The Importance of Crop Protection Products for The New Zealand Economy

NZIER Report to Agcarm

July 2019

About NZIER

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Each year NZIER devotes resources to undertake and make freely available economic research and thinking aimed at promoting a better understanding of New Zealand's important economic challenges.

NZIER was established in 1958.

Authorship

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Foreword

Agcarm is the peak New Zealand industry association of companies which manufacture, distribute and sell crop protection and animal health products. Our mission is to protect and enhance the health of crops, animals and the environment - through innovation and responsible use of quality products and services.

This report highlights the importance of the crop protection industry to New Zealand's economy. It's a small robust industry that has a significant impact on our land-based sectors. Even a small increase in horticultural productivity has a ripple effect in boosting the economy.

Without crop protection products, it is estimated that New Zealand's economy would lose between $7.5 to $11.4 billion.

Not only does the crop protection industry have an important part to play in supporting the economy, it is also vital for producing safe food and protecting our environment. From managing damaging pests and diseases, through to research and disposal, the industry is committed to the responsible use of crop protection products right throughout the product life-cycle.

This stewardship begins at the research and development phase of a product, going on to distribution and use, through the eventual phase-out and disposal of waste.

We are one of the founders, and a trustee, of the Agrecovery programme which recycles plastic containers and collects surplus agrichemicals. Our members fund the programme by paying a levy on the sale of products.

Ensuring farmers are trained on the most environmentally sound and responsible methods for protecting crops from pests is a priority for the crop protection industry. Our members work with trainers, regulators and growers to achieve the best pest control practices. This ensures we meet the global shared goals of health and safety to people, the environment and the food chain.

We also develop tools to manage biosecurity incursions which damage our native species and crops, along with leading initiatives to protect the health of bees.

Our industry focusses on stewardship and ensuring that there continues to be a variety of new products to offer pest control solutions for growers and farmers. Agrichemicals that are more environmentally-friendly, more effective and more targeted allow farmers to better control target pests, while protecting human health and allowing beneficial flora and fauna to prosper.

It is a combination of innovation and good plant health that will boost efficiency in farming practices and allow increasingly sustainable food production.

Pauline Calvert
President, Agcarm

Mark Ross
Chief Executive, Agcarm

Key points

The purpose of this report is to:

- » Estimate the economic impact of Crop Protection Products (CPP) in the New Zealand economy
- » Demonstrate the impacts of CPP on land-based industries
- » Illustrate the likely impacts of delays by the Environmental Protection Authority (EPA) on product assessments.

A small industry… with a big reach over the New Zealand economy

The crop protection industry represents a strong and stable generator of economic activity within the New Zealand economy.

- » Its economic contribution was $142.5 million in **2018**
- » The bulk of that impact is on industries that generate exports
- » The crop protection industry is less than 1% of GDP but the industries it services represent 10% of GDP
- » The crop protection industry is a small industry with a massive impact on New Zealand land-based industries
- » Table 1 sets out the approximate impacts of CPP. Withdrawing CPP from the market would cost between $7.5 and $11.4 billion to New Zealand.

Table 1 CPP contribution to crops,
Averaged 2016 - 2018, in $ million, Contribution to GDP

Crop	Value ($ million)	Impact ratio	Total impact ($ million)	Comment
Forestry	$5,500	0.07 – 0.27	$44 –$1,723	Mainly herbicides
Pasture	$17,100	0.05 – 0.20	$855 – $3,400	Mainly herbicides
Horticulture	$5,000	0.75	$3,800	Mainly fungicides and insecticides. Some herbicides
Vegetables	$1,400	0.88	$1,200	Mainly fungicides and insecticides. Some herbicides
Field crops	$2,100	0.52	$1,100	A combination of fungicides, insecticides and herbicides
Other	$135	0.80	$108	
Total	**$31,240**	**0.24–0.36**	**$7,500–$11,400**	

Source: NZIER

The direct contribution of CPP

As well as the $142.5 million in GDP contribution the crop protection industry:

- Directly employs 310 highly skilled workers
- Creates between 1,000 and 1,100 indirect jobs in sales, marketing, agronomy, spray contractors, transport etc.

This is based on turnover estimated at $350 million at the wholesale level[1].

Small increases in productivity can have major impacts

- A small increase in productivity can be worth between $10 million and $100 million in horticulture
- The impact of the crop protection industry during the PSA – V crisis illustrates how critical CPP can be in safeguarding horticultural productivity and managing the risk of a massive loss in production
- Without CPP we would have a severely reduced kiwifruit production capability
- Also, the steady incremental productivity advances that underpin horticulture's success would be eroded.

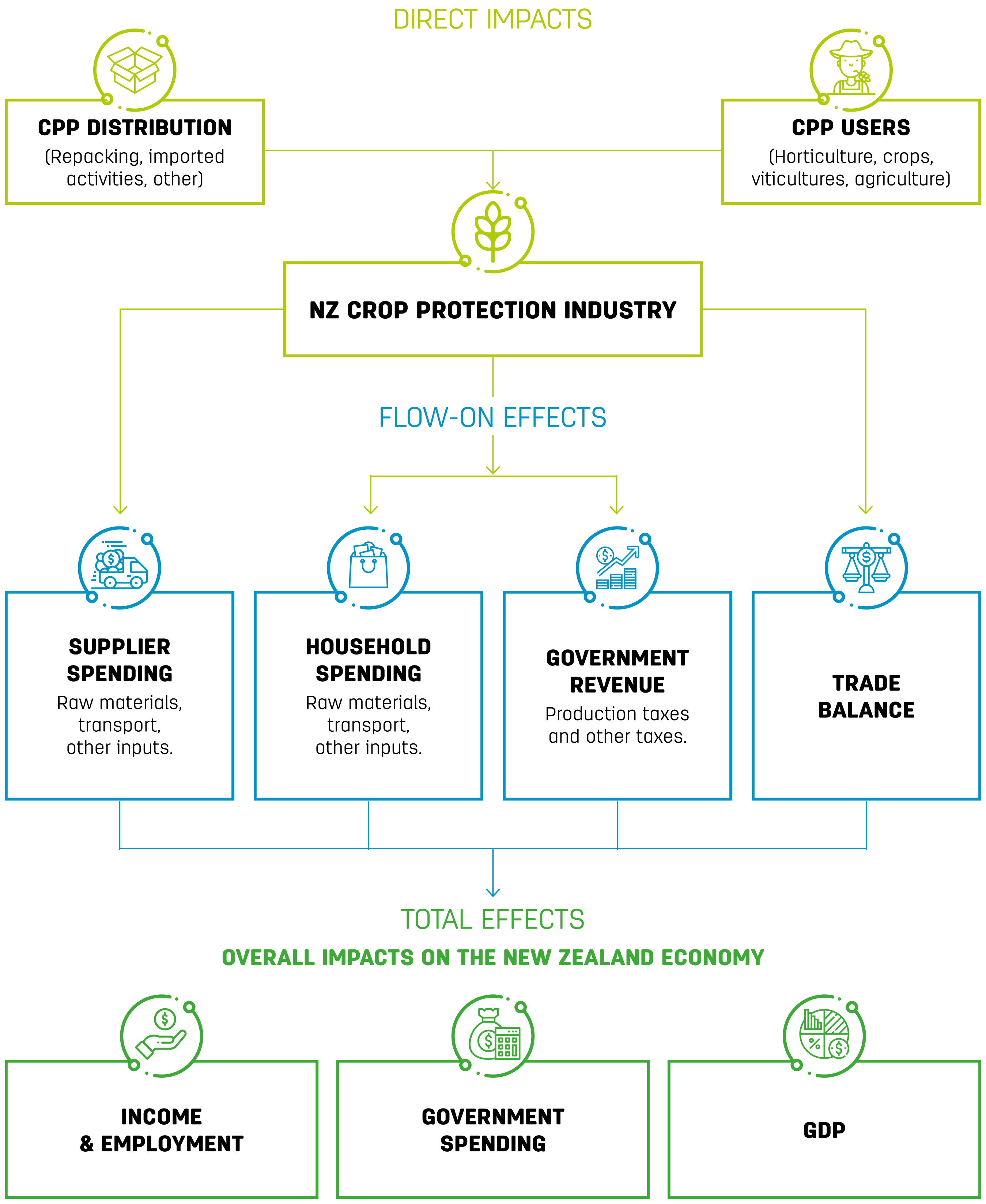
Cost of delays is damaging to the economy and environment

In the last five years the time taken for EPA to approve applications has doubled. This has both economic and environmental implications.

- Over ten years, this costs New Zealand between $7 million and $70 million (discounted at 6%) in contribution to GDP
- Because CPP are becoming softer (i.e. lower toxicity), the delay means that harder chemicals are kept on the market longer; impacting on the environment.

[1] Agcarm

Figure 1 Impact of the crop protection industry on the New Zealand economy



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1/ The importance of CPP

1.1. The task

We have been asked by Agcarm to demonstrate the value of the crop protection products (CPP) industry and its impact on land-based industries; and illustrate the impact of efficiency (specifically the time delays being experienced) in the regulatory system that governs CPP.

This report identifies the crop protection industry's current contribution to the New Zealand economy and looks at other economic impacts of the crop protection industry in New Zealand.

CPP include herbicides, fungicides, insecticides and other crop protection products, which are widely used in land-based production to protect production and increase its productivity.

We include chemical products that are synthetic and naturally occurring.

