REPORT

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Emerging technologies and research for New Zealand's economic development and associated risk management

Economic and Scenario Modelling

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1 Introduction

1.1 Purpose of this report

The Centre for International Economics (CIE) was commissioned by New Zealand's Ministry for the Environment to study the implications of emerging technologies and research for New Zealand's economic development and associated risk management.

Implementation of this project involves two major stages of outputs. The first is the production of a literature review (presented in a separate report) to identify emerging research, technologies and developments worthy of further study. The second is further study of technologies identified in the literature review through scenario and quantitative modelling of their likely overall impacts on New Zealand's economy and the risks and opportunities these technologies pose for health and environmental management.

The literature review identified the following as technologies worthy of further study:

- Nanotechnology with primary application to the dairy sector and secondary application to a range of manufacturing sectors;
- Epigenetics/functional genomics with primary application to animal and horticultural industries;
- Biopharmaceuticals with their primary application in dairy and poultry based drug production pathways; and
- Nanochemicals with primary application to consumer and personal health care products.

The purpose of this report is to subject the four identified technologies above to a comprehensive impact assessment in terms of their implications for variables of economic, health and environmental interest for New Zealand.

1.2 The economics of emerging technologies

Emerging technologies are an important source of economic growth. Three main sources of economic growth can be identified, namely increases in capital, increases in labour and increases in productivity. Emerging technologies can be a significant source of productivity gain. Moreover they can stimulate new capital investment and concomitant increases in labour participation or growth.

The emerging technologies identified in our literature review are likely to be among the next generation of technologies to have a substantial impact on productivity and economic growth. Like new technologies from earlier generations such as electricity, the electric motor and information technology they have the potential to permeate the economy and change it in dramatic ways. They can cause large profound changes in input use, input/output relationships, capital:labour ratios, imports, exports, the terms of trade and the exchange rate, the rate of capital expansion, the employment rate, the rate of development of new products and markets and other macroeconomic indicators. Understanding the extent and potential of such changes is a complex issue requiring a detailed sectoral model of the whole economy with linkages to trading partners. Even then, it is difficult to be precise about the course of a new technology through the economy, but it is possible to use plausible scenarios to illustrate the extent and nature of possible changes.

Productivity change is of particular interest in the case of new technologies. It is the starting point that may drive other changes and change many input and output prices over time. A detailed model can track such second round changes. But the important starting point is in understanding the scope for initial productivity gains and their spread.

Productivity is a measure of output from a production process per unit of input, where these inputs will typically comprise labour, capital, land or other intermediate inputs. More specifically, economists refer to the concept of multifactor productivity (MFP) where a 1 per cent MFP improvement means that a firm will require 1 per cent less inputs to produce the same amount of products if there is no change in input and output prices. Thus an increase in productivity in effect allows societies to derive more value from existing resources, and hence leads to sustained increases in output, in other words, economic growth.

Of the three sources of economic growth, increases in productivity are the most relevant to our modelling. For the emerging technologies identified, we can model the direct or 'first order' effect of an emerging technology as inducing an increase in the MFP of the specific industry sectors which adopt this technology. This is because each of these technologies can be understood as facilitating new production processes which allow firms to produce more output from the same amount of inputs. The magnitudes of the productivity 'shocks' from these technologies are based on estimates derived from our understanding of the literature on these technologies and historical experience of what is possible and plausible. In only one of these cases (nanochemicals) have we modelled the first order effect as being an increase in household demand for particular goods because the direct impacts of that particular technology are primarily considered in qualitative terms, resulting in the creation of new kinds of consumer products.

By injecting such initial shocks into the model, the model can then trace through all other changes this can put in train.

Adoption of new technology

It takes time for most new technologies to reach their full impact. How the full impact is reached is described by so called adoption profiles. It is therefore essential in analysing the impact of a new technology that the adoption profile of the technology is well understood as an adoption profile indicates the following information:

- How soon the full impact will be reached e.g. whether it is 5, 10, 15 or more years;
- How much is the full impact:
  - It is worth noting that the full impact is a product of two factors: the impact of a technology and the maximum proportion of firms in a sector which can adopt the technology.
  - It is unlikely that a technology will be adopted by all firms, that is, a 100 per cent of adoption rate.
  - For instance, we have assumed that the adoption of epigenetics leads to 3 per cent improvement in productivity in the final years in the adopting sectors. This could be the result of a full adoption with 3 per cent improvement, or by a more plausible 75 per cent adoption rate times 4 per cent improvement in productivity.
- How the adoption evolves – how many more firms adopt the new technology each year, and/or how much more effect achieves each year.
  - Adoption profiles are commonly defined by S-shaped logistic functions. This S-shape makes sense because at the beginning, there are a limited number of firms willing to take the risk and opportunity and the adoption process appears slow. After a certain period when the benefit of the initial takers starts to emerge, there will be a period of rapid adoption with many more firms copying their peers. After that, the additional adoption becomes slow again as the adoption approaches to its saturation status.

The value of a general equilibrium perspective

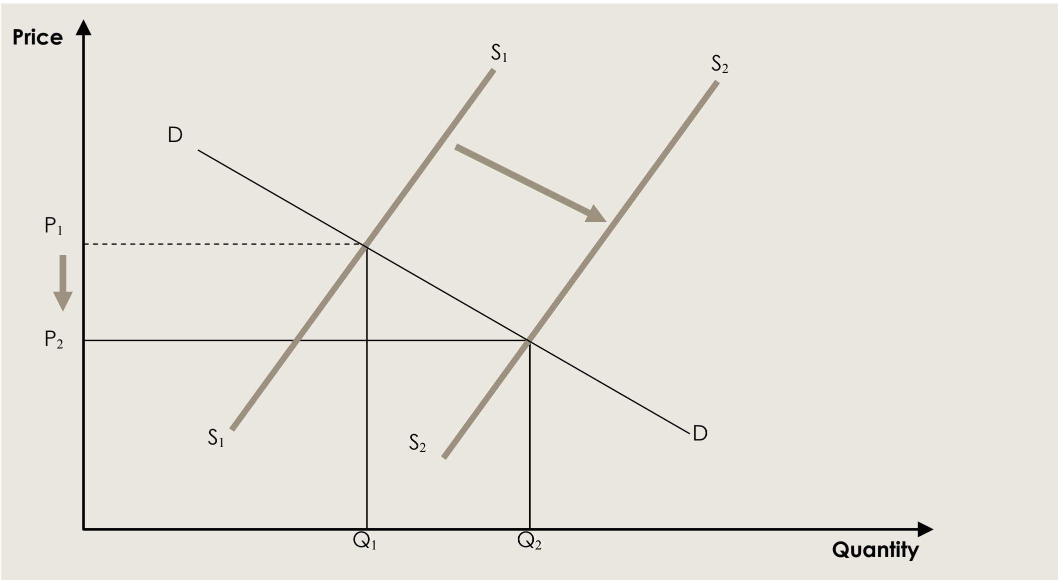
The nature of technological developments is such that they are likely to have significant multisectoral impacts. What this means is that their full impacts cannot be restricted to one market alone. Of course, this is also true of any other economic impact – for instance, an increase in the price of cotton will be likely to have impacts not only on the market for cotton but also in the market for other products which use cotton as an input into production, markets which use cotton products, and so on. The value of general equilibrium modelling is that it allows us to capture not only the first order effects but the second order, third order and other 'flow on' effects from the adoption of a new technology in a particular sector.

In the further 'upstream' or 'downstream' from the market where the most direct impact is felt (in this case the market for cotton), it is likely that the magnitudes of these impacts whatever they may be, will diminish. In some cases, these indirect effects may be negligible. However in other cases, the accretion of these various indirect impacts can end up making a substantial difference to overall economic outcomes so that there is a significant divergence between the results of general equilibrium modelling and what we would expect from only analysing the first order effects of the change through partial equilibrium analysis. We can describe some of the most likely first order and indirect impacts of the emerging technologies as below, but only through general equilibrium modelling can the magnitude of these effects be quantified so it can be determined which effects dominate the others.

First order impacts

For any of the model simulations, sectors may be grouped into three types: the adopting sectors which are the most directly affected because by adopting the new technology they enjoy productivity improvements e.g. the dairy sector affected by the nanotechnology; the sectors providing inputs into the directly affected sectors; and other sectors. Productivity improvement caused by the new technology will have different impacts on these three types of sectors.

1.1 **Impact of productivity improvement on production cost**



Data source: The CIE

For the directly affected sectors, productivity improvement means lower production cost. Diagrammatically, the supply curve of these sectors would shift downwards, as shown in Chart 1. Lower production cost leads to lower product prices which in turn lead to higher consumption of the products of the adopting sectors. As a result, the adopting sectors will experience increased outputs with lower prices.

For normal demand and supply relationships, the reduction in price would be expected to be smaller than the cost reduction implied by the productivity improvement. In other words, both producers and consumers will benefit from the productivity improvement. The extent of the gains enjoyed by producers and consumers is an empirical question, and may be calculated by the model.

Indirect impacts – expansion effects versus resource competition effects

As these adopting sectors expand, they may increase their demand for inputs. Although productivity improvement means less inputs are required per unit of production, the total demand for intermediate inputs may still be higher because the expansion of directly affected sectors is higher than the productivity improvement.

On top of the higher demand for inputs, there is also likely to be higher demand due to overall income effects. Households will become wealthier, and thus household demand for goods and services increases. Thus, there are likely to be 'expansion effects' which lead to increases in household demand for consumer goods and industry demand for intermediate inputs.

However, there are offsetting effects for all other sectors due to 'resource competition effects'. As resources, such as land, capital and labour, are limited, expansion in the adopting sectors would attract more resources from other sectors, and thus cause other sectors to shrink.

For the sectors providing inputs to the expanding sectors, the positive impacts are likely to dominate, and they would also experience expansion.

For other sectors, the direction of change is ambiguous. The 'resource competition effects' may dominate the 'expansion effects', but it is also likely that some of them may experience some expansion, especially if some of them may provide inputs into other expanding sectors. Which of these effects dominates will help determine net changes in output in the economy. However, where the adoption of technology by other countries is also taken into account, there will be other effects mediated through trade which will also feed into the final changes in output and consumption. These are discussed below.

Trade effects

While it is easy to describe the likely trade effects of technology adoption, the overall direction of changes is again likely to be ambiguous and can only be resolved by quantitative general equilibrium modelling.

For the directly affected adopting sectors, the reduction in production costs facilitated by the technology is likely to increase the competitiveness of their exports. This may lead to an increase in net exports from that adopting sector, as illustrated by the change in imports and exports of dairy products in the simulations of nanotechnology. However, because of the increased wealth facilitated by productivity improvements (the expansion effects described earlier), some of the resulting increase in household demand may spill over into increased imports and reduced exports so that the overall direction in the change of aggregate exports is uncertain.

The direction of this change may vary further depending on whether other countries adopt the same technology, because on the one hand, this may mean that the competitiveness of New Zealand exports does not rise that much relative to competing products from other countries and on the other hand, the increase in foreign household demand for goods and services due to expansion effects in those other countries may also spillover into further increased demand for New Zealand exports. The first effect would tend to further reduce aggregate exports while the second would increase it.

Overall impacts

As is evident from the discussion above, the overall impact of an emerging technology being adopted in New Zealand will depend on a range of effects, some of which are mutually reinforcing while others are mutually negating. These include the 'expansion effects' of the technology on the adopting sectors and the sectors which supply them with inputs, 'competition effects' on other sectors which have to pay higher prices for use of their inputs, the wealth effects on New Zealand households resulting from expansion effects (and impacting on demand for goods and services including imports) and the wealth effects on overseas households in the case where other countries also adopt the same technologies (impacting on demand for goods and services including New Zealand exports).

The overall domestic impacts of these technologies are likely to be clearer - productivity improvement in the adopting sectors should be expected to generate expansion effects (including expansion effects in other countries which adopt this technology spilling over into increased demand for New Zealand exports) which dominate the decline in production in other sectors. As a result, real GDP and real household income would be expected to increase, as would investment. However, the direction of trade impacts may be more ambiguous.

1.3 Our approach

As explained in further detail in the Methodology chapter, the impact assessment of these four technologies is primarily performed by use of the general equilibrium model GTAP. The model was developed in Purdue University in the United States. It is well adapted to the needs of this project as it is multiregional and multisectoral in coverage and incorporates a number of technical innovations such as the way it treats international trade and transport margins. It is also one of the few general equilibrium models which has had its specifications tested and adjusted against historical experience.[1] The CIE has used this model in a number of past projects requiring the use of similar analytical capabilities as are required in this report, such as the modelling of the impacts of free trade agreements.

The industry sectors identified as being the primary adopters of the technology are subject to appropriate 'shocks' in the model which are based on our estimates of their likely impacts on productivity, and in one case, on household demand. The resulting impacts on the New Zealand economy from these shocks are then simulated, and their results reported in the Results chapter. However, in addition to this, where there are important implications from adoptions of these technologies, particularly as they relate to environmental and health management which cannot be quantitatively modelled, these are also discussed separately in the Results chapter.

1.4 *Illustrative value of modelling performed*

The simulation results of such modelling should not be interpreted as forecasts of the actual impacts of the adoption of the technology, as the scenarios being modelled are subject to very specific assumptions regarding the adoption profile, the primary adopting industries, and even the magnitude of productivity or other shocks in the relevant industry sectors resulting from the adoption of the technology. While every care has been taken to ensure that these assumptions are formed on the best available estimates in the literature, the adoption of these technologies is subject to too great a degree of uncertainty for the resulting simulation results to serve as practical forecasts.

Therefore the value of the simulation results reported should be seen primarily in their illustrative role – that is, they demonstrate how a new technology may impact on a sector and affect economic activity and outcomes for that sector and the New Zealand economy as a whole, thereby providing an economic perspective for informing regulatory processes which may be required for these emerging technologies.

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1 See https://www.gtap.agecon.purdue.edu/models/cge_gtap_n.asp

2 *Methodology*

2.1 *Identifying emerging technologies and their likely impacts*

The wide range of emerging technologies and potential applications mean that it would be possible to model a similarly wide range of scenarios for illustrative purposes. Factors taken into account when deciding on possible case studies included;

- having a mix of different types of technology (nanotechnology, biotechnology);
- applications in sectors of economic relevance to New Zealand (e.g. primary industries); and
- a consumer product focus.

The emerging technologies selected for further analysis were:

- Nanotechnology coating and materials;
- Epigenetics and functional genomics;
- Biopharmaceuticals; and
- Nanochemicals.

The CIE then proceeded to formulate for each of these technologies:

- Assumptions regarding which industry sectors would adopt and therefore be affected in the first instance by these technologies;
- Assumptions regarding the possible impact of these technologies on the adopting sectors in terms of increases in multifactor productivity and in some cases, greenhouse gas emissions and household demand.

Again, these assumptions were formulated taking into account the findings of our literature review and insights from the workshops organised on emerging technologies.

To model the full economic impacts of these emerging technologies not only in terms of productivity growth impacts in adopting sectors but across the New Zealand economy as a whole, the CIE relied on a general equilibrium model of the world economy, the Global Trade Analysis Project (GTAP).

2.2 *Modelling*

The modelling involves the following steps:

- Modifying the original model to better suit the needs of the analysis;
- Identifying affected sectors and associated shocks;
- Assuming a reasonable adoption profile of the new technologies; and
- Implementing the shocks and carrying out the simulations.

Aggregation of countries/country groups in the model

The original GTAP model database includes 113 countries or country groups. In order to focus our analysis on the New Zealand economy, while keeping some international linkages, we aggregate the 113 countries/country groups into 6 country groups:

- New Zealand
- Australia
- Rest of Asian and Oceanic countries
- United States of America
- Europe
- Rest of the world

Australia is separated from other Asian and Oceanic countries due to its close economic relationship with New Zealand.

Mapping the affected sectors and associated shocks to the GTAP model's sectors

The affected sectors which were identified previously based on our literature review were defined according to the Australian and New Zealand Standard Industry Classification (ANZSIC). However, their ANZSIC definitions then had to be mapped into relevant GTAP sectors.

Although GTAP has a fairly detailed sectoral breakdown of the New Zealand economy with 57 defined industry sectors, its sectors are nonetheless still more broadly defined than the ANZSIC sectors. There is a potential problem when mapping the ANZSIC sectors affected by the new technologies into the GTAP sectors – some of the ANZSIC sectors may account for only a part of the GTAP sectors.

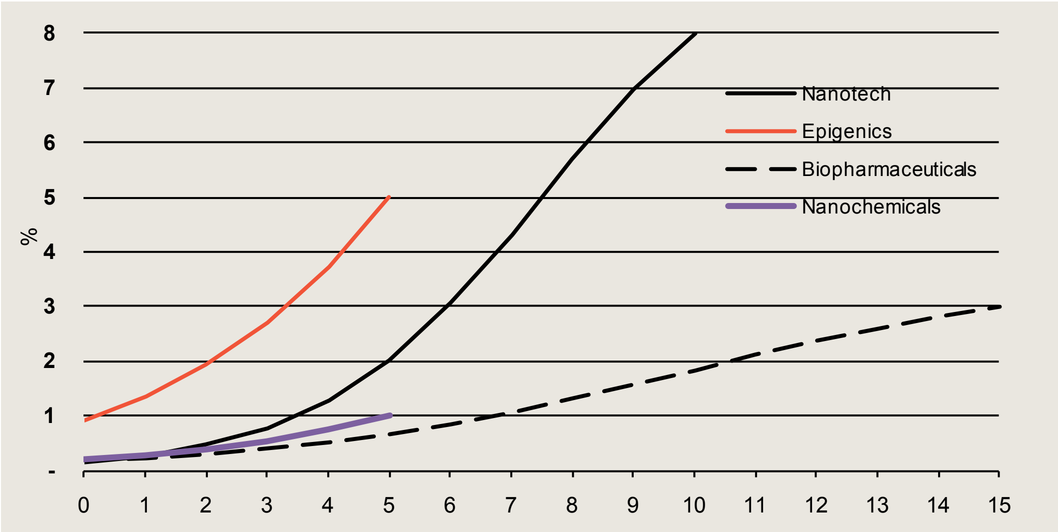
This problem can be solved by carefully formulating the shocks to the GTAP sectors. For example, if a technology leads to 10 per cent reduction in production cost of a ANZSIC sector, and the sector accounts for half of a matching GTAP sector, then a 5 per cent reduction shock could be implemented to the whole GTAP sector.

However, this solution requires detailed economic data for each of the ANZSIC sectors which is not available. As an alternative, we assume smaller shocks for those GTAP sectors where the affected industries comprise only a part of these sectors.

Adoption profile

Chart 2.1 illustrates the assumed adoption profiles of the technologies. The horizontal axis in the chart refers to the time period elapsed – in this case, years. For instance, it is assumed that biopharmaceuticals has an adoption period of 15 years.

2.1 **Adoption profiles**



Data source: CIE assumption.

We have assumed for all the technologies modelled that technical complexity will not be a major constraint on the rate of adoption, mainly because the selected technologies have moved from strategic science to product development and deployment.

The uptake of emerging technologies however may be affected by various political, regulatory or other social factors. We do not attempt to model directly the potential impact(s) of such factors. Instead, we use an assumed 'adoption profile' to reflect assumed net effects of such factors on the rate at which an emerging technology is taken up and applied in different industry sectors. In particular, we have assumed that adoption will be slower where there may be significant regulatory processes involved (e.g. biopharmaceuticals).

The adoption profile also shows the potential impact of specific technologies on selected sectors, as discussed in section 1.2.

Simulations

The shocks implemented in the simulations are productivity improvements for all technologies except nanochemicals where household demand is shocked. For nanotechnology, the productivity improvement in energy use is assumed while for epigenetics and biopharmaceuticals multifactor productivity (MFP) improvement is assumed. A 1 per cent MFP improvement means that a firm will require 1 per cent less inputs to produce the same amount of products if there is no change in input and output prices.

The simulations are carried out with the shocks of full impact in the last year of the adoption period. The impacts in a particular year within the adoption period before full impact are then worked out with the assumed adoption profile as illustrated in Chart 2.1.

The results are typically reported as percentage change from the baseline level, that is, where there is no adoption of the discussed technology. An advantage of reporting results as percentage deviation from the baseline is that it avoids a deliberate projection of the baseline which is not a trivial exercise. For example, a 1 per cent increase in real GDP relative to the baseline means the discussed technology may generate an additional 1 per cent of GDP relative to whatever it might be without the adoption of the technology. Suppose the 1 per cent increase in GDP happens in 10 years time, it means it is a 1 per cent higher than the GDP in that year, not 1 per cent higher than the current level.

3 Results

This chapter sets out a more detailed discussion of the results of the various quantitative modelling and scenario analysis exercises conducted on the emerging technologies that we have chosen to focus on based on our literature review.

As noted in the previous chapter, the emerging technologies selected for further analysis were:

- Nanotechnology coatings and materials;
- Epigenetics and functional genomics;
- Biopharmaceuticals; and
- Nanochemicals.

In the case of all but one of these technologies (namely nanochemicals) the economic 'shock' that was assumed to have resulted from the adoption of the technology was an increase in productivity (in the case of nanotechnology, this is achieved through the reduction in energy costs in the sectors that adopts the technology (the adopting sectors), whereas for epigenetics/functional genomics and biopharmaceutical an immediate increase in multifactor productivity in the adopting sectors was assumed. Two scenarios are simulated in our quantitative modelling – one assuming only New Zealand adopts the technology (only New Zealand adoption), while the other assuming all countries in the world adopt the technology with the same adoption profile (all adoption).

These assumed shocks then drive the final results of the modelling reported in terms of changes in:

- Domestic prices of the products of the adopting sectors;
- The general price level in New Zealand;
- The world prices of the products of the adopting sectors;
- Domestic consumption of the products of the adopting sectors;
- Exports of the products of the adopting sectors and aggregate exports;
- Output of the adopting sectors in New Zealand;
- The gross domestic product in New Zealand.

The final resulting changes in the variables listed above appear to be determined by a number of economic effects and depend on which of these effects predominate.

3.1 Overview of results

The different technology/sector/adoption profile combinations modelled here reflect some key features of the New Zealand economy;

- The share of New Zealand's total GDP made up by services sectors exceeds that of the other sectors combined, including those sectors where the emerging technologies are adopted. This in turn constrains the modelled impact on total GDP of the emerging technologies studied. Overall the impact of these technologies on aggregate variables such as GDP, aggregate exports and consumption is modest, with the majority of these technologies having cumulative impacts of under 1 percent over the entire adoption period. Notably the cumulative impacts of the adoption of nanochemicals is even smaller, amounting to changes of under 0.2 per cent, though the modelling of this technology is subject to significant caveats;

- The relative size of the industry sector to which an emerging technology is applied also matters. All other things being equal, emerging technologies applied to large industry sectors, such as dairy, can therefore be expected to lead to larger aggregate impacts on GDP than where technologies are applied to sectors that make up smaller proportions of total economic activity. However, in the case of nanotechnology coatings and materials discussed below which was applied to the dairy industry, the overall impact is further limited because the shock only affects a fraction of the production costs incurred by that industry.

