Global Climate Change Policy: Implications for Australia & Australian Agriculture

Farrer Memorial Oration, 1994

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Global Climate Change Policy: Implications for Australia and Australian Agriculture

Farrer Memorial Oration

Brian Fisher

In the early 1920s Keynes observed that 'In the long run we are all dead'. That was an appropriate observation to make in the early postwar period when economies were subject to serious inflation and political unrest. Urgent short term action was required. It is not however an observation that would have sat comfortably with William James Farrer, a man who dedicated the latter part of his life to the painstaking search for new wheat varieties. It is in large measure to Farrer that we owe the early development of the Australian wheat industry. And even today the wheats he bred form part of the pedigree of many modern cultivars.

A long term vision is required for successful plant breeding. It is also required for successfully tackling environmental policy issues such as climate change and the enhanced greenhouse effect.

Apart from reminding each of us of the important work done by Farrer, the objective in this address is threefold. First, I will briefly outline the nature of climate change and the enhanced greenhouse effect. Second, I will describe the institutional environment and the international policy settings that have shaped developments in this area to date. And third I will outline the implications of climate change for Australia and Australian agriculture.

This address focuses on the economics of the greenhouse policy problem but I will first briefly describe some of the scientific issues to set the stage.

The greenhouse effect – the ability of the earth's atmosphere to trap some of the radiant heat that the earth emits after receiving solar radiation – is essential for life. This effect means that the earth's surface is about 18 ^{o}C warmer than otherwise. The important natural greenhouse gases in the atmosphere are carbon dioxide (CO_2), methane (CH_4), oxides of nitrogen, ozone (O_3) and water vapour. Other greenhouse gases include chloroflurocarbons (CFCs), other halogenated compounds and carbon tetrachloride (CCl_4).

(Figure 1 up)

When the earth's climate system is in equilibrium, incoming short-wave solar radiation is balanced by outgoing long-wave infrared radiation from the earth and the atmosphere. Any change in the energy balance is referred to as radiative forcing of the climate.

Sources of radiative forcing include effects that change both incoming and outgoing radiation. The most important influence on incoming radiation is the level of solar activity.

The level of solar radiation reaching the earth's surface is also influenced by variations in the earth's orbit around the sun and the absorption and reflection of energy by aerosols in the upper and lower atmosphere. Changes in the reflective capacity of the earth's surface, brought about by desertification, land clearing and urbanisation are also important.

(Figure 1 down)

But the most important source of anthropogenic radiative forcing – the enhanced greenhouse effect – is due to the build up of greenhouse gases as a result of human activities such as fossil fuel burning.

The most important greenhouse gas is CO_2 – estimated to have directly contributed about 64 per cent to global warming in 1990. Methane, released in the production of coal and natural gas, from rice paddies and ruminant animals and animal wastes, from biomass burning and from domestic sewerage treatment and landfills is the second most important greenhouse gas. Together, CO_2 and CH_4 accounted for about 83 per cent of the radiative forcing due to anthropogenic greenhouse gas emissions in 1990.

The pre-industrial concentration of CO_2 was about 280 parts per million by volume. Today the concentration is around 360 ppmv. There has been more than a twofold increase in the concentration of methane in the atmosphere since the industrial revolution.

The impact on climate from the build-up of greenhouse gases is uncertain. The Intergovernmental Panel on Climate Change has estimated that global mean surface air temperature has increased by between 0.3 and 0.6^{o}C over the last 100 years. However, they also observe that such warming is of the same order of magnitude as natural climate variability.

Despite the scientific effort to date there still exists gross uncertainty about both the extent of any past warming and the relationship between the enhanced greenhouse effect and climate change. Even though average global surface temperature appears to have increased in the past 100 years, temperatures in some regions show no statistically significant trend. In addition, scientific understanding of the effects of aerosols on climate, the effect of CO_2 fertilisation on plants and the part it plays in enhancing CO_2 sinks, and the relative radiative forcing effect of each greenhouse gas is imperfect.