To assess the value of CPP and the effect of time required for regulator decisions we will:

» Use NZIER's Computable General Equilibrium (CGE) model of the New Zealand economy to examine how the crop protection industry impacts on spending and employment in the New Zealand economy

» Focus on the crop protection companies and their operations within New Zealand given their significant support of agriculture, forestry, crops, and horticulture

» Focus on the interaction between the crop protection industry and the regulatory agencies, specifically discussing the significance of delays with registration of crop protection products.

We have drawn on international studies, case studies, information from the crop protection industry, past assessments, and other independent sources.

The analysis is intended to give industry stakeholders and policy makers an indication of the benefits of the CPP industry and the importance of the efficient application of regulation. The efficient application of regulation is critical for smaller countries since smart and efficiency regulation is a competitive weapon that cannot be replicated in larger economies with more cumbersome regulatory regimes.

The report provides estimates of economic contribution: Gross output less intermediate output (running or variable costs) and CPP impact.

As such, the estimates of economic contribution (Section 2) and the impact on other industries (Section 3) cannot be added together [2].

[2] Section 2 estimates Contribution to GDP (Gross Out – Intermediate Production) of the CPP industry and Section 3 focuses on Gross Output of the industries that use CPP.

1.2. The CPP industry in New Zealand

1.2.1. Overview of the sector

CPP are a big deal in the New Zealand economy. The economic value of the crop protection industry is estimated at $350 million at the wholesale level [3].

CPP are a vital part of New Zealand's land-based production systems. Over the long term, New Zealand's land-based exports would be undermined without these products. The industry is dynamic with a trend for products with new active ingredients to be of lower toxicity, while older products, usually with higher toxicity are being withdrawn.

The drive for 'softer' products is consumer driven since food safety is a highly sensitive subject. Consumers are demanding that the food that they eat has minimal residues. CPP companies have responded by reducing toxicity in new products.

In New Zealand, regulation of CPP is conducted by two agencies:

» The Agricultural Compounds and Veterinary Medicines (ACVM) group. The ACVM group is part of the Food Safety division of the Ministry for Primary Industries (MPI) which registers individual trade name products that are either agricultural compounds or veterinary medicines. Specifically, ACVM examines efficacy, manufacturing, crop safety, residues, and labelling [4]

» The Environmental Protection Authority (EPA) operates under the Hazardous Substances and New Organisms (HSNO) Act. The EPA's objective is to keep people and the environment safe while promoting economic progress. It is also required to meet obligations under various international agreements. The EPA reports to the Ministry for the Environment which monitors EPA activities.

The industry is dynamic with a trend for products with new active ingredients to be of lower toxicity.

[3] Agcarm
[4] For further information see https://www.mpi.govt.nz/processing/agricultural-compounds-and-vet-medicines/

1.2.2. What products and what are they used for?

CPP can be classified into four category areas:

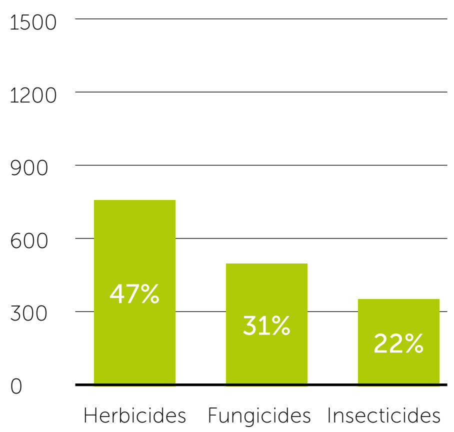
- **Herbicides.** Products intended to prevent or suppress weeds that are:
  - Specifically used to target weeds without killing crops
  - Non-specific chemicals that target all plants
- **Insecticides.** Products that attempt to control insects in plants and crops
- **Fungicides.** Products that control and prevent fungal diseases in plants
- **Other.** These include plant growth regulators, surfactants and other products used in pest management.

CPP work to increase productivity by:

- Decreasing and controlling pests and disease
- Reducing the competition between crops and weeds
- Increasing yields and/or protecting biodiversity
- Protecting infrastructure such as buildings and roads through pest and weed control.

Figure 2 gives an indication of the significance of the various CPP used in New Zealand. The number of herbicide products illustrate the dominance of herbicide use – particularly in pasture. They are also used in forestry and cereal crops.

Figure 2 Number of crop protection products registered, 2018*



Protecting infrastructure such as buildings and roads through pest and weed control.

* Source: New Zealand Food Safety/ ACVM register, NZIER

1.2.3. The report is based on methodologies used in the United States, Canada and Australia

Recent studies in the industrialised world have been commissioned to illustrate the importance of CPP on agriculture. Below we examine some of these studies.

Mark Goodwin Consulting (2011) details the value of selected crops that are significantly supported (and therefore attributable) to CPP. The methodology determined the proportion of crop value attributable to CPP using methods developed by Gianessi et al (2006).

The impact of CPP on the United States is very large. The direct contribution of CPP to the United States economy is approximately US$ 81 billon, with flow-on benefits of US$ 166.5 billon across at least 20 industries, and approximately 1 million domestic jobs depend on these products.

CropLife Canada (2011) examined contributions of CPP as well as plant biotechnology. It quantified the yields between conventional and organic crops. It then set out crop attribution as the difference in yields multiplied by the price of the crop. It calculated that the value to Canada is approximately CA$ 8 billion.

In Australia, the AEC Group (2002) developed a cost benefit analysis on government management of pest and weed management in Queensland. It found that for every A$1 spent on pest and weed management the return was between A$10 and A$27.

In a study for the New Zealand MAF, Giera and Bell (2009) estimated that the total cost of pests and weeds was approximately New Zealand$ 2.1 billion. While no estimate was given to show the impact of CPP, the large scale weed and pest problem suggests that the impacts of CPP in supressing weeds and pests are substantial.

Two further studies by Deloitte Access Economics (2013, 2018) estimated the contribution of CPP in Australia. In the 2018 study, using the Mark Goodwin Consulting (2011) methodology, it estimated that the industry was worth A$ 2.3 billion to the Australian economy and that A$ 20.6 billion of agricultural output can be attributed to the use of CPP.

In all these cases, the impact of CPP is substantial. The literature demonstrates that CPP underpin land-based industries in Canada, Australia and the United States to the point that the industry is one of the cornerstones of success in modern agricultural production.

2/ CPP contribution to the New Zealand economy

The CPP marketing chain generates income for the participants and the New Zealand economy. This section sets out the economic contribution CPP make including the direct economic contribution and indirect contribution associated with inputs bought to keep the industry running (intermediate consumption).

Figure 3 sets out the CPP marketing chain relationships. The supplying sectors deliver services from other industries such as transport, electricity, and raw materials.

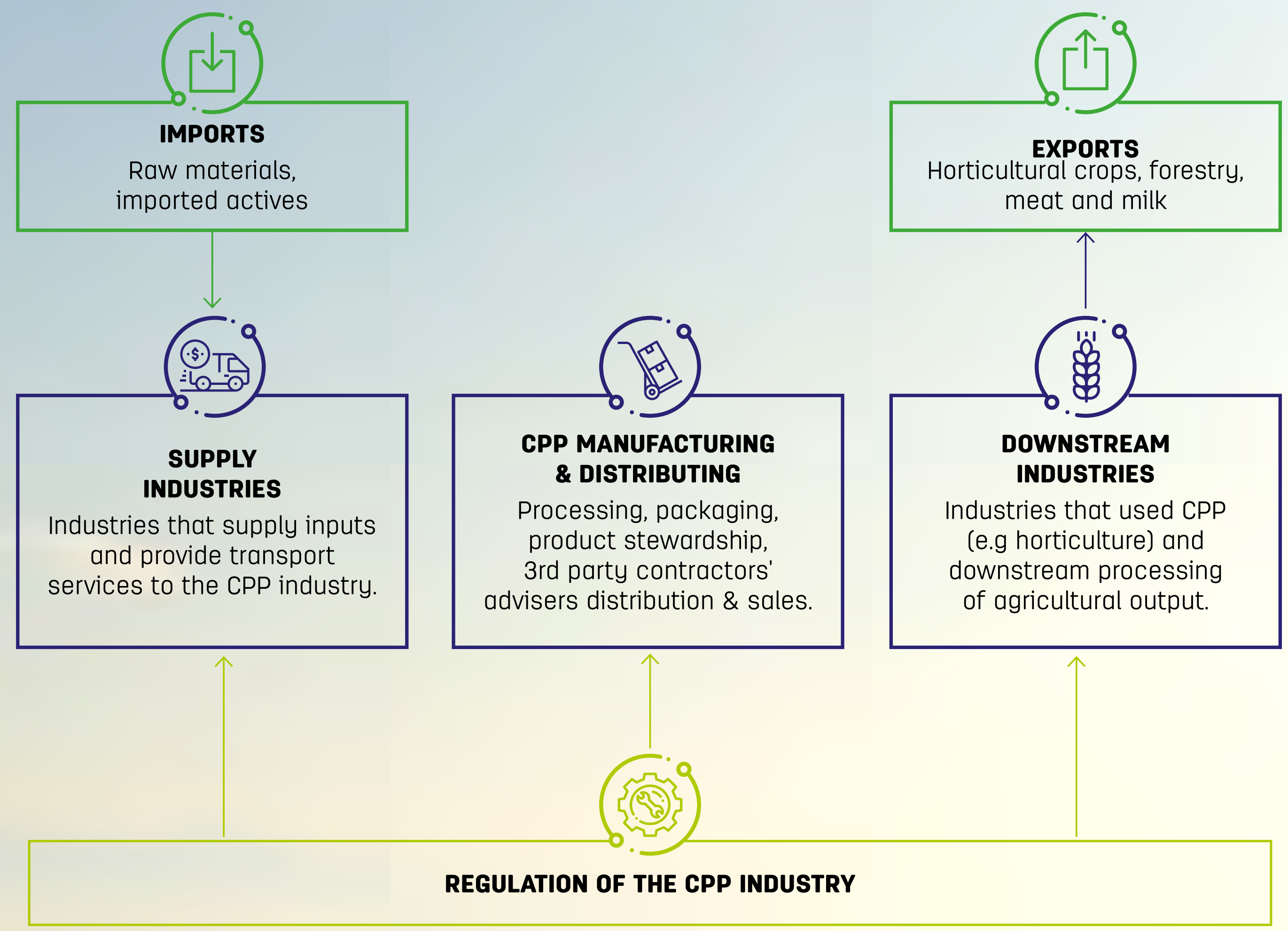
The manufacturing and distribution chain set out how the imported active ingredients are combined with domestically-produced ingredients (transport and warehousing and other inputs) and the ways the products are distributed and collected after use. This includes private consultants as well as those employed by companies.