Domestic prices of the products of the adopting sectors and general price level

As noted in a previous chapter, the productivity improvements assumed to flow to the adopting sectors should bring down the prices of the products of those sectors i.e. there is an initial **price reduction effect** from introduction of the technology. By bringing prices down, household demand for those products increases. However, at the same time, this increased household demand also means increased demand for production inputs such as raw materials, land and labour and the adopting sectors will be competing for these increasingly demanded inputs with other sectors of the economy. The resulting increased demand for these inputs may bid up their prices again (even if the prices of some of these inputs had originally gone down because of increased productivity) i.e. the **resource competition effect** discussed previously.

Where the initial price reduction effect from the productivity improvement dominates the resource competition effect, then there will be an overall net reduction in domestic prices of the products of the adopting sector. An additional consideration where adoption of the technology in other countries is also assumed is that the adopting sectors in other countries will also enjoy cost and price reductions, which may lead to cheaper imports of their product into New Zealand. These cheaper imports may then place further downward pressure on prices of the domestic products they compete with (**the cheaper imports effect**).

The results show that the initial price reduction effects in the adopting sectors tend to exceed the resource competition effect from other sectors and these price reductions are even larger under the 'all adoption' scenario because of the added pressure of the cheaper imports effect. One notable exception to this rule is the dairy processing sector under the adoption of nanotechnology coatings and materials – this exception can be explained by the fact that for this technology, it was assumed that other sectors with little or no connection to dairy processing such as various manufacturing and construction also adopted this technology. As a result, these unrelated sectors also expanded their size because of the price reduction effect and ended up competing with each other for resources. Thus the resource competition effect became more significant in the modelling for this technology.

For all the productivity enhancing technologies modelled, an increase in the general price level is projected under the only New Zealand adoption scenario but a fall is projected under the all countries adoption scenario. What this suggests is that there are overall net household demand expansion effects both because of the increase in demand for products of the adopting sector due to cost reductions, and increased household employment and income from this expansion in demand, which inflates prices. However, when adoption by other countries is taken into account, the cost reductions this facilitates in imports leads to an overall decline in the general price level in New Zealand due to import competition putting downward pressure on domestic producers.

A slightly different set of considerations enters into the modelling of price effects for nanochemicals because this technology is assumed to have a shock in the form of increased household demand for products of the 'chemical and rubber products' sector (in reality, only cosmetic and beauty products though this GTAP sector is the closest in approximation and the assumed shock has been accordingly adjusted downwards to account for the fact that only a small part of this sector is affected). While, as would be expected, this demand shock would lead to an increase in prices of products from the adopting sector, when it is assumed that the rest of the world also adopts the technology, there is also a **'terms of trade'** effect which has to be taken into account.

The terms of trade refers to what quantity of imports can be purchased through the sale of a fixed quantity of exports. A change in the terms of trade can have implications for the income of domestic households and therefore affect their demand and by implication, the price of products.

In the nanochemicals results, we find that the deterioration of the terms of trade under the 'all adoption' scenario actually has a depressive impact on household income and therefore leads to a fall in demand which exceeds the initial increase in demand postulated, leading to an overall fall in prices of products from that sector.

This depression in household incomes and demand carries over into the general price level which records a small reduction due to lower overall household demand.

World prices

It would be expected that where only adoption by New Zealand is assumed, the impact on world prices of products of the adopting sectors is negligible. This reflects the limited impact of New Zealand's small contribution to world production, whereby changes in the cost of producing these goods in New Zealand have a similarly limited impact on world prices. The results confirm these predictions. Only when all countries are assumed to adopt the technologies of interest are there observable changes in the world price.

Domestic consumption of products of the adopting sectors

If only adoption in New Zealand is taken into account, changes in domestic consumption should be consistent with changes in domestic price. That is, where prices fall (because the initial price reduction effects dominate resource competition effects) consumption should increase and where prices rise (because resource competition effects dominate) then consumption should fall. This straightforward result is confirmed for epigenetics/functional genomics and biopharmaceuticals. In both these cases, the increase in domestic consumption is smaller under the all countries adoption scenario. This can be explained by the fact that other countries also increase the competitiveness of their products (**the increased international competition effect**), rather than New Zealand being the only beneficiary of the technology, so New Zealand's increase in household income and therefore household consumption is also smaller.

Again, slightly different considerations are applicable for the nanochemicals results where what is modelled is a shock in the form of increased household demand. Here, the deterioration in the terms of trade has a depressive impact on New Zealand household incomes and therefore on consumption under the all countries adoption scenario.

Exports of the products of the adopting sectors and aggregate exports

The net change in exports of products from the adopting sectors would be expected to be determined by:

- The initial price reduction effect – this has a positive impact on exports by increasing the competitiveness of New Zealand exports from the adopting sectors;
- Resource competition effects – this has a negative impact on exports by increasing the price of inputs into production and therefore reducing the competitiveness of New Zealand exports from the adopting sectors;
- The increased international competition effect discussed earlier which is relevant under the all countries adoption scenario – this has a negative impact on exports

by reducing the competitiveness of New Zealand exports from the adopting sectors;

- The **increased foreign household demand effect** which arises under the all countries adoption scenario because the adoption of the technology in other countries increases the income and wealth of foreign households by reducing their cost of living and therefore increases their demand for New Zealand exports.

The results show that under the all countries adoption scenario, exports of products of the adopting sectors fall, which suggests that the increased international competition effect is predominant in this scenario. However for 2 out of the 3 productivity enhancing technologies (epigenetics/functional genomics and biopharmaceuticals), aggregate exports increase under both scenarios. This means that the reduction in exports from the adopting sectors is exceeded by increases in exports from other sectors. While it might seem strange that the adopting sectors are not the immediate beneficiaries in terms of export performance, this is accounted for by the fact that the sectors which most increase their exports are those which use the products of the adopting sectors as inputs into their own production (and therefore enjoy cost reductions and an increase in their international competitiveness).

A different set of considerations applies to the nanochemicals results where the assumed shock is an increase in household demand for products of the adopting sector. Under the only New Zealand adoption scenario, this increased household demand 'eats into' production, resulting in less left over for exports. Where all countries adopt this technology, the resulting deterioration of terms of trade (due to increased demands for the products of the adopting sector leading to increased import prices) cuts into household incomes, reduces general demand for goods and services and therefore reduces costs of production in the adopting sector in New Zealand. These effects induce a counter-intuitive increase in exports from the adopting sector in New Zealand as well as aggregate exports.

Outputs of the adopting sectors and gross domestic product

The outputs of the adopting sectors are ultimately either for domestic consumption or for exports and therefore all the effects relevant to these two variables combined will determine ultimate changes in output of these sectors. The results for the productivity enhancing technologies tend to vary depending on the sector with the general theme that output from the adopting sectors is more likely to fall under the all countries adoption scenario. This suggests that when the technology is adopted by all countries, the products of their adopting sectors become as competitive as or more competitive than exports from New Zealand of the same products.

Despite this, for all the productivity enhancing technologies, there is a projected increase in GDP though this increase is smaller under the all adoption scenario (again, probably because of the increased international competition effect).

A different set of considerations applies to the nanochemicals results which projects an increase in production from the adopting sectors under both scenarios because of the assumed increase in household demand. However, a slight decrease in GDP is projected under the all countries adoption scenario because of the deteriorating terms of trade effect discussed earlier.

3.2 Nanotechnology coatings and materials

Nanotechnology is a general purpose toolkit contributing to product innovations in virtually all kinds of manufactured goods. Impacts tend though to be broad, rather than deep, as the "nano-advantage" is often embedded at an early stage of the value chain (e.g. raw nano-materials), where it can remain largely invisible to the end-user.

Our modelling assumed that nanotechnology coatings and materials would lead to an ultimate saving in energy costs of 30 per cent, particularly for processes involving fluid flows. As the New Zealand dairy processing sector would be an early adopter of this technology it would achieve this saving in 5 years while selected manufacturing sectors would achieve this energy cost saving in 10 years. The manufacturing sectors assumed to adopt the technology are:

- Paper & Paper Products;
- Chemical Rubber Products;
- Non-Metallic Minerals;
- Fabricated Metal Products;
- Motor Vehicles;
- Electronic Equipment;
- Water;
- Construction; and
- Other Transport.

Full descriptions of the modelled industry sectors and the issues surrounding the definition of appropriate industry sectors are set out in Appendix 1.

We further assumed that there will only be partial adoption of this technology in New Zealand manufacturing but close to full adoption in dairy processing because the dairy processing sector is dominated by large firms (e.g. Fonterra) that are very exposed to international competitive pressures, whereas other manufacturing sectors generally are much less exposed internationally and are therefore likely to be much slower/partial in their adoption rates.

Impact on prices

Charts 3.1 to 3.4 illustrate the impact on various prices for dairy products, raw milk, paper products and printing, and electricity. Note that the horizontal axes in these charts and the rest of the charts in this chapter refer to the time elapsed in years. Thus in this case the horizontal axis reflects our assumption that the adoption period of nanotechnology is 10 years. It is also worth emphasizing that the percentage changes shown on the vertical axis of the charts refers to percentage changes relative to the baseline (i.e. if the technology had not been adopted), as explained previously.

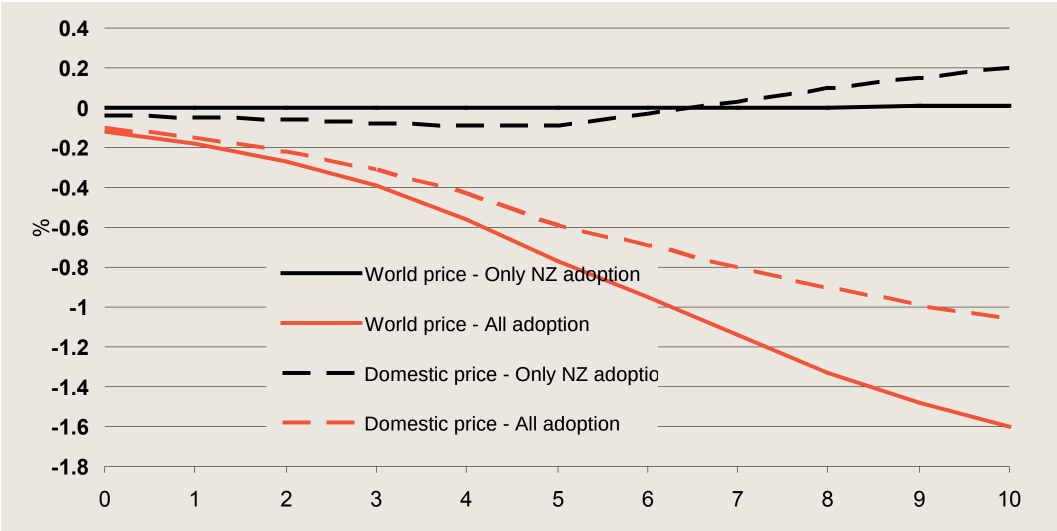
Also, in all of the charts in this chapter, the scenario where only New Zealand adopts the technology is represented by 'Only New Zealand adoption' while the scenario where all countries adopt the technology is represented by 'All adoption'.

Impacts on prices of selected products if only New Zealand adopts the technology

The solid black lines represent the world price, if only New Zealand adopts the technology. As New Zealand is a small economy, changes in New Zealand have little impact on the world price. This is evident from the charts where the solid black lines stay at zero over time.

The dashed black lines represent the domestic price (also called the 'export price' in the model) in New Zealand if only New Zealand adopts the technology. The impact on domestic price varies depending on the product.

3.1 **Impact on prices of dairy products**

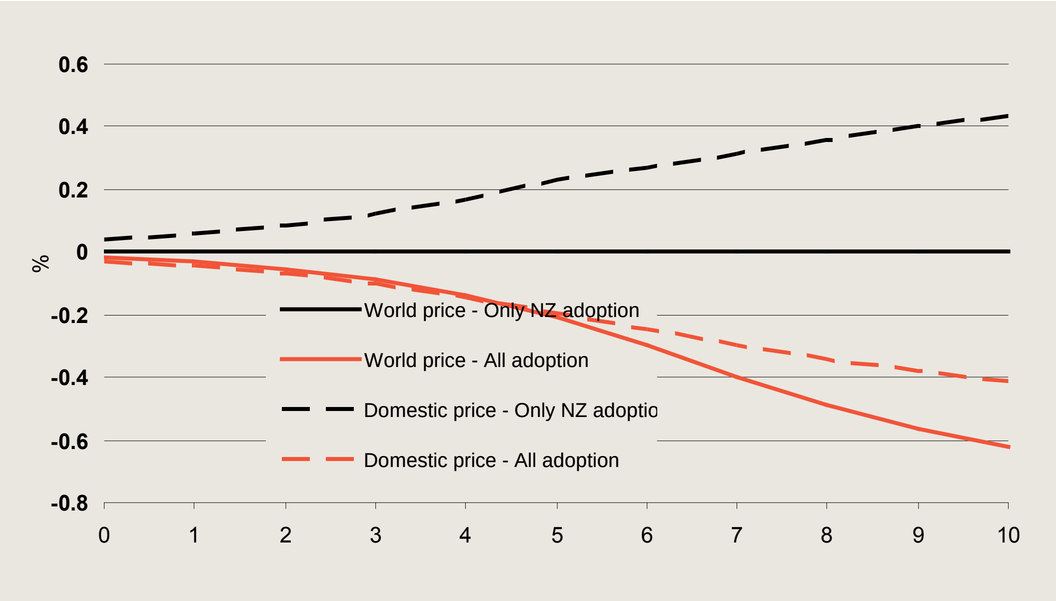


Data source: GTAP simulations

Dairy products price in New Zealand will fall initially and start rising after Year 7 if only New Zealand adopts the technology. The change in prices is determined by the balance between two countervailing forces – the initial price reduction effect due to the cost savings postulated and the resource competition effect caused by cost savings in other sectors which also adopt the same technology. Because the dairy products sector adopts the technology at a quicker pace than other sectors, the initial price reduction effect dominates in the first few years. However, as more and more firms of other manufacturing sectors adopt the same technology and reduce their costs, the competition for resources from those sectors becomes stronger and stronger, and eventually dominates, pushing up the costs and thus the prices of dairy products.

The mechanism of the price change in raw milk is somewhat different. There are two major reinforcing factors behind the price change. Raw milk is the major input to the dairy products sector. As the dairy products sector expands, the demand for raw milk rises, pushing up the raw milk price. Because there is no productivity shock to the raw milk sector, the resource competition effect from other sectors with productivity improvement would push up the price of raw milk even further.

3.2 **Impact on prices of raw milk**

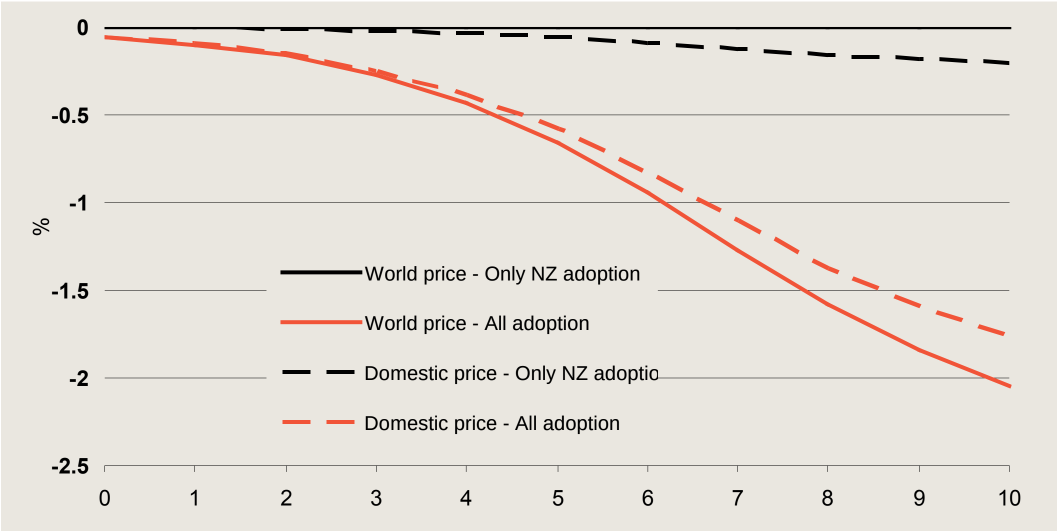


Data source: GTAP simulations.

The paper products and publishing sector is among the other manufacturing sectors with slower adoption of nanotechnology. But this sector has higher energy intensity than dairy according to the model database. As a result, the cost saving effect dominates for all the period. The reduction in price gets larger over time as the reduction in energy costs increases over time.

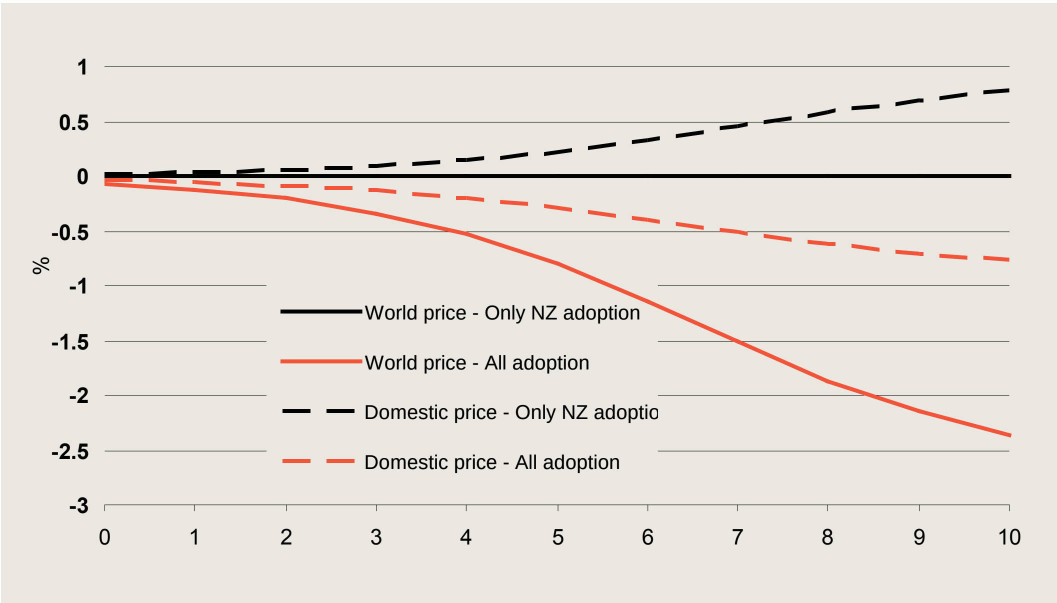
The electricity sector represents another special type of sector. The aim of the nanotechnology adoption is to reduce the use of electricity in dairy and other manufacturing sectors. Less demand would normally drive down the price. However, the cost of generating electricity is higher because the prices of inputs (e.g. infrastructure, labour) into power generation increases due to higher demand for these inputs from expanding sectors. As a result, the electricity price rises.

3.3 Impact on prices of paper products, publishing



Data source: GTAP simulations

3.4 Impact on price of electricity



Data source: GTAP simulations.

Impacts on prices of selected products if all countries adopt the technology

If all countries adopt the cost saving technology, the world price would fall, as represented by the solid red lines in the above charts.

New Zealand's domestic prices of the selected products would fall as well, as represented by the dashed red lines in the above charts, but with a smaller magnitude than the world price. The fall in the domestic prices reflects two major forces. First, competition from other countries' imports become stronger as other countries adopt the cost saving technologies as well, leading to less demand for New

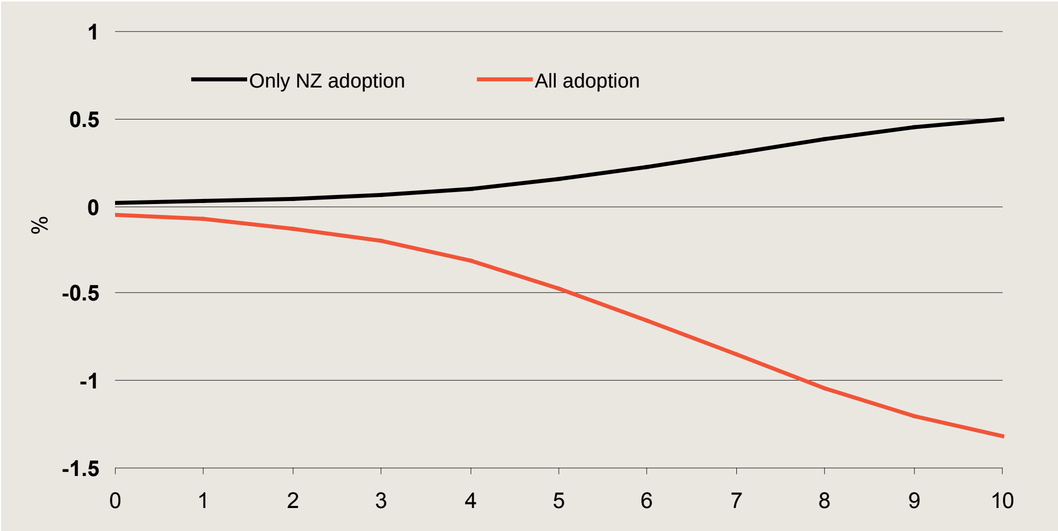
Zealand products. Second, the worldwide cost reduction in other manufacturing sectors may help reduce the cost of New Zealand products.

Impact on overall price level

Chart 3.5 illustrates the change in consumer price index (CPI). Under the only New Zealand adoption scenario, higher domestic demand drives up the overall domestic price level (the black line).

By contrast, under the all adoption scenario, cost savings in other countries are able to provide cheaper imports to New Zealand, offsetting the pressure on domestic prices. As a result, New Zealand's overall domestic price level falls under this scenario (the red line).

3.5 **Impact on consumer price index**



Data source: GTAP simulations.

Impact on exports

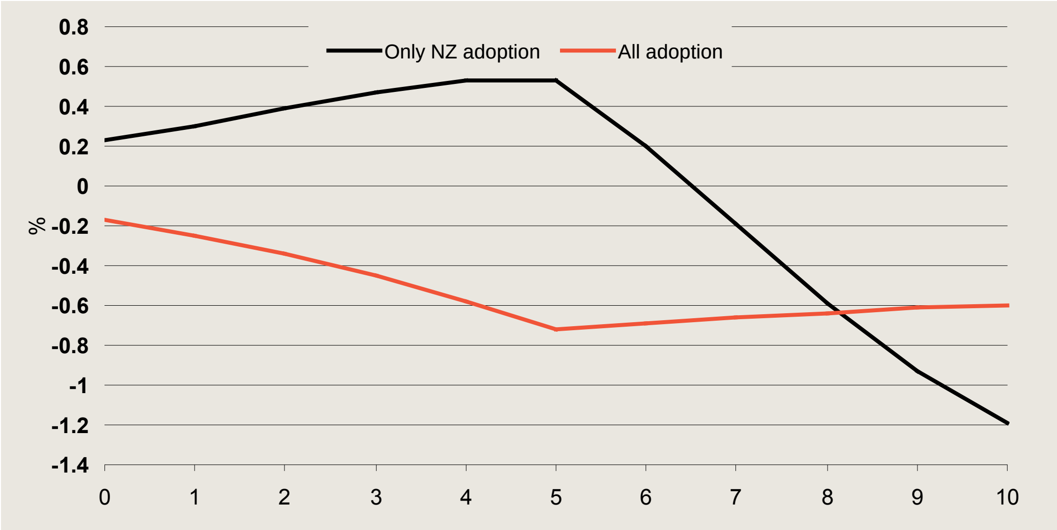
Charts 3.6 and 3.7 illustrate the impact on New Zealand exports of dairy products and paper products and publishing. The black line denotes the scenario that only New Zealand adopts the technology, while the red line denotes the scenario that all countries adopt the technology.