Estimates from climate modelling studies suggest that the effect of a doubling of CO_2 concentrations is 'unlikely to be outside the range 1.5 to 4.5^{o}C'. Such changes are projected to occur within the next century. An important feature of this projection is the *rate* at which climate may change. If the projection is realised then the climate could change at a rate unprecedented over geological time.

The consequences of such a change are difficult to assess. The best estimates are that minimum night time temperatures would rise in many areas, that rainfall may be more intense and storms more severe and that some regions would become drier and hotter. Changes of the projected magnitude could put severe pressure on some ecosystems. Ecosystems are constantly adapting. However, as mentioned already, the projected rate of change is unprecedented and the ability of many ecosystems to adapt has been reduced by their fragmentation as a result of economic development.

Given the possibility of large (but uncertain) consequences of climate change, 154 countries (including Australia) signed the UN Framework Convention on Climate Change in Rio de Janeiro in June 1992. The Framework Convention, with its objective of 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system', was ratified by the required 50 countries and came into force on 21 March 1994.

The Convention does not explicitly set out targets or timetables but the most frequently discussed target is that of stabilising gross emissions of CO_2 at 1990 levels by the year 2000.

As an aside it is worth noting that stabilising emissions does not lead to stabilisation of atmospheric concentrations of CO_2 for several hundred years. About 6 billion tonnes of carbon were emitted in 1990. To stabilise atmospheric concentrations at 650 ppmv it is estimated that emissions would have to be ultimately reduced to 2 to 4 billion tonnes of carbon per year. To achieve stabilisation at 450 ppmv would require emissions of 1 to 2 billion tonnes of carbon per year.

The issue of targets and timetables, together with the important question of 'burden sharing' (sharing the costs of emissions reductions between countries) will be taken up in March 1995 by the Convention's decision making body, the 'Conferences of the Parties'.

Under the Convention, commitments to take action on emissions fall most heavily on the so-called Annex I countries (developed countries and those economies such as the economies of eastern Europe that are described as economies undergoing the process of transition to market economies).

In response to the outcome in Rio de Janeiro, Australia reaffirmed its commitment to its own interim planning target adopted in October 1990. This target involves the stabilisation of all greenhouse gas emissions at 1988 levels by the year 2000 and a reduction of emissions by 20 per cent from 1988 levels by 2005.

At the time of announcing the target the government indicated that it would not adopt measures that would have a net adverse economic impact or would damage Australia's trade competitiveness, in the absence of similar measures being taken by major greenhouse gas producing countries.

It now seems likely that measures to reduce greenhouse gas emissions will be taken by other industrial countries. However, the impact on these countries will depend importantly on the characteristics of their economies and the particular policies adopted.

About 75 per cent of global anthropogenic CO_2 emissions come from burning fossil fuels. About 31 per cent results from burning solid fuels such as coal while a further 31 per cent results from consumption of liquid fuel. At the beginning of this decade around 23 per cent of emissions resulted from land clearing and changes in land use.

(Figure 2 up)

In the case of methane, about 8 per cent results from the production of coal with a further 4 per cent from the combustion of coal. About 25 per cent of all methane emissions come from the production and use of fossil fuels. Land fills and domestic sewerage treatment contribute about 23 per cent of total emissions. Animal wastes and ruminant animals contribute a further 26 per cent while biomass burning and rice paddies are the source of the remaining 25 per cent of emissions.

(Figure 2 down)

In Australia by far the largest source of CO_2 emissions is the burning of coal. Use of solid fuels contributes about 50 per cent of emissions. Use of liquid fuels contributes a further 29 per cent and gas 11 per cent. Land clearing and changes in land use have been estimated to contribute about 10 per cent of emissions but there is considerable uncertainty about the magnitude of this estimate.

While these data show that the use of fossil fuels contribute the largest share of greenhouse gas emissions, activities associated with agriculture such as land clearing, cultivation and animal production, are both important as a source of and as a sink for greenhouse gases.

As mentioned earlier, the characteristics of economies will be important in determining how greenhouse policies might affect them.