It shows the industries that use CPP (including horticulture, viticulture, forestry, and agriculture) and downstream processing (meat and milk processing).

The imports associated with bringing in the active ingredients and the exports of finished products, either raw or processed, highlight the importance of international trade for CPP and how CPP underpin important New Zealand exports.

An important part of the CPP marketing chain is how it is regulated. If regulation – particularly in a small country – is part of its comparative advantage (i.e. more nimble, able to balance the benefits, costs, and risks more quickly than others, and looks to be a fast follower) then we need to further understand how well regulation is working for New Zealand. This is discussed in more detail in section 4.

Figure 3 CPP marketing chain relationships



2.1. Direct CPP impact on GDP

CPP contributes $142.5 million of GDP to the New Zealand economy. This includes GST, rates, labour, and returns to capital (see Table 2).

Total gross output is estimated at $350 million at the factory gate[5]. This has increased in recent years on the back of a growing horticultural sector – particularly the increase in export crops of kiwifruit, avocados, and apples.

Herbicides (see Figure 2) represents the dominant product range. This is not surprising, given the strong focus on pasture and forestry-based products.

Table 2 Contribution of the CPP industry to the New Zealand economy, National income 2018

	$ millions	Comments
Tax on commodities	$1.0	Mainly GST
Production taxes	$3.0	Rates
Labour	$37.5	Wages
Capital	$95.2	Return on capital
Land	$2.8	Return on land
GDP	**$142.5**	

Note: Numbers rounded.

Source: NZIER

[5] Agcarm

2.2. Direct and indirect jobs

The number of jobs reflects the small size of the crop protection industry and the large land-based sector impacts.

We estimate that the crop protection industry employs around 310 full-time equivalents (FTEs). Typically, these people are well paid professionals overseeing the CPP imports, dealing with crop trials, and communicating with regulatory authorities. Some staff dealing with New Zealand regulatory issues are based in other countries (particularly Australia). This signals the global nature of the business.

The number of indirect jobs is more significant given the size of the industries that depend on CPP. Many of those involved in the sales and marketing of CPP are also marketing a portfolio of other products to farmers. Therefore, they are only working part time in the industry. The types of jobs include:

- those involved in aerial application of CPP
- those who mix chemicals
- spray contractors for ground spray application
- sales staff
- transport

Spray contractor estimates are the most difficult to pin down since there are an estimated 150 companies involved in this activity. Some of these registered companies are regional councils. The best industry estimate of indirect jobs is between 1,000 and 1,100 FTEs.

2.3. Where are the products used?

Figure 4 sets out where products are used. The crop protection industry is a small industry in the New Zealand context. Much less than 1% of the New Zealand economy.

This is not the full story, when you include the industries that it services (the land-based agricultural industries and their downstream processing and exporting industries) the impact is very large, i.e. 10% of New Zealand's GDP.

Table 3 CPP and industries serviced by CPP, 2018

	Impact (NZ$)	Impact (%)
New Zealand GDP	$284,363,000,000	
CPP contribution to GDP	$142,500,000	Much less than 1%
Industries CPP services' contribution to GDP	$28,383,000,000	10%

Source: NZIER

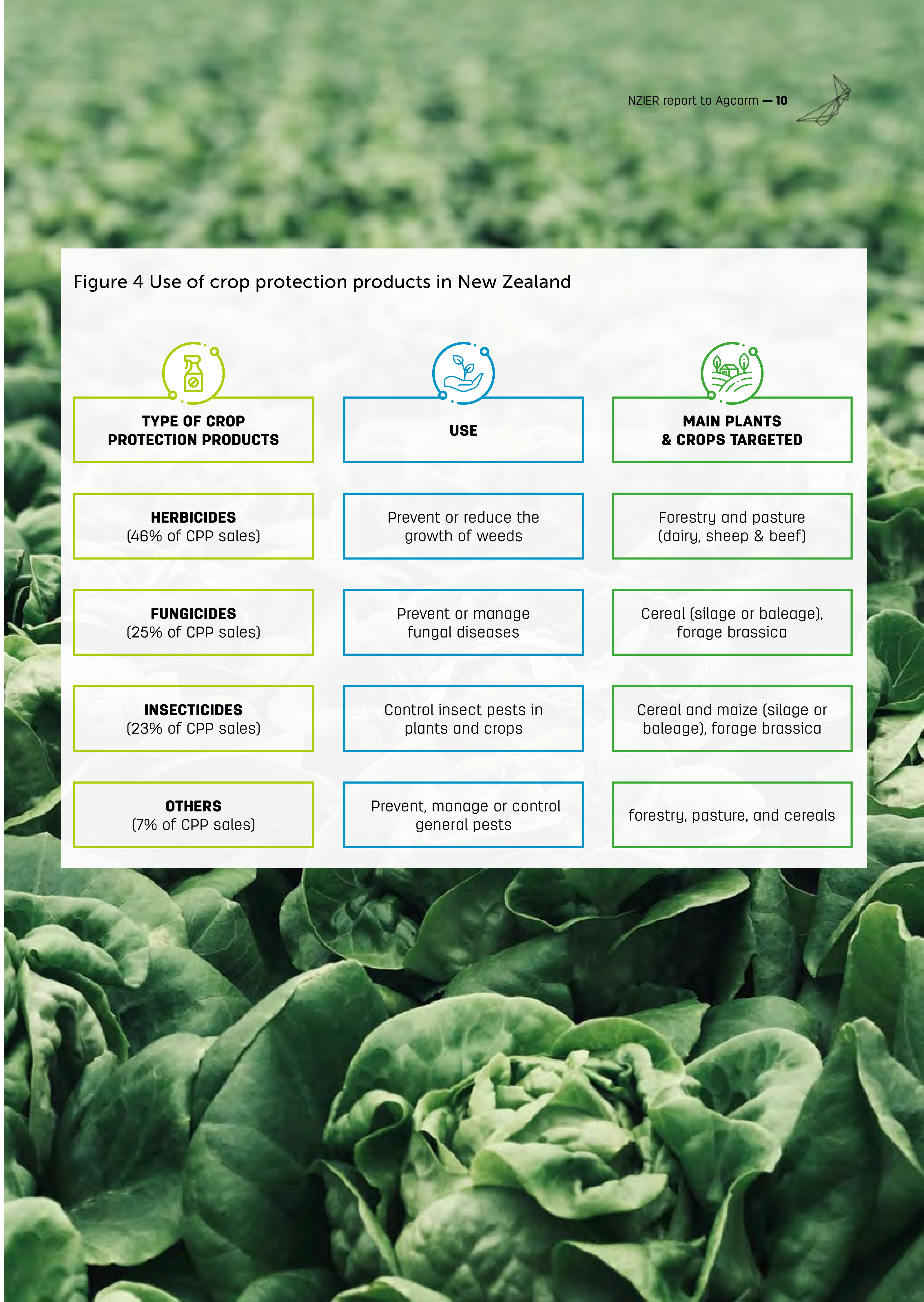


Figure 4 Use of crop protection products in New Zealand

TYPE OF CROP PROTECTION PRODUCTS	USE	MAIN PLANTS & CROPS TARGETED
HERBICIDES (46% of CPP sales)	Prevent or reduce the growth of weeds	Forestry and pasture (dairy, sheep & beef)
FUNGICIDES (25% of CPP sales)	Prevent or manage fungal diseases	Cereal (silage or baleage), forage brassica
INSECTICIDES (23% of CPP sales)	Control insect pests in plants and crops	Cereal and maize (silage or baleage), forage brassica
OTHERS (7% of CPP sales)	Prevent, manage or control general pests	forestry, pasture, and cereals

2.4. Economic impact of the crop protection industry in New Zealand using CGE

2.4.1. Our modelling approach

Below we assess the macroeconomic and industry contribution of CPP in New Zealand.

To evaluate these impacts, we use the NZIER's ORANI top-down computable general equilibrium (CGE) model of the New Zealand economy [6]. ORANI-NZ is based on the latest Stats NZ Input-Output table* that identifies the structure of industries involved.

As this CGE model is static, it looks at 'before' (i.e. current situation) and 'after'. For our scenario design, we implement a productivity increase in horticulture to measure the impact of dynamic efficiency gains across a wide range of horticultural crops and in pasture that result from the use of CPP. We focus on horticulture as CPP are used extensively in this industry [7].

To model this 'shock' (in the modelling jargon), we assess its potential magnitude. This was a challenging task given the lack of New Zealand relevant empirical studies.