Under the only New Zealand adoption scenario, New Zealand export of dairy products increases first, and then falls. This is consistent with its domestic price movement (as shown in chart 3.1).

As explained above, in the early years the cost savings effect in the sector dominates the resource competition effects from other sectors, and thus New Zealand products become more competitive than those of other countries, leading to higher exports. However, as more resources are used up by other expanding manufacturing sectors, the cost of New Zealand dairy products becomes higher, hurting the competitiveness of exports accordingly.

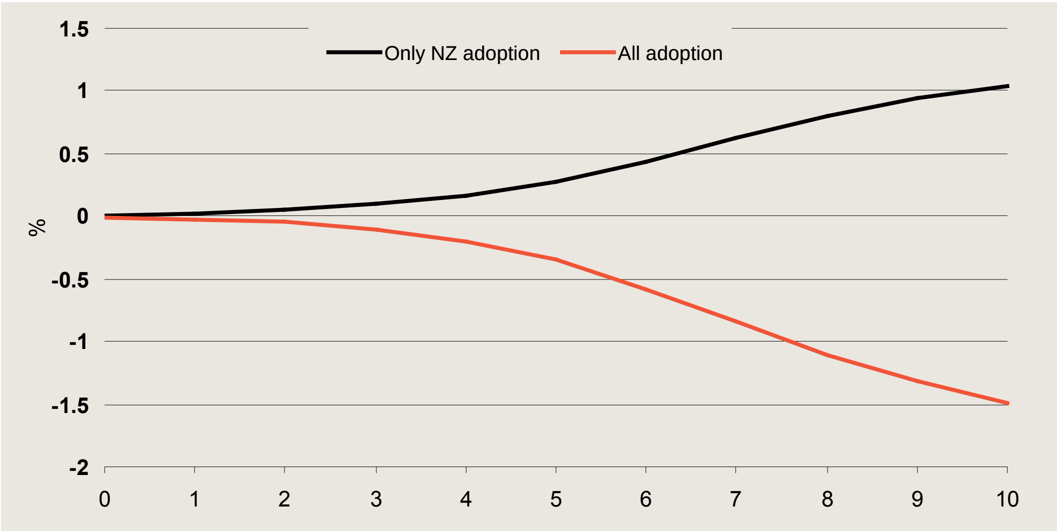
Under the only New Zealand adoption scenario, exports of paper products and publishing (as a representative of manufacturing and other sectors to adopt this technology) increases, because these New Zealand products become more competitive as indicated by the falling price in chart 3.7.

3.6 **Impact on New Zealand exports of dairy products**



Data source: GTAP simulations

3.7 **Impact on New Zealand exports of paper products and publishing**



Data source: GTAP simulations.

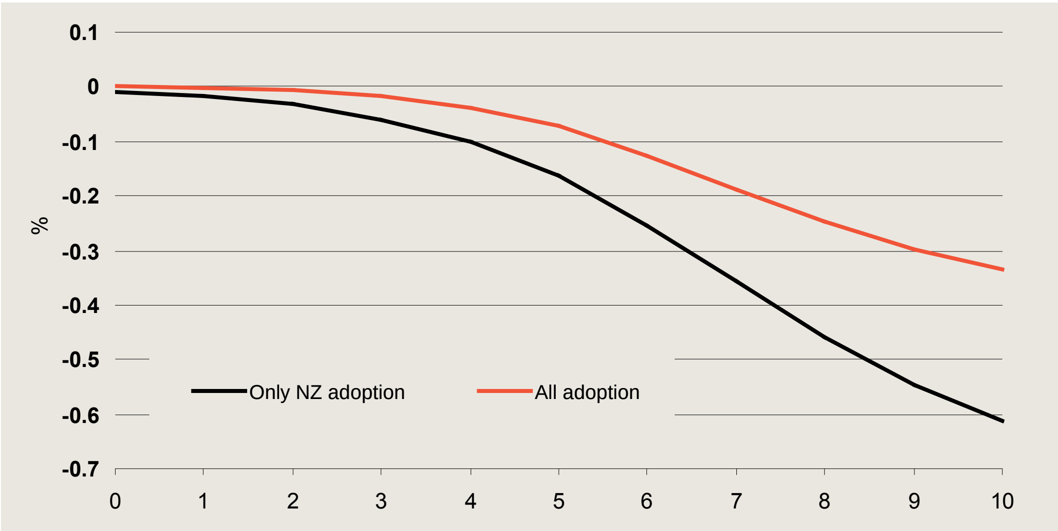
If all countries adopt the cost saving technology, New Zealand products become less competitive than other countries, because its domestic prices fall less than the world prices. As a result, the exports of both dairy products and paper products and publishing would fall under this scenario. This is also reflected in the fall in outputs from these sectors as seen below. For the other adopting sectors (not charted here) falls in exports are also observed under both scenarios.

New Zealand's aggregate exports are expected to fall from the baseline level after the adoption of nanotechnology, as illustrated by chart 3.8.

The reason for the fall in aggregate exports may be due to the higher domestic demand following higher household income and higher domestic activity, leading to the diversion of production away from export production.

The all adoption scenario appears to have a less negative impact on New Zealand's aggregate exports than the only New Zealand adoption scenario. This is because the demands from other countries also become higher under the all adoption scenario, and thus partly offsets the impact of higher domestic demand in New Zealand on production for export.

3.8 **Impact on aggregate New Zealand exports**



Data source: GTAP simulations.

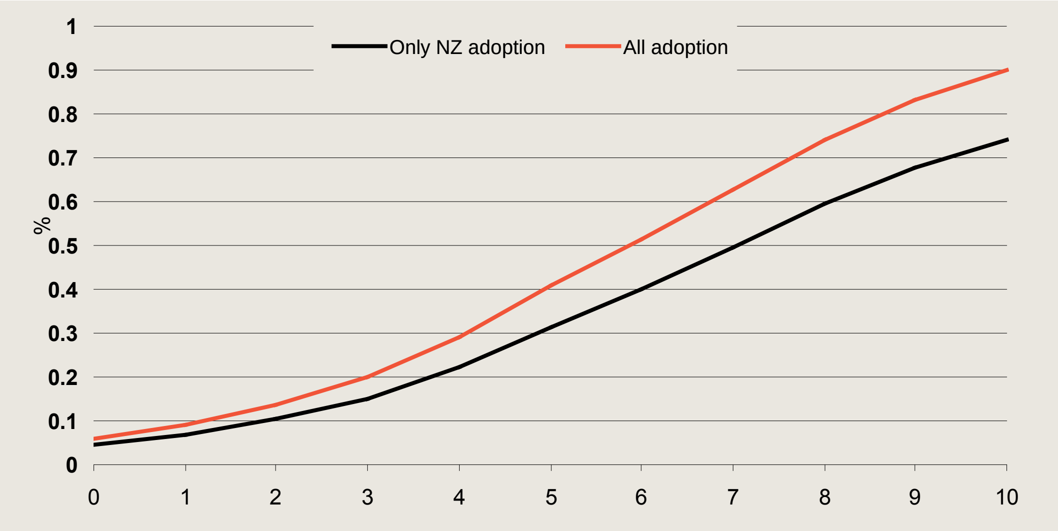
Impact on consumption

Charts 3.9 and 3.10 illustrate the impact on New Zealand's household consumption of dairy products and paper products and publishing, while chart 3.11 shows the impact on overall household consumption.

Basically, cost savings in dairy and other manufacturing sectors (represented here by paper products and publishing) increases households' real wealth and leads to higher consumption demand.

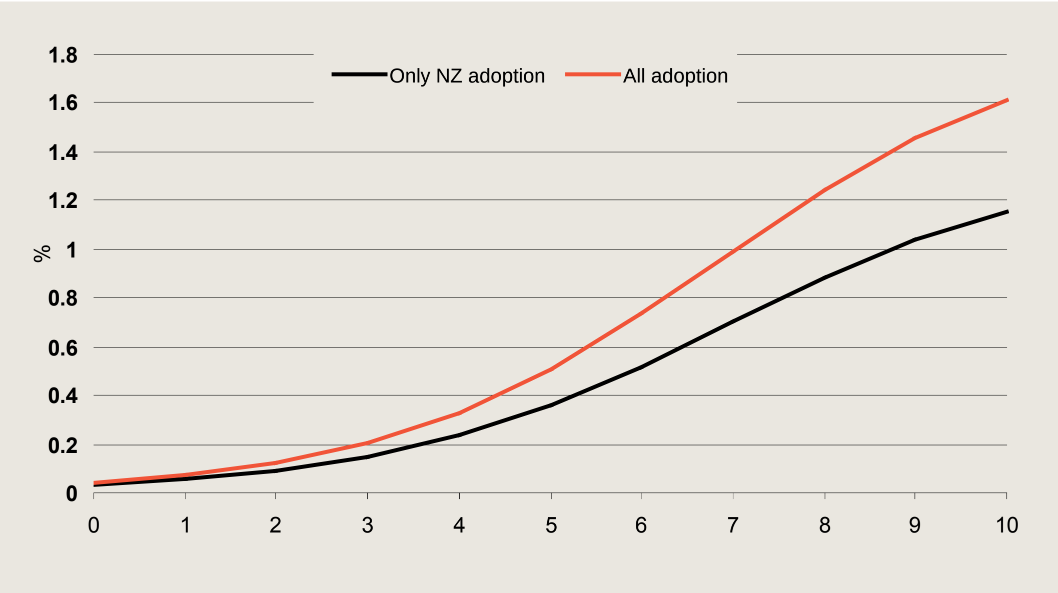
The increase in household consumption is higher under the all adoption scenario than under the only New Zealand adoption scenario. This is because the extent of cost savings is higher under the all adoption scenario (as New Zealand households benefit from cheaper imports from other countries which have also adopted the technology) and thus the increase in household income (and consequently in household demand) is also higher.

3.9 **Impact on consumption of dairy products**



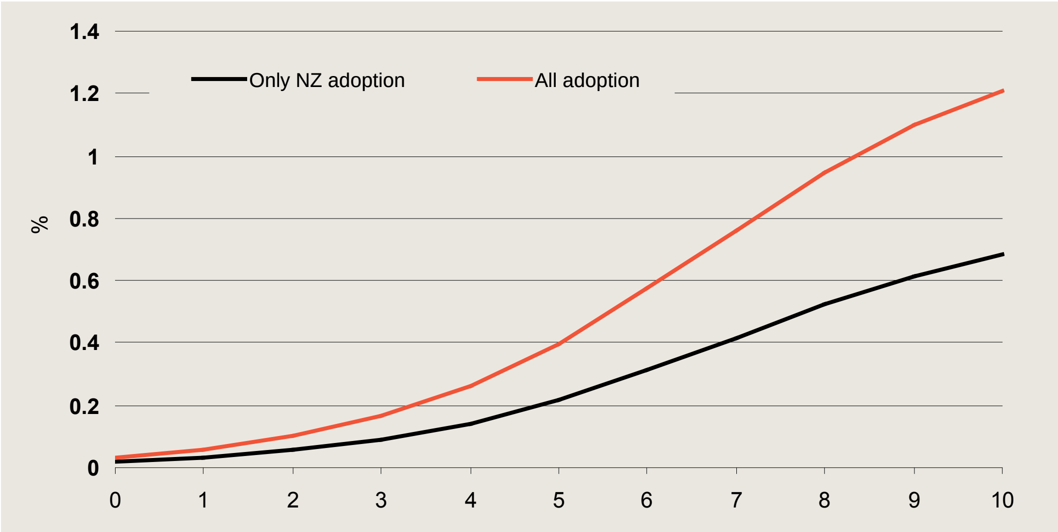
Data source: GTAP simulations

3.10 **Impact on consumption of paper products and publishing**



Data source: GTAP simulations.

3.11 **Impact on real household consumption**

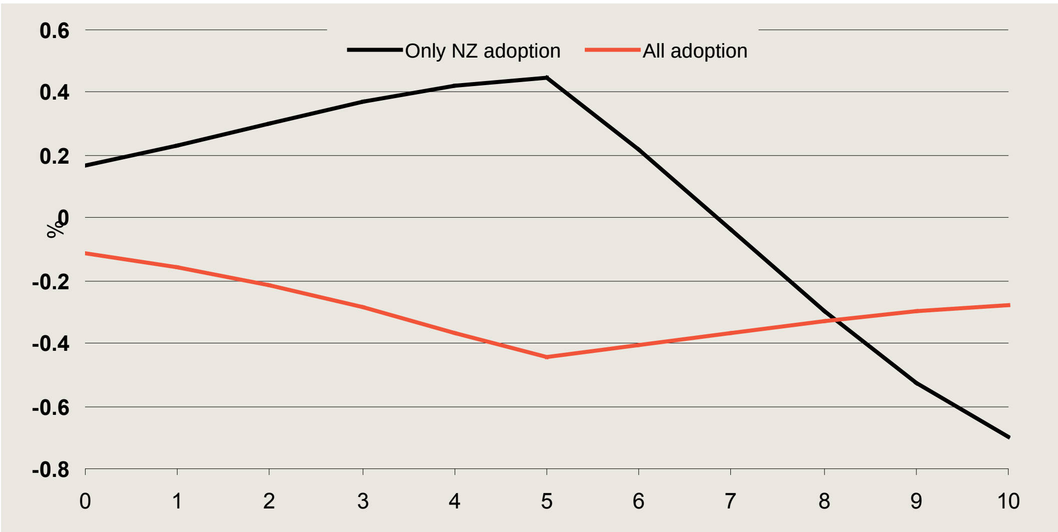


Data source: GTAP simulations.

Impact on production

Charts 3.12 to 3.15 show the impact on production of dairy products, raw milk, paper products and publishing (representative of the other adopting sectors), and electricity. The changes in production are consistent with the changes in prices shown previously.

3.12 **Changes in output of dairy products**



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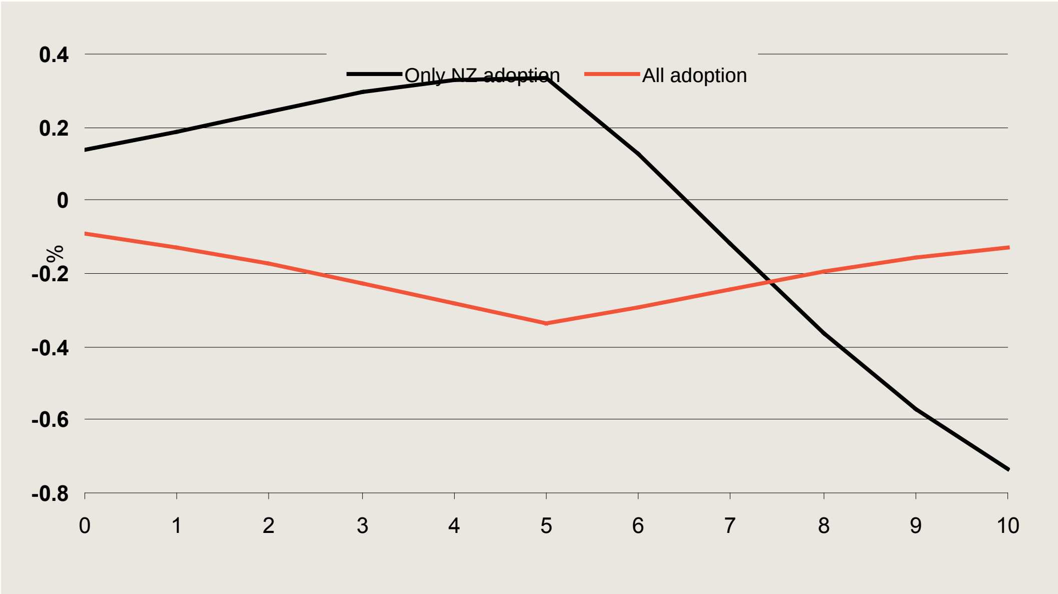
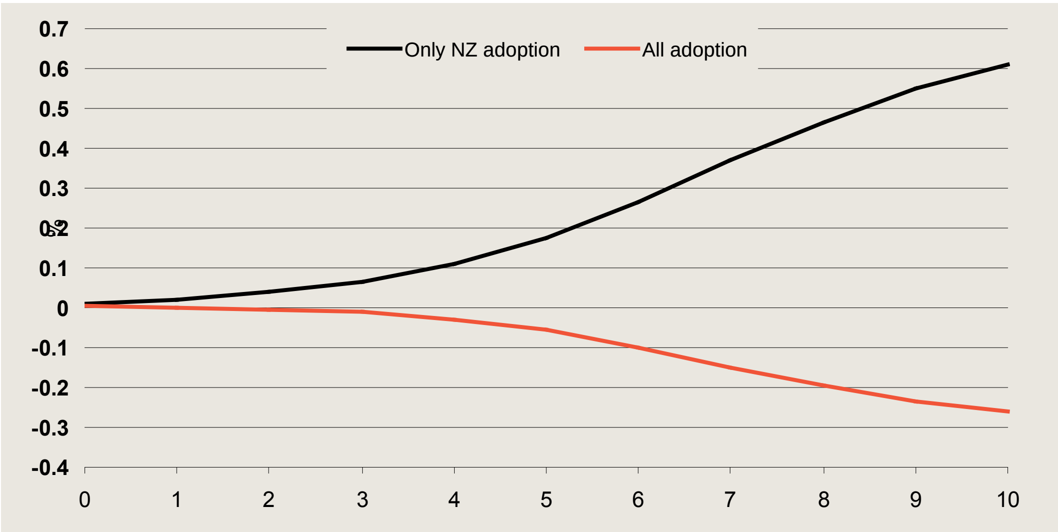
Data source: GTAP simulations

3.13 **Changes in output of raw milk**



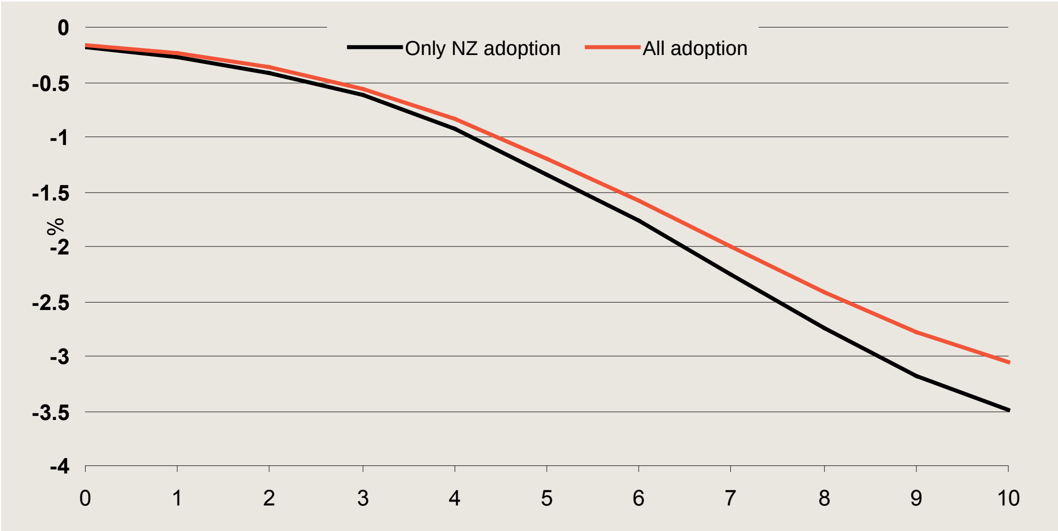
Data source: GTAP simulations.

3.14 **Changes in output of paper products and publishing**



Data source: GTAP simulations

3.15 **Changes in output of electricity**



Data source: GTAP simulations

The dairy products sector faces two major offsetting effects — the expansion effect caused by the cost savings in the dairy sector, and the resource competition effect caused by the cost savings in other manufacturing sectors. At the beginning the expansion effect dominates, leading to higher production. At the later stage, the resource competition effect dominates, leading to lower production of dairy products.

As raw milk is the major input of dairy products sector, the production of raw milk moves in the same direction and with similar magnitude as the dairy products production.

The production of paper products and publishing will increase under the only New Zealand adoption scenario, reflecting the expansion effect caused by cost savings in the sector.

By contrast, its production will fall under the all adoption scenario because New Zealand products face competition from other countries where cost savings are also present. This is also true of other adopting sectors (not charted here) which record falls in production under the all adoption scenario.

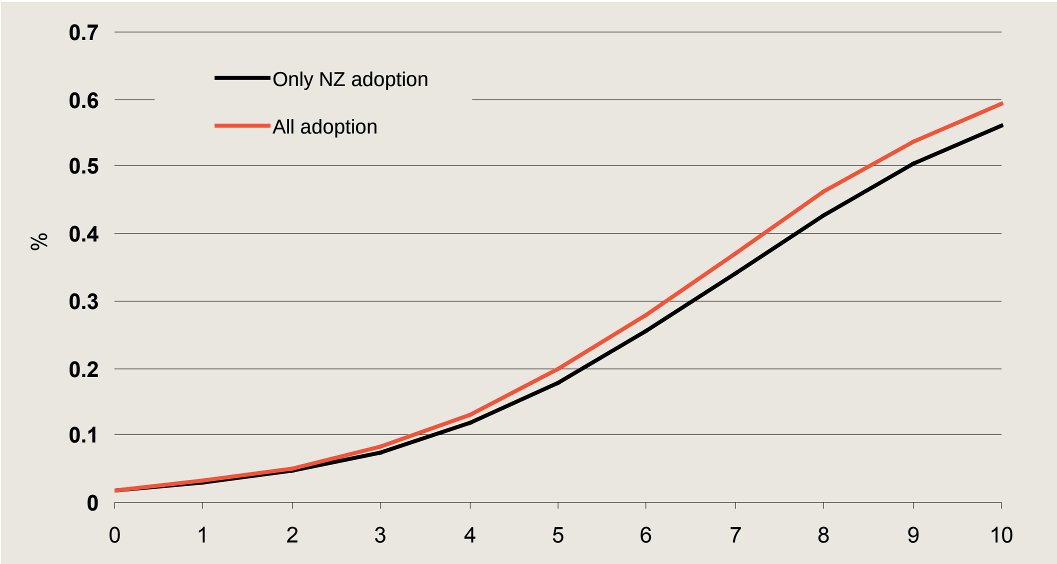
As one of the energy products, electricity production will fall after adopting the nanotechnology which will reduce energy use. The fall in electricity production is smaller under the all adoption scenario than under the only New Zealand adoption scenario because of the overall household wealth and thus demand that would be relatively higher under the all adoption scenario due to households benefiting from cheaper imports.

Impact on real gross domestic product

Chart 3.16 shows the impact of adopting nanotechnology on the real gross domestic product (GDP). Cost savings in dairy products and other manufacturing sectors will have an overall positive impact on the economy, as illustrated by the higher real GDP in the chart.

