Economic impact of research and development in the wine sector

NZIER report to Bragato Research Institute (BRI)

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Key points

Bragato Research Institute (BRI) commissioned NZIER to estimate the impact of research and development (R&D) in the wine sector, and the impact of BRI activities on the Marlborough region, the national winegrowing industry and the wider economy.

BRI has created a unique business model adding value to the Marlborough and national economies

Over the last couple of years, BRI has led and partnered in a wide range of innovative and influential research projects. Opened in February 2020, BRI has built a new research winery facility alongside key industry and research partners at the NMIT/MRC campus in Blenheim. The new research winery provides facilities to enable research winemaking at a scale and degree of experimental control not possible before in New Zealand. The research institute is owned by the industry and provides a strong link between the industry and research by ensuring the research is aligned with the industry's needs.

Our review of three historical industry funded research projects, mechanical shaking, timing of pruning and trunk disease, suggests a productivity gain of between 1.04 and 3.1 percent for the wine sector (in total).

R&D in wine has led to:

1.17 percent (total factor) productivity gains

Our extensive review of the literature suggested that the contribution of research to annual economic growth of the wine industry was between 20 and 25 percent. The ratio of the estimated economic growth of the sector from total wine production is equal to 1.17 percent productivity gain for the sector.

$64.5 million boost to the national economy driven by higher productivity

The result of our assessment of the impact of R&D in the wine sector suggests a significant $64.5 million contribution to New Zealand's GDP per year. There is also a significant contribution to the welfare (consumption) of New Zealand households, increasing that by $37.2 million.

With generating 258 new jobs in New Zealand and maintaining those jobs each year, and significant contribution to the Marlborough and Auckland economies

The outcomes from wine R&D investments increase employment in regional economies (with 121 new jobs) as much as larger cities (with 137 new jobs). The largest gains among regional economies are for Marlborough and Hawke's Bay with 17 and 16 jobs, respectively. Larger cities have high concentration of employment in the wine sector. For example, Auckland has the second largest employment in the wine sector after Marlborough. A large proportion of the increase in job opportunities in large cities is the indirect impact of wine sector activities on a wide range of other services relevant to the wine sector that are located in larger cities. That's the reason for high gains to the economy of Auckland from R&D in wine. The investment brings positive outcomes for all regions.[1]

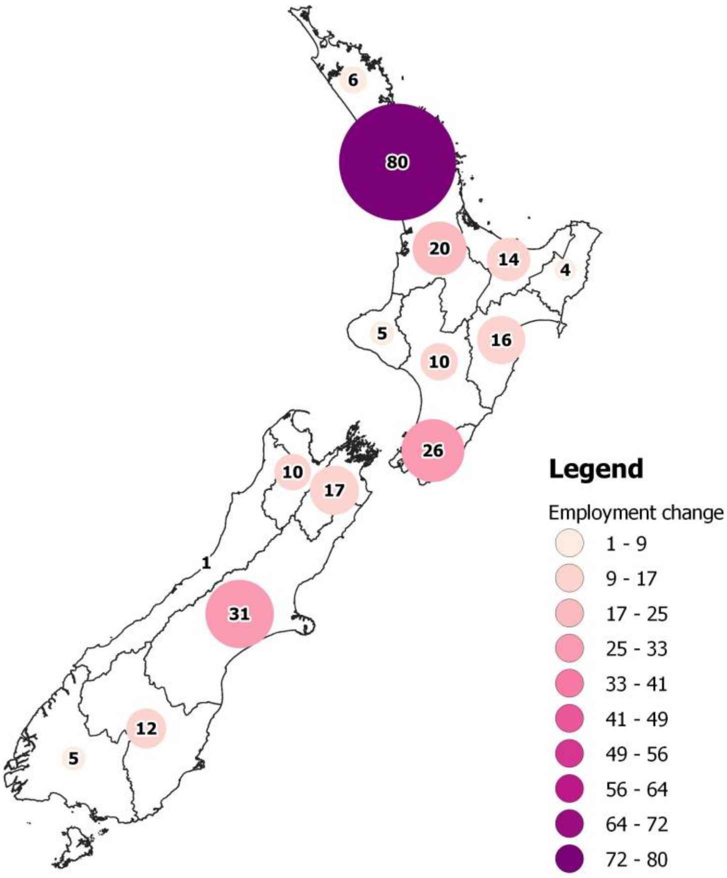
BRI's contribution to the national economy will be around $8 million per annum,[2] including the benefits from economic activities from 30 new jobs that BRI created for the New Zealand economy

We estimate that BRI's share of the total research fund will be between 10 to 15 percent.

