Shaking Windows; Rattling Walls

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Abstract

Bob Dylan's famous 1960s song 'The times they are a-changing' captured the mood of the times and ushered in a period of intense social and technological change. This was as true for agriculture as for any other activity. Within a few years, the so-called 'green revolution' in Asia averted a world food shortage. In recent times there have been other examples of dramatic change (the 'shaking of windows and rattling of walls' predicted by Dylan). Several examples of the adoption of new technology are examined:

1. The rapid adoption of information technology by people everywhere, including farmers. The World Wide Web emerged as the primary carrier of internet traffic in 1995, when there were about 25 million internet users world-wide. Within ten years almost one billion people – 15% of the world's population - had internet access, including more than half Australia's farmers and almost 80% of farmers with an estimated value of agricultural operations of $1 million or more.

2. The remarkable adoption of genetically modified (GM) crops by farmers in some countries and for some crops. Within a ten-year period to 2004, the area of GM crops grew from virtually zero to 80 million hectares – 5% of the world's area of sown crops. The key driver was probably farmer profit: a cumulative benefit of USD 27 billion at the level of farm incomes, shared by approximately 8 million farmers in 17 countries but particularly by growers of soybeans, cotton and to a lesser extent maize and canola in North America, Argentina, China and Brazil. The rapid adoption is continuing despite strong consumer resistance in Europe and the activities of some non-government organisations.

3. The relatively slow but steady adoption of tropical forage legume technology. After 50 years of research and promotion, by 2005 about 5 million hectares had been sown to these legumes world-wide. At least two thirds of this area was in developing countries, and at least half a million farmers had benefited from the use of tropical forage legumes in a wide range of farming systems. A key factor in their adoption was their deployment in profitable farming systems, and in many cases such systems had not been foreseen by those who originally developed the legumes. Other critical factors were the determined and long-term commitment of researchers and governments and the creation and maintenance of critical partnerships (including with the private sector), particularly to provide reliable supplies of seed.

A recent history of the Australian beef cattle industry (Henzell, in press) reveals that the rate of adoption of new technology in that industry was slow for more than 150 years. Several factors combined to cause significant change in the second half of the 20th century. These included the development of new beef export markets commencing in the 1950s, the availability of new cattle breeds that were more resistant to ticks and other stresses, and regulations leading to the eradication of bovine tuberculosis and brucellosis. As with other innovations mentioned above, the opportunity for farmers to make a profit and/or reduce the costs of production was probably crucial to the adoption of new technology.

These examples of technology adoption lead to the conclusion that personal or private benefits (particularly profit) and government regulation are key drivers of agricultural technology adoption, and the private sector is typically a significant partner. Of course, other factors affect the rate and ceiling level of adoption, but these drivers stand out.

Introduction

In the 1960s, an American folk-singer called Bob Dylan wrote a song called 'The times they are a-changing'. The song captured the mood of the times. It not only became the anthem of the civil rights movement in the United States, but it also heralded a period of sustained social and technological change probably unequalled in the history of the world.

It is trite to say that times are changing. We live in a time of such pervasive and dramatic change that we are hardened to it. When I was a boy, I lived for a few years with my grandfather, who was then in his eighties, and I remember thinking that he had lived through an amazing period of change. As a teenager, he had ridden his horse from Sydney to Cobar to visit his sister. There were no motor cars, and most people still travelled by horse-drawn vehicle or steam train. By the time he died, all his children owned motor cars, the aeroplane had made rapid international travel possible for the rich, transistor radios were just becoming available to the masses and TV had been invented. We were beginning to write with ball-point pens.

The process of change was as significant in the fields of agriculture as it was in other aspects of daily life. My grandfather lived through the period in which William Farrer's improved wheat varieties were released. Federation wheat was released in 1901, was widely available by 2003, was the leading variety in Australia from about 1910-25, achieved about 80% penetration of the sown area and generated

large benefits for farmers (Russell 1949). Federation and other varieties bred by Farrer were part of a package of innovations (including the extension of the railway system, the mechanisation of harvesting, the use of superphosphate and the soldier settlement scheme after World War I) that led to significant change in the Australian wheat industry during those years.