In lieu of empirical evidence, we developed our scenarios through an iterative process with industry stakeholders. We used our estimations of CPP on horticultural crops (see section 3.1.4) and on dynamic efficiency gains (see section 4.2.4) to build three scenarios of productivity increase in horticulture.

Our three scenarios are a:

- High scenario, in which we consider a higher increase in productivity (2.76%) in horticulture
- Medium scenario, in which we consider a medium productivity increase (1.17%) in horticulture
- Low scenario, in which we model a lower increase (0.17%) in productivity in horticulture.

We acknowledge that other parameters could have been selected for this modelling exercise. These scenarios are purely illustrative, and should more empirical evidence come to light, it would be easy to re-design the scenarios and re-run the CGE modelling.

Once we have shocked the model [8], we can then determine the flow-on effects throughout the national economy on GDP and household income.

More detail on the simulations can be found in Appendix B.

[6] See Appendix B.2 for a description of the model. [7] Also, horticulture is a growth sector which is highly dependent on CPP.
[8] For this modelling exercise, we choose a short-run closure. Further details can be found in Appendix B.5.
* We used the Statistic NZ Input-Output table for 2013 released in November 2017. We also used the latest National Accounts from Statistic NZ, for year ended March 2018, to scale up our database and make sure our database takes into account the latest GDP figure.

2.4.2. New Zealand's economy is expanding

Table 4 shows the macroeconomic impacts of a productivity increase in the horticulture industry.

Table 4 Macroeconomic effects of higher productivity in horticulture, Changes from baseline (2018), in $ million (in real terms) and percent.

Indicator	High		Medium		Low	
	% change	Level ($m)	% change	Level ($m)	% change	Level ($m)
Real GDP	0.04%	$101.5	0.02%	$55.4	0.004%	$10.0
Household consumption	0.04%	$57.5	0.02%	$31.4	0.003%	$5.6
Employment	0.03%	$24.5	0.01%	$13.3	0.00%	$2.4
Exports	0.13%	$28.1	0.07%	$15.3	0.013%	$2.8
Imports	0.00%	-$27.1	0.00%	-$14.8	0.000%	-$2.7
Investment	0.04%	$24.7	0.02%	$13.5	0.004%	$2.4
Capital stock	0.04%	$44	0.02%	$24	0.004%	$4

Source: NZIER

2.4.3.National industry outputs expand

Table 7 sets out the direct and flow-on impacts associated with the industry.

Table 5 Direct and flow-on effects on supporting industries, Changes from baseline (2018), in $ million (in real terms)

Industry	High	Medium	Low
Horticulture & fruit growing	$109.09	$59.51	$10.68
Food manufacturing	$5.68	$3.14	$0.57
Meat manufacturing	$3.66	$1.99	$0.36
Dairy product manufacturing	$3.44	$1.87	$0.34
Agriculture, forestry, & fishing support services	$3.02	$1.66	$0.30
Grocery & liquor product wholesaling	$2.34	$1.27	$0.23
Road transport	$2.18	$1.19	$0.21
Machinery & equipment wholesaling	$2.01	$1.10	$0.20
Food & beverage services	$1.57	$0.87	$0.16
Basic material wholesaling	$1.32	$0.72	$0.13
Other goods wholesaling	$1.29	$0.70	$0.13
Supermarket & grocery stores	$1.19	$0.65	$0.12
New Zealand industry output	**$145.50**	**$79.53**	**$14.30**

Source: NZIER

2.4.4.Real exports increase marginally

Table 6 shows the impact of yield increase on real exports. New Zealand exports increase marginally by 0.13% ($28 million). Supporting industries also experience an increase in their commodity exports, along with their outputs.

Table 6 Impacts on exports, Changes from baseline (2018), in percent

Industry	High	Medium	Low
Other fruit & nuts	7.97%	4.32%	0.77%
Vegetables	6.33%	3.44%	0.61%
Living plants & other crops	6.01%	3.26%	0.58%
Apples and pears	4.08%	2.22%	0.40%
Kiwifruit	3.35%	1.82%	0.33%
Cattle	0.32%	0.17%	0.03%
Bakery products	0.26%	0.14%	0.03%
Forage products, fibres & sugar crops	0.23%	0.12%	0.02%
Macaroni & noodles	0.16%	0.09%	0.02%
Prepared vegetables	0.16%	0.09%	0.02%
Prepared fruit & nuts	0.14%	0.08%	0.01%
Wool	0.12%	0.07%	0.01%
Sugar & confectionery products	0.12%	0.07%	0.01%
Animal feed	0.12%	0.06%	0.01%
Grain products	0.10%	0.05%	0.01%
Total New Zealand exports	**0.13%**	**0.07%**	**0.01%**

Source: NZIER

2.4.5. Employment and wages rise

Table 7 presents the impacts of higher yields in horticulture on employment and wages. National employment increases by 2.6% in the high scenario, by 1.4% in the medium scenario and by 0.3% in the low scenario.

Table 7 Impacts on employment and wages, Changes from baseline (2018), in $ million and percent

Industry	High	Medium	Low
Horticulture & fruit growing	2.159%	1.175%	0.210%
Agriculture, forestry, & fishing support services	0.156%	0.086%	0.015%
Food manufacturing	0.119%	0.066%	0.012%
Warehousing & storage services	0.116%	0.064%	0.011%
Labour unions & other interest groups	0.069%	0.038%	0.007%
Fertiliser & pesticide manufacturing	0.067%	0.037%	0.007%
Grocery & liquor product wholesaling	0.065%	0.035%	0.006%
Building cleaning & other support services	0.064%	0.035%	0.006%
Non-residential property operation	0.061%	0.034%	0.006%
Basic material wholesaling	0.052%	0.029%	0.005%
Supermarket & grocery stores	0.050%	0.028%	0.005%
Machinery & equipment wholesaling	0.048%	0.026%	0.005%
Motor vehicle parts wholesaling	0.048%	0.026%	0.005%
Road transport	0.047%	0.026%	0.005%
Fuel retailing	0.047%	0.025%	0.005%
Specialised food retailing	0.046%	0.025%	0.005%
Total	**2.670%**	**1.461%**	**0.263%**

Source: NZIER

2.5. The impact of CPP in the PSA crisis

The estimates in Table 7 show how sensitive the horticulture industry is to changes in productivity (from innovation).

While innovation can come from anywhere (e.g. changes in farm practice, new varieties, increased scale, new markets etc.) most come from small changes, sometimes imperceptible to those outside the industry. In this respect, CPP have a role to play. We know this because of the willingness of farmers and growers to buy CPP, the field trials that demonstrate improved production from use of CPP, and large numbers of indirect FTEs that participate in the industry over the long term.

To give meaning to the impacts set out in the previous section, it is useful to illustrate the impact of a particular productivity shock.

For illustrative purposes, we have chosen to look at the PSA crisis and the role of CPP.

Certain diseases have subtle impacts on horticulture products and others are much more dramatic. The impact of one strain of the PSA (PSA -V) bacteria on kiwifruit was dramatic.

PSA had the ability to kill the vine if left unmanaged:

» Once established in the kiwifruit plant, it multiplied very quickly and choked the plant

» Dieback occurs within one season, particularly in the case of gold kiwifruit 16a

» Even with crop protection products, disease in gold kiwifruit 16a was not able to be managed.

The last point is very important since control of PSA required a number of elements to be combined before the disease could be managed and the industry was able to thrive again.

These included:

» The fast-tracking of a new yellow variety SunGold 3, which was much more tolerant of PSA-V

» Good agronomy practices

» Good fertiliser programmes

» A comprehensive watering schedule

» Use of CPP.

The willingness of growers to dump 16a and plant SunGold 3 was the most significant factor in the crisis to manage PSA–V (interview with Joel Vanneste, Plant and Food Research).

However, we know that CPP were a significant part of the solution. The importance of CPP was signalled by the scramble by government (in the form of Plant and Food Research) to work out which chemicals could have an impact.

Over 300 chemicals were tested and half a dozen were found to be effective. Plant and Food knew that only a few products would work, but wanted to make sure that it could say to the industry that it had tried everything and that no product/compound had been left out of the analysis (interview with Joel Vanneste, Plant and Food Research).

The products that were effective included:

Copper and zinc products. These products were the mainstay of the programme

Plant antibiotics e.g. streptomycin

Elicitors e.g. Actigard

Biological products.

Once the products were identified, the ACVM (who registered the products) fast-tracked them through the regulatory system. The products were exempted from field trials and tests were done on potted vines to generate proof of efficacy.

This type of action, in a national emergency, was necessary. However, all stakeholders are not advocating for field trials to be dropped. Both the government and the crop protection industry face significant reputational risk if efficacy is compromised or unintended consequences result from a shortened regulatory assessment process.

The global nature of the industry means that the actions of New Zealand regulators and CPP companies can have reputational effects. It is important to note that the government and the kiwifruit industry believed it was important that companies were lobbied to take part in this process. This is due to the fast-tracking risks that needed to be taken in such a crisis.

Without CPP, kiwifruit would have suffered substantial drops in production, particularly in 2012 and 2013 when the young SunGold 3 vines were being established and their immunity to the virulent strain was low. Plant antibiotics and elicitors had an important role in ensuring that SunGold 3 could resist the disease.

While the PSA crisis was a special case, it does highlight the importance that CPP play in the New Zealand economy.

The last section provides some explanation of the typical year-on-year impacts that innovation has on an industry.

This section shows that the crop protection industry is part of that innovation mix which sustains land-based industry growth.

