is that with computers we started from scratch whereas DNA has literally evolved over billions of years so we've got a computer program and the first step is to figure out what's in it. That's happening with the human genome project. It started in 1998 and is expected to have the first stage results in about 2003. That's a project that is effectively decoding the human genome computer program.

But the really exciting stuff starts after that when having got one and zeros, or the equivalent of it – just think of decoding Windows in a whole lot of ones and zeros – you begin to figure out what it all means working out the function of the sub-programs in the genome. And then once you've understood what's going on you can begin to reprogram it and that's when it becomes very clear that the general purpose technology of biotechnology is probably going to have more of a structural impact that any general purpose technology that we've seen before. There'll be massive technological and ethical implications such as targeted drugs, drugs targeted very clearly at disease functions, artificial life and modified life forms. There'll also be enormous wealth creation and transfers of wealth as a result of the technology.

So how is Australia positioned for this particular development? Well Australia has a very strong competitive position in R&D generally as can be seen from this chart. [Slide 8 - Competitive Advantage in R&D] This comes from a source called the World Competitiveness YearBook that comes out annually and looks at around 46 countries ranking them on a whole range of competitiveness positions. Australia doesn't do too well in too many but R&D is one in which we do reasonably well. You can see some of things that they look at in R&D – the number of Nobel prizes, patents in force, research cooperation and expenditure on R&D. So we've got quite a strong competitive position and we've got a particularly strong competitive position in medical research as illustrated by our four medical Nobel prize winners. [Slide 9 - Australian Nobel Prize Winners in Medicine]

Given this position, it's not surprising that we do have a reasonable number of dedicated biotechnology companies. There are around 130 companies in Australia dedicated to biotechnology of which about 10 are publicly listed. This compares with the United States where there are 350 listed dedicated biotech companies and about 1,000 that are privately owned. There are also the major pharmaceutical companies in the US and these raise a very interesting further parallel with information technology.

I wonder if any of you know who built the world's first solid state mainframe computer? If you know shout out. It was NCR, National Cash Register. They built the first such computer in 1957. Well, where are NCR now? NCR is still a listed company, its has a value of about $6 billion Australian dollars which compares with Microsoft's $530 billion Australian dollars. NCR missed some of the big structural changes.

The pharmaceutical companies are very wary of the same thing happening to them. And some of them are reinventing themselves as so called Life Sciences companies where they're really concentrating on biotechnology. Novartis is a company in that category. If you're not involved in pharmaceuticals you may never of heard of it but it's a company worth $153 billion Australia dollars. Australia's biggest pharmaceutical company, CSL, is worth $1.7 billion. About ninetieth the size of Novatis.

Looking at all this evidence I come to the conclusion that Australia has underachieved badly in taking advantage of the opportunity that is presented to it in biotechnology, given its strength in medical research and general research positioning which is historically quite strong. Not to mention also bioagricultural research, which Australia has a long heritage stretching back to our agricultural background.

The reason for this are manyfold and my aim tonight isn't to go into these in detail. In summary there has been a problem with lack of funding, a lack of venture capital to support start-up companies. There has been a culture that has been lacking in entrepreneurship – the US (both in the IT and biotech sector) has been driven by entrepreneurs who have gone off and set up these thousands of small companies, some of which have failed, some of which have succeeded. And there has been quite a range of government impediments – the tax system, lack of encouragement for research and general structural impediments at the micro level.

I first raised some of these problems in a publication that I put out at the beginning of January 1998 entitled "The Biotechnology Revolution – A Unique Opportunity for Australia". If you're interested in that you can see it at our website – county.com.au. There has been dramatic progress since I undertook that research and I think the situation is now probably more encouraging for biotechnology in Australia than at any time in the past. Both the recent State and Federal Government budgets have been highly supportive and there are also signs of increased entrepreneurism and support in the business community.

County has undertaken one initiative to try to encourage the collaboration between research and business – something called the Medical Research Investment Fund. Once again, I don't want to go into this in a great deal of detail but it shows the sort of innovative funding that is needed to try to encourage some of this development in Australia.

[Slide 10 - County MRIF]This is a schematic overview of what we're looking to achieve with the Medical Research Investment Fund. The taxpayers already give a fair amount of money to the National Health and Medical Research Council which on merit selects research projects in medical research organisations to be funded. Now in the past what's happened with respect to commercialisation of some of the outputs has been somewhat haphazard and we probably haven't necessarily got the return to the taxpayer in terms of commercial return even though we probably got a pretty good return on our investment in terms of improved quality of life.

There have been other developments on the financial side in Australia recently that has led to a fairly large build up of money – hundreds of millions of dollars in superannuation funds to which probably most of you are contributing. What we're looking to do with the Medical Research Investment Fund is convince people in Super funds to invest money into medical research. The way we're doing that is putting together a portfolio of projects that have been effectively rated by the NHRMC as worthy. We're looking to invest superannuation money into those projects in return for an intellectual property management agreement and then lending assistance to the commercialisation of the projects with commercial returns flowing back to the Super funds. We're still at a fairly early stage of getting this going – there is a lot to be done – but it looks very encouraging. What we're looking to do in this fund is not pick winners amongst the projects. Rather, we're looking to invest in a diversified portfolio because we just don't know from where the winners are going to emerge from early research. I think that's a characteristic of research that's very often overlooked. So what we're effectively doing is investing in the intellectual capital that is tied up in those research projects.