(Figure 3 up)

The next graph shows the level of energy consumption by fuel in millions of tonnes of oil equivalent for selected countries.

The United States is the single largest energy consumer, followed by the European Union and Russia. China is also a significant user.

(Figure 4 up)

This next slide shows the share of each fuel in the energy mix for each country. As can be seen from the graph, of the industrial countries, Australia has the heaviest dependence on coal. This is of relevance because, of all the fossil fuels, coal burning emits the highest level of CO_2 per unit of energy produced. Of long term global importance is the heavy dependence of China on coal given the projected growth rates of that country.

A number of factors are important in determining likely future growth in emissions of greenhouse gases. Important among these are the rate of population growth, the level of economic growth, the speed of technological change, and the policy settings in each country.

First, population growth.

(Figure 5 up)

Over the period from 1990 to 2050 the World Bank has estimated that world population will grow at a rate of about 1 per cent a year. Most of the growth will be concentrated in Asia, Africa and Latin America with more than half occurring in south Asia and Africa.

(Figure 6 up)

In 1990 there were 5.3 billion people on earth. Today there are about 5.6 billion rising to an estimated 9.5 billion by 2050. As you can see from the graph, the share of the world's population living in countries which are classified as 'developing' today will grow over time.

About half the world's people will live in cities by the end of this decade. Urbanisation and the encroachment of urban areas onto agricultural land will become an important issue in determining food production in many countries in the next century. Also of importance will be the ability of the environment around megacities to absorb the wastes generated.

(Figure 7 up)

The next slide shows the share of CO2 emissions by region by 2010 given a plausible emissions scenario. Notice that the share of emissions from OECD countries drops from 48 per cent in 1991 to 42 per cent in 2010. The share for China grows from 11 to 16 per cent and for other developing countries from 20 to 28 per cent. This is an important observation given that the Framework Convention commits industrial countries to action on climate change – but clearly significant future growth in emissions will occur in developing countries.

(Figure 7 down)

The future levels of economic and population growth are interrelated and also depend on the policy settings adopted by governments. Generally it has been observed that human fertility is negatively related to the level of income. Partially offsetting this relationship, in terms of total population level, is the observation that longevity is positively related to the level of income.

The pace of technological change and the speed of its adoption are also uncertain. Given projected population growth, a target of stabilising the concentration of CO_2 in the atmosphere at levels even close to double today's level would require radical shifts in both the sources of energy and the efficiency with which fossil fuels are used.

(Figure 8 up)

This slide gives some idea of the differences that currently exist in the thermal efficiency of power stations around the world. A gap of about 15 per cent currently exists between the least efficient plants in developing countries and the best in industrial countries. This highlights the opportunities for gains to be made by technology transfer to developing countries with projected high future growth in emissions as new plant is put in place. It also illustrates an important but little understood point that the cost of abatement for an additional tonne of carbon emissions in developing countries is often substantially less than that in industrial countries. From a global efficiency point of view it follows that abatement in developing countries should not be ignored as an option, despite the way in which the Framework Convention has been formulated.

(Figure 8 down)

Having outlined the problem it is now time to ask what are the possible consequences of climate change and what are the policy solutions?

It is important to draw a clear distinction between the impacts of climate change itself and the impacts of any policies that might be adopted to mitigate climate change. The impacts are uncertain because our scientific understanding is imperfect. In addition, both ecosystems and economic systems are changing all the time and will adapt, to some extent, to climate change.

Turning to the possible direct impacts on global agriculture, much of the empirical evidence available is based on simulations of climate change using general circulation models that have been shocked by a doubling of the concentration of CO_2. Recently the US Department of Agriculture has combined results from such simulations with a global model which contains a range of regions/land classes each with their own production structures for livestock, crops and forest products.

This structure allows the simulation of adaptive responses by farmers to changes in the environment in the sense that it allows for responses to price changes. As such it captures both some of the direct and indirect effects of, and responses to, climate change. However, the model is limited in the sense that it does not allow for other important adaptation such as responses by plant breeders in producing new cultivars better suited to the new climatic conditions. More generally we can expect major technological advances over the next 100 years – most of the world's capital stock will be replaced at least twice during that period and much of it many more times.