If all countries adopt the cost saving technology, the positive impact on New Zealand economy would be higher than if only New Zealand adopts the technology, as evidenced by the red line lying on above the black line in the chart. This is due to two factors. First, global wealth increases more if all countries adopt the cost saving technology, and thus drives up the overall demand. Second, cost savings in other countries, especially for manufactured products, help to reduce the input costs of New Zealand products, further boosting New Zealand production.

3.16 **Changes in real GDP**



Data source: GTAP simulations

3.3 Epigenetics and functional genomics

Epigenetics and functional genomics are technologies being developed and applied to improve understanding of the genetic basis of different traits – in plants, animals and humans. This in turn is enabling more active screening and selection.

As technological advances in this field are developing quickly, a shorter period of adoption than was the case for nanotechnology can be assumed (hence the assumption of 5 years rather than 10 years).

Two sets of assumptions about impacts were modelled for this technology under each of the two scenarios (the only New Zealand and all countries adoption). Thus altogether, four different scenarios are modelled.

Under the first (original) set of assumptions we assumed that adoption of epigenetics and functional genomics would lead to a 5 per cent increase in multifactor productivity (relative to the baseline) over 5 years in the following GTAP industry sectors (due primarily to increased yields and reduced pesticide use):

- Vegetables and Fruit;
- Cattle[2]; and
- Other animal products (particularly poultry and sheep)[3].

Full descriptions of the modelled industry sectors and the issues surrounding the definition of appropriate industry sectors are set out in Appendix 1.

Under the second (modified) set of assumptions, this impact was reduced to a 3 per increase in multifactor productivity (relative to the baseline) over 5 years in those same sectors. This was done because we later decided that a lower productivity shock was more plausible for this technology.

Nonetheless we present the results for both sets of productivity shock assumptions subject to the caveat that the second set is the more plausible one for guiding conclusions regarding this technology.

As technological advances in this field are developing quickly, a shorter period of adoption than was the case for nanotechnology can be assumed (hence the assumption of 5 years rather than 10 years).

Based on our literature review we also conclude that adoption of this technology may result in a 5 per cent reduction in greenhouse gas emissions in the livestock sectors over the 5 year adoption period. However this benefit of GHG emissions

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2 This sector encapsulates the following livestock and livestock products - Cattle: cattle, sheep, goats, horses, asses, mules, and hinnies and semen thereof– see the Appendix.

3 This sector is meant to encapsulate the following though the primary application of the technology is to poultry and sheep - swine, poultry and other live animals; eggs, in shell (fresh or cooked), natural honey, snails (fresh or preserved) except sea snails; frogs' legs, edible products of animal origin n.e.c., hides, skins and furskins, raw , insect waxes and spermaceti, whether or not refined or coloured.

reduction is not modelled, as possible reductions in production costs associated with such changes in GHG emissions are not yet clear.

Impact on prices

Charts 3.17 to 3.22 illustrate the impact on various domestic and world prices of the products of the adopting sectors (vegetables and fruit, cattle and other animal products) under the various adoption and productivity impact scenarios modelled.

Impact if only New Zealand adopts the technology

The solid lines represent the scenario where only New Zealand adopts the technology. The black lines represent the original scenario of a 5 per cent increase in MFP over 5 years in the adopting sectors while the red lines represent the revised scenario of a lower 3 per cent increase in MFP.

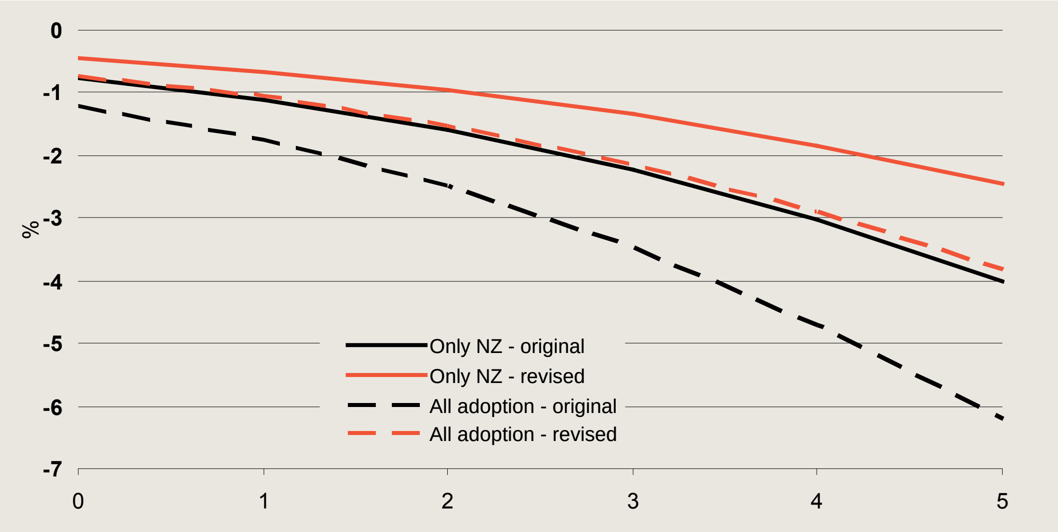
The charts show that under the only New Zealand scenario, domestic prices of the outputs of the adopting sectors fall due to the increases in MFP facilitating cost reductions in these sectors. Obviously the fall in price is steeper under the original assumption of a 5 per cent increase in MFP. Because New Zealand is only a small economy, the only New Zealand scenario leads to virtually no changes in the world price of the products of these sectors.

Impact if all countries adopt the technology

There is the same pattern of reductions in domestic price of the products of the adopting sectors under the 'all countries scenario'. However the magnitude of domestic price reductions is higher than in the 'only New Zealand' scenario. This is because the cost and price reductions facilitated in other countries which have also adopted the technology leads to cheaper imports competing with the products of the domestic sector, bringing down the domestic price further.

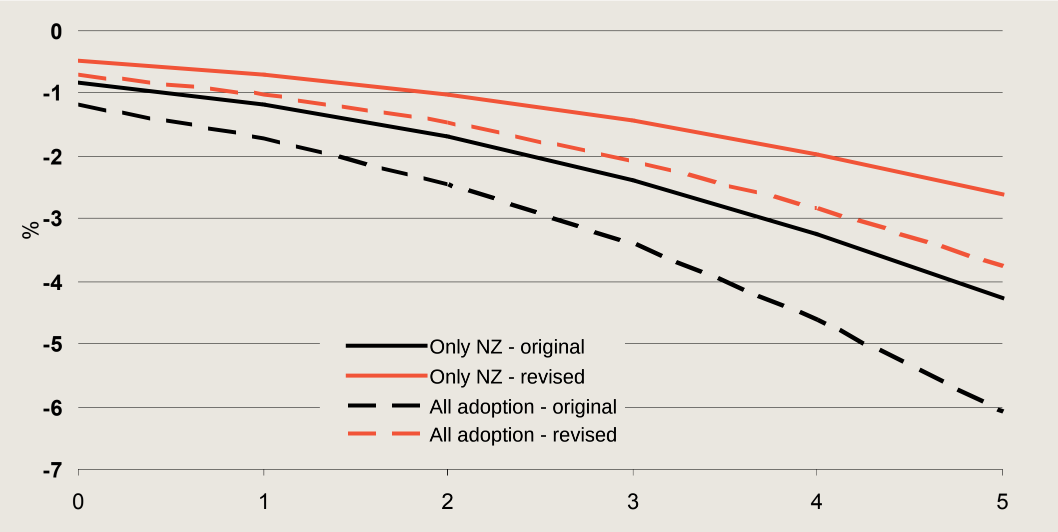
Unlike the case in the 'only New Zealand' scenario, adoption of the cost saving technology by all countries will have an impact on the world price of the products of these sectors of interest which falls over the 5 year period.

3.17 **Impact on domestic price of vegetables and fruits**



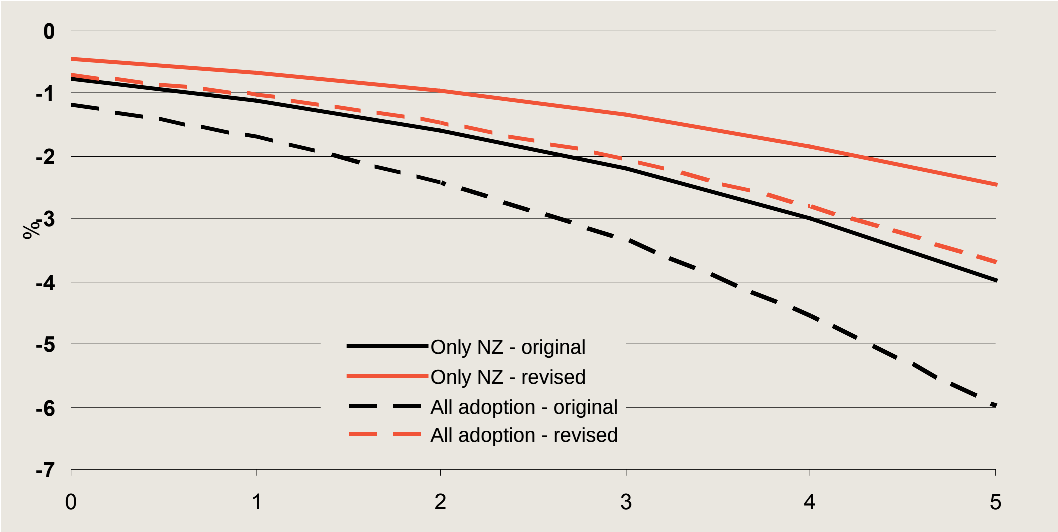
Data source: GTAP simulations.

3.18 **Impact on domestic price of cattle**



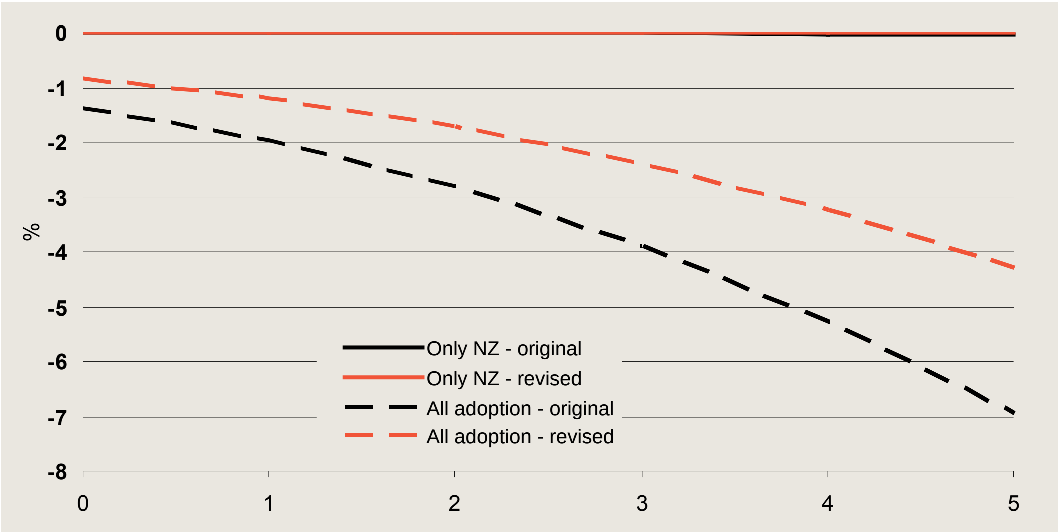
Data source: GTAP simulations

3.19 **Impact on domestic price of other animal products**



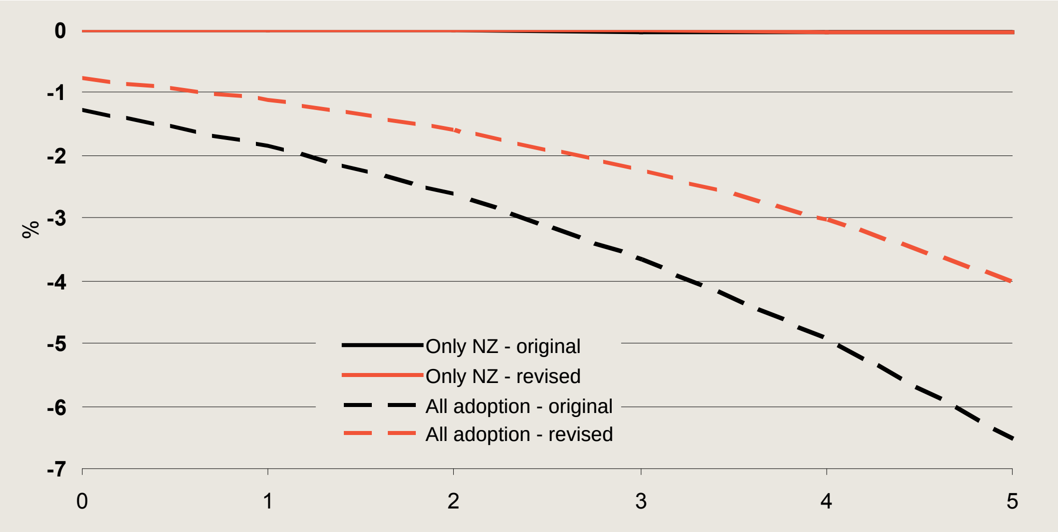
Data source: GTAP simulations.

3.20 **Impact on world price of vegetables and fruits**



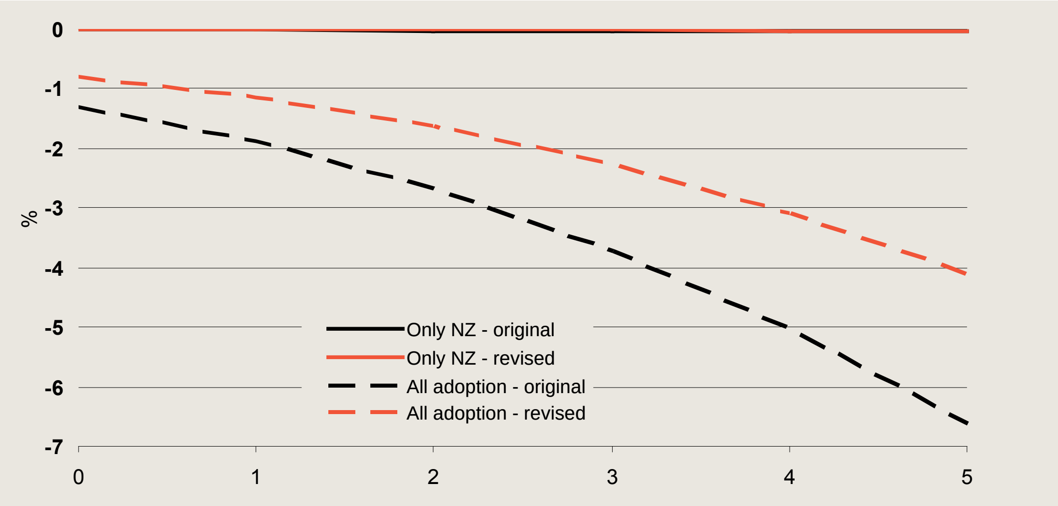
Data source: GTAP simulations.

3.21 **Impact on world price of cattle**



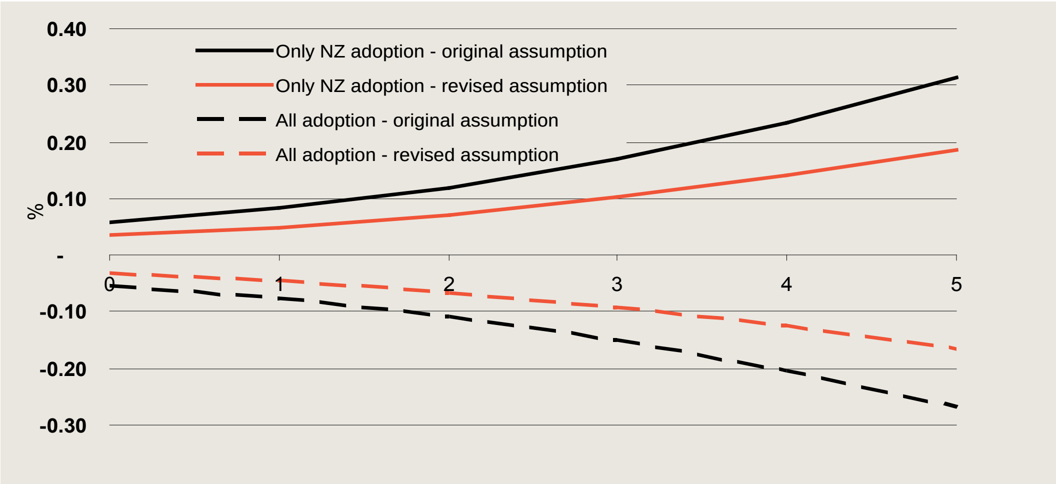
Data source: GTAP simulations.

3.22 **Impact on world price of other animal products**



Data source: GTAP simulations.

3.23 **Impact on consumer price index**



Data source: GTAP simulations.

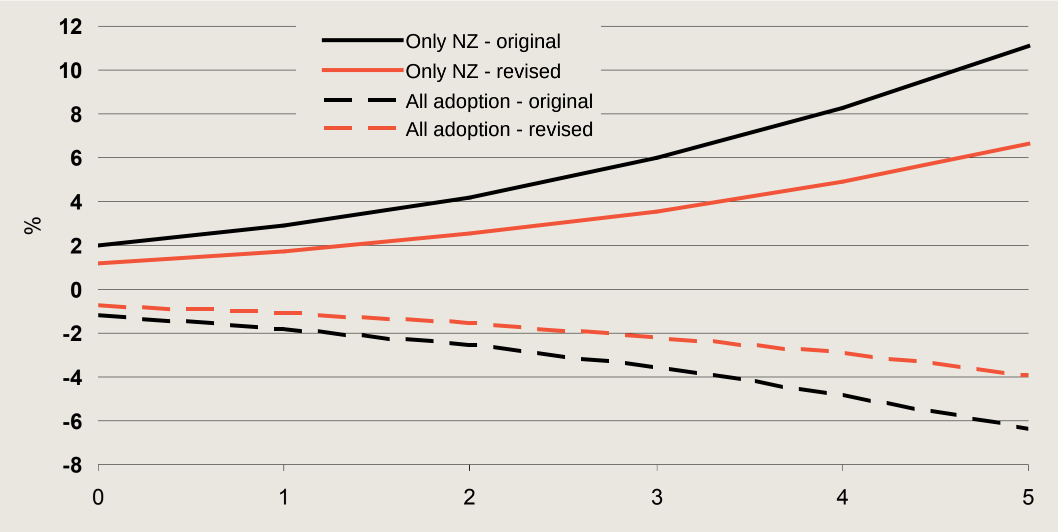
Impact on overall price level

The overall impact on the price level as shown in Chart 3.23 is slightly more complex. Under the only New Zealand scenario, higher domestic demand due to the increased household wealth from cost reductions drives up the domestic price – this high demand effect exceeds the price reduction effect in the sectors which have adopted the technology. However, under the all adoption scenario, cost savings in other countries lead to cheaper imports which put competitive pressure on domestic prices, offsetting the high demand effect. As a result, New Zealand's overall domestic price level falls under this scenario.

Impact on exports

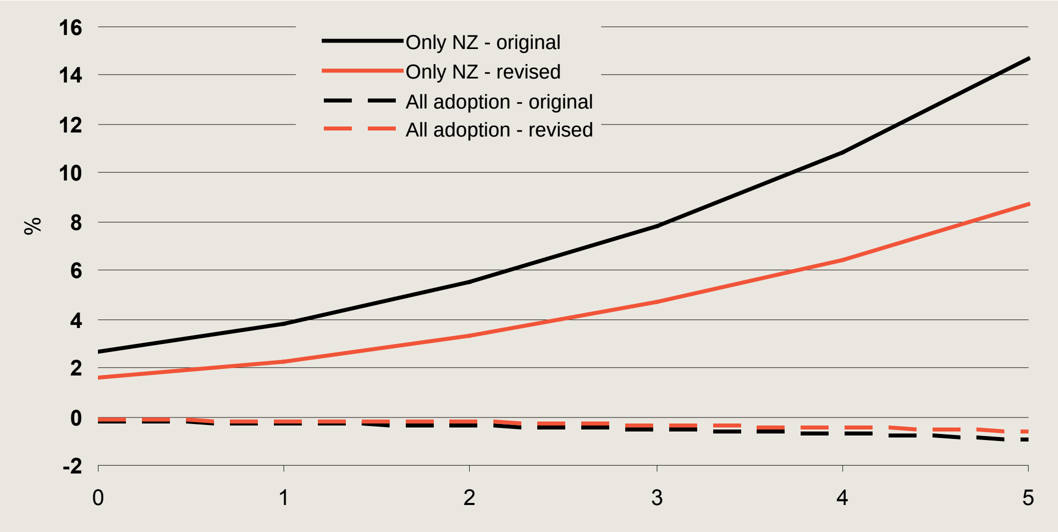
Under the New Zealand only scenarios, exports from the sectors that adopt the technology are expected to rise over the period of adoption because cost reduction in these sectors improves the competitiveness of New Zealand products (see Charts 3.24 to 3.27). However, New Zealand exports from these sectors are expected to fall if all countries adopt the technology. This is because the cost reduction effects in the equivalent sectors in other countries from adopting the technology may be higher than in New Zealand so that overall New Zealand sector exports become less price-competitive. It is worth noting that the projected fall in exports appears to be smallest for the cattle producing and other animal products sector which suggests that in these sectors at least, the competitive advantage of other countries post-adoption is not as overwhelming.

3.24 **Impact on New Zealand exports of vegetables and fruit**



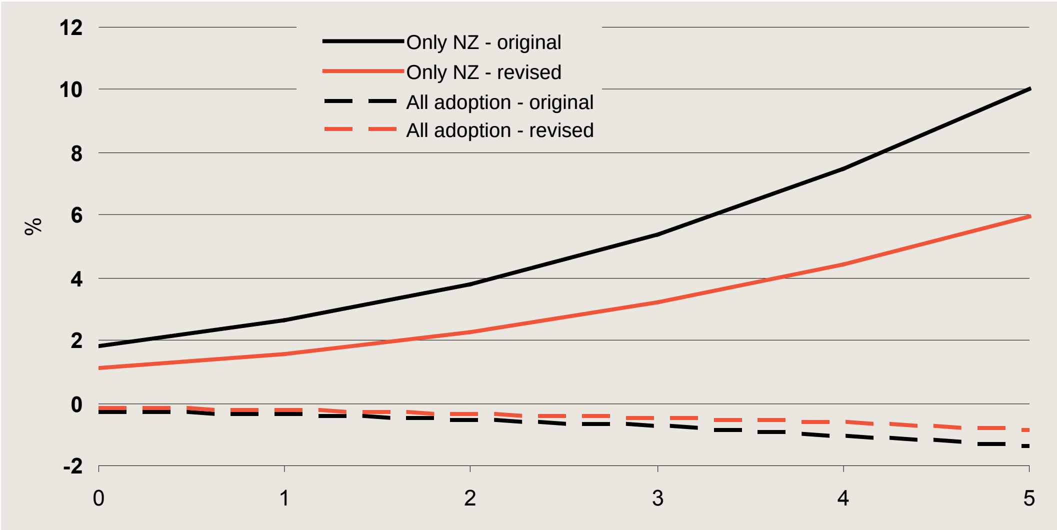
Data source: GTAP simulations.

3.25 **Impact on New Zealand exports of cattle**



Data source: GTAP simulations.