That then leads me on to the final topics that I wanted to talk about tonight. Both the IT and biotech revolutions point to an overarching structural change of major importance. That involves the role of intellectual capital in our production processes. I've simplistically represented what I think of as classical economics in this diagram here. [Slide 11 - Production in classical economics] A typical economic model involves taking labour and capital and things that capital will buy like land, putting them into a production system and producing goods and services that you sell. This has been the production function effectively from agrarian times where you had a scarce resource – land – and a scarce resource – labour – you put them into a production function and you produced goods.

The world has changed though as illustrated by the topics that I've been talking about. I now think of the production function of the 21$^{st}$ century as being correctly represented in this diagram where we've got two of the inputs being the same but we add a third, intellectual capital. [Slide 12 - Production in the 21$^{st}$ century] Out of the production function, as well as goods and services, we also produce intellectual property.

 

Once again, Microsoft, acts as a really brilliant exemplar of this. Microsoft didn't have any capital when it started up and it didn't really have any labour – it had a couple of people – but they represented intellectual capital. The whole business ever since has grown on the basis of primarily intellectual capital inputs. The only reason that Microsoft is listed on the stock exchange is so that it can reward its staff - its intellectual capital – with stock options that they can then liquefy. Microsoft has got something like $25 billion US cash in its kitty - it doesn't use much labour, it doesn't need capital and the stuff that it produces is intellectual property which it can distribute without great production systems. So it's a major change of the production paradigm.

This is very poorly understood by most decision-makers, in particular politicians. Politicians and many of the economists that advise them think in terms of that old production model and they haven't really adapted to this new model. That will probably lead them to make policy mistakes because if you've got the wrong model you end up making mistakes. The key message that comes out of this is that the key to the wealth of a nation in this model is increasingly represented by the store of intellectual capital of its people rather than their labour capacity or store of natural resources. And that's the message that I think universities in particular need to get across to politicians and other decision-makers that affect them.

In this 21st century world, the education system in general and universities in particular play a vital role as the source of intellectual capital for the country. Just as paddocks and mines were the source of Australia's wealth in the last century, the education system will be the source of our wealth in the next century.

The origins of universities, centuries before the industrial revolution, were learning and scholarship. Post the industrial revolution, the role of universities has increasing shifted towards training and applied technology. The danger for Australian universities is that they now miss the structural change that I have just been talking about and fail to adapt their role to one appropriate for the information world of the 21st century.

As we approach the end of the second millenium, I believe that universities should be returning to their philosophical roots established around the end of the first millenium. That is, to learning and scholarship.

I must admit that, until recently, I had not thought much about the role of universities since I was involved in them over 20 years ago. This meant that I was able to tackle the topic from a fresh perspective which commenced with thinking about my own university experiences.

I entered university knowing only one thing. That was that I wanted to understand the laws of the universe. I was fortunate to win scholarships to fund my undergraduate education and my time in London working on my Ph.D. and during the entire period I can't remember once thinking about how I was going to make a living or what my role in society was going to be.

And now you find me speaking to you as an investment banker, who has been involved in the creation of considerable wealth for his shareholders and whose role in life is to manage money primarily to ensure that Australians can live comfortably in retirement

I see my university education as a model for what is required from universities in the age of intellectual capital. I was taught to think. I undertook scholarly research of no practical application but it taught me to innovate and solve problems. These abilities have been vital in my subsequent career. They are the competencies required for wealth creation in the emerging era.

The role of university science is particularly clear if you accept my view that general purpose technologies are the engines of wealth. Scientists are the discoverers of the principals leading to general purpose technologies and are the developers of those principals in the technological dynamism that is characteristic of GPTs.

This does not mean that Universities should be involved in the commercialisation of GPTs. Rather, having worked on the Medical Research Investment Fund, I am convinced that commercialisation activities should be kept well clear of universities but that there should be mechanisms for academics to retain their university affiliations while working in commercial ventures. Such a model is prevalent in the United States.

So what about government funding of Universities? If University education and research is the source of wealth that will accrue to the individual, then why should it be publicly funded. The answer is that the wealth does not generally accrue to the individual. Much of the wealth developed through the actions of the university system accrues to the nation and not contemporaneously.

One of the key roles of government is to redistribute wealth intergenerationally.  Such redistribution is especially pertinent to pure research, where the payoff from research funded today is likely to benefit future generations of tax payers. You never know, maybe even the work that I did on black holes 20 years ago will have application sometime in the next millennium.

The role of university science in creating wealth for Australia in the next century is clear to me and I am sure it will increasingly be recognised by those who count.