According to this work the resulting changes in climate from a doubling of CO_2 would lead to a reduction in the area of tundra and boreal forest and in the area of tropical season forest and rain forest but a global increase in the area occupied by all other land classes. Such changes would have the most bearing on areas currently used to produce rice, maize and sugar cane.

The simulated impacts on total world crop, livestock and forest products reported are small, ranging from a fall of 1 per cent to a rise of just over 3 per cent. However, these small global changes mask large simulated changes within regions. For example, in the case of crops some regions experience simulated falls in production of up to 65 per cent while others experience rises of up to 47 per cent. Regional changes in the production of livestock and forest products are more moderate. Such results are generally consistent with those reported in earlier work in the USDA using a different modelling framework.

Clearly, if such changes at a regional level were to come about they would have substantial ramifications. For example, the possibility exists of regions which currently have large populations, such as southern Africa, coming under significant pressure. This raises the question of the availability of adequate water resources, the increased incidence of serious pests and diseases and the vulnerability of complete ecosystems in central southern Africa under plausible climate change scenarios. It should be noted however that severe pressure on the environment already exists in many parts of Africa. Further extended periods of drought may only serve to hasten the already established process of desertification.

Major regional changes which lead to pressure on food supplies carry with them significant policy implications. At the extreme it is possible to imagine pressure developing to allow the migration of large numbers of people. Migration policy and the possibility of regional conflicts then become an important consideration.

At the other end of the spectrum is the likelihood of growing pressure on governments to ensure food self-sufficiency and 'food security' at the country or regional level. Such an outcome could lead to pressure to reverse the current trend toward trade liberalisation and, in fact, exacerbate commodity price fluctuations and the vulnerability of regions to food deficits.

Free trade effectively provides a risk pooling mechanism for the world – in any one year commodity deficit countries trade with commodity surplus countries to smooth supplies and prices. Any tendency toward protection in an attempt to ensure food supplies would reduce access to markets and lead to an increase in the variability of world prices, resulting in a reduction in supply of agriculture products from the traditional exporting countries. Dividing the world up into separated regions would reduce access to spatial diversity and the gains from trade.

As is the case for other countries, estimates derived from global climate models designed to simulate conditions in Australian regions are highly uncertain. In the longer term, the enhanced greenhouse effect may have a significant influence on the Australian agricultural sector. For example, increases in temperature are likely to affect the pome and stone fruit industry. But decreased fruit production in some regions may be offset by increased production in others.

The effect on livestock is also likely to be varied. In responses to changing climate, growers are likely to change to breeds that are more suited to their region. It is also likely that there will be inter-regional substitution effects.

Rainfall patterns may change in terms of quantity, seasonality, variability and intensity. Although most rural regions in Australia are likely to benefit from increased summer rainfall, there may be adverse effects on agricultural activities as a result of increased rainfall variability. Increased frequency of rainfall with greater intensity may also promote greater levels of soil erosion.

Also of relevance to agriculture is what is known as the 'carbon dioxide fertilisation effect'. With increased concentrations of carbon dioxide in the atmosphere as a result of the greenhouse effect, increased rates of photosynthesis are likely to occur in some plant species. This, in turn, may increase their storage of carbon, provided water and other nutrients are not limiting. Subsequently, production of more efficient crops may increase.

Changes in climatic variables may also influence soil nutrient levels and the types, number and range of pests and diseases which affect crops and livestock.

Having looked briefly at the possible impacts of climate change I now turn to the policy problem.

The enhanced greenhouse policy problem is a global problem in the sense that, in the long term, the emission of a tonne of carbon in Australia or in China or in Sweden has the same effect on climate because the major greenhouse gases are well mixed in the atmosphere. The problem arises because the atmosphere is a common good – the full cost of polluting it with greenhouse gases is not borne by any one individual or country and from this it follows that the atmosphere will be over-exploited as a repository for pollution. It also follows that no one country acting alone can solve the enhanced greenhouse problem – a coalition of countries acting together will be required before effective progress can be made.