But we now see that the period of change during my grandfather's life, impressive as it seemed at the time, was mild compared with the period of change commencing in the 1950s and particularly the 1960s. And the pace of change is accelerating, not declining.

When I left school, just before Bob Dylan wrote about changing times, I planted wheat using a kerosene-powered tractor, and I harvested it using a ground-drive header. My crop grew higher than my head, about half of it fell over, and I harvested six bags of grain to the acre (about 1.2 tonnes per hectare). It was carted in bags to the nearest silo. My crop was not quite equal to the district average, but it was not bad for the times, and I made enough money to go to university.

Today, Australia's average wheat yield is approaching 2 tonnes per hectare (still low by world standards) and increasing by about 1% per year. Farmers work their land with large air-conditioned diesel-powered tractors using remote sensing (global positioning systems) technology, sow low-growing wheat varieties, use heavy applications of agricultural fertilisers and other chemicals, harvest the crop with motor harvesters, store the grain on-farm, transport it in bulk, sell it to quality-conscious markets around the world, and trade in grain futures and options in Sydney and Chicago.

On the global scene, the 1960s and 1970s also witnessed the so-called green revolution, particularly in Asia, where new varieties of wheat and rice were grown by countless millions of small farmers, thus averting a potential world food shortage. It was perhaps the greatest example of widespread adoption of new agricultural technologies in the history of agriculture.

What brings about such dramatic changes in agriculture? What can we learn from studying patterns of technology adoption? In the remainder of this oration I would like to look at several examples of technology adoption and see what conclusions can be drawn.

Information and Communication Technology:

The Internet

The current revolution in information technology (IT) has significant implications for everyone, including farmers, and internet communication is among its most remarkable manifestations. The internet originated in the USA, and grew slowly between 1969 and 1989, when there were about 100,000 users (Clarke 2004). The World Wide Web emerged during the early 1990s. By 1995 the Web was the main carrier of internet traffic, and a variety of services including search engines and internet access providers was emerging. There

were then about 25 million internet users (Benschop 2003). From that point onwards, growth was spectacular. In 2005, just ten years later, 957 million people - 15% of the world's population - one person in every seven people on the planet - had access to the internet (Internet World Stats 2005).

Australians are particularly avid internet users; only a small handful of countries (Sweden, the USA and perhaps the Netherlands) may be heavier users per head of population. The pace of adoption is so great that figures are quickly out of date. In 2003, more than half of Australian households had internet access (Australian Bureau of Statistics, 2005; Caslon Analytics 2005), and three quarters of the adult population were 'active internet users'. This included 54% of Australian farmers – more than four times as many as in 1998 (Australian Bureau of Statistics 2005). There was a strong relationship between farm size and internet usage: 79% of farms with an estimated value of agricultural operations of $1 million or more used the internet in 2003, compared with 30% of those with an EVAO of less than $50,000. The better farmers increasingly use the internet to access weather information, follow commodity prices and futures markets, access agricultural information and decision support services and communicate with other farmers. A USA study in 2002 showed that use of the internet significantly improved the productivity of grain farmers (Hopkins and Morehart 2002), and the same seems likely to apply in Australia.

Genetically Modified (GM) Crops

The history of adoption of GM crops is well documented, particularly by ISAAA (International Service for the Acquisition of Agri-Biotech Applications) who distribute a weekly summary of world developments. A good deal of the information in this section has been derived from this source. Commercial adoption commenced in 1996, when 1.7 million hectares were grown (Table 1; James 2005). Since then, the rate of adoption has been extraordinary. In 2004, there were 81 million hectares (200 million acres) of GM crops sown – up by 20% from 2003 (67.7 million hectares). If the total world area of arable land and land under permanent crops is taken to be around 1.5 billion hectares (FAO 2005), at least one hectare in every 19 hectares of sown crops is now sown to GM varieties. GM crops were grown by more than 8 million farmers in 17 countries in 2004 – up from 7 million farmers in 2003.