This will be equal to a total of:

- $8 million increase in the size of the national economy, with 30 new jobs for New Zealand. This is an increase in employment opportunities per year and is additional to the economy in absence of BRI. The immediate effect of BRI was the creation of 13 new positions – this is listed on their website.[3]
- $2.2 million **increase** in the size of Marlborough's economy, including 3 more jobs.

Figure 1 Regional employment impact of R&D in the wine sector



Source: NZIER

1 This is important to note that the investment will not lead to any cannibalisation across the regions.

2 This suggests that BRI activities will increase the size of the economy by $8 million and will keep maintaining that size of the economy for each year.

3 Four of the current positions are located outside Marlborough.

Our estimated value of R&D would be higher if we were to account for an unobserved future

Our study provides an estimation of the impact of R&D compared to the counterfactual of no R&D investment in today's economic circumstances. However, there are many other investments that are planned in different sectors across the country. A wide range of these investments are focused on the primary sector, which competes with the wine sector, to attract limited resources, including land and labour (see for example, Torshizian et al. (2020)). In the absence of R&D, the wine sector will be at a competitive disadvantage to the other sectors. Therefore, the estimated value of R&D in the wine sector would be significantly higher if we were to consider the unseen future investments in other sectors of the economy.

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1 Introduction

Bragato Research Institute (BRI) asked NZIER to estimate the economic impact of wine research and development (R&D), and BRI's research on the industry and the wider economy at regional and national levels.

For this analysis, NZIER used its regional The Enormous Regional Model of the New Zealand economy (TERM). This provides a detailed understanding of the relationships between the wine sector and other sectors of the economy. It also provides us with a precise estimation of the interactions between regional economies.

The positive externalities from an improved regional economy will in turn impact other regions' economies. The improved productivity of the economic sectors affected by the wine industry directly improves outcomes for New Zealand households, in particular their incomes and their consumption, and drives other (potentially indirect) positive impacts, such as improved health and subjective wellbeing.

The report first looks at the productivity gains from three research topics. Then in Section 3 we review the literature on the impact of research on productivity of the wine sector and the return on investment. Section 4 provides a description of the wine sector and R&D investment in New Zealand. In the last section, we present our results of the impacts on the national and regional economies.

2 BRI's value creation

BRI is the research centre of New Zealand Winegrowers. The vision of BRI is to transform the New Zealand grape and wine industry through research, innovation and extension. Opened in February 2020, BRI has built a new research winery facility alongside key industry and research partners at the NMIT/MRC campus in Blenheim. The new research winery provides facilities to enable research winemaking at a scale and degree of experimental control not possible before in New Zealand.