3/ New Zealand agricultural reliance on CPP

This section examines the impact of CPP on New Zealand land-based industries. This cannot be compared with GDP impact from productivity changes estimated in the last section, rather it is an estimate of the reliance of New Zealand land-based industries on CPP.

For many land-based industries it would not be possible to grow commercial quantities of a crop without CPP. In other cases, it would be possible, but yields would be much lower (therefore, less profitable) and the impact on the economy would be substantial. The estimates of land-based production reflect this fact.

We are not seeking to run an experiment to remove CPP from the economy since the economic impact would be difficult to gauge. Such a scenario would involve changes in practice that may partly offset the absence of CPP. Instead we will report estimates that show the current production attributable to CPP, based on current practice.

To illustrate the attribution, we have used the US and Australian studies (Deloitte Access Economics (2013, 2018), Gianessi L. (2009), and Mark Goodwin Consulting (2011) as a guide to the approximate value as well as domestic estimates. Those reports detail the value of selected crops attributable to CPP (specifically herbicides, insecticides and fungicides).

This is discussed in the following sub sections.

3.1. Adjustment factors required

Australia, the United States and New Zealand have very different agricultural industries given our geography, latitude/longitude, and other factors.

Of specific importance are:

- New Zealand has a temperate climate with higher rainfall than many parts of Australia and the United States. This means some weeds grow well relative to warmer climates, such as Australia, but it does not have insects such as fruit fly
- New Zealand is a small island (relative to Australia). Despite increasing amounts of trade and pest incursions, many of the most harmful pests and diseases are not present in New Zealand
- New Zealand has a wide variety of soils from very young to old (although not as old as Australia). The wide variety of soils has implications for fertiliser use, competition from weeds, and use of CPP
- Farmers in both Australia and New Zealand have, over recent decades, sustained incremental increases in crop and livestock production. At the same time, there have been adjustments in industries towards economies of scale, mechanisation, specialisation, and higher use of inputs.
- New Zealand agriculture labour costs are about 70% of their Australian counterparts [9]. Possibly, Australian producers are more likely to substitute CPP for labour. New Zealand agricultural labour costs are higher than those in the United States.

The difference set out above translates into differences in the use of CPP. Application rates for all herbicides, fungicides and insecticides will differ per unit between countries. Also, as New Zealand has a large number of different soil types and micro climates, applications of CPP may vary between regions.

To gain perspective of the New Zealand situation, we interviewed staff at crop protection companies and considered the Australia and United States data. Further, New Zealand agriculture has a different mix of products with a strong emphasis on pasture and forestry use of herbicides.

As you would expect, the mix of different crops has a major impact on the impact of CPP e.g. higher applications of CPP are generally used in high-value horticultural production compared to field crops. The use of herbicides in forestry is minimal.

The share of production attributable to CPP also changes e.g. it is higher for covered crops than it is for wheat and barley.

These differences are accounted for in the calculation of the proportion of the total value of production of each broad category attributable to the use of CPP (see Table 8).

[9] See for example: https://countryeconomy.com/countries/compare/australia/new-zealand?sector=Average+Wage&sc=XEAB#tbl

Table 8 Crop value and reliance on crop protection products
Averaged 2016 - 2018, in $ billion, Contribution to GDP

Crop	Value estimates[1] ($ billion)	Impact ratio on crops using CPP	Degree of reliance
Horticulture	$4.9	0.76	Very reliant on crop protection products
Vegetables	$1.4	0.88	Very reliant on crop protection products
Forestry	$5.5	Btw 0.07 and 0.27	Some reliance on herbicides
Pasture	$17.1	Btw 0.05 and 0.20	Some reliance on herbicides (conservative estimate)
Field crops	$2.1	0.52	Reliant on crop protection products
Total	**$31.0**		

Note [1] includes approximate estimates of domestic consumption, processing and exporting
Source: NZIER

We have used data from a variety of sources to estimate impacts. These include:

- New Zealand spend on CPP (Agcarm)
- Domestic spend on production crops (NZIER 2015)
- Fresh facts (various years) for current export value[10].

The aim has been to average the crop value, processing, and exporting over a number of years to estimate likely impacts. This also helps to take account of year-to-year fluctuations in weather conditions.

US and Australian data were drawn from Deloitte Access Economics (2013, 2018) on crop protection and also from interviews with industry.

The use of herbicides in forestry is minimal.

[10] http://www.freshfacts.co.nz/

3.1.1. Value of CPP methodology

In this study we have examined 6 categories. The average herbicide, insecticide, and fungicide contributions to the production of each crop category have been estimated based on the mix of individual crops. Adjustments have also been made based on interviews and impacts overseas.

Below we look at each sector separately.

3.1.2. Forestry

The main plantation forestry crop is Pinus radiata comprising 90% of the area planted and 93% of the harvested volume. Douglas fir is 4% of the planted area with other exotic forests comprising of California Redwoods, Eucalyptus, Cupressus, and other minor species.

Controlling vegetation that competes with the establishment of forests planted for timber or fibre production is vital. Wagner et al (2006) reports that the volume improvements from early weed control are between 7% and 27% in New Zealand conditions [11].

According to Rolando (2013), glyphosate is the most widely used active ingredient in pre-plant weed control, with terbuthylazine and hexazinone used most widely for post-plant weed control. Together these herbicides comprise 90% of the estimated 447 tonnes of active ingredient that is annually used on the approximately 1.7 million hectares of planation forests.

Table 9 CPP contribution to forestry 2018
Averaged 2016 - 2018, in $ million, Contribution to GDP

	Value ($ million)	Impact ratio	Total impact ($ million)	Comment
Value to New Zealand	$5,500	0.07–0.27	$447–$1,723	Mainly use of herbicide

Source: NZIER

[11] Forestry industry participants also report that herbicides also assist growth and survival in quite unexpected ways. Not only does herbicide reduce competition for light it also reduces foresting. Frosting stops movement of air, particularly grasses on flat and high altitude central North Island forests. Weed removal can increase air temperature by 1-3 degrees which is generally enough to avoid frosting, particularly of season i.e. February when there is abundant new growth on the seedling.

3.1.3. Pasture

Pasture is essential to the New Zealand economy. Without a productive pasture the New Zealand economy would struggle to deliver the economic growth gains we have enjoyed over the past twenty years.

Ryegrass, clover, plantain, chicory, browntop,cocksfort, tall fescue etc. have a major impact on New Zealand livestock farming. Pasture provides around 90–95% of the dietary/energy requirements for livestock.

The importance of pasture is highlighted by a recent AgResearch report (Ferguson et al 2019) that puts the cost of pasture losses at between $1.7 billion and $2.3 billion. This reinforces the importance of CPP in keeping production at current levels given the constant struggle to keep weeds under control.

The role of CPP in supporting pasture could be in the range of 5% to 20% of livestock production, processing and exporting (interviews). This, we believe, is conservative given that controlling weeds in one year assists in controlling them in subsequent years. Also, the impact of herbicide weed control during pasture renewal is vital.

Typically, the more intensive the agriculture (e.g. dairying), the more likely that impact will be higher because the returns are higher from using CPP.

In this situation we have not compared and contrasted the Australian and United States use of pasture since their livestock systems are quite different (grain-fed). Therefore, the importance of pasture is much less.

Table 10 CPP contribution to pasture 2018,
Averaged 2016 - 2018, in $ million, Contribution to GDP

	Value ($ million)	Impact ratio	Total impact ($ million)	Comment
Value to New Zealand	$17,100	0.05–0.20	$855–$3,400	Mainly use of herbicide

Source: NZIER

3.1.4. Horticulture (fruit and nuts)

Horticulture comprises of export crops such as kiwifruit, apples, avocados, grapes (wine), prunus, and many domestic crops such as citrus, feijoas, and tamarillos.

While some herbicides are used, fungicides and insecticides are mainly used to support horticultural production. The weighted average contribution of herbicides, insecticides, and fungicides has been estimated using estimates from the United States, Australia, publications (Deloitte Access Economics (2013, 2018), Gianessi L. (2009), and Mark Goodwin Consulting (2011)), and industry interviews.

In some cases, fungicides alone account for 100% of horticulture production, although herbicides and insecticides also contribute to the value of horticultural production. We have estimated the impact of CPP across horticulture at around 75%.

As with other industrialised nations, this is a significant impact. Horticulture is reliant on CPP for commercial production (see Table 11).

Table 11 CPP contribution to horticulture 2017,
Averaged 2016 - 2018, in $ million, Contribution to GDP

	Value ($ million)	Impact ratio	Total impact ($ million)	Comment
Value to New Zealand	$5,000	0.75	$3,800	Mainly fungicides and insecticides. Some herbicides

Source: NZIER

3.1.5. Vegetables

Vegetable crops are mainly for domestic consumption and include broccoli, carrots, onions, potatoes, and covered crops (tomatoes, cucumber, capsicums etc.). Vegetable exports to Australia over the past 20 years, though, have increased dramatically.

Vegetables are dependent on CPP, particularly fungicides. Crops like onions would be very difficult to grow without fungicides. In many cases the contribution of herbicides, fungicides, and insecticides is greater than 100%. We have estimated the impact as 88% given industry and US literature, Gianessi L. (2009).

In many cases the contribution of herbicides, fungicides, and insecticides is greater than 100%.

Table 12 CPP contribution to horticulture 2017,
Averaged 2016 - 2018, in $ million, Contribution to GDP

	Value ($ million)	Impact ratio	Total impact ($ million)	Comment
Value to New Zealand	$1,400	0.88	$1,200	Mainly fungicides and insecticides. Some herbicides

Source: NZIER

3.1.6. Field crops

Field crops include wheat, barley, fodder crops (fodder beet, maize, corn) and other crops.