Given agreement to tackle the policy problem, where should any one country start? The most obvious first step is to ask whether there are changes to current policy settings or obvious market failures that can be corrected that would lead to both a more efficient allocation of resources and a reduction in greenhouse gas emissions. These are the so-called 'no regrets' options. They amount to finding 'free lunches'. While it is possible, prima facie, to identify cases of market failure in energy markets it is much more difficult to find cost effective free lunches.

However, having said that, there may be opportunities to change some policy settings and incidentally reduce emissions. For example, both energy prices and production are subsidised in many countries. Removing such subsidies would both increase national welfare and lead to more efficient allocation of resources in the energy sector. It is also possible that total greenhouse gas emissions would be reduced as a side benefit. This observation begs the question of why governments do not remove such subsidies now.

It has been suggested that energy consumers are often ill-informed about their energy usage and the gains that can be made by altering their use patterns or changing their household appliances. While there may be some gains to be made, for example, by the provision of better information about the characteristics of household appliances, such gains are likely to be small.

Some governments may choose to set mandatory standards on equipment that uses fossil fuels in an attempt to reduce emissions or may mandate fuel efficiency targets. Others may choose to subsidise the development of renewable energy sources and encourage the enhancement of sinks by promoting forest development or restricting clearing. The main problem, however, lies in the fact that those responsible for emitting greenhouse gases do not bear the full cost of their actions. The most efficient way to address this problem is to ensure that emitters face the true cost.

To achieve this a range of policy instruments are being discussed – chief among these is a carbon tax, tradable emission quotas and joint implementation. To illustrate how such policies might impact on Australia and Australian agriculture I'll now outline the results of two simulations from ABARE's MEGABARE model.

MEGABARE is a global trade model that includes detailed commodity coverage and greenhouse gas emissions accounting.

(Figure 9 up)

In the first simulation, the model was solved for the level of a carbon tax in each Annex 1 country that would reduce carbon dioxide emissions in that country by 20 per cent. Under the second simulation, a tradable quota scheme was modelled for industrial countries allowing for joint implementation projects with developing countries to achieve the same reduction in global emissions as the first simulation. Joint implementation is a term used to describe actions taken by a number of countries in cooperation to jointly reduce emissions.

With the first simulation, it was found that the level of a carbon tax required to achieve the required reduction in emissions in Australia and Japan was more than three times the level required for other industrial countries.

(Figure 10 up)

For Australia, the result reflects the higher carbon intensity of the economy due to abundant supplies of low cost coal. Electricity generation is the most important single source of carbon dioxide emissions globally. In Australia more than 80 per cent of electricity is generated from coal fired sources which is a higher proportion than in any other industrial country.

It would be economic to switch to less carbon intensive energy sources only under extremely high carbon taxes and there is limited scope to substitute non-energy inputs for energy inputs. For Japan, the high carbon tax required reflects the dependence of the economy on high cost sources of imported fuel and the high levels of energy efficiency that have been achieved following the oil price shocks of the 1970s.

(Figure 11 up)

In terms of the impact on real aggregate consumption levels, Australia would be the most severely affected industrial country and suffer a much greater decline in aggregate consumption than Japan.

The terms of trade, that is the price of exports relative to the price of imports, would move against Australia due to the decline in the price of fossil fuels. Thus, a given volume of Australian exports would purchase a reduced volume of imports. In contrast, as an importer of fossil fuels, the terms of trade would move in favour of Japan. A given volume of exports would purchase a larger volume of imports which helps to maintain the level of consumption in Japan.

Although carbon taxes are confined to industrial countries in the simulation, all non-Annex 1 countries suffer mainly due to reduced demand for their exports by industrial countries. OPEC suffers the greatest decline in aggregate consumption levels due to the reduced volume and price of oil exports.

(Figure 11 down)

Under the second simulation it was assumed that a tradable quota scheme in industrial countries together with joint implementation in developing countries would result in the marginal costs of abatement being equalised across countries. In other words, emission reductions would be undertaken where it is cheapest to do so.