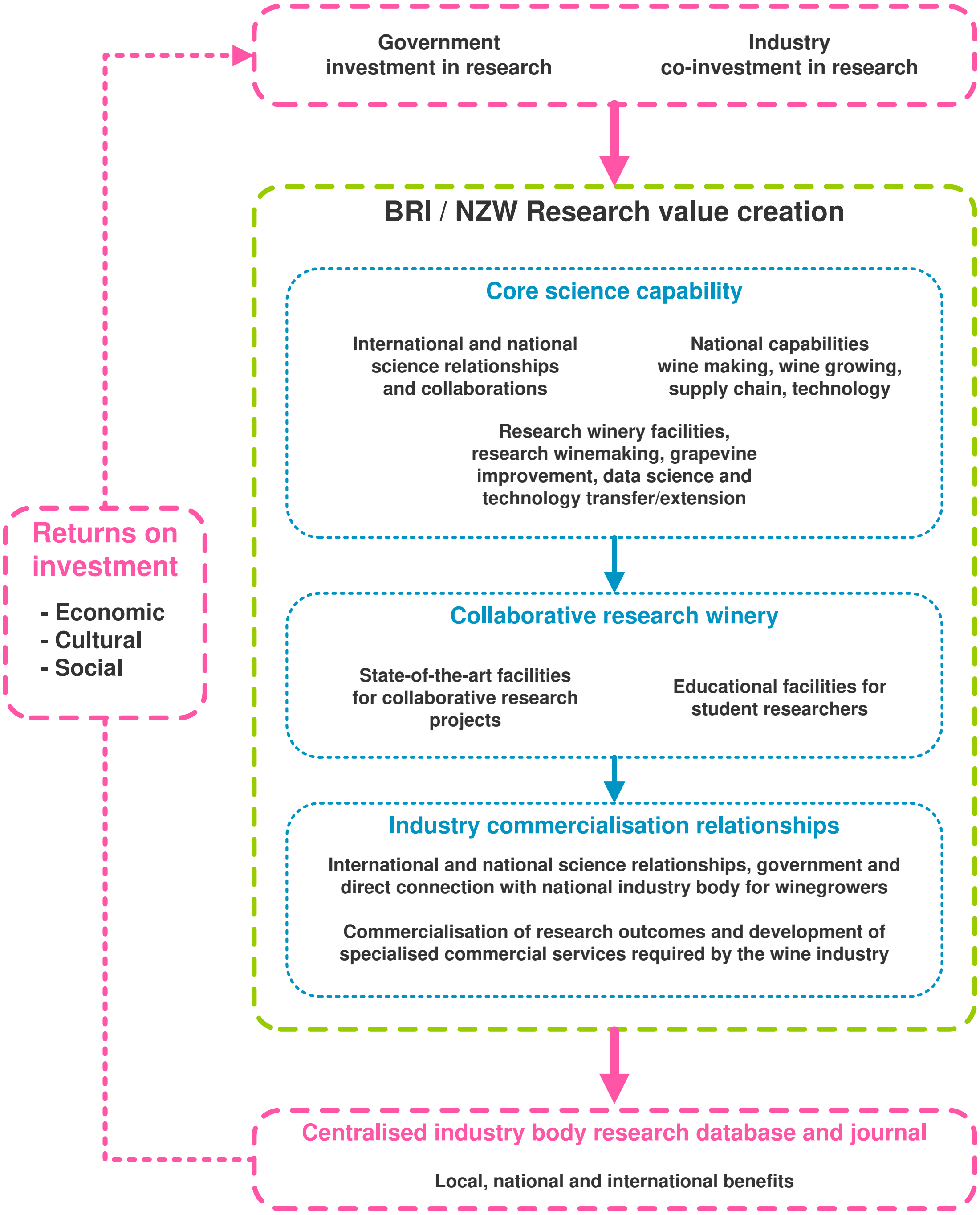
Industry research affects a wide range of drivers of productivity of the wine sector, including:

- the quality of soil
- vineyard management practices
- mix of grape varieties
- pest and disease control
- efficient use of water
- number of workers
- quality of workers (human capital)
- yield per hectare
- chemical inputs

- technology.

BRI and NZIER identified a number of past and planned projects contributing to productivity. A list of relevant studies by New Zealand Wine (NZW) and BRI is presented in Appendix A. BRI has contracted $1.3 million in external spend with a range of research providers to be completed within the next four years.