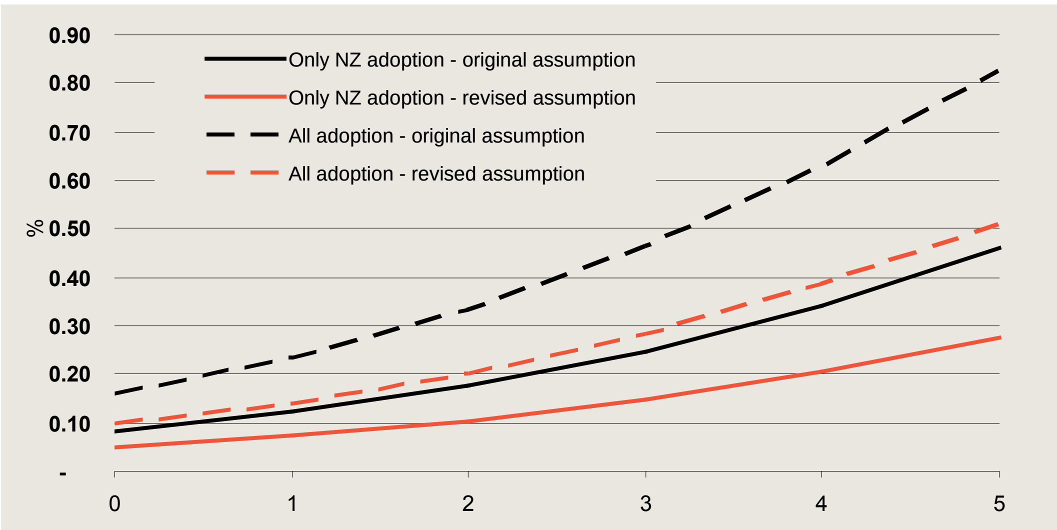
3.26 **Impact on New Zealand exports of other animal products**



Data source: GTAP simulations.

The picture is different for aggregate exports, which are projected to increase above the baseline both under the only New Zealand adoption scenario and the all adoption scenario. Indeed, the rise in exports is higher under the all adoption scenario because the increased household wealth caused by cost reductions in other countries leads to higher demand including higher demand for New Zealand's exports. Since, as we have seen, exports from the sectors which adopt the technology are supposed to fall under this scenario, this implies that the growth in exports of other sectors in New Zealand exceeds the fall in exports from the sectors which adopt the technology.

3.27 **Aggregate exports**



Data source: GTAP simulations.

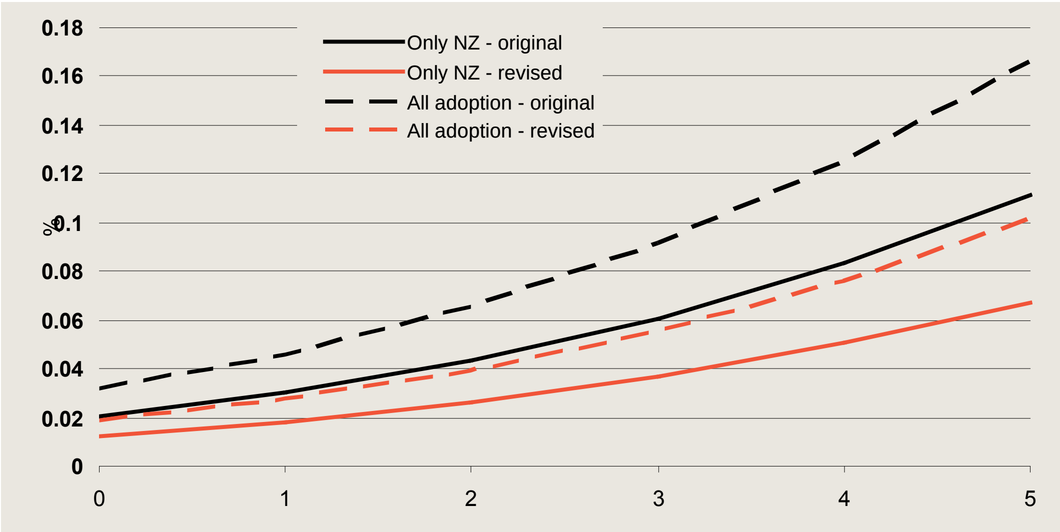
It is worth noting that the model results show that the two sectors which enjoy the highest increases in exports over the adoption period are the leather products sector and the bovine meat products sector. This makes sense as these two sectors use the products of the cattle sector as inputs into production. This means that the export competitiveness of these two sectors' products is significantly improved by the cost reductions facilitated in the cattle sector.

Impact on consumption

Domestic consumption of the products of the adopting sectors is higher under all scenarios but is clearly higher under the all adoption scenario as can be seen from Charts 3.28 and 3.29 (we have omitted charting the consumption of products from the cattle sector in this case because cattle is an 'intermediate' product for households). The higher domestic consumption can be explained by cost reductions in the adopting sectors leading to lower prices which encourage higher demand for these products. Under the all adoption scenario, domestic prices of the products of the adopting sectors are lower still because they face additional pressure from cheaper imports.

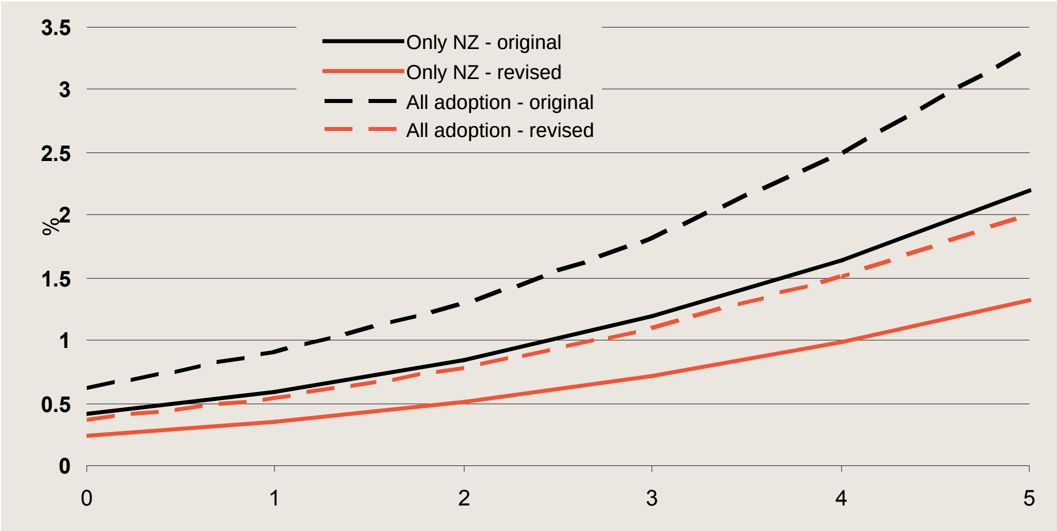
Overall household consumption increases by a smaller amount under the all adoption scenario than under the New Zealand only scenario (chart 3.30) because other also countries improve their export competitiveness from application of the same technology. Thus New Zealand's export competitiveness relative to other countries is not as enhanced as it would be under the New Zealand only scenario, and therefore the growth and consumption boosting effects of the technology are smaller.

3.28 **Impact on household consumption of vegetables and fruits**



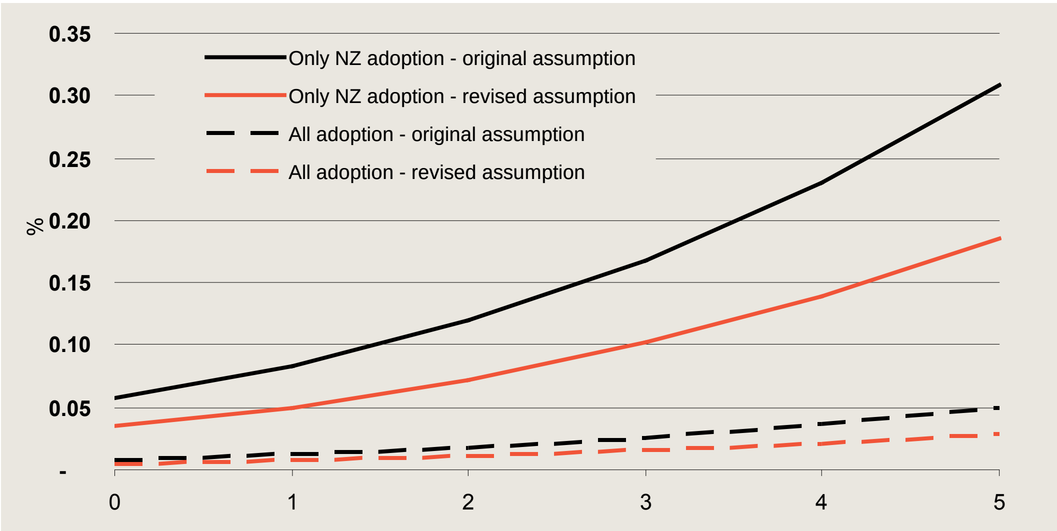
Data source: GTAP simulations.

3.29 **Impact on household consumption of other animal products**



Data source: GTAP simulations.

3.30 **Impact on real household consumption**

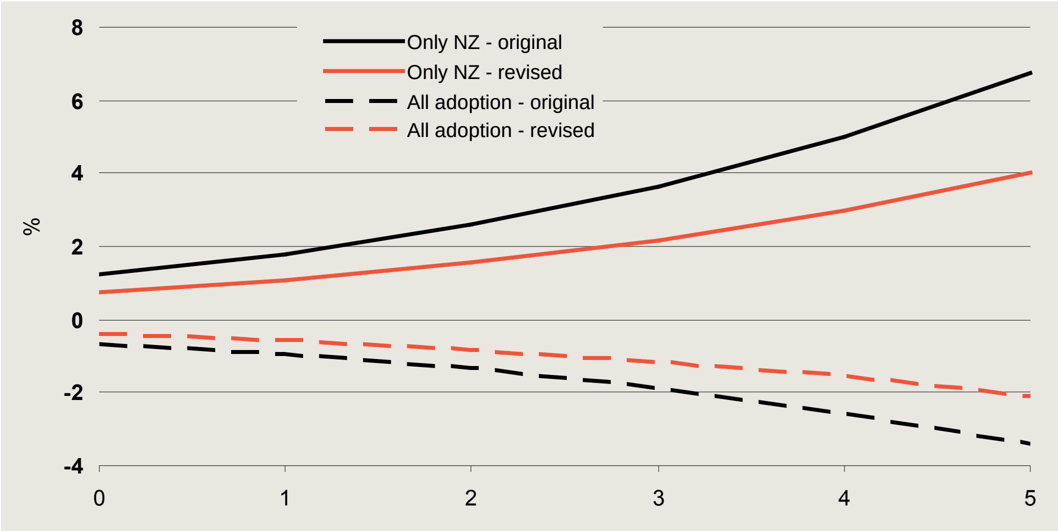


Data source: GTAP simulations.

Impact on production

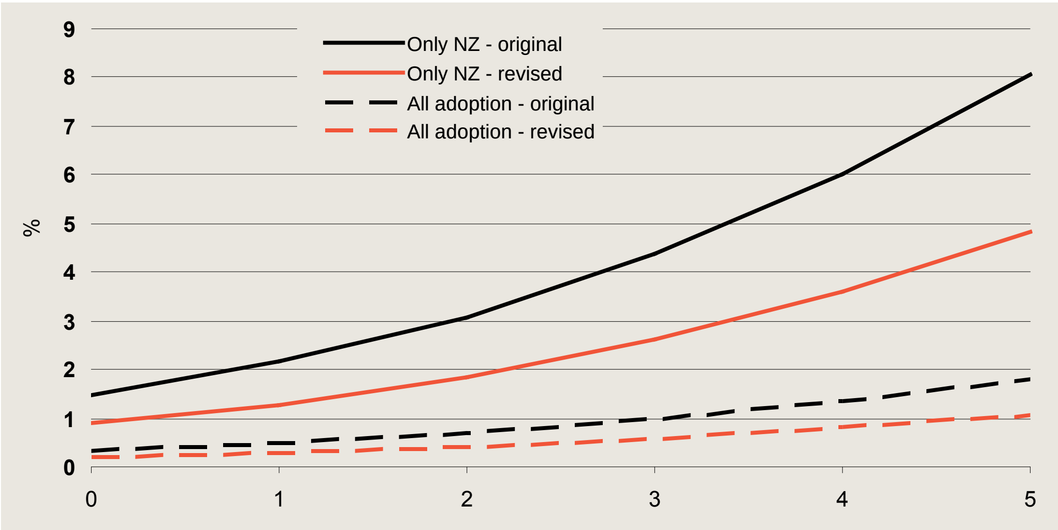
Output of the adopting sectors increases under the only New Zealand scenario (see Charts 3.31 to 3.33). The increase in output can be attributed to the expansion in demand for these products due to cost savings facilitated by the adoption of the technology. However, under the all adoption scenario, there is projected to be a fall in the output of the vegetables and fruits and other animal products sectors with smaller increases in the output of the cattle sector. This suggests that under the all adoption scenario, these sectors in other countries become relatively more competitive than New Zealand products so the domestic sector loses some domestic and export market share, leading to a fall or smaller increase in production. This is consistent with earlier findings on changes in exports from these sectors and the finding that the cattle sector appears to be the most internationally competitive of the three sectors under the all adoption scenario.

3.31 **Changes in output of vegetables and fruits in New Zealand**



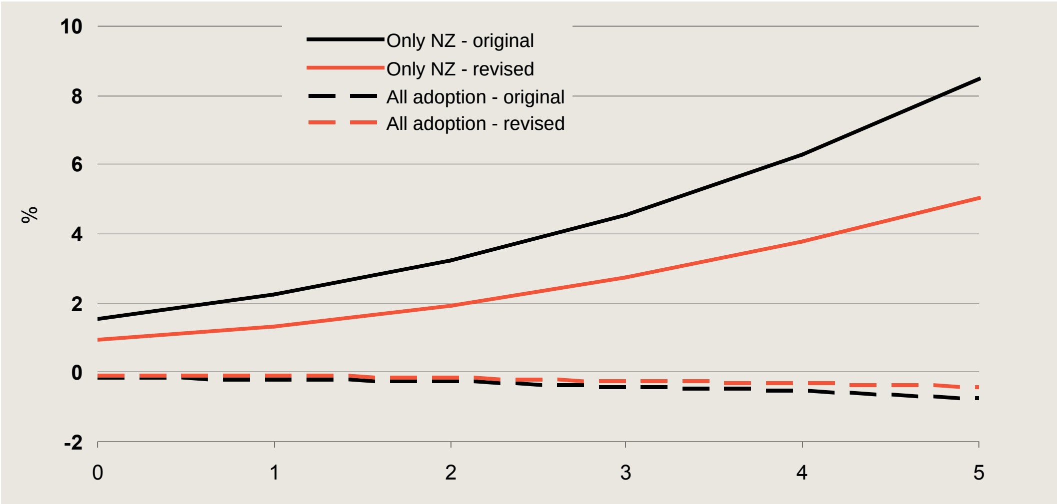
Data source: GTAP simulations.

3 32 **Changes in output of cattle in New Zealand**



Data source: GTAP simulations.

3.33 **Changes in output of other animal products in New Zealand**

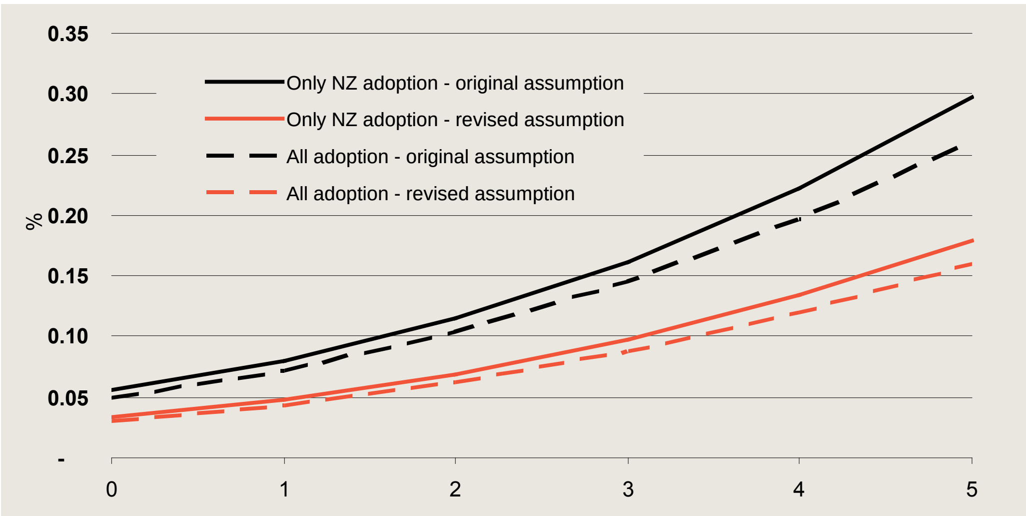


Data source: GTAP simulations.

Impact on real gross domestic product

Higher real GDP is projected under all the scenarios (Chart 3.34), due to the fact that the cost savings facilitated in the adopting sectors will increase household wealth and income through some combination of lower prices and higher export earnings. However, if all countries adopt the technology, the GDP increase is slightly lower than if only New Zealand adopts the technology. This is because other countries improve their export competitiveness from application of the same technology. Cost savings in other countries hurt New Zealand's competitiveness and depress the wealth growth in New Zealand resulting from the productivity improvement. This is consistent with the smaller increase in aggregate household consumption under the all adoption scenario.

3.34 **Changes in real GDP**



Data source: GTAP simulations

3.4 Biopharmaceuticals

Biopharmaceuticals involve the production of pharmaceutical products in biological systems, such as animals or plants modified genetically to produce key drug proteins. The timeframe for adoption of biopharmaceuticals has been assumed to be longer than that for epigenetics or nanotechnology, mainly because of general timeframes for regulatory approvals in the broader pharmaceuticals sector. In addition, it is more likely that for this technology, some of this development could be offshore with New Zealand mainly being used as a location for production. In order to more fully explore the implications of this possibility, in the modelling for this technology we included a third adoption scenario where New Zealand does not adopt the technology but the rest of the world does.

It is assumed that this technology will lead to a 3 per increase in multifactor productivity (relative to the baseline) over 15 years in the following industry sectors which are assumed to adopt it:

- Cattle; and
- Other animal products (particularly poultry).

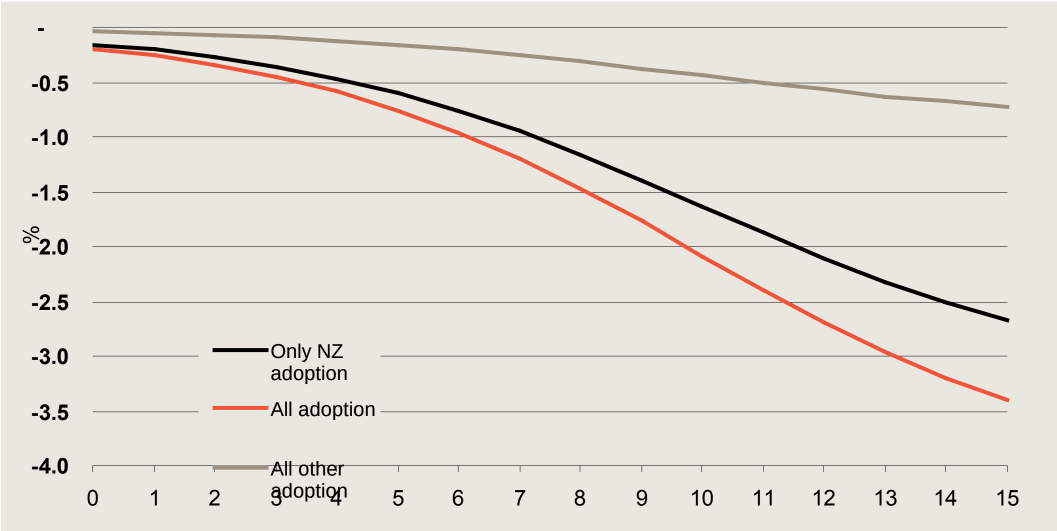
These sectors have been chosen because they include species that may be modified for biopharmaceutical production. The scale of impact in these sectors overall is assumed to be modest, as the new biopharmaceutical component is likely to be modest relative to the value of continuing output of traditional products from these sectors. Full descriptions of the modelled industry sectors and the issues surrounding the definition of appropriate industry sectors are set out in Appendix 1

Impact on prices

The results show that adoption of the technology results in a decline in the domestic price of products of the adopting sectors under both the 'only New Zealand' and 'all adoption' scenarios (Charts 3.35 and

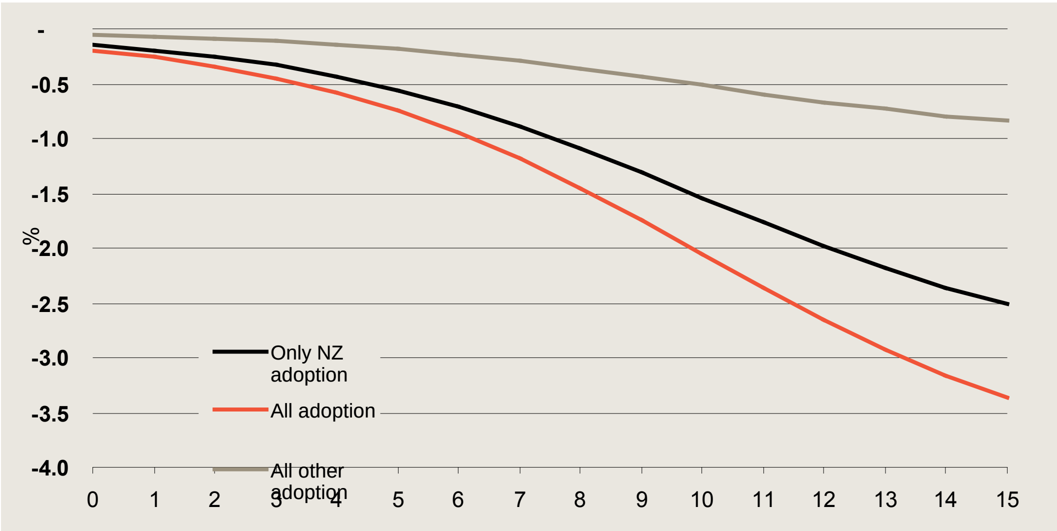
3.36). However, the reduction in domestic prices is larger under the all adoption scenario. This reflects the fact that cost reductions in the same sector in other countries facilitated by adoption of the technology leads to cheaper imports which keep prices in the domestic sector down further. It is smallest under the scenario where other countries but not New Zealand adopt the technology –in this case, the reduction in the domestic price of cattle is due to a the pressure put on it by a lower world price caused by the cost reductions achieved by other cattle producing countries.

3.35 **Impact on domestic price of cattle**



Data source: GTAP simulations.