Table 1. Areas sown to genetically modified (GM) crops world-wide (millions of hectares) by years

1996: 1.7	1999: 39.9	2002: 58.7
1997: 11.0	2000: 44.2	2003: 67.7
1998: 27.8	2001: 52.6	2004: 81.0

The principal GM crops in 2004 were soybeans, cotton, canola, and maize. In 2004, 56% of the world's soybean crop, 28% of the world's cotton crop, 19% of the canola crop and 14% of the maize crop was sown to GM varieties. The main countries growing GM crops were the USA, Argentina,

Canada, Brazil, China and Paraguay. Each of these countries planted more than 1 million hectares of GM crops during 2004. Interestingly, four of these six countries are developing countries, and more than half the global increase in the area sown to GM crops between 2003 and 2004 occurred in developing countries.

A key driver of the adoption of GM crops is farmer profit. A recent analysis of the benefits of GM crops to date, at the level of **farm incomes**, indicates that a cumulative benefit of USD 27 billion had been received by farmers to 2004 (Brookes and Barfoot 2005). These authors showed that 95% of the farm income benefits had been received by growers of soybeans, cotton and maize in the USA; of soybeans and maize in Argentina and Brazil; and of cotton in China. Most of these benefits had resulted from savings in the costs of production. Environmental benefits were also substantial. Adoption of GM crops had resulted in a 15% reduction in pesticide use in cotton crops (77 million kg less insecticide applied since the introduction of GM cotton) and a total reduction of 172 million kg of insecticides applied to all GM crops. And greenhouse gas emissions had been reduced by 10 billion kg.

Many people believe that Asia will be a key battleground for adoption of GM food crops, and that adoption of GM rice will open a floodgate of approvals. China has the largest plant biotechnology capability outside North America (Huang et al. 2002), and has invested heavily in GM rice. Numerous potential GM cultivars have been field-tested (some since 1998), and it seems likely that several cultivars resistant to rice pests and/or diseases, drought and salinity may be released during the next year. Release has been delayed by concerns about global anti-GM crops sentiment (Karplus 2003), but in the end the potential benefits to farmers and consumers may be irresistible. Huang et al. (2003) have estimated that the adoption of GM rice would be worth approximately USD 4 billion a year to China by 2010, even if other countries ban imports of rice from China. Farmers would benefit from increased yields and lower production costs, and other consumers would benefit from lower rice prices.

Adoption is occurring in the face of strong resistance from consumers in some developed countries, notably in Europe, and from some Non-Government Organisations. Confronted with this resistance, many countries are proceeding extremely cautiously. For example, European pressure has been influential in conditioning African attitudes to GM crops in countries other than South Africa. But European resistance appears to be weakening. In May 2004 the European Union lifted its six-year de facto moratorium on GM crop and food approvals. Since then, several European countries have moved to approve the planting of GM maize.

The annual increase in the extent of adoption of GM crops seems certain to continue at levels of 10-20%. James (2005) predicts the area will reach 150 million hectares by 2010. Continued expansion of the area sown to GM cotton seems particularly likely. In China, the share of the cotton crop sown to GM cultivars is projected to increase from 45% of area in 2001 to 92% of the area by 2010 (Huang et al. 2003); India is projected to plant 1 million hectares of GM cotton in 2005 (up from about 550,000 hectares in 2004); and Brazil is set to plant GM cotton in 2005 (GM cotton was approved in March 2005), with the rate of adoption in that country constrained mainly by the limited availability of GM seed.

Tropical Forage Legumes

I spent a good deal of my career working on tropical forage legumes. The idea was that these plants would fill the same kind of role in tropical pastures as their counterparts do in temperate and Mediterranean pastures – providing high-quality feed for livestock and contributing nitrogen that would lift the productivity and quality of associated grasses for livestock production and provide nitrogen for crops grown in rotation with pastures. For about 50 years from 1950-2000, there was a very significant investment in tropical forage legume technology in Australia, and the work spilled over to the international arena, particularly in CIAT, ILRI and other international agricultural research centres, in Brazil and in several developing countries.