Obviously, developing countries would agree to participate in joint implementation only if it would make them better off than the outcome they could expect as a result of any action taken by industrial countries acting as a group on their own. And in fact it would be possible to operate a tradable quota scheme together with joint implementation in such a way that both industrial and developing countries would be made better off.

There are several important policy implications to be drawn from these results. Fossil fuel exporters such as Australia would be severely disadvantaged by proposals such as an equal percentage reduction in emissions. There are significant gains for all countries from an efficient approach to emission reduction that involves equalising the marginal costs of abatement across countries.

Aside from short term efficiency gains, as mentioned earlier there are also longer term reasons why it is important to involve developing countries in an abatement program. Growth in emissions from developing countries is projected to be significantly higher than from industrial countries. A scheme confined to developed countries would become increasingly ineffective at curbing the growth in world emissions. Such a problem would be compounded in the absence of a policy response by the relocation of emission intensive industries from industrial to developing countries.

To illustrate the impact of possible global mitigation policies on agriculture, the two MEGABARE simulations already mentioned were run with the agricultural sector in the model disaggregated.

The percentage change in output for each sector in Australia and the world is shown in the next slide.

(Figure 12 up)

There is a smaller decline in the output of agriculture for Australia and the world than for manufactured products. Such a result reflects factors on both the demand and the supply sides. On the demand side, it is well known that as 'necessities' of life, agricultural products have low income elasticities of demand. As income declined under a carbon tax, demand for agricultural products would be better maintained than for manufactured products.

On the supply side it is also generally true that in most economies, the share in total costs of oil based products and electricity is lower in agriculture than in manufacturing. Since oil based products and electricity are the input prices most affected by a carbon tax, the direct increase in costs is greater for manufacturing than for agriculture.

Turning to the sectoral detail, both Australian and world output of rice increase. Some substitution of rice for wheat occurs in the aggregate pattern of world consumption. In the major wheat exporting countries, the United States, Canada, Australia and the European Union, wheat is the agricultural industry where oil based products have the highest share in total costs.

Oil based products have a lower share in total production costs of rice in industrial countries and also in developing countries where oil based products are not taxed. The improved cost advantage of rice over wheat results in some expansion in production in industrial countries such as Australia and Japan and also in some developing countries.

The relatively higher share of oil based products in costs in the United States wheat industry is central to explaining the changing international pattern of wheat production. Production in the United States declines by 6 per cent while the market share improves for all other major exporting countries such as Australia, Canada and the European Union.

The improvement in the competitive position of Australia is somewhat retarded by the higher carbon tax required to meet emission targets in Australia compared with the United States. Production in the European Union, which has the lowest share of oil based products in total costs, actually increases by 1 per cent. Wheat production in developing countries also increases due to the decline in the comparative advantage of the major exporting countries. Production in these countries is not as highly mechanised as in the major exporting countries and, of course, oil based products in developing countries are not subject to a carbon tax by assumption.

The decline in the comparative advantage of the United States grain industry is also relevant in explaining the changing pattern of international production in the other livestock products sector. International trade in this sector is dominated by trade in beef. The United States industry is based on grain feeding animals. Wheat and other crops account for 25 per cent of the total costs of production of other livestock products in the United States. The corresponding cost share for the predominantly range fed industry in Australia is only 2 per cent.

Production of other livestock products in the United States declines by around 1 per cent while exports decline by 10.5 per cent and imports increase by 3.5 per cent. In contrast, there is a slight increase in Australian production, and exports increase by 2.3 per cent. The decline in the relative competitive position of the United States industry stems primarily from the greater increase in costs arising from heavier reliance on grain feeding. The European Union also relies more heavily on grain feeding animals than Australia with wheat and other crops accounting for 6 per cent of total production costs. The relative competitiveness of the European Union in other livestock products also declines with both production and exports declining.