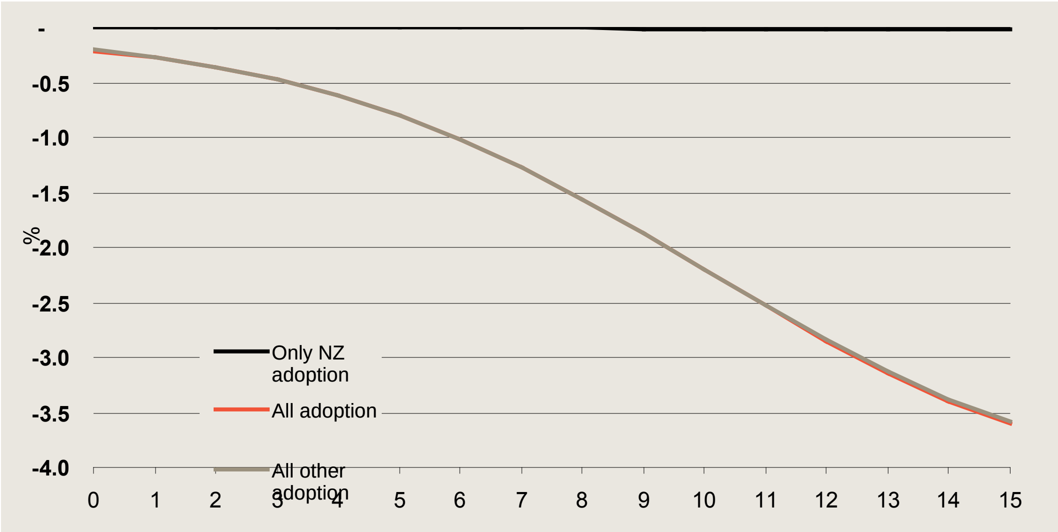
3.36 **Impact on domestic price of other animal products**



Data source: GTAP simulations.

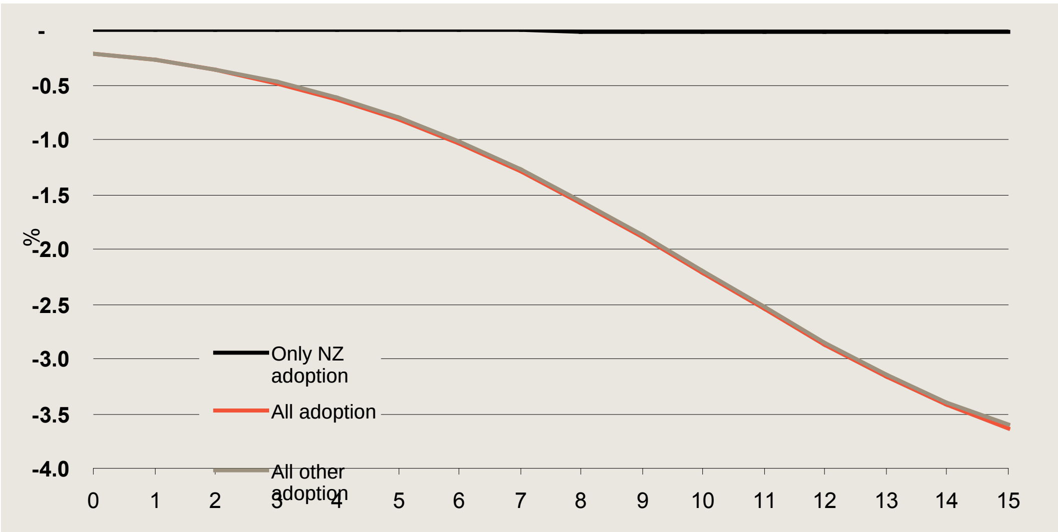
As would be expected, the only New Zealand adoption scenario leads to no change in the world price because the New Zealand economy is too small to have much of an impact on world prices but the all adoption scenario does lead to reductions in the world price of products from the cattle and other animal products sectors and the outcome where other countries except New Zealand adopt the technology is almost identical to one where all countries adopt the technology(Charts 3.37 and 3.38).

3.37 **Impact on world price of cattle**



Data source: GTAP simulations.

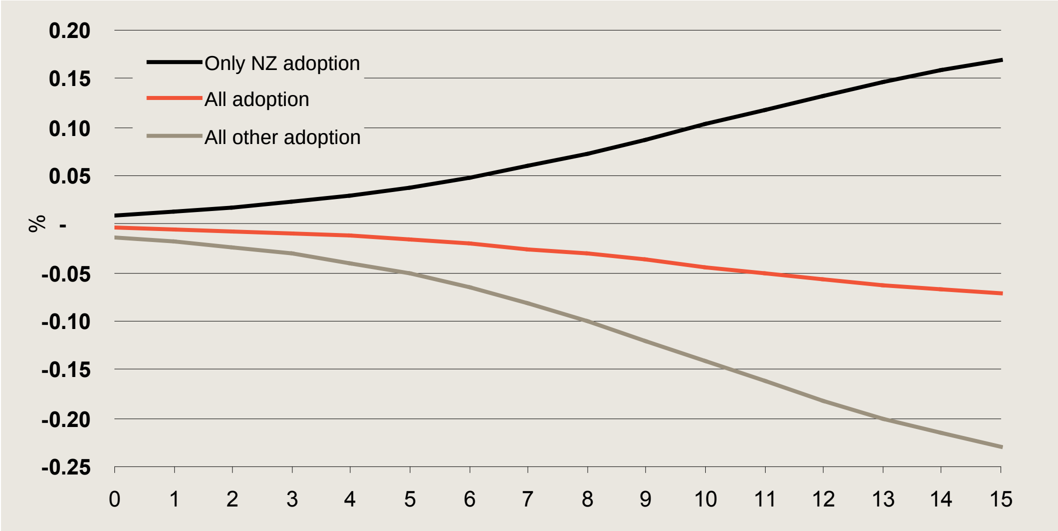
3.38 **Impact on world price of other animal products**



Data source: GTAP simulations.

Overall, under the only New Zealand adoption scenario, there is an increase in CPI relative to the baseline (Chart 3.39). This is because the increase in demand due to increased household wealth facilitated by cost reductions in the products of the adopted sectors exceeds the reductions in domestic prices of goods from those sectors. By contrast, under the all adoption scenario, cost savings in other countries lead to cheaper imports which compete with domestic products and thereby keep downward pressure on domestic prices. Where all the countries except New Zealand adopt the technology, the reduction in CPI is lower still, probably because of the absence of any resource competition effects that might otherwise arise if the technology were also in place in New Zealand.

3.39 **Impact on consumer price index**



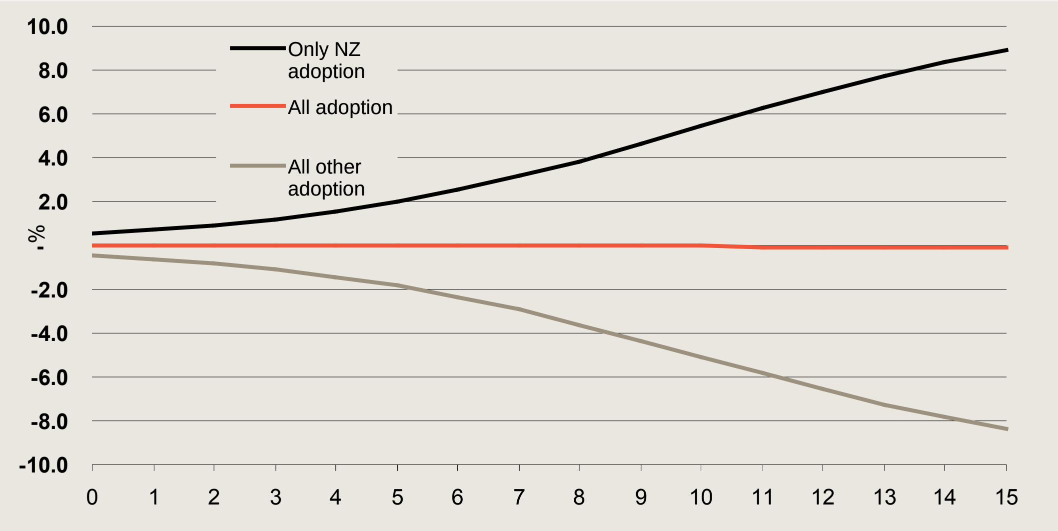
Data source: GTAP simulations.

Impact on exports

Under the only New Zealand adoption scenario, exports from the adopting sectors rise substantially relative to the baseline (Charts 3.40 and

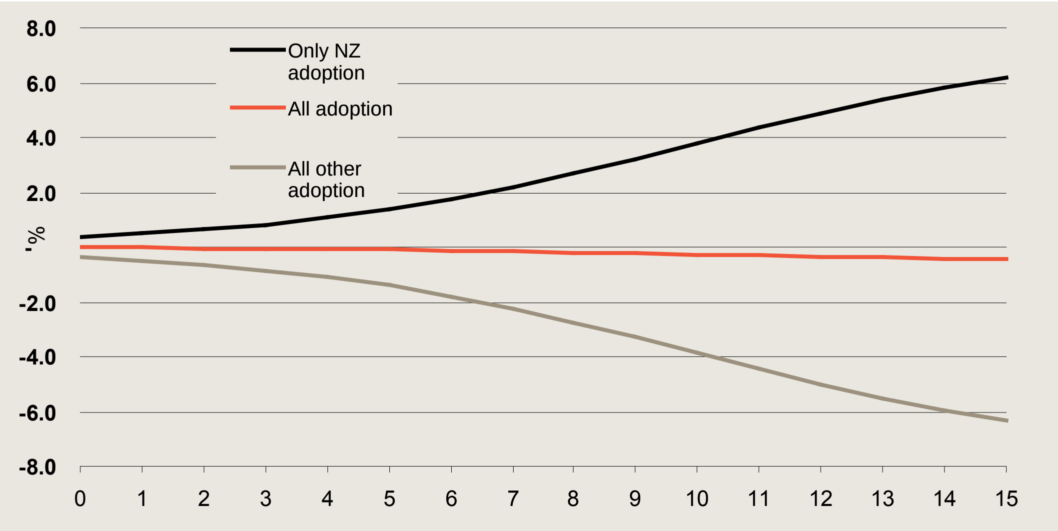
3.41). However, exports from these sectors fall slightly under the all adoption scenario. This is because under the all adoption scenario, New Zealand products from these sectors become less competitive than the same products from other countries which have also adopted the technology. Where other countries except New Zealand adopt the technology, the decline in exports is larger still as these countries increase the competitiveness of their cattle exports.

3.40 **Impact on New Zealand exports of cattle**



Data source: GTAP simulations.

3.41 **Impact on New Zealand exports of other animal products**

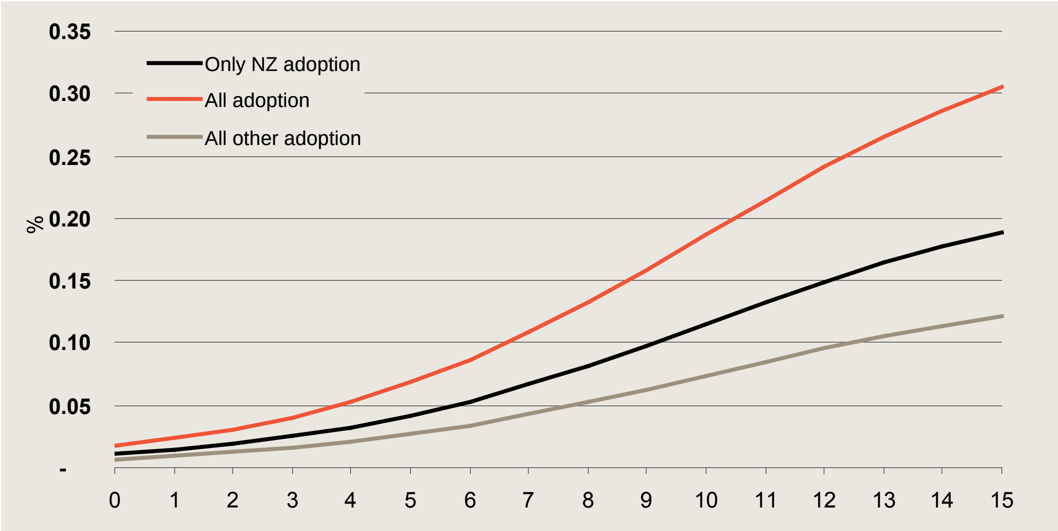


Data source: GTAP simulations.

However, aggregate exports rise under all scenarios though the magnitude of the rise is higher under the all adoption scenario (Chart 3.42). This reflects the fact that adoption of the technology, by increasing household wealth in other countries from the cost reductions facilitated, increases demand for New Zealand exports. The resulting increase in exports from other New Zealand sectors exceeds the slight reductions in exports from the adopting sectors.

It is worth noting that the two sectors which enjoy the highest increases in exports over the adoption period are the leather products sector and bovine meat products sector. These are sectors which use the products of the cattle sector as inputs into production. This means that the export competitiveness of these two sectors' products is significantly improved by the cost reductions facilitated in the cattle sector.

3.42 **Impact on aggregate New Zealand exports**



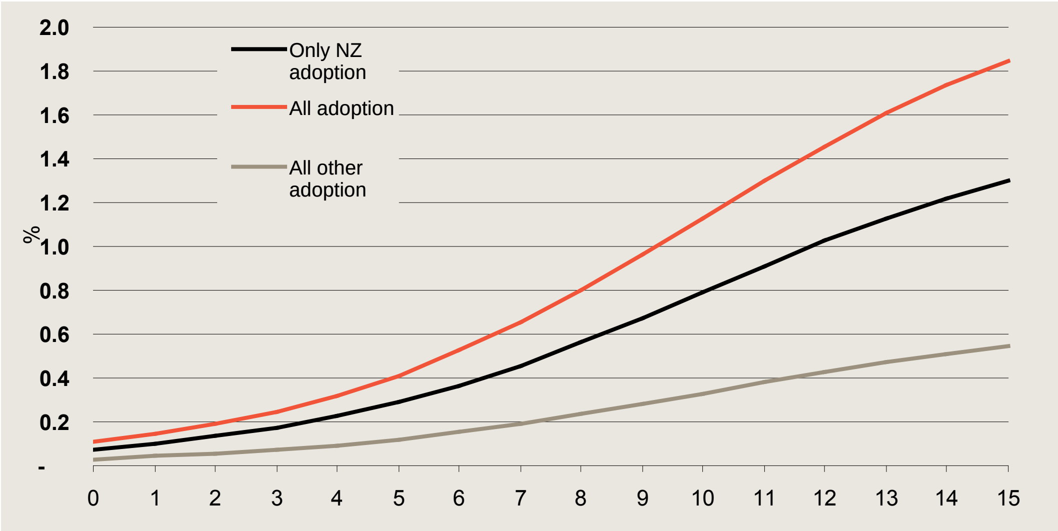
Data source: GTAP simulations.

Impact on consumption

As shown in Chart 3.43, the adoption of the technology leads to an increase in consumption of other animal products under all three scenarios though the increase in consumption is highest under the all adoption scenario (we have omitted charting the consumption of products from the cattle sector in this case because cattle is an 'intermediate' product for households). This is because of the cheaper imports facilitated under the all adoption scenario which compete with products from the domestic sectors, keeping additional downward pressures on prices of products from these sectors and promoting higher demand.

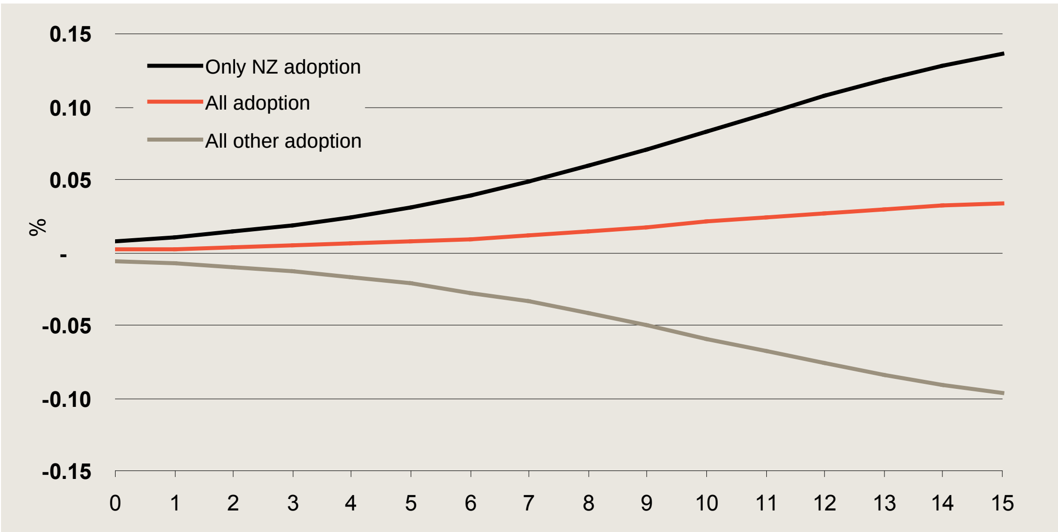
However, the same pattern does not emerge for overall household consumption (Chart 3.44). Though under both the only New Zealand adoption and all adoption scenarios, there is an increase in real consumption over the period, this increase is higher under the New Zealand only scenario, while there is a fall in overall consumption under the 'other countries' scenario. One possible explanation for this is that under the 'all adoption' scenario, other countries improve their export competitiveness from application of the same technology. Thus New Zealand's export competitiveness relative to other countries is not as enhanced as it would be under the New Zealand only scenario, and therefore the growth and consumption boosting effects of the technology are smaller under the all adoption scenario. This is consistent with the impacts of the technology on real GDP as discussed below. Under the scenario where New Zealand is the only country not to adopt the technology, it forgoes any gains both in terms of increased export competitiveness and cheaper domestic products and thus the income of New Zealand households declines, leading to a fall in consumption.

3.43 **Impact on household consumption of other animal products**



Data source: GTAP simulations.

3.44 **Impact on real household consumption**

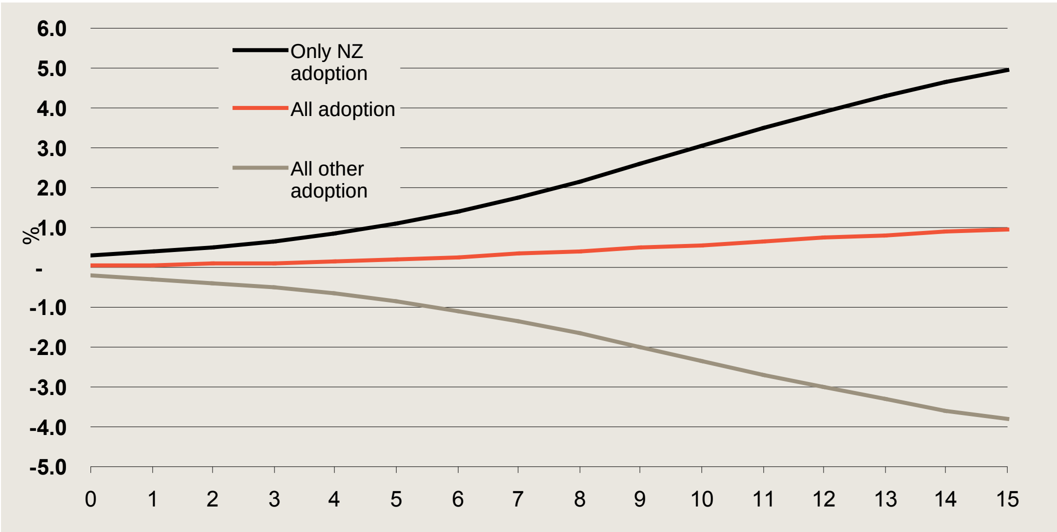


Data source: GTAP simulations.

Impact on production

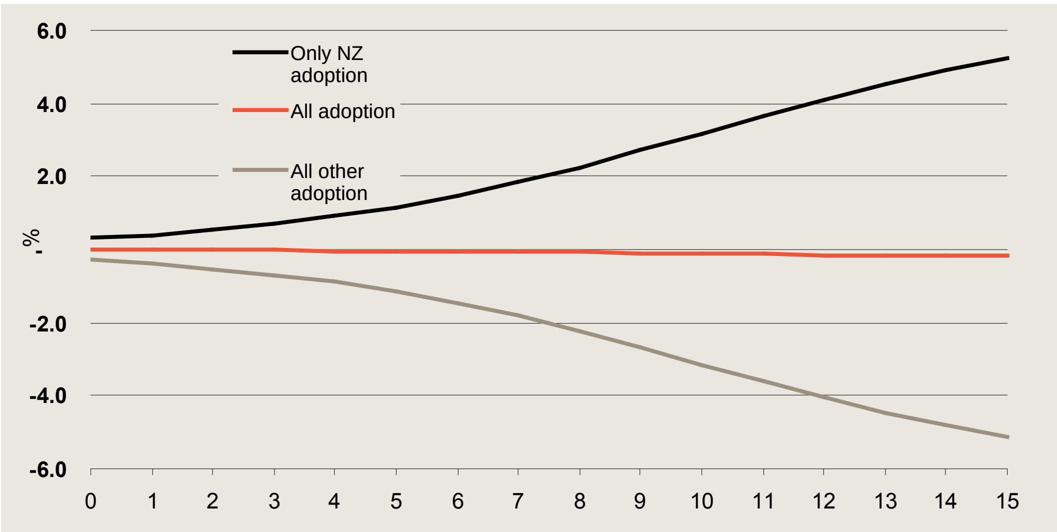
Output of the adopting sectors increases under the only New Zealand adoption scenario (Charts 3.45 and 3.46). The increase in output can be attributed to the expansion in demand for these products due to cost savings. However under the all adoption scenario, it increases with a smaller magnitude for cattle but decreases for the other animal products sector. This is because New Zealand is now facing tougher competition from other countries adopting the same technology. For cattle, the expansion effect from New Zealand adopting the cost saving technology dominates the competition effect from other countries, leading to smaller increase in production. For other animal products, the competition effect dominates, leading to a fall in production. Where all countries except New Zealand adopt the technology, New Zealand falls behind in competitiveness and so naturally, these sector suffer a fall in output.

3.45 **Changes in production of cattle in New Zealand**



Data source: GTAP simulations.

3.46 **Changes in production of other animal products in New Zealand**

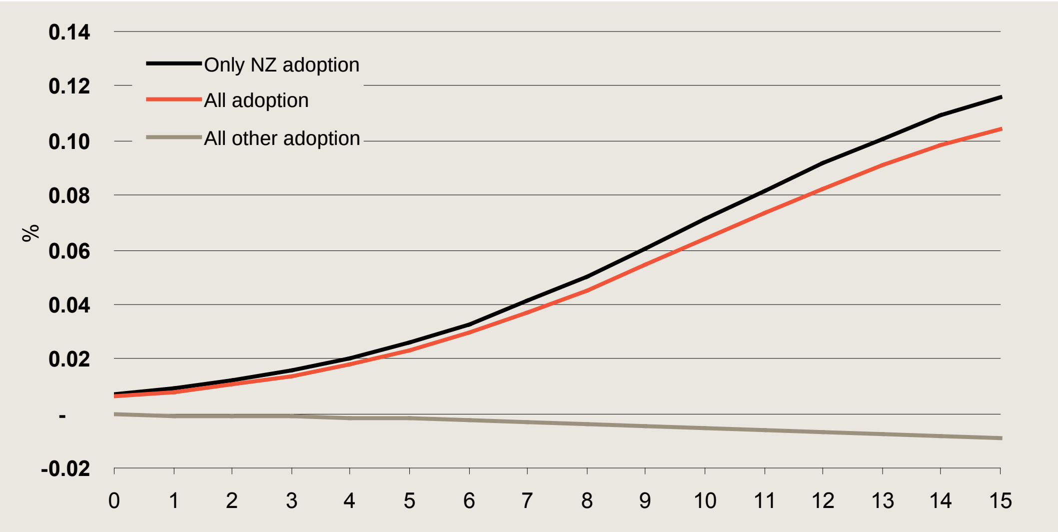


Data source: GTAP simulations.