The adoption of tropical forage legumes in Australia has been summarised by numerous authors (eg Clements 1996). Unlike the dramatic adoption of internet technology and GM crops, adoption of tropical forage legumes in Australia has been relatively slow. By 1995, about 1.0 million hectares had been sown to stylo (*Stylosanthes* spp), and another 0.5 million hectares had been sown to other legumes. However, a benefit/cost analysis of the investment in *Stylosanthes* technology alone (Chudleigh and Bramwell 1996) showed the Net Present Value of the technology to be $263 million (benefits projected to 2020). The costs of establishing legume-based pastures and investing in additional cattle are significant, but the analysis showed that the returns to farmers were of the order of 7-30%, depending on the level and value of the increased productivity – a reasonably profitable investment, but perhaps not sufficiently profitable to drive rapid adoption of the technology. The area of sown tropical forage legumes in Australia may have reached 2 million hectares by 2005.

At the time of the 19th International Grassland Congress in Brazil (2001), a consensus was emerging that there had been very little adoption of tropical forage legumes except in Australia. A survey of adoption around the world was therefore undertaken, and nineteen poster papers were commissioned to present information from particular countries or regions. The results (Shelton *et al.* 2005) are summarised in Table 2.

The data show that about 5 million hectares had been sown to tropical forage legumes by 2005; that about two thirds of this area was in developing countries; and that at least 500,000 farmers were benefiting from the use of the technology. The most significant legumes were *Stylosanthes* species (approximately 2.4 million hectares), *Vigna unguiculata* [dual-purpose cowpeas] (1.4 million hectares), *Pueraria phaseoloides* [kudzu] (about 480,000 hectares) and

Leucaena leucocephala (about 170,000 hectares – almost certainly under-estimated).

Authors of the commissioned papers also provided their views on reasons for successful adoption (Shelton *et al.* 2005). In order of declining perceived importance, these included:

• The technology met farmers' needs and provided profits

• The technology matched farmers' socio-economic circumstances and skills

• Critical partnerships were in place (eg governments, private sector, farmers)

• Key stakeholders provided long-term commitment

• Farmer-centred R,D&E programs were implemented.

The availability of reliable supplies of good-quality seed was crucial to the successful adoption of these legumes. In some cases the private sector provided the seed supply. In other cases the seed was supplied by or organised by governments, or by NGOs.

Another feature of the results was the very wide range of farming systems in which the legumes were employed. An extreme example was the use of stylo leaf meal as a component of rations for monogastric animals in China.

A less extreme example was the Amarasi system in Indonesia, in which leucaena was cut and fed to tethered cattle. In Australia and Brazil, extensive grazing by cattle was the norm. In numerous cases the legumes fitted farming systems that had not originally been contemplated by the researchers who developed the legumes.

The Beef Cattle Industry in Australia

We have considered three particular examples of agricultural technology and its adoption. More generally, it is helpful to look at the development of an entire industry sector. In this case I have chosen to examine the history of development of the beef cattle industry in Australia, and I am relying heavily on the historical research conducted by Henzell (in press).

As Henzell points out, the Australian beef cattle industry in its earliest days used technology derived mainly from Britain. This included cattle farming practices, breeds and meat processing technologies. There were some clear differences associated with an early differentiation of beef cattle from dairy cattle in Australia, and a greater reliance on natural pastures as the source of cattle feed. Mechanical refrigeration technology was available from the 1870s, and the first shipment of frozen beef from Australia occurred in 1879/80, but exports developed quite slowly until the 1950s – a period of well over 50 years – partly because other countries had captured Britain's markets.