Within this category of crops, the proportion of value attributed to CPP (such as herbicides) range from 20% for maize to 100% for fodder beet. The value contribution of herbicides, insecticides, and fungicides were estimated based on data from Gianessi (2006 and 2009) and industry interviews.

Compared to horticulture and vegetables, the use of CPP is much less, with value attributed to CPP estimated at 52%.

Table 13 CPP contribution to field crops 2017,
Averaged 2016 - 2018, in $ million, Contribution to GDP

	Value ($ million)	Impact ratio	Total impact ($ million)	Comment
Value to New Zealand	$2,100	0.52	$1,100	A combination of fungicides, insecticides and herbicides

Source: NZIER

3.1.7. Others

A small number of crops, mainly flowers, seeds and bulbs are also dependent CPP. We have relied on industry views - suggesting that it would be very difficult to grow these products without CPP. We have assumed the crop impact at 80% (on a value of $135 million).

3.2. Total contribution of CPP to crops

The total value of CPP to New Zealand land-based industries is the sum of the contribution to each of the categories discussed.

In aggregate, it is estimated that between $7,500 million and $11,400 million of horticultural, vegetable, forestry, pasture, and cropping production is attributable to the use of CPP, or between 24% and 36% of the total value of production, processing, and marketing (see Table 14).

Most importantly it is fungicides and their impact on horticultural and vegetable crops which is a significant contribution. This includes estimates from organic production which uses CPP derived from natural substances.

Table 14 CPP contribution to crops 2017,
Averaged 2016 - 2018, in $ million, Contribution to GDP

Crop	Value ($ million)	Impact ratio	Total impact ($ million)	Use
Forestry	$5,500	0.07 – 0.27	$447 – 1,723	Mainly herbicides
Pasture	$17,100	0.05 – 0.20	$855 – $3,400	Mainly herbicides
Horticulture	$5,000	0.75	$3,800	Mainly fungicides and insecticides. Some herbicides
Vegetables	$1,400	0.88	$1,200	Mainly fungicides and insecticides. Some herbicides
Field crops	$2,100	0.52	$1,100	A combination of fungicides, insecticides and herbicides
Other	$135	0.80	$108	
Total	**$31,240**	**0.24–0.36**	**$7,500 $11,400**	

Source: NZIER

4/ Implications for the regulatory regime

The implications for the food system in New Zealand are significant. New Zealand is highly dependent on food production for the economy's wellbeing and as an export generator. The food system in turn is highly dependent on CPP.

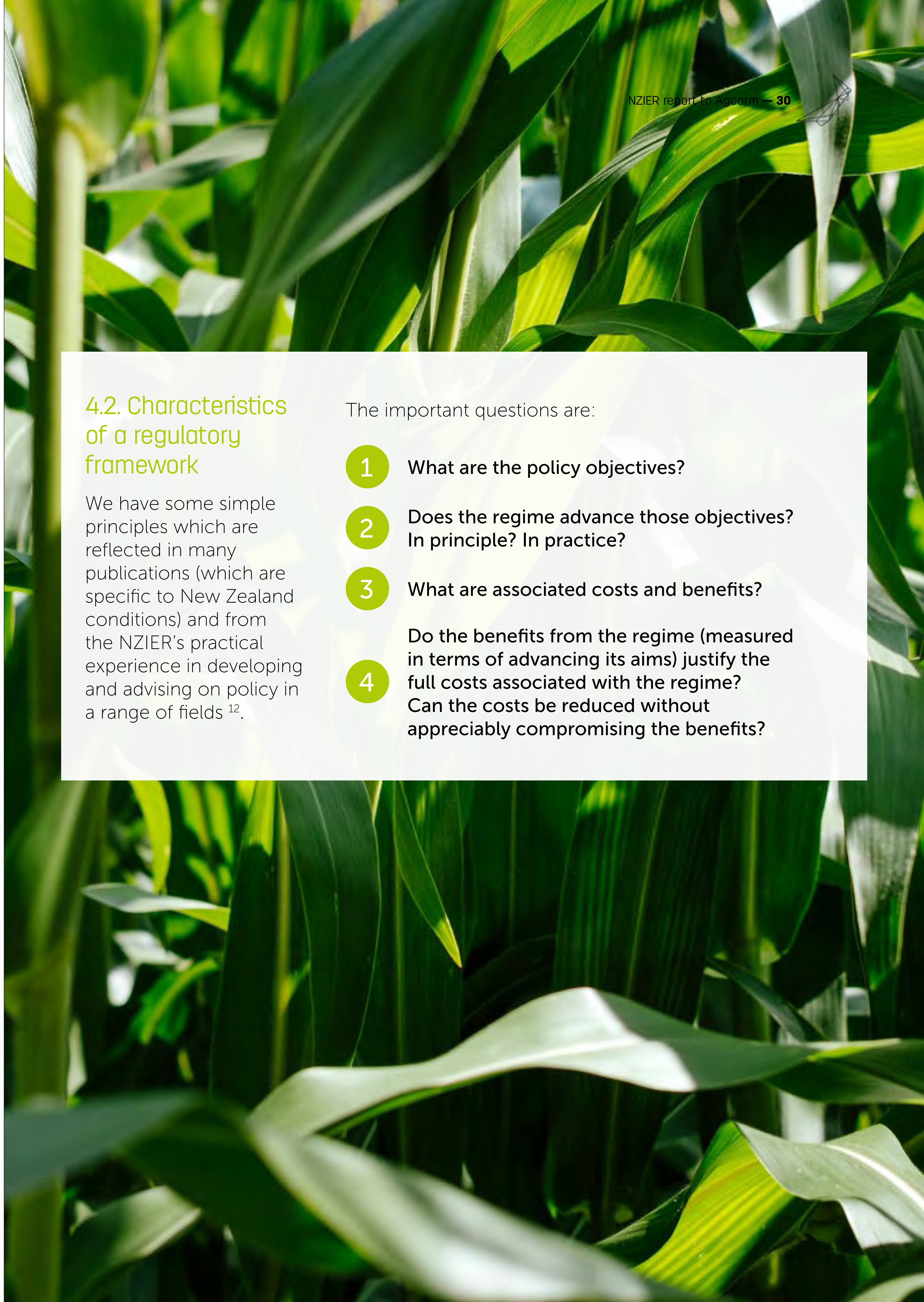
Therefore, the regulatory system needs to strike the right balance between protecting New Zealanders (given current scientific understanding) and allowing the industry to flourish and innovate. CPP and those that regulate CPP are a major part of the food system and a vital cog in its continued productivity.

4.1. What are we looking for in a regulatory policy framework?

A well performing policy framework should:

- maximise welfare over time with respect to the environmental risk and cost as well as production and consumption. In an ideal world, the market takes care of these outcomes. In real world situations, market failure can occur which necessitates regulatory intervention i.e. society wants crop protection products regulated
- minimise the amount of legislation and regulation. People should be free to engage in activities unless they are prohibited for some good reason
- signal the importance of innovation for economic growth, and the maintenance and enhancement of New Zealand's standard of living.

[12] See for instance: Gruensprecht and Lave (1989), and Rose-Ackerman (1996), which contain good background material. For New Zealand policy, see Hawke (1993) for a sound overview. More recently Susy Frankel at Victoria University has edited or co-edited three books on regulation (2011, 2013, 2014) that look at many of these issues in detail.



4.2. Characteristics of a regulatory framework

We have some simple principles which are reflected in many publications (which are specific to New Zealand conditions) and from the NZIER's practical experience in developing and advising on policy in a range of fields [12].

The important questions are:

1. **What are the policy objectives?**
2. **Does the regime advance those objectives? In principle? In practice?**
3. **What are associated costs and benefits?**
4. **Do the benefits from the regime (measured in terms of advancing its aims) justify the full costs associated with the regime? Can the costs be reduced without appreciably compromising the benefits?**

4.2.1. Policy objective

The pursuit of economic growth without any constraints will cause environmental damage. Some restraints are needed on the types of activities that may be undertaken, and the manner in which they are undertaken. For example, climate change policy and water quality are clear areas where government interventions are necessary.

This is 'sustainability', which is at the core of the Resource Management Act (1991). The policy question then becomes, how to design a balanced and appropriate regulatory regime, in terms of the substantive rules, the associated processes and institutions, and specifically how those rules are practically applied.

4.2.2. Is the application of regulation workable in principle? In practice?

An efficient and effective regime requires an examination of the substantive rules, procedures, and institutions. It involves asking whether:

» The substantive rules accurately capture the policy objectives

» The institutions and processes involved will, in practice, apply those substantive rules, in an appropriate and timely way, so that the objectives will be actually achieved.

The regime will need to deal with various types of (possibly overlapping) issues, and strike balances between them. The list of issues includes: technical/scientific, environmental, cultural and ethical, social and economic.

One of the major criticisms levelled at the EPA, which administers the CPP rules and regulations in respect to environmental impact, is the way those regulations are currently applied. Specifically, the industry believes that the EPA moves extremely slowly on its approvals, taking little account of economic issues that impact on crop protection companies, their customers, and the economy[13].

The application of the HSNO Act, in this way, may well cause completely unintended results such as:

» Increasing or maintaining the amount of 'harder' substances within the New Zealand environment – relative to the environment under previous approaches/stances [14]

» An opportunity cost of slowing the introduction of newer 'softer' product on to the market that can improve the productivity for farmers and the economy.