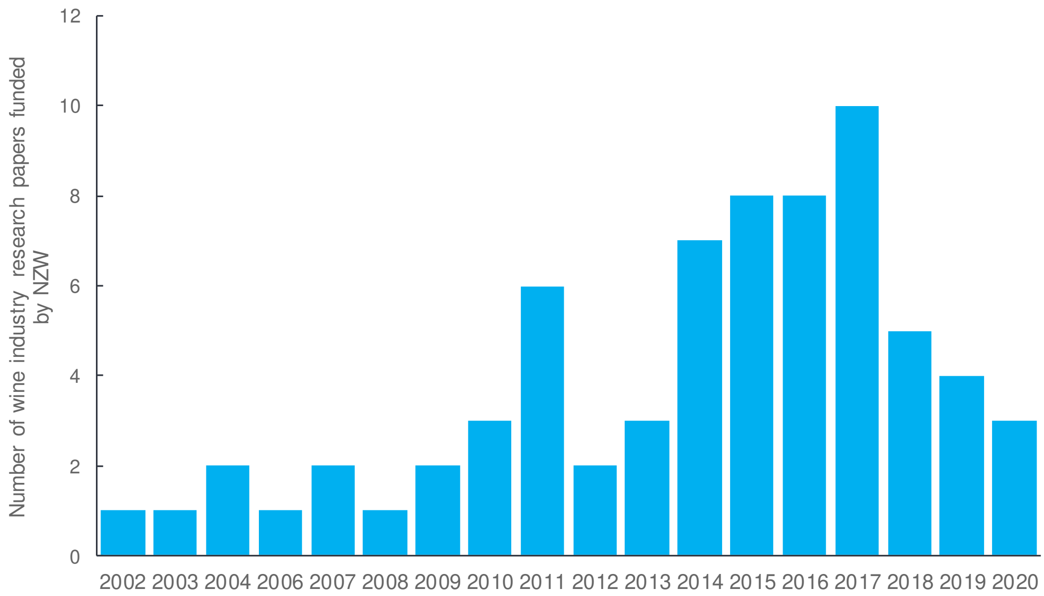
Figure 2 BRI's value creation



Source: NZIER

In Figure 3, we present the number of scientific publications arising from wine industry funded research between 2002 and 2020. The outcomes of the research contribute to the accumulation of knowledge and further partnerships in the future.

Figure 3 Wine industry funded research contribute a wealth of knowledge



Source: BRI

We review the potential impact of a few of these studies on the production of the wine sector below.[4]

2.1 Mechanical shaking 2011–2014[5] (NZW levy funded)

The mechanical shaking of trash, e.g. dead leaves and shoots, out of bunches reduces the opportunity for infection with botrytis. Mechanical shaking is common in New Zealand and experts suggest that it is the preferred method in Marlborough, Gisborne and Nelson, with around 50 percent of the regions' vineyard area being mechanically shaken.[6]

Results from the research found at least a 50 percent reduction in botrytis levels for shaken vines with no crop loss (Peerce, 2015). Incidence of botrytis in Sauvignon Blanc vines reduced from 12.6 percent to 2.2 percent after vines were shaken. Similar results were found for Waipara Chardonnay, reducing botrytis levels from 13.6 percent to 3.6 percent. Winegrowers benefit from increasing the value of their crop yields where they would otherwise be penalised for high botrytis levels or risk having crops having unacceptable botrytis levels and not being harvested.

4 We have used the available information to estimate the impact of the studies. However, we do not have enough information on the rate of adoption of the outcomes from the studies. Hence, we have assumed that the use of the recommended outcomes from the research studies indicate the adoption of their findings.

5 https://issuu.com/ruralnewsgroup/docs/wg_92_june-july_new

6 The proportion is derived from the best information available to us based on experts' advice.

Table 1 Reduction of botrytis incidence from mechanical shaking

Variety and region	Control % of total incidence	Shaken % of total incidence	Botrytis % of reduction
Sauvignon Blanc Marlborough	9.5	3.5	63.0
Chardonnay Marlborough	3.6	0.6	83.0
Pinot Noir Abel/Tasman & Marlborough	3.0	0.7	77.0
Sauvignon Blanc 25-yr-old vines Marlborough	12.6	2.2	83.0
Riesling Waipara	5.3	1.3	76.0
Chardonnay Waipara	13.6	3.6	74.0

Source: NZ Winegrowers, 2015

Estimated cost for botrytis p.a. is $3,960 per hectare, accounting for costs in hand thinning grape bunches and the replacement costs of lost crop. Conditions vary year to year, so that high botrytis levels occur in 8