Table 2. Summary of areas sown to tropical forage legumes in 2005			
Country or region	**Principal species**	**Area sown ('000 hectares)**	**Number of farmers**
Australia	*Stylosanthes* spp	1,500	n.a.
Australia	*Leucaena leucocephala*	100	400
Australia	*Clitoria ternatea*	100	500
Australia	*Centrosema pascuorum*	5	100?
Brazil	*Stylosanthes* spp	150	n.a.
Brazil	*Pueraria phaseoloides*	480	5,400
Brazil	*Arachis pintoi*	65	1,000
USA (Florida)	*Arachis glabrata*	8	n.a.
USA (Florida)	*Aeschynomene Americana*	65	750
USA (Florida)	*Desmodium heterocarpon*	14	200
West Africa	*Vigna unguiculata* (dual purpose)	1,400	350,000
West Africa	*Stylosanthes, Centrosema* and *Aeschynomene* spp	19	27,000
East Africa	Various tree legumes	4 million metres of hedges	40,000
China	*Stylosanthes* spp	200	30,000
Thailand	*Stylosanthes* spp	300	12,000
India	*Stylosanthes* spp	250	5,000
Indonesia (NTT)	*Leucaena leucocephala*	70-93	n.a.
Indonesia (Lombok)	*Sesbania grandi ora*	n.a.	65,000
Nepal	*Arachis pintoi*	n.a.	20,000
TOTAL		**4,726**	**557,350**

For many years Australia relied on British breeds to upgrade the founding herds, which were derived from mixed sources –India, the Cape of Good Hope and England. Within 40 years pure-bred representatives of most of the British breeds had been introduced and used as sires, but it took many more years for the upgrading process to be completed. By 1848, Shorthorns were the predominant breed in Victoria and the preferred breed nearly everywhere, and by 1889 (100 years from first settlement) they were the predominant breed throughout Australia. During the 20th century, other British breeds became prominent in southern Australia, but Shorthorns were still the main breed in northern Australia until after the Second World War. Brahman cattle were re-introduced to Queensland in 1933, but it was not until the second half of the 20th century that Brahmans and Brahman crosses began to displace British breeds in the north. Such adoption of technology can hardly be described as rapid. Indeed, Henzell notes that northern cattlemen strongly opposed CSIRO's research on tropical breeds of cattle, which showed that such breeds had greater resistance to heat, ticks and worms and did better on low-quality feeds than British breeds. Henzell suggests that in the end, the change was probably triggered by the need to control cattle ticks, which had built up resistance to the various chemical controls that were then available.

Turning to cattle production practices, it is hard to find an example of a rapidly-adopted technology, especially in the north, until the last quarter of the 20th century. The task of fencing in Australia's cattle herd occurred fairly quickly in the south, but took much longer in northern Australia. Thus, improvements in mating, weaning, fattening and other aspects of herd management developed slowly in northern Australia, over time periods measured in decades. Better feeding practices including those based on improved pastures were adopted slowly, as we have seen. The limited profitability of the northern beef industry provided few incentives for technology adoption until the second half of the 20th century.

When change did come in northern Australia late in the 20th century, it was relatively dramatic and was almost certainly driven by profit. The opening of new export markets from 1957 onwards, including a profitable live cattle trade, provided new financial incentives for cattle producers. Between 1950 and 1980, Australian beef exports increased more than tenfold, until about two-thirds of the total beef produced was exported. The percentage of the northern beef cattle herd containing genes from tropical breeds grew from 4% in 1950 to 12% in 1965, 43% in 1973, 54% in 1977, 65% in 1982 and about 85% in the 1990s (Bindon and Jones 2001).

In the period between 1970 and 2002 an $8.1 billion profit bonanza for graziers resulted from this adoption of tropical breeds alone (Griffith et al. 2003). By 1995, 25% of the cattle grazed at some stage of their lives on 7 million hectares of improved pastures (Clements 1996), and graziers shared annual gross benefits of $80 million arising from the use of

introduced tropical pasture plants, mostly grasses (Chudleigh and Bramwell 1996). Premium prices for high-quality products drove investment in feedlots, commencing in the 1970s. By 1999, 20% of the beef cattle slaughtered in Australia had been through a feedlot.

