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SCIENCE, INNOVATION AND HOW TO GET RICH

Nick Birrell

"Why are we so rich and they so poor?"

My original title for this article was "Science, Innovation and the Wealth of Nations" but I thought I might get more readers with the current title. Whatever its title, this article is about how science leads to innovation which leads to wealth, be it your personal wealth or the wealth of Australia or the World.

In the Richard T Ely Lecture in 1989, David Landes[1] asked the question "Why are we so rich and they so poor?". When you find that the national income per head of population in 2007 in Australia was about $42,000 while, for example, in Burundi it was $127[2], you realise that this is a really important question[3].

Like scientists, economists produce models to try to explain observations, such as the large disparities in wealth between the nations of the world. Economic Growth Theory, in the form largely developed by Paul Romer[4], provides a theoretical basis for explaining how economies grow. The Romer model of economic growth can be used to explain differences in national wealth in terms of three critical inputs[5]:

- Capital investment per head of population
- Educational attainment of the labour force
- Labour assisting technology.

The first of these is probably not surprising – the more money invested the richer the country becomes. The second is probably only slightly less surprising – the better educated the workforce the richer the country. The final component relates to the technology that comes from centuries of scientific research and innovation.

In a paper looking in more detail at the impact of these components on the economic growth of the United States between 1950 and 1993, Charles Jones[6] shows that about a third of the growth can be attributed to increase in educational attainment, while about 50% can be attributed to the increase in the amount of research undertaken by the Group of Five leading industrial nations. Put another way, over 80% of the enormous national income of the United States in the period in question resulted from the world of ideas, knowledge, innovation and technological advancement.

As the countries of the developed world have moved from agrarian to industrialised to knowledge based, the contribution of research leading to new ideas leading to new technologies leading to increased productivity and new ways of creating wealth has become an increasingly large part of economic life. However, it is not just today and in the developed world that scientific development, innovation and technological

advancement have led to increasing wealth and higher standards of living. It has been so ever since man first innovated, perhaps with the first stone tool.

Technologies that change our lives

A particular type of technological advancement is considered to have played a particularly significant role in creating wealth for mankind. Such technologies have been given the name General Purpose Technologies ("GPTs")[7]. A GPT can be defined[8] as a single generic technology, recognisable as such over its whole lifetime, that initially has much scope for improvement and eventually comes to be widely used, to have many uses, and to have many spillover effects.

An example of a GPT is semiconductor technology. The transistor was first used as a single component replacement for vacuum tubes in what would now be considered relatively simple devices (such as early transistor radios). The advent of semiconductor technology led to a range of new products such as portable music machines (e.g. Sony's "Walkman") that have continued to evolve to become, for example, sophisticated music-communication-computing machines (e.g. the Apple iPhone). These new products have then led to so-called spillover effects with the introduction of new applications and industries, such as the on-line music industry. In the meantime, semiconductor technology has evolved so that there are now 820,000,000 transistors on the latest Intel processor chips[9].

The discovery, introduction, development and spillover impacts of GPTs have driven economic development for millennia as can be seen in Table 1[8], which lists some important GPTs from 9000BC to the present time.

At a personal level, individuals who have foreseen the impact of specific GPTs and who have positioned themselves well to benefit financially from such impact have become some of the wealthiest individuals in history. The richest person in the world for many years according to Forbes magazine[10] and now the third richest, with an estimated wealth of US$58 billion, is William Gates III, the founder of Microsoft, who clearly gained his enormous wealth by being instrumental in the development of the GPT of the computer. A far earlier example of such personal wealth creation from a GPT was the introduction of the railway to the United States creating considerable wealth, particularly for a number of individuals who came to be known as "robber barons"[11].

Table 1 Some important General Purpose Technologies

GPT	Date
Domestication of plants	9000—8000 BC
Domestication of animals	8500—7500 BC
Smelting of ore	8000—7000 BC
Wheel	4000—3000 BC
Writing	3400—3200 BC
Bronze	2800 BC
Iron	1200 BC
Waterwheel	Early medieval period
Three-masted sailing ship	15th century
Printing	16th century
Steam engine	Late 18th to early 19th century
Factory system	Late 18th to early 19th century
Railway	Mid 19th century
Iron steamship	Mid 19th century
Internal combustion engine	Late 19th century
Electricity	Late 19th century
Motor vehicle	20th century
Airplane	20th century
Mass production, continuous process, factory	20th century
Computer	20th century
Lean production	20th century
Internet	20th century
Biotechnology	20th century
Nanotechnology	Sometime in the 21st century

Roles in the creation of wealth from science

At the level of the individual, it is interesting to study some of the roles in the creation of wealth from science and innovation.