Impact on real gross domestic product

Real GDP is projected to increase under both the only New Zealand and all adoption scenarios (Chart 3.47), while falling under the scenario where other countries but not New Zealand adopts the technology. However the increase is higher under the only New Zealand scenario. This implies that the GDP advantage enjoyed by New Zealand under the only New Zealand scenario is due to the fact that it exclusively enjoys the direct cost reducing benefits of the technology. If other countries adopt the cost saving technology, the positive impact on New Zealand economy would be lower because these other countries are also better off by increasing the competitiveness of their exports.

3.47 **Changes in real GDP**



Data source: GTAP simulations.

3.5 *Nanochemicals*

This technology is different from the others examined so far because the applications of this technology are likely to be more significant in retail and consumer terms than in production terms. In particular, the main application of this technology will be in the production of new kinds of cosmetic and beauty products such as sun-screens and anti-aging products. We have tentatively modelled the impact of this technology in the form of two possible impact scenarios:

- An increase in household demand for products of the 'chemical rubber products'[4] manufacturing sector of 0.1 per cent over the assumed adoption period of 5 years;
- An increase in household demand for products of the 'chemical rubber products' manufacturing sector of 0.5 per cent over the assumed adoption period of 5 years.

Full descriptions of the modelled industry sector and the issues surrounding the definition of appropriate industry sectors are set out in Appendix 1

Thus, in combination with the 'only New Zealand' and 'all adoption scenarios' this involves the modelling of four different scenarios in total.

It is worth noting that the impact assumptions adopted for this technology are even more speculative than the impact assumptions used for the other technologies because we are attempting to model the impact of the technology in 'creating' new demand for a segment of consumer beauty products rather than a productivity impact. Small impacts were chosen because consumer beauty products form only a segment of the total 'chemical and rubber products' manufacturing sector.

Realistically the induced higher demand from such a small segment of manufacturing could be even smaller than the impacts chosen but we have formulated these assumptions taking account of the possibility that advances in nanochemicals might lead to the creation of other new products within the 'chemical and rubber products' manufacturing sectors besides cosmetic and anti-ageing products, though it would be purely speculative at this stage to determine what the overall percentage of the sector likely to be affected by these advances will be.

On the other hand, the modelling does not take attempt to precisely quantify the demographic consideration that the ageing of the New Zealand population would be likely to further add to the significant new demand for anti-ageing products. Finally it is worth noting that the projections in this model resulting from the assumed increase in demand for products from the adopting sector assumes that the confidence of the New Zealand public will be sustained because the risks from the

4 These encompass basic chemicals, other chemical products, rubber and plastics products.

technology are not significant or proven. The implications of this particular assumption are discussed in further detail in the subsection on non-quantitative aspects of scenario modelling.

Non-quantiative aspects of scenario modelling

Some difficult to quantify but potentially important aspects of scenario modelling of the adoption of nanochemicals relate to:

- The impacts on social and community attitudes to nanotechnology;
- The implications of changes in these attitudes to future adoption patterns for nanotechnology;
- The compliance regime that would be need to be formulated to manage the risks of such technologies.

We are not aware of any comprehensive study to date of existing New Zealand public attitudes to nanotechnology. A survey of public attitudes to biotechnology that included a brief reference to nanotechnology[5] found that public support was generally more favourable for medical applications and less favourable for food applications.

3.48 **Australian public support for applications of nanotechnology**

Nanotechnology application	*Australian public approval in 2008 (%)*
Medical – clearing arterial clots and cancer cells	94
Environmental – controlling pollutants from entering environment	95
Environmental – breaking down waste and garbage	93
Protective suits against chemical and biological weapons	74
Stain repellent fabrics	51
Miniature surveillance devices	34
Computers in clothes or goods	31
Changing nutrients in foods	32

Source: Cormick 2009

[5] Fairweather, J., Campbell, H., Hunt, L. and Cook, A. 2007. Why do some the public reject novel scientific technologies? A synthesis of results form the Fate of Biotechnologies Research Programme. www.lincoln.ac.New Zealand/Documents/3253_RR295_s10005.pdf

As an approximation for New Zealand, we can look at studies of public attitudes in Australia. The three studies conducted to date suggest that the Australian public has very high expectations of nanotechnology and their concerns with respect to nanotechnology are only moderate, while knowledge and awareness are low. The public appears to be strongly supportive of nanotechnology, though it depends on the particular applications. In particular, there is high support for the use of nanotechnology in medical and environmental applications (around levels of 90 per cent of respondents and over). However levels of support for the use of nanotechnology in consumer goods are far below 50 per cent.[6] Table 3.48 summarises these findings.

On the other hand, the same surveys also found that between 2005 and 2008, the Australian public's perception of the benefits outweighing the risks increased (from 39 per cent to 53 per cent) while the perception of risks equalling benefits diminished (from 35 per cent to 18 per cent). The only high concern expressed (28 per cent) related to the use of nanotechnology in food.

Insofar as Australian attitudes to nanotechnology may be reflective of New Zealand attitudes, this research suggests that there is likely to be some initial resistance to the use of nanochemicals in cosmetic and beauty products. However, one caveat to this analysis is that currently many New Zealand consumers remain unaware of the use of nanochemicals in such products. These products are already widely available in New Zealand and thus can be said to already forming a percentage of sales of such products.

The current approach to the regulation of nanotechnology in New Zealand can be described as principles-based. The Hazardous Substances and New Organisms Act (HSNO Act) deals generically with hazardous substances with the Environmental Risk Management Authority (ERMA New Zealand) assessing and deciding on applications to introduce hazardous substances or new organisms into New Zealand, including nanomaterials.

The use of nanotechnology in cosmetics raises the question of whether there should be more nanotechnology specific regulation. Currently, consumers have little or no knowledge regarding which products contain nanomaterials as there is no official national register of nanotech-based products. This same lack of information makes modelling of quantitative outcomes of the introduction of nanochemicals difficult and accounts for the much less rigorously based estimates discussed in the modelling section below. Because of these constraints, we also have little knowledge of the extent to which current household demand for nanochemical-based cosmetic and beauty products would be sustained, reduced or increased if knowledge of their

6 These studies are summarised in Cormick, C. 2009, 'Why Do We Need to Know What the Public Thinks about Nanotechnology', *Nanoethics*.

ingredients was more widely known, though we do know based on research conducted by consumer and other organisations that cosmetic products which use nanochemicals are already 'on the shelves' in both Australia and New Zealand.

The main risk factors associated with the use of nanochemicals in beauty products are:

- Hitherto unknown consequences of concentrated chemicals to the human skin; and
- Risks of possible concentration/aggregation of chemicals in human organs (after absorption through the skin.

For instance, according to the US National Institute of Environmental Health Sciences, generally the smaller the particles, the more reactive and toxic are their effects while the UK Institute of Food Science and Technology has argued that ingested nanoparticles are more likely than larger particles to penetrate into tissue and cells, influencing accumulation and storage and toxicity risks.[7]

While generally the risk factors for nanotechnology will depend on the specific materials, in the case of nanochemicals used in cosmetic and beauty products, it is likely that a substantial part of such materials will comprise nanoparticles, which may enter the body when applied to broken skin. This may increase the degree of possible exposure risks to the population. On the other hand, and this is the dilemma faced by regulators around the world, there is currently very little data which decisively settles the question of the magnitude of such risks. Because of this, it is unclear what the most optimal regulatory response is.

The possible regulatory response can range from the relatively more flexible generic approach currently adopted in New Zealand to a more precautionary approach targeted more specifically on nanotechnology, and which involves restricting sales of nanochemical-based products until evidence of safety and of the absence of adverse effects emerges from testing. Most recently, the European Union has opted for the more restrictive approach, passing laws in 2009 which required all cosmetics and sunscreens using nanomaterial derived from existing chemicals to be individually tested for safety before being released on the market.

While the EU approach is a feasible one and may even eventually set a standard that consumers and non government organisations in other countries demand for products sold in their countries, it is one that may involve a more significant foregoing of economic opportunities than a more intermediate approach. There is great economic potential in exploitation of nanochemicals in consumer products. In

7 As summarised in Ludlow, K. 2009, 'The Readiness of Australian Food Regulation for the use of Nanotechnology in Food and Food Packaging', available at http://www.austlii.edu.au/au/journals/UMonashLRS/2009/14.html

the US alone it is estimated that nanotechnology was incorporated in $82 billion worth of manufactured goods and appeared in over 800 consumer products in the market. The rate of product commercialisation involving nanotechnology internationally is estimated at 3-4 products per week.[8]

The projections discussed below are based on the optimistic assumption that projected increases in household demand for beauty products due to the incorporation of nanochemicals into their production, making for more novel and higher quality products that arouse consumer interest, will be sustained because the risks mentioned above turn out to be unproven and consumers then respond positively to the new product choices available to them in the market.

Under this more optimistic scenario, if these risks turn out to be unproven, in addition to the projections discussed in the next subsection, though they suggest mixed results (a slight increase in exports but a slight reduction in GDP). 'Trouble-free' use of nanochemicals in beauty products is likely to significantly increase public confidence in nanochemicals more generally,given that the application of nanotechnology in consumer products is in some sense, the 'last frontier' and the main area where consumer anxiety about the application of nanotechnology has to be overcome. This in turn has broader implications that would not be taken into account in our quantitative modelling as it would promote the faster diffusion of nanotechnology use into other areas of the economy with all the productivity and growth promoting benefits this entails.

Putting this another way, the safe adoption of these nanochemical based consumer goods in cosmetic and beauty products may pave the way to substantially increased public acceptance of nanotechnology in other products, helping to make New Zealand a relatively early adopter of this technology. This will lead to further increases in consumption, investment and economic growth but also imports of manufactures unless there is also the concomitant development of domestic manufacturing using nanotechnology.

By contrast, under the more pessimistic scenario where the risks associated with these products are significant, if the existing regulatory system in place is unable to minimise or avoid the emergence of these risks, this would lead to a fall in support for the use of nanotechnology in consumer products to negligible levels. It is likely that even support for the use of nanotechnology in non-consumer products could be adversely affected by such a development, setting back the economic exploitation of this technology significantly. In other words, there could be a 'ratchet effect' whereby the under-regulation of nanochemicals, by failing to deal appropriately with the hazards of the technology, leads to an over-reaction in the opposite direction, as consumer and voter sentiment turn against the use of this technology in other areas

8 Sustainability Council 2010, 'The invisible revolution'.

where the risks are low relative to the benefits. This effect could be particularly serious for consumer products, including cosmetics where brand perception is so important, but may have implications beyond that if, as a result, there are public demands for a more restrictive approach such as that adopted by the EU. This would lead to New Zealand ultimately lagging behind in the adoption of nanotechnology.

This is putting aside what may also be significant costs and risks to public health and the environment arising from the failure to properly regulate this area of technology to both health and the environment. As there is too little information or certainty about both the likely volumes of sales of such products in future (before these health risks emerge) or the actual probabilities and magnitudes of these health risks, we have not attempted to quantify any of these costs. However these health costs would take the form not only of increased mortality but also increased morbidity (and hence diminished labour supply) and increase costs on the healthcare system. In addition, given the tendency of nanoparticles to bind to contaminating substances already pervasive in the environment, it is possible that they can become a mechanism for long-range and widespread transport of pollutants in groundwater.[9]

It is apparent from the discussion above that it is important both in terms of consumer health and safety as well as in safeguarding public confidence in the appropriate use of nanotechnology and avoiding the kind of 'ratchet effect' described that a sufficiently robust regulatory system is in place to manage the possible risks of nanochemicals in this context.

In a recent assessment of emerging international trends relating to regulatory for nanotechnology, Pelley and Saner[10] identified six guiding regulatory principles:

- The regulatory response should be coordinated. This should include coordination at the international level, between states, provinces or member states, as well as coordination at the inter-departmental inter-agency level in individual jurisdictions;
- Regulatory approaches to nanotechnology should be flexible and adaptive;
- Information gathering initiatives, a key first step in an adaptive regulatory system, should be designed with the end-points in mind, should offer incentives for participation, and should involve both industry and academic researchers;
- Risk management approaches should strive to be comprehensive, by incorporating a lifecycle approach to govern the potential risks of

9 Little, T. et al 'Beneath the skin: Hidden Liabilities, Market Risk and Drivers of Change in the Cosmetics and Personal Care Products Industry'.

10 Pelley, J. and Saner, M. 2009. International approaches to the regulatory governance of nanotechnology. RGI Regulation Papers. ISBN 978-0-7709-0530-9.

nanotechnology and should be designed with the importance of scope and timing horizons in mind;

- Risk management approaches should strive for balance and proportionality between the costs and benefits of regulating. The regulatory impact of mandatory versus indirect approaches versus an absence of regulation should be considered;
- An understanding of the profile of the beneficiaries of nanotechnology and the risk bearers in concert with who is accountable would go a long way toward ensuring the appropriate deployment of both technology and regulatory oversight. Stakeholders should be engaged appropriately and regulatory systems should be transparent.

As noted already, New Zealand currently does not have many regulations targeted specifically at nanotechnology risks but instead adopts a generic approach where nanochemicals are assessed on a case by case basis like other materials. To date, there have been some information collection requirements imposed by the government on the use and importation of nanochemicals. Specifically, manufacturers or importers of cosmetics are currently required to report the use of nanochemicals in cosmetics and personal care products to the Environmental Risk Management Authority (ERMA) though not all nanoscale ingredients are included in the reporting scheme. Furthermore, these requirements currently do not empower ERMA to trigger further action unless evidence of hazard is already available.

In the absence of more detailed information, the CIE is unable to determine whether greater regulation than current requirements is needed. However, as part of our scenario modelling we will briefly consider the costs that would be involved of New Zealand adopting an intermediate approach between its current generic regulation and a more restrictive 'precautionary' approach targeted specifically at nanotechnology.

One possible intermediate approach is provided by the UK House of Lords' Science and Technology Committee enquiry report into the use of nanotechnology, which, although specifically focused on the regulation of nanotechnology in food products, sets out a model that can be adapted to other areas where nanotechnology is applied to consumer products. The report, published in January 2010[11], made the following recommendations:

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[11] Summarised in http://www.ajpark.com/articles/2010/04/nanotechnology_and_food_regulation_in_NEW ZEALAND.php

- Regulators must develop a definition of nanomaterials, which should be based on functionality rather than size of a nanoparticle. The Committee recommends that all materials with a dimension under 1000 nm are included in regulation.
- Any regulatory definition of 'nanomaterials' should exclude those created from natural substances, except for nanomaterials that have been deliberately chosen or engineered to take advantage of their nanoscale properties.
- To avoid products being inappropriately under- or over- regulated, there must be clear guidelines for what fraction of a product needs to be at the nanoscale before nano-specific regulatory oversight is triggered.
- Maintaining a public registry of foods containing nanomaterials is preferable to requiring blanket labelling of nanomaterials on packaging.

Such an approach would involve some increase in compliance costs for importers and manufacturers as well as greater enforcement and administrative costs by regulators compared to the present minimal reporting requirements. However, it preserves a significant degree of flexibility while at the same time increases regulators' capacities to manage any emerging risks from this technology. Some degree of both specificity and flexibility in the regulatory treatment of nanotechnology applications is also supported by the contrasting results from the adoption of nanotechnology in New Zealand manufacturing and dairy processing (as discussed previously) which yields significant benefits to New Zealand as a producer and exporter, and more mixed results from the adoption of nanochemicals in New Zealand consumer beauty products as discussed below. It is sensible to adopt a preemptive approach of tightening regulation in nanotechnology generally to safeguard public confidence in this technology and thus avoid the 'ratchet effect' discussed previously which might otherwise result in adoption of both these applications of nanotechnology being stifled altogether.

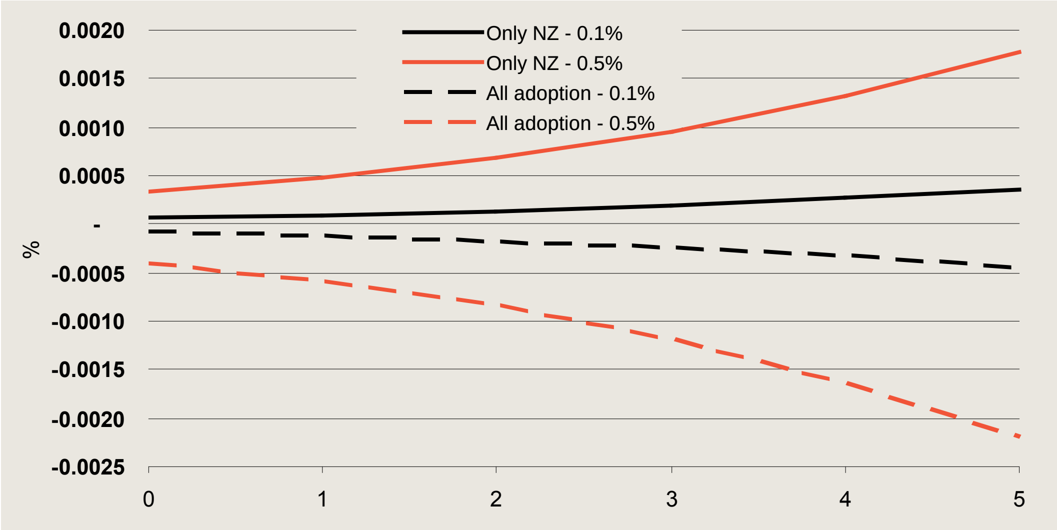
Quantitative results

Impact on prices

Under the 'only New Zealand' adoption scenario, the domestic price of products from the adopting sector will rise, as would be expected, though the increase is not significant, though note that this is the case for all the impacts discussed here which are very small fractions of one per cent in scale (Chart 3.49). An assumed increase in demand for outputs of this sector would be expected to increase the domestic price of these outputs. However, when all other countries also adopt the same technology, resulting in an increase in their households' demand for similar products, the overall result is a fall in the domestic price of these products in New Zealand. This is due to the effect of a deterioration in the terms of trade (because the increased demand for products in other countries increases the price of imports of those products). The deterioration of the terms of trade under the 'all adoption' scenario leads to a fall in

New Zealand household incomes and therefore a fall in demand for these products which exceeds the initial increase in demand postulated.

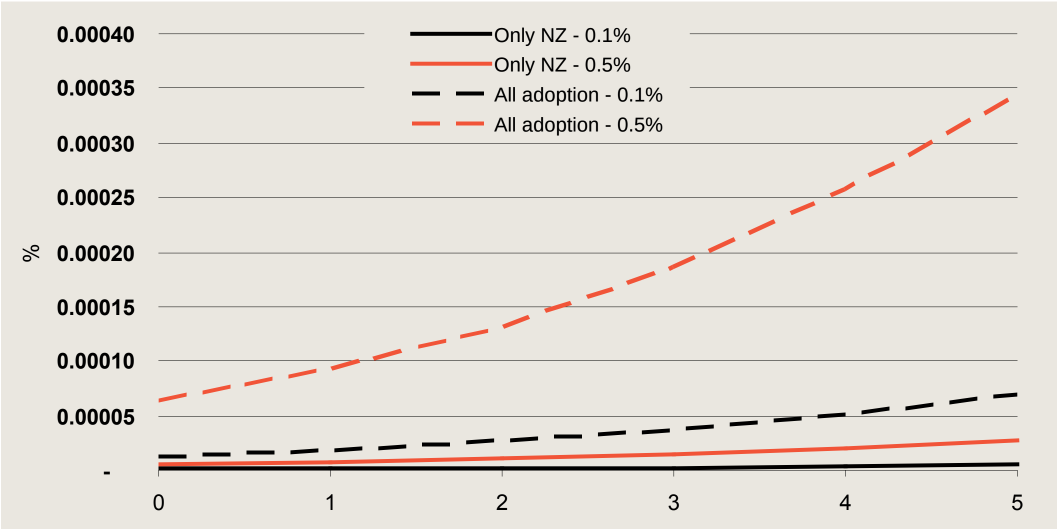
3.49 **Impact on domestic price of chemical and rubber products**



Data source: GTAP simulations

As would be expected, an increase in New Zealand household demand for the products of the adopting sector has only a negligible impact on world prices but world prices rise more significantly when the technology is adopted in all countries, leading to a more perceptible (though still small) increase in the world price of products from the sector (Chart 3.50).

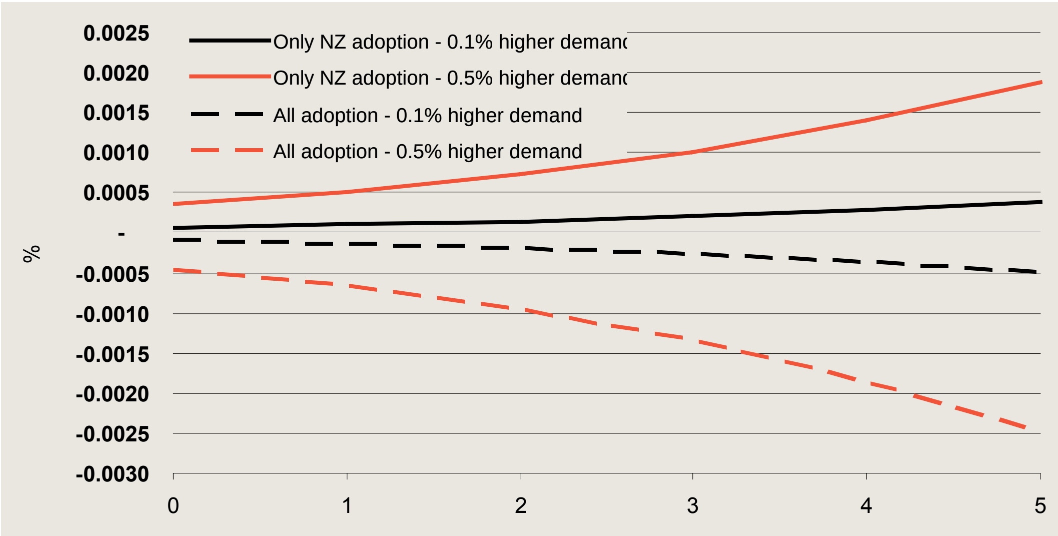
3.50 **Impact on world price of chemical and rubber products**



Data source: GTAP simulations

Under the only New Zealand adoption scenario, the CPI goes up, reflecting the increase in the price of outputs from the adopting sector, but goes down under the all adoption scenario (Chart 3.51). The reduction in CPI under the all adoption scenario is again due to the depressive impact on household incomes and demand of the deteriorating terms of trade.