A similar dramatic change occurred as a result of government regulation. Concern to protect export markets in the 1970s led to a scheme to eradicate bovine tuberculosis and brucellosis, and this in turn required northern cattle producers to fence their properties and muster cattle cleanly using helicopters. By the early 1990s Australia was effectively free of these two diseases, and the scheme had led to significant improvements in herd control and station management.

In summary, after a very long history of resistance to change, in the last quarter of the 20th century a mixture of financial incentives and government regulation led to rapid adoption of technology in the Australian beef cattle industry. It was indeed a period of shaking windows and rattling walls.

Lessons Learnt, and Conclusions

There is an enormous literature on the adoption of technology by farmers. Quite a lot of this has a sociological flavour. However, some of the most convincing analyses describe a typical sigmoid adoption curve, where the slope indicates the rate of acceptance and the ceiling measures the level of usage when adoption stabilises (Griliches 1957).

Looking back at these examples of technology adoption, it is hard to escape the conclusion that two key drivers of adoption are personal utility (particularly profit) and government regulation. Profit is probably the key motivator, and profitability may explain differences in both the slope and ceiling of the adoption curve (except, perhaps, in the case of internet communication). This is in line with the classical studies of Griliches (1957) and other economists who conducted early studies on determinants of technology adoption, but it seems to have been downplayed or perhaps even forgotten by successive generations of technology adoption theorists. The examples also lead me to offer two generalisations which might prove helpful in promoting adoption of desirable technologies in the future:

- If there is limited profit, technology adoption will be slow in the absence of other drivers; and

- If potential profits are large enough, adoption can take place even in the face of significant impediments.

Others may choose to replace the word 'profit' in these generalisations with a phrase such as 'personal utility' or 'personal satisfaction', recognising that 'profit' may not fully capture the range of personal motivators. These might include greater food security, reduced personal exertion (labour-saving technologies) and intellectual satisfaction (eg an interest in new machinery or electronic gadgets). It is also not clear from these examples whether profit remains such a key motivator after a certain minimum personal or farm

income is reached, or for adoption of technologies that affect long-term sustainability or off-farm impacts.

Of course, many other factors must influence the rate and extent of adoption, including the regulatory environment, the availability of information about the technology, availability of the technology itself and associated infrastructure and institutions, affordability of the technology, ease of adoption, the degree of risk and so on. These and other factors are dealt with extensively in the literature. Affordability of the technology and risk (or fear) of failure may have been critical factors in the case of tropical forage legume technology, where the significant investment required for pasture establishment and maintenance and additional livestock and the risk of establishment failure may have been much greater barriers to adoption than was realised at the time. Interestingly, in a survey conducted by McDonald and Clements (1999), 72% of Northern Australian graziers and farmers identified the high cost of pasture establishment as a severe or very severe constraint to the future use of tropical pasture plants, and 64% identified the high cost of pasture maintenance as being almost as severe a constraint.

In delivering GM crops to farmers and more generally in technology transfer, the role of the private sector is crucial, and the stimulus for private sector investment is again profit. Significantly, the managers of agricultural research for development increasingly recognise the need for greater investment by the private sector to deliver technologies to small farmers in developing countries, and a range of public/ private partnerships is being investigated. In the adoption of sown tropical pastures for example, unless the private sector provides a reliable and timely supply of cheap, good quality seed, the public sector may need to intervene to fill the gap.

The role of government regulation is probably also greatest when market failure occurs. For example, when profitability for the individual farmer is low (eg where benefits cannot be appropriated by the individual farmer, or where benefits occur off-farm), regulation may be needed to raise the slope or ceiling of the adoption curve. Conversely, the excessive regulatory environment for GM crops is slowing down their adoption, but the profitability of the technology seems to be high enough to overcome this constraint.

Bob Dylan's song reminded us that change can be rapid and merciless in replacing obsolete technology ('…you better start swimming or you'll sink like a stone…. There's a battle outside and it's raging'). He probably didn't have profit or personal utility in mind as a driver of social and technological change, but he should have.

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