The most obvious role is that of the scientist, the individual who works to push the frontiers of scientific knowledge and who occasionally discovers something that has the potential to change our lives, such as the inventions in the Inventors' Hall of Fame[12]. However, a scientist is typically most interested in pursuing scientific knowledge and not in taking their invention to the point of being in common use and of economic value to society. This is perhaps nowhere more evident than in medical research, where the discovery of a possible new drug by a scientist or scientific team is only the first step in a process of development and testing that can take a decade or more and cost hundreds of millions of dollars.

Seeing the social and economic potential of a scientific discovery and driving it through to the point where it is valuable and in common use is often the role of the so-called "entrepreneur". A good definition of an entrepreneur[13] is a person who undertakes the creation of an enterprise or business that has the chance of profit or success.

There have been scientists who were also entrepreneurs, perhaps the most famous example being Thomas Edison, the inventor of the electric light (amongst many other things)[14]. Generally, however, scientists are either not natural entrepreneurs or are not interested in leaving their scientific research to build a business on their invention. Thus the scientist and the entrepreneur are natural partners, be it in establishing a new company to exploit an invention or driving a new invention to the market in a large corporation such as a pharmaceutical company.

Business Week magazine in its 2004 celebration of *The Great Innovators* provides an excellent recounting of the partnering of a scientist and an entrepreneur creating what is now the multi-billion dollar biotechnology industry. Here is a short quote from the article[15] which makes clear the important interaction between the two roles: *"In 1976, Robert Swanson and Herbert Boyer created the biotechnology industry over a couple of beers at a San Francisco bar called Churchill's. Swanson, at just 29, was an ambitious venture capitalist who wanted to commercialize a new way of engineering drugs based on splicing DNA from one organism into the genome of another. Boyer, a 40-year-old biochemistry and biophysics professor at the University of California at San Francisco, had co-developed an ingenious technique for doing exactly that. So Swanson cold-called Boyer, stopped by his lab, and the two retreated to the bar to sketch out a business plan. They were about to change the drug industry forever."*

There is a third role that often plays an essential part in providing a critical ingredient to take science from the laboratory to the market. That ingredient is money and the role is that of the financier. Finding money to develop a new idea or discovery can be tough as there is generally much uncertainty around whether the resulting new product or service will be a success in the market place. One source of such funding for the early stages of a new business is venture capital, and the third member of a team creating the business is often a venture capitalist. In the case of Genentech, the company founded by Swanson and Boyer, the venture capitalist[16] was Tom Perkins of

venture capital firm Kleiner Perkins Caufield & Byers[17], which has also been involved in the financing of a number of other notable technology companies, such as Google and Compaq.

The interaction between the threesome of scientist, entrepreneur and financier is not greatly discussed nor appreciated as a driving force behind the process of turning innovation to wealth. An imbalance between the three roles, for example too many scientists and not enough entrepreneurs, financiers and finance, can lead to a misallocation of resources.

If large amounts of money are spent on scientific research but there are not the people and resources to take the economically prospective results of that research and turn it to social good and economic wealth, then those research funds may have been wasted or could have been put to better use elsewhere. Or if the research funds are provided by say Australian taxpayers but there are insufficient entrepreneurial and financial resources in Australia to commercially develop the results of the research, then the main economic benefit of the research may end up with residents of another country.

How fares Australia?

So how is Australia doing in this regard? Are we generating an appropriately large amount of economic value from our taxpayer funded scientific research? This is a difficult question to address, although there have been attempts by, for example, the Productivity Commission[18] and Access Economics[19]. Whatever the findings of these and other reviews, there is clear evidence that we should be aiming to do much better. This evidence comes from our overseas trade statistics[20].

Australia is benefiting from a resources boom of dramatic impact. For example, in the year to May 2008 we exported over $21 billion of coal, coke and briquettes, up from $9.3 billion ten years earlier. However, despite this boom, in the year to May 2008 we imported goods and services with a value of over $21 billion more than we exported. That is $21 billion that was paid from Australia to other countries. What is going on?