> The regime will need to deal with various types of issues, and strike balances between them.

[13] Industry interviews.

[14] While we recognise that new management techniques will improve the effectiveness of 'older' chemical technology (i.e. with the use of IPM type systems and use of biological control methods), newer 'softer' innovative chemicals are more specific in purpose and will cause less toxicity and be less persistent in the environment.

As a result, the current application of the HSNO Act may not adequately demonstrate how 'protection' can be achieved effectively and at minimum cost. This is despite the heavy emphasis on protection of the environment and communities.

4.2.3. Balancing costs and benefits

One of the more challenging valuation exercises is valuing the costs and benefits of innovation in the form of new products and services. These include direct costs for the government and for participants and indirect costs such as opportunity costs. The main form of indirect cost is what economists call opportunity cost. That is, if the regime results in some valuable activity not being pursued, the loss of the potential contribution is a cost of the regime. This may occur where a prohibition catches not only the target 'evils' but also innocent 'bystanders'.

The approach taken by economists, despite the very real difficulties in measuring the impact of regulation, is a cost benefit framework. The strength of this approach is to help clarify the effects, which are implicit in all decisions. Economic appraisal is valuable if used as an informative, rather than prescriptive, tool since it provides a consistent approach to harnessing available information and ordering priorities. This process clearly identifies (either qualitatively or, if possible, quantitatively) whether the benefits outweigh the costs.

Nearly all companies are experiencing delays, through the EPA, that are having real effects for:

» The retailers and their sales and extension teams that are attempting to demonstrate the impact of new chemistry on farm (again a relatively small impact on the national economy, but hugely disruptive)

» The customers, since new products can contribute to improved productivity and improved returns. They also assist in meeting tighter and tighter international requirements

» New Zealand Inc. because it causes unnecessary tension in the regulatory system and causes delays that should be avoidable. Also, the way regulatory requirements are being administered is acting as a handbrake on innovation with no discernible gain for the environment or human health

» The companies involved (the companies are small, but the delays are hugely disruptive in their ability to plan and bring products to the market)

In all cases, companies report that the time taken to deliver new chemistry to the market has increased from 12 months to 24 months.

4.2.4. How might we further understand the economic impact of delays?

Some of the delay costs are affecting dynamic innovation. The Commerce Commission (1998) suggests that dynamic innovation costs are roughly 3% of gross output of an industry [15].

It is also clear that not all innovation in the agricultural and horticultural sectors come from the introduction of new chemistry on to farms. However, it must have some value since it is contributing $142.5 million per annum to the New Zealand economy, employing over 310 staff directly, and over 1,000 indirectly.

For illustrative purposes we have assumed the dynamic innovation from new chemistry is roughly 1% and 10% of dynamic innovation gains (i.e. 3% of total gross output) in any particular year. This is a proxy, but it does give an indication of the impact.

To be conservative we have also removed herbicide from the calculation since the amount of innovation in controlling weeds is less than the new fungicide and insecticide products.

Over ten years the impact of a one-year delay could be between $7 million and $70 million in contribution to GDP (see calculations in Table 15).

A further problem is that competitors who have faster access to new chemistry gain a competitive advantage over New Zealand. This has not been factored into this illustration.

Over ten years the impact of a one-year delay could be between $7 million and $70 million in contribution to GDP.

Dynamic Innovation refers to innovation at the margin and changing to new activities over time. While it is incremental it typically is the main driver of industries overtime.

Table 15 Approximate economic impacts of delays over time ($ million)

Years		1	2	3	4	5	6	7	8	9	10
Total Gross Output increasing at 1% per annum		31,251	31,564	31,879	32,198	32,520	32,845	33,174	33,506	33,841	34,179
Remove herbicides	this removes forestry and pasture										
		8,650	8736	8824	8912	9001	9091	9182	9274	9367	9460
Focus on value added	Remove intermediate consumption										
		3,460	3,495	3,530	3,565	3,600	3,636	3,673	3,710	3,747	3,784
Make assumptions on the level of dynamic efficiency	Approximately 3% (Commerce Commission)										
		104	105	106	107	108	109	110	111	112	114
	Deduct the 'without delays' from the 'with' delays										
Make assumptions about the attribution to CPP											
At the 1% level of Dynamic Efficiency	69.76	-	10.5	10.6	10.7	10.8	10.9	11	11.1	11.2	11.4
At the 10% level of Dynamic Efficiency	6.98	-	1.05	1.06	1.07	1.08	1.09	1.1	1.11	1.12	1.14

Source: NZIER

5/ Conclusions

We have set out to illustrate the impact of the crop protection industry to New Zealand. We show:

- That the industry is small, but with large impacts on the sectors that matter to the New Zealand economy
- The contribution of the industry to the New Zealand economy is approximately $142.5 million
- CPP are valuable contributors to dynamic innovation in land-based industries. In crisis situations, such as with the PSA incursion, they were a critical part of the response
- The contribution of CPP to land-based industries is very large. It is estimated at between $7,500 million and $11,400 million
- The impact of EPA delays is significant for New Zealand's economy (between $7 million and $70 million, over 10 years). This does not include the impact on the CPP companies or the environmental impact.

These estimates are approximate and are intended to show the order of magnitude of the impacts.

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Appendix B CGE Modelling

B.1 We used our CGE model to assess the economic value of crop protection in New Zealand

To capture the economic value of crop protection products in New Zealand, we use one of our CGE models.

CGE models are data-driven and used to capture the effects of a new policy or technology or other external shocks affecting economic activity. They capture the economy-wide effects of changes ('shocks' in modelling jargon) directly on the affected industry, as well as indirectly on supplying industries, competing industries, and factor markets (labour and capital). CGE models show the full effect of a change which includes impacts from indirect effects which aren't immediately obvious. The cumulative impact of indirect effects can outweigh the direct effect of a change.

CGE models also estimate the effect of a shock on macroeconomic variables such as GDP, employment, wages and trade.

CGE models are a powerful tool, allowing economists to explore empirically many issues on which econometrics or multiplier analysis would be unusable. For these reasons, CGE models have become widely used internationally (e.g. by OECD, IMF, World Bank) for economic impact analysis.

B.2 Our CGE model ORANI-NZ

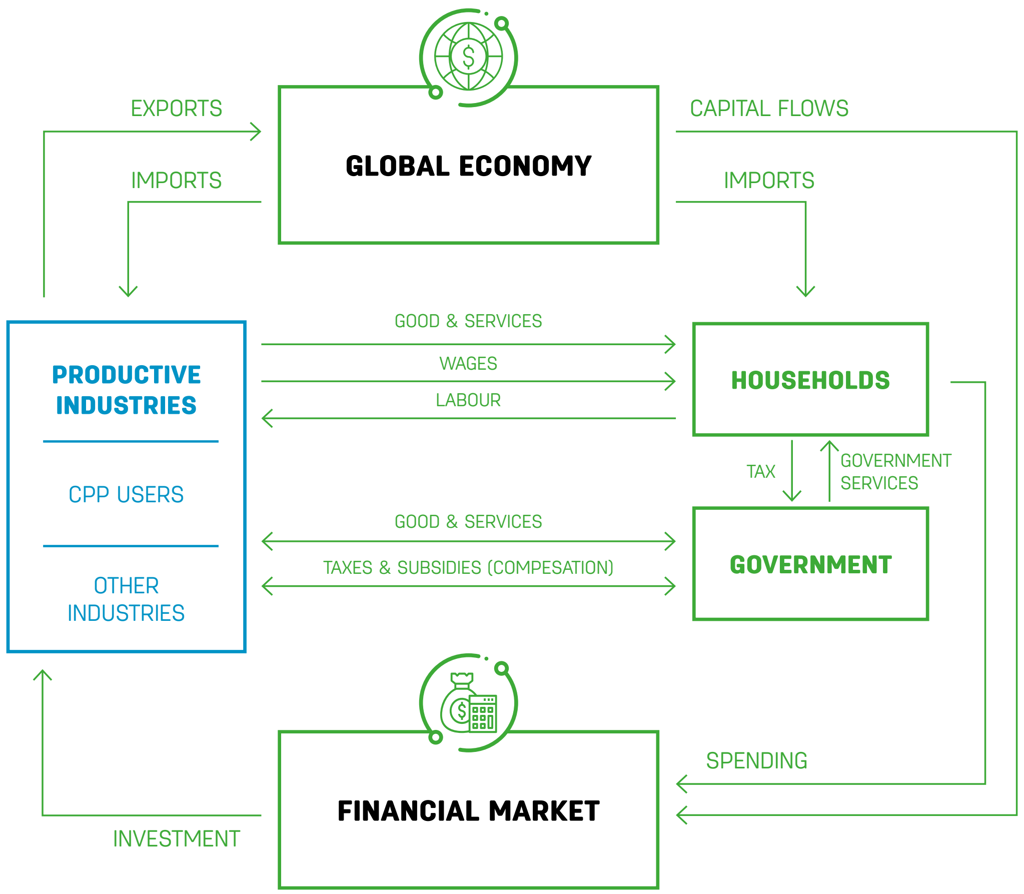
NZIER's ORANI-NZ [16] model is the only top-down CGE model of the New Zealand economy.

ORANI-NZ is based on a Stats NZ's Input-Output table that identifies the structure of the industries involved. It contains information on 106 industries, 201 commodities and fifteen regions. It therefore offers a unique capability to highlight the role of the GS1 standards in retailing and wholesaling in the New Zealand economy.