3.51 **Impact on consumer price index**



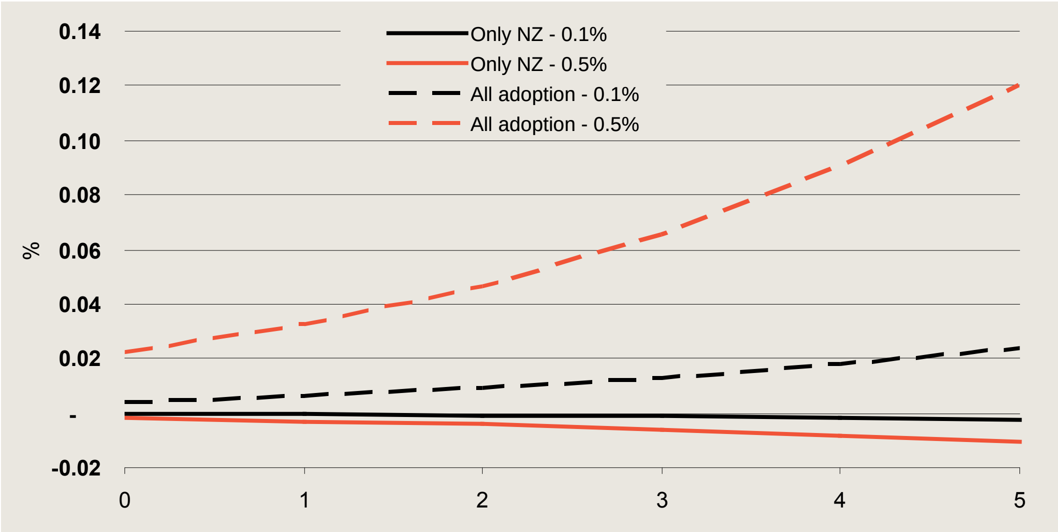
Data source: GTAP simulations

Impact on exports

Under the only New Zealand adoption scenario, exports of products from the adopting sector are projected to fall because increased domestic demand for products from this sector diverts some of their output to production for the domestic market instead (Chart 3.52). However, where all countries adopt this technology, the resulting deterioration of terms of trade (due to increased demands for the products of the adopting sector leading to increased import prices) cuts into household incomes, reduces general demand for goods and services and therefore reduces costs of production in the adopting sector in New Zealand. These effects induce a counter-intuitive increase in exports from the adopting sector in New Zealand as well as aggregate exports.

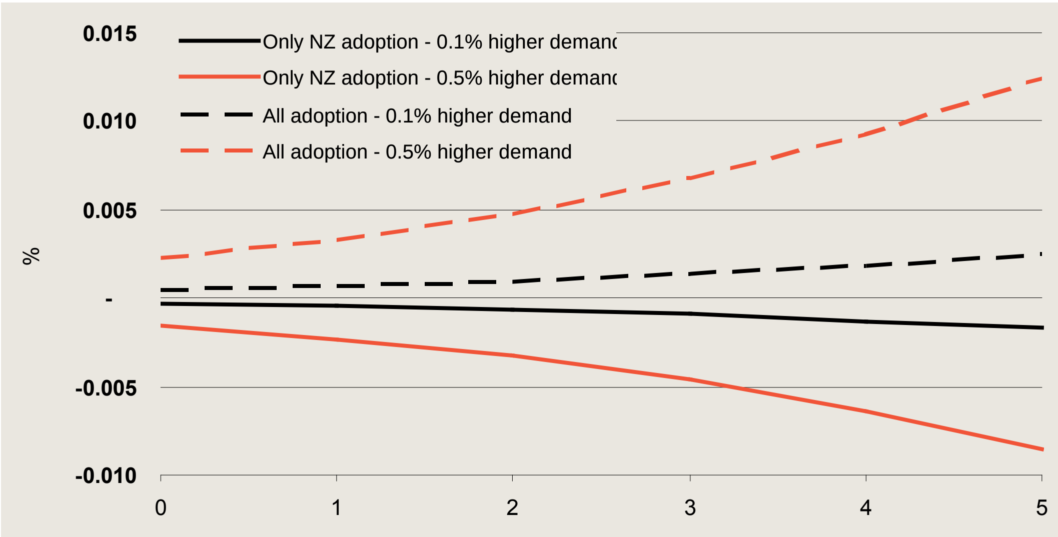
Overall, under the only New Zealand adoption scenario, aggregate exports are projected to fall slightly because of the diversion of production to meet higher domestic demand for products of the adopting sector (Chart 3.53). However, when all countries adopt the technology, New Zealand exports are projected to rise for the terms of trade based reasons discussed above.

3.52 **Impact on New Zealand exports of chemical and rubber products**



Data source: GTAP simulations

3.53 **Impact on aggregate New Zealand exports**

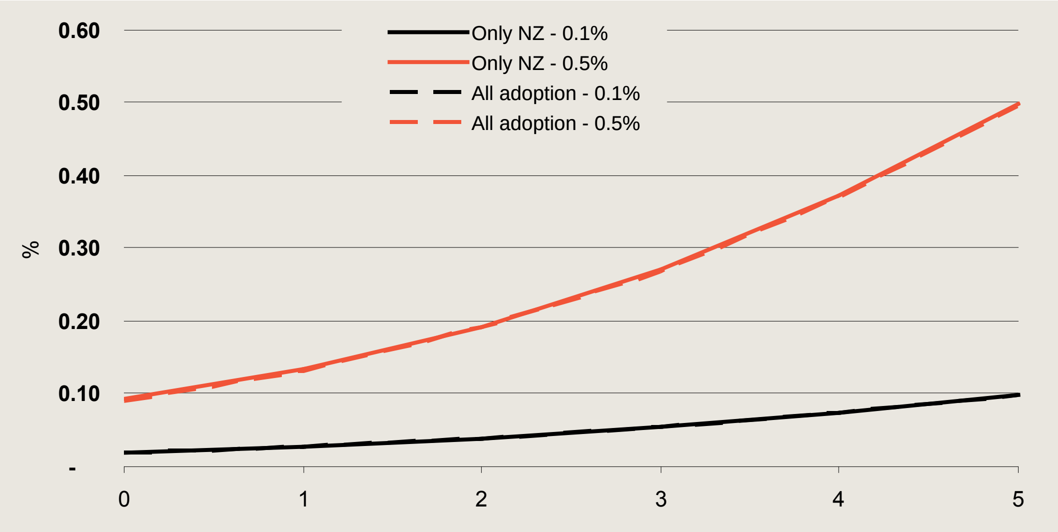


Data source: GTAP simulations

Impact on consumption

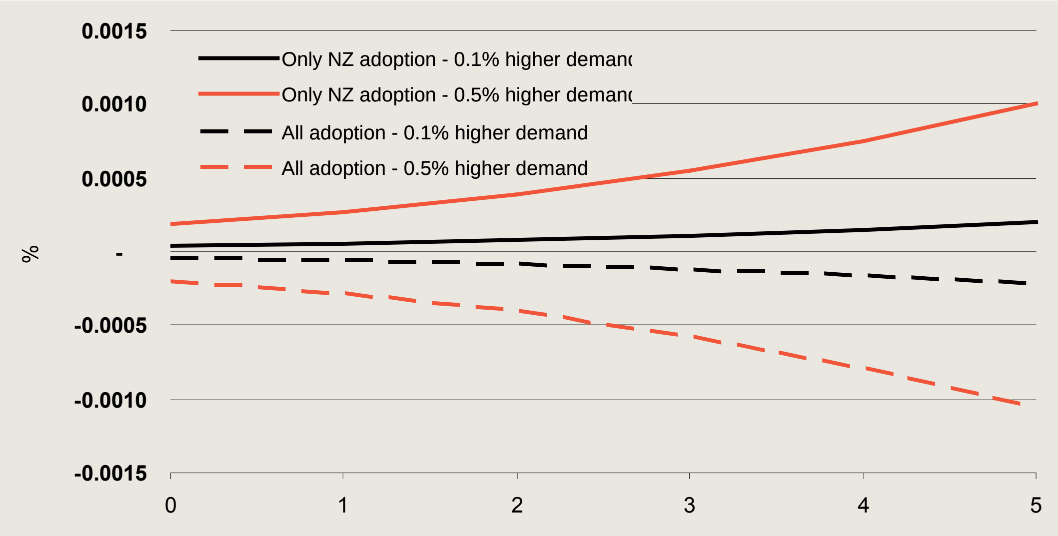
Changes in consumption of products from the adopting sector under both adoption scenarios are identical, with increases in consumption projected as assumed (Chart 3.54). However, at an aggregate level, this translates into a reduction in real household consumption over the adoption period under the all adoption scenario due to the deterioration in terms of trade reducing household incomes (Chart 3.55).

3.54 **Impact on household consumption of chemical and rubber products**



Data source: GTAP simulations

3.55 **Impact on real household consumption**

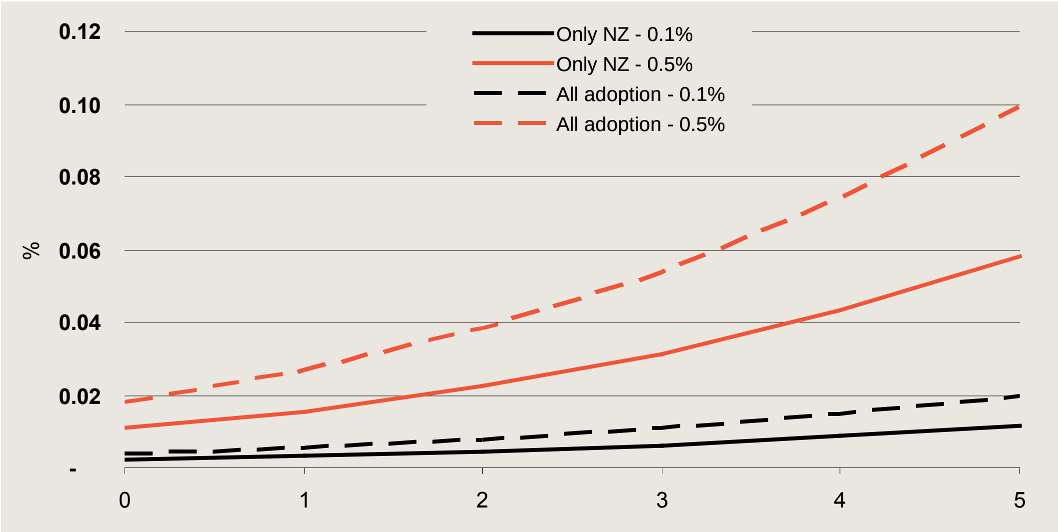


Data source: GTAP simulations

Impact on production

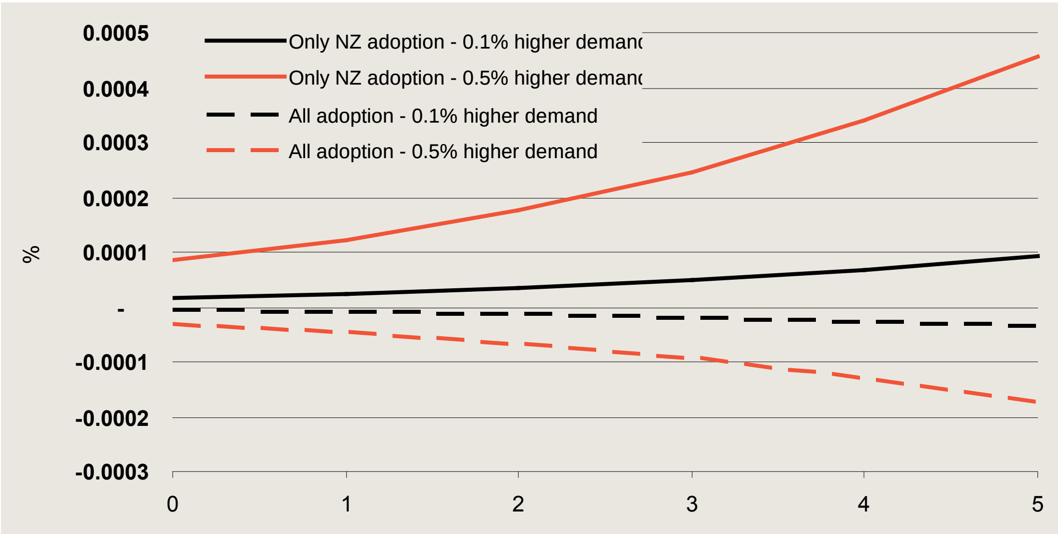
Under both adoption scenarios, the output of the adopting sector is projected to increase through the magnitude of the increase is larger under the all adoption scenario, reflecting increased demand for New Zealand exports (Chart 3.56). However, though real GDP is projected to increase under the 'only New Zealand' adoption scenario, it falls under the all adoption scenario, again due to the deterioration in the terms of trade (Chart 3.57).

3.56 **Change in production of chemical and rubber products in New Zealand**



Data source: GTAP simulations

3.57 **Changes in real GDP**



Data source: GTAP simulations

4 *Summary and conclusions*

The illustrative modelling of economic impacts of emerging technologies carried out here demonstrates complex relationships between immediate productivity changes in an industry sector, flow-on effects in other sectors, and outcomes for consumers and the economy as a whole.

All but one of the emerging technologies modelled are assumed to have the ultimate impact of increasing productivity (in the case of nanotechnology, this is achieved through the reduction in energy costs). Almost all of these productivity enhancing technologies will, as a first order impact, lead to a reduction in prices of products from the industry sectors adopting these technologies because this initial price reduction effect outweighs the 'resource competition effect' from other sectors. When the impact of other countries adopting the technology is taken into account, these price reductions are reinforced by the effect of competition from cheaper imports.

One exception to this general tendency for resource competition effects to be dominated by price reduction effects was seen in the case of nanotechnology which was adopted by a number of unrelated sectors which would clearly be in direct competition with each other for resource such as dairy processing and selected other manufacturing sectors, with the result that under the 'only New Zealand' adoption scenario, adoption of this technology led to an overall increase in the price of dairy products.

As would be expected given the small size of the New Zealand economy, the 'only New Zealand' adoption scenario led to effectively no impacts on the world prices of the products of the adopting sectors.

As the 'all countries' adoption scenario is the most realistic of those modelled, the results of these scenarios should be the main guide to thinking about regulatory approaches. Bearing this in mind, other notable patterns in our results are as follows:

- The productivity enhancing technologies all promote reductions in the general price level under the all countries adoption scenario, most probably because of the impact of cheaper imports.
- Increases in domestic consumption of products of the adopting sectors were observed for all the productivity enhancing technologies, but given that they are smaller under the all countries adoption scenario, this suggests where technology adoption is no longer restricted to New Zealand, other countries also increase

their competitiveness, reducing the gains in income and wealth of New Zealand households and therefore reducing the increases in domestic consumption.

- Though reductions in exports of the products of the adopting sector were observed under the all countries adoption scenario, reflecting the impact of technology adoption in enhancing the international competitiveness of other countries, aggregate exports nonetheless increased for 2 of the 3 technologies. This reflected increases in the international competitiveness of other sectors which rely on the products of the adopting sector as inputs.
- Where a new technology (e.g. biopharmaceuticals) is adopted everywhere but New Zealand, there is a strongly negative effective on the New Zealand economy.
- Finally, increases in GDP were projected as arising from the adoption of all three of the productivity enhancing technologies.

The results for nanochemicals are more anomalous and in some cases counterintuitive. This may simply reflect the very small changes projected from adoption of this technology, which has been assumed to lead to shifts in household demand rather than productivity. Another important driver of the results for nanochemicals is the effect of a deteriorating terms of trade under the all adoption scenario, which leads to reduced household incomes in New Zealand. However the general applicability of the quantitative results for nanochemicals is limited because the more speculative nature of the shocks postulated and it is important not to ignore the more qualitative aspects of adopting that technology such as the likely impact on public opinion and acceptance of the broader use of nanotechnology which in turn can have implications for wider nanotechnology adoption rates.

In any case, what these results have in common is that they demonstrate that

- long-run economic growth reflects the cumulative effects of many small contributions from individual technologies, so any regulatory approach needs to be sensitive to the longer-run trend-line of technology development – not just the potential immediate impact of the discrete technology being considered at any point in time; and
- for some technologies, economic benefits throughout the economy may fall quite a way from the point of immediate application of the technology (i.e. they have dispersed impacts and benefits).

It is worth emphasising that for most of these technologies, it is highly unlikely that New Zealand will be an exclusive adopter, so the global adoption profile is the one of most interest. As the results from all countries adoption show overwhelmingly net benefits flowing into New Zealand in the form of higher GDP and higher exports, this suggests that the key question for regulators is how to ensure that access to that potential flow of benefits is not inadvertently constrained while still maintaining an optimum risk management approach for health and environmental effects of adoption.

A Appendix 1: List of GTAP industry sectors

As discussed in the main body of the report, the affected sectors which were identified previously based on our literature review and input from workshop participants were defined according to the Australian and New Zealand Standard Industry Classification (ANZSIC). However, their ANZSIC definitions then had to be mapped into relevant GTAP sectors. However ANZSIC uses a more detailed sectoral breakdown of industry sectors than GTAP, creating a potential problem when mapping the ANZSIC sectors affected by the new technologies into the GTAP sectors as some of the ANZSIC sectors may account for only a part of the GTAP sectors. This problem was solved by carefully formulating the shocks to the GTAP sectors. For example, if a technology leads to 10 per cent reduction in production cost of a ANZSIC sector, and the sector accounts for half of a matching GTAP sector, then a 5 per cent reduction shock could be implemented to the whole GTAP sector. However what this means is that the GTAP sector used in the modelling and discussed in the results may be broader than the sector to which the technology being discussed is actually applicable.

Number	***Code***	***Description***
1	pdr	Paddy Rice: rice, husked and unhusked
2	wht	Wheat: wheat and meslin
3	gro	Other Grains: maize (corn), barley, rye, oats, other cereals
4	v_f	Veg & Fruit: vegetables, fruitvegetables, fruit and nuts, potatoes, cassava, truffles,
5	osd	Oil Seeds: oil seeds and oleaginous fruit; soy beans, copra
6	c_b	Cane & Beet: sugar cane and sugar beet
7	pfb	Plant Fibres: cotton, flax, hemp, sisal and other raw vegetable materials used in textiles
8	ocr	Other Crops: live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds, beverage and spice crops, unmanufactured tobacco, cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets, plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes, sugar beet seed and seeds of forage plants, other raw vegetable materials

9	ctl	Cattle: cattle, sheep, goats, horses, asses, mules, and hinnies; and semen thereof
10	oap	Other Animal Products: swine, poultry and other live animals; eggs, in shell (fresh or cooked), natural honey, snails (fresh or preserved) except sea snails; frogs' legs, edible products of animal origin n.e.c., hides, skins and furskins, raw , insect waxes and spermaceti, whether or not refined or coloured
11	rmk	Raw milk
12	wol	Wool: wool, silk, and other raw animal materials used in textile
13	frs	Forestry: forestry, logging and related service activities
14	fsh	Fishing: hunting, trapping and game propagation including related service activities, fishing, fish farms; service activities incidental to fishing
15	col	Coal: mining and agglomeration of hard coal, lignite and peat
16	oil	Oil: extraction of crude petroleum and natural gas (part), service activities incidental to oil and gas extraction excluding surveying (part)
17	gas	Gas: extraction of crude petroleum and natural gas (part), service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	Other Mining: mining of metal ores, uranium, gems. other mining and quarrying
19	cmt	Cattle Meat: fresh or chilled meat and edible offal of cattle, sheep, goats, horses, asses, mules, and hinnies. raw fats or grease from any animal or bird.
20	omt	Other Meat: pig meat and offal. preserves and preparations of meat, meat offal or blood, flours, meals and pellets of meat or inedible meat offal; greaves
21	vol	Vegetable Oils: crude and refined oils of soya-bean, maize (corn),olive, sesame, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and canola, mustard, coconut palm, palm kernel, castor, tung jojoba, babassu and linseed, perhaps partly or wholly hydrogenated,inter-esterified, re-esterified or elaidinised. Also margarine and similar preparations, animal or vegetable waxes, fats and oils and their fractions, cotton linters, oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; degras and other residues resulting from the treatment of fatty substances or animal or vegetable waxes.
22	mil	Milk: dairy products
23	pcr	Processed Rice: rice, semi- or wholly milled
24	sgr	Sugar
25	ofd	Other Food: prepared and preserved fish or vegetables, fruit juices and vegetable juices, prepared and preserved fruit and nuts, all cereal flours, groats, meal and pellets of wheat, cereal groats, meal and pellets n.e.c., other cereal grain products (including corn flakes), other vegetable flours and meals, mixes and doughs for the preparation of bakers' wares, starches and starch products; sugars and sugar syrups n.e.c., preparations used in animal feeding, bakery products, cocoa, chocolate and sugar confectionery, macaroni, noodles, couscous and similar farinaceous products, food products n.e.c.
26	b_t	Beverages and Tobacco products
27	tex	Textiles: textiles and man-made fibres
28	wap	Wearing Apparel: Clothing, dressing and dyeing of fur
29	lea	Leather: tanning and dressing of leather; luggage, handbags, saddlery, harness and footwear

30	lum	Lumber: wood and products of wood and cork, except furniture; articles of straw and plaiting materials
31	ppp	Paper & Paper Products: includes publishing, printing and reproduction of recorded media
32	p_c	Petroleum & Coke: coke oven products, refined petroleum products, processing of nuclear fuel
33	crp	Chemical Rubber Products: basic chemicals, other chemical products, rubber and plastics products
34	nmm	Non-Metallic Minerals: cement, plaster, lime, gravel, concrete
35	i_s	Iron & Steel: basic production and casting
36	nfm	Non-Ferrous Metals: production and casting of copper, aluminium, zinc, lead, gold, and silver
37	fmp	Fabricated Metal Products: Sheet metal products, but not machinery and equipment
38	mvh	Motor Vehicles: cars, lorries, trailers and semi-trailers
39	otn	Other Transport Equipment: Manufacture of other transport equipment
40	ele	Electronic Equipment: office, accounting and computing machinery, radio, television and communication equipment and apparatus
41	ome	Other Machinery & Equipment: electrical machinery and apparatus n.e.c., medical, precision and optical instruments, watches and clocks
42	omf	Other Manufacturing: includes recycling
43	ely	Electricity: production, collection and distribution
44	gdt	Gas Distribution: distribution of gaseous fuels through mains; steam and hot water supply
45	wtr	Water: collection, purification and distribution
46	cns	Construction: building houses factories offices and roads
47	trd	Trade: all retail sales; wholesale trade and commission trade; hotels and restaurants; repairs of motor vehicles and personal and household goods; retail sale of automotive fuel
48	otp	Other Transport: road, rail ; pipelines, auxiliary transport activities; travel agencies
49	wtp	Water transport
50	atp	Air transport
51	cmn	Communications: post and telecommunications
52	ofi	Other Financial Intermediation: includes auxiliary activities but not insurance and pension funding (see next)
53	isr	Insurance: includes pension funding, except compulsory social security
54	obs	Other Business Services: real estate, renting and business activities
55	ros	Recreation & Other Services: recreational, cultural and sporting activities, other service activities; private households with employed persons (servants)
56	osg	Other Services (Government): public administration and defense; compulsory social security, education, health and social work, sewage and refuse disposal, sanitation and similar activities, activities of membership organizations n.e.c., extra-territorial organizations and bodies
57	dwe	Dwellings: ownership of dwellings (imputed rents of houses occupied by owners)

Source: GTAP database documentation