The wool industry suffers the greatest decline in output of Australian agricultural industries and the wool industry also suffers the greatest decline of agricultural industries globally. Such a result is driven primarily by demand side factors. Of all the agricultural industries, wool probably has the greatest proportion of final consumption in industrial countries. These countries suffer the greatest decline in income under a carbon tax. Furthermore, in the other agricultural industries, Australia was able to increase its market share at the expense of other industrial countries that had a cost structure with a heavier dependence on oil based products. Such is not the case in wool where Australia dominates world exports and competitors such as New Zealand have a similar cost structure to Australia. In fact, New Zealand appears to have a lower dependence on sales to industrial countries than Australia and in the simulation was able to increase its share of the world market relative to Australia.

(Figure 13 up)

Under the second simulation, there is a much more efficient spreading of the costs of emission reduction throughout the world, resulting in a much smaller decline in world GDP. There is a mild decline in GDP in all countries apart from China. Under this simulation, China makes a major contribution to reducing world emissions and the compensation it receives from industrial countries actually results in an increase in GDP in China of about 1 per cent.

(Figure 14 up)

The percentage change in output for each sector in Australia and the world is shown on this slide.

The percentage changes are of a much smaller magnitude than under the previous simulation due to the smaller decline in world GDP. Again agriculture fares better than manufacturing and the same factors discussed in the first simulation are relevant. In addition, in the present simulation, the increase in GDP in China stimulates increased demand for agricultural products although much of this is met from increased production in China and hence does not affect world trade and prices to any great extent.

In the case of Australia, the absolute change in the level of output from any agricultural sector does not exceed one per cent. The increased costs to US agriculture, due to the dependence of that country's agriculture on oil based products that was a dominating factor in the first simulation, is much less significant in the present simulation. In the present simulation the carbon tax equivalent in the United States is less than one third of its level in the first simulation. Thus, there is a much smaller decline in the competitiveness of United States agriculture under the second simulation. Furthermore, since the decline in GDP in industrial countries is much lower than under the first simulation, the demand for wool is better maintained.

(Figure 14 down)

It is worth noting that the results I've just discussed are for policies designed to reduce CO2 emissions. Some differences could be expected with policies designed to reduce the emissions of all greenhouse gases because of the varying importance of different industries as sources of emissions. In the case of methane, for example, the rice industry is a major source of emissions.

Concluding comments

Mr Chairman, its time to sum up.

The main conclusions I draw are as follows.

First, both the nature and the impact of climate change are highly uncertain. But, the evidence on the trends is enough for many governments to have committed themselves to some action.

The direct impacts of climate change on agriculture at the global level over the next 100 years have been projected to be small. It is likely, with ongoing technological change that agriculture will have the capacity to feed the world. At the same time it is also possible that regional disparities in income will rise. Climatic shifts that lead to drier, warmer weather in some regions could lead to extended periods of drought and crop failure in areas where population pressure is already mounting. One way to reduce the impacts of regional differences in production is through trade and a continued trend toward international trade liberalisation would assist in minimising the extent to which the effects of swings in production pass through to price variability.

The problem of climate change is a global one. But the Framework Convention on Climate Change at this stage commits only industrial countries to some action. Yet the major sources of future growth in population, industrial output and greenhouse gas emissions are in the developing world. The real challenge lies in developing policies and engaging the major developing countries in a cooperative solution – is there a policy from which the gains are large enough for the winners to compensate the losers and still be left better off? I think there probably is. At its heart lies a policy that encourages technology transfer between industrial and developing countries in order to both help reduce the growth in greenhouse gas emissions and to stimulate income growth. Only as incomes grow will population growth rates fall and countries dedicate more of their wealth to look after the environment.

And finally Mr Chairman let me return to William James Farrer. Farrer was a man of vision. He took a long term view. A role for such people in agriculture exists more than ever today despite shrinking research budgets and falling student numbers in faculties of agriculture around Australia. Over the next 100 years there will need to be major scientific breakthroughs if the global population is to be properly fed.

There is no time like the present to embark on that task.

Ladies and gentlemen, Mr Chairman, thank you.