Figure 5 shows how the model captures the complex and multidirectional flows between the various actors of the national economy and how they interact with the rest of the world. More technical details on the model are available upon request.

[16] ORANI-NZ was developed at NZIER based on the original Australian ORANI model created by Professor Mark Horridge of the Centre of Policy Studies, Victoria University-Melbourne, Australia. http://www.copsmodels.com/term.htm. NZIER maintains close connections with the Centre, ensuring that our modelling techniques reflect international best-practice.

Figure 5 Components of a CGE model



Source: NZIER

Key features of the model are:

- each industry can produce a number of different commodities
- production inputs are intermediate commodities (domestic and imported) and primary factors (labour, land and capital)
- the demand for primary factors and the choice between imported and domestic commodities are determined by Constant Elasticity of Substitution (CES) production nests. This means an increase in price of one input shifts sourcing towards another input
- intermediate goods, primary factors and other costs are combined using a Leontief production function. This means the proportion of production inputs is held constant for all levels of output
- the production mix of each industry is dependent on the relative prices of each commodity. The proportion of output exported or consumed domestically is also dependent on relative prices
- policy impacts are often unevenly spread across industries and regions. To capture these heterogeneous effects, the model is extended to include a regional component. A 'top-down' approach is used to decompose national impacts to the regional level, using regional data as weighting[17].

the production mix of each industry is dependent on the relative prices of each commodity.

[17] The regions in the model are: Northland, Auckland, Waikato, Bay of Plenty, Gisborne, Hawkes Bay, Taranaki, Manawatu-Wanganui, Wellington, Tasman-Nelson, Marlborough, West Coast, Canterbury, Otago, Southland. For the purposes of this analysis and to speed-up the computational process, we have applied our shocks directly to the Southland region and aggregated all the other regions into Rest of New Zealand

B.3 Core data is based on Stats NZ's input-output tables

The model is based on a large database containing the value flows of the economy. The database defines the initial structure of the economy, which is assumed to be in equilibrium in all markets. In other words, the sectors in the economy start off in a stable relationship with each other and are then 'shocked' by new spending on construction or new tourism, before settling back into slightly new relationships caused by the additional activity in the economy.

The structure of the database is broadly similar to traditional input-output tables. For example, commodities may be used as intermediate inputs for further production, used in investment, exported or consumed by households and the government. Industry costs include the cost of intermediates, margins, taxes and primary factor costs for labour, land and capital.

The database has been sourced initially from Stats NZ's 2013 input-output tables. We calibrate the database to 2018 levels using Stats NZ's latest National Accounts.

Once we have calibrated the model and developed a baseline in which all markets are in equilibrium and all resources employed, we then 'shock' key parameters to simulate the effects of the public, private developments and increased tourism spending.

B.4 Simulations

For illustrative purposes we designed 3 scenarios (high, medium and low) to measure the role of CPP in the New Zealand economy. To do so, we have identified a potential channel through which the use of CPP benefits the primary sector and wider economy:

» Increased yields due to dynamic efficiency gains across a wide range of horticultural crops, leading to a rise in exports and domestic sales.

To model this channel (or 'shock' in the modelling jargon), we had to assess its potential magnitude. This was a challenging task given the lack of New Zealand relevant empirical studies.

In lieu of empirical evidence, we developed the scenarios through an iterative process with industry stakeholders. We used our estimations of CPP on horticultural crops (see section 3.1.4) and on dynamic efficiency gains(see section 4.2.4) to build three scenarios of productivity increase in horticulture.

Our three scenarios are the following:

» **high scenario,** in which we consider a higher increase in productivity (2.76%) in horticulture

» **medium scenario,** in which we consider a medium productivity increase (1.17%) in horticulture

» **low scenario,** in which we model a lower increase (0.17%) in productivity in horticulture.

To model this channel, we had to assess its potential magnitude.

We acknowledge that other parameters could have been selected for this modelling exercise. We have used three alternative scenarios to take uncertainty (due to a lack of data) into account. These scenarios are purely illustrative, and should more empirical evidence come to light, it would be easy to re-design the scenarios and re-run the CGE modelling.

Provided with more empirical evidence, we also would be able to refine our scenarios with the addition of several other channels we have also identified through which the use of crop protection products can benefit the primary sector and wider economy:

» a rise in imports of crop protection products

» labour costs monitoring and treating crops and plants

» lower sorting costs to pick out damaged fruit and vegetables

As our CGE model is static, it can only look at 'before' (i.e. current situation) and 'after'. We therefore do not explicitly model the timing of the changes in investment, tourism spending and employment. Instead, we analyse a static, long-term scenario that estimates the overall economic effects of yield increase in a wide range of crops in horticulture and pasture with the use of crop protection products.

Results of the simulations give us an overview of what the regional and national economies will look like following a shock on productivity in horticulture.

We then determine the flow-on effects of our shocks throughout the national and regional economies on GDP, household consumption and industry output.

B.5 Closure

In any CGE model, it is important to understand which factors have been allowed to vary and which remain fixed by assumption (also known as exogenous variables). The particular combination of fixed factors is known as the closure.

Since our CGE model is static, we don't know the solution path over time. Instead, we assume that the New Zealand economy operates within a certain timeframe either along-run or a short-run depending on the purpose of our simulations.

For this project, we choose a short-run closure. The main assumptions which characterise a short-run closure are the following (see Table 16):

- real wage is rigid, labour is completely mobile between industries and regions, and the national employment adjusts.
- regional household consumption follows regional wage income
- national household propensity to consume is fixed
- rates of return adjust to maintain fixed national investment. However, capital is mobile between industries and regions.
- foreign currency prices of imports are naturally exogenous.
- real government consumption is also exogenous.
- other exogenous variables include rates of production tax, technological coefficients, national population, and national labour supply.

Table 16 Fixed elements of the CGE model with a long-run closure

Variables	Variables
Taxes on production	National population
Technological change	National real wages
Government demand	Import prices, foreign currency
Gross growth rate of capital	Foreign demand for New Zealand exports
National real investment	Land use
Number of households	

Source: NZIER

B.6 How we analysed the modelling results

We determined the flow-on effects of our shocks throughout the national and regional economies on GDP and industry output.

B.6.1 Macroeconomic effects

The national and regional results flow logically from the direct and indirect impacts. We focus on key macroeconomic variables such as Gross Domestic Product (GDP), exports, employment and household expenditure, which we use as a measure of economic welfare (how 'well off' we are).

B.6.2 Direct and indirect effects

In analysing the modelling results we track the impacts as they flow through the economy, beginning with the direct impacts on the construction and tourism sectors itself. We then analyse the flow-on or indirect impacts. It can aid understanding to split indirect impacts into the following categories:

- **supplying industries –** industries that supply the tourism and construction sectors with intermediate inputs are likely to benefit. Such industries include meal service providers, and business service industries.
- **household expenditure industries –** industries that households spend money on are likely to benefit from increased income that comes through employment and wages, and increased returns to capital from a growing tourism industry. Such industries include housing and real estate (which takes a large share of households' budgets), and those for consumption goods like the retail trade.
- **competing export industries –** industries that suffer from the tourism industry's growth as they compete for resources, which are now more expensive, and also face a stronger New Zealand dollar. Typically, these industries are the labour-intensive export industries such as horticulture and manufacturing.

industries that households spend money on are likely to benefit from increased income…

Appendix C Attribution estimates

Table 17 Dependency of agricultural products on crop protection products
Percent
Notation: H: horticulture, V: vegetables, FC: field crops, O: other

Product	Herbicides	Insecticides	Fungicides	Total CPP	Category
Apples	15	93	86	100%	H
Asparagus	55	67	22	100%	V
Aubergines		25		25%	V
Avocados		48		48%	H
Barley			9	9%	FC
Beans (broad)				100%	V
Beans (green)	20	58	65	100%	V
Beetroot				80%	V
Blueberries	67	69	75	100%	H
Brassicas & brassics for fodder				100%	V
Browntop				10%	O
Capsicums				100%	V
Carrots	48	10	95	100%	V
Celery	0	48	92	100%	V
Cherries				100%	H
Chicory				100%	O
Chillies			44	44%	V
Citrus			88	88%	H
Clover (red & white)				10%	O
Cocksfoot				10%	O
Cucurbita species	30	20	10	30%	V
Feijoas				10%	H
Garlic			61	61%	V
Grapes	1	35	100	100%	H
Hops	25	100	100	100%	O

Table 17 (cont'd)

Product	Herbicides	Insecticides	Fungicides	Total CPP	Category
Kiwifruit			33	33%	H
Kumara	20	45		65%	V
Lettuce	13	50	85	100%	V
Lucerne				10%	O
Maize - Corn	20	3		20%	FC
Nuts				100%	O
Oats				100%	FC
Olives		90	84	100%	H
Onions	43	22	100	100%	V
Parsnip				100%	V
Passionfruit				1	H
Pears		85	89	1	H
Peas	20	22		0.42	V
Persimmons				0.2	H
Potatoes	32	29	94	1	V
Prunus				1	H
Radish				0.2	V
Ribes				1	H
Ribwort plantain				10	O
Rubus				100	H
Rye				0.1	O
Ryegrass				10	O
Silverbeet				0.2	V
Spinach				0.2	V
Strawberries	20	20	20	20	H
Tall fescue				30	O
Tamarillos				20	H
Tea					O
Timothy				10	O
Tomatoes	23	53	77	1	H
Wheat	25	3	9	0.37	FC
Fodder beet				1	

Source: NZIER, Agcram

www.nzier.co.nz