Examining another part of the overseas trade statistics gives a strong clue. In the year to May 2008 Australia exported almost $4 billion of Medicinal and Pharmaceutical products. This may seem a lot and a good payoff for the investment that we make in medical research, however, we see that in the same period we imported almost $8 billion of such products, leaving a deficit (the net payment from Australia to the rest of the world) of $4 billion. Similarly, in the same period, Australia ran a trade deficit of over $8 billion in the category of Office Machines and Automatic Data Processing Machines (i.e. computers and similar equipment).

As a developed nation our biggest demand is for goods and services based on ideas, knowledge, innovation, research and development and even in the middle of a dramatic resources boom we are unable to pay for them with the commodities that we dig out of the ground to fuel the economic growth of emerging nations such as China. We clearly have to do better at turning ideas and research to economic value.

The root cause of the problem

A problem that has been well documented[21] is the decline in the number of students enrolling in Science degrees at university. However, studies such as those quoted above[18 19] from the Productivity Commission and Access Economics do not point to a lack of quality scientific research in Australia as a source of the problem just identified. Rather, I believe that a significant part of the cause of the economic problem facing Australia would be revealed by asking student readers of this Journal the following question: "Who is attracted to pursuing studies in Science because they see it as a way of becoming wealthy?" I suspect that the results of such a survey would be a very small percentage. This would contrast with the results of asking the question: "Who is attracted to pursuing studies in Medicine/Accounting/Law/Business because they see it as a way of becoming wealthy?"

Unfortunately, studies in Science tend to be seen as a way to a career standing at a laboratory bench being paid a modest salary, rather than as a way of acquiring knowledge that can create both national and personal wealth in a range of roles as discussed above.

In 2007, Monash University launched a unique postgraduate degree program[22] available to students with an undergraduate degree in a science or technology discipline to teach them business skills required to turn scientific research into economic wealth. The first graduates of the program have taken jobs leading to careers in, amongst other areas, banking and research commercialisation. As Australia increases the number of people skilled in bridging the worlds of science and business we should see more of our outstanding scientific research and inventiveness converted to national wealth.

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[1] D Landes, *The American Economic Review*, Vol. 80, No. 2, Papers and Proceedings of the Hundred and Second Annual Meeting of the American Economic Association (May, 1990), pp. 1-13

[2] International Monetary Fund, *World Economic Outlook Database*, October 2007

[3] In recent times it has become increasingly evident that monetary wealth is not the only measure of national success that should be considered in reviewing economic growth but that the impact of growth on the environment must be accounted for. While this is a vitally important topic, it is complex and still being developed and will not be considered in this article. For an example of research on this topic see: A Xepapadeas, *Economic Growth and the Environment*, www.soc.uoc.gr/xepapadeas/Courses/EnvironEcon_Grad_UOC/GrowtEnvironXepapadeasAugust03.pdf

[4] P Romer, *Endogenous Technological Change*, Journal of Political Economy, Vol. 98, No. 5, Part 2. For an introduction to Economic Growth Theory, including references to original sources and a detailed explanation of factors affecting disparate national wealth see: Charles I Jones, *Introduction to Economic Growth,* W W Norton and Company, 2002. The author's web site has a large amount of relevant information: **http://elsa.berkeley.edu/~chad/**

[5] R E Hall & C I Jones, *Quarterly Journal of Economics*, February 1999, Vol. 114, pp. 83-116

[6] *Sources of U.S. Economic Growth in a World of Ideas,* American Economic Review, March 2002, Vol. 92 (1), pp. 220-239

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[8] Lipsey, Carlaw & Bekar , *Economic Transformations – General Purpose Technologies and Long Term Economic Growth*, 2005

[9] *Timeline of the Transistor*, Intel, http://www.intel.com/technology/timeline.pdf

[10] http://www.forbes.com/2008/03/05/richest-people-billionaires-billionaires08-cx_lk_0305billie_land.html
[11] See the list at http://en.wikipedia.org/wiki/Robber_baron_(industrialist) especially those with "railroads" mentioned as their business.
[12] http://www.invent.org/hall_of_fame/1_1_search.asp
[13] R C Dorf, T H Byers, *Technology Ventures From Idea to Enterprise*, McGraw Hill, 2008
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[15] *Robert Swanson and Herbert Boyer: Giving Birth To Biotech,* Business Week, October 18, 2004, http://www.businessweek.com/magazine/content/04_42/b3904017_mz072.htm
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[20] Australian Bureau of Statistics, *International Trade in Goods and Services – 5368.0*, http://www.abs.gov.au/AUSSTATS/abs@.nsf/mf/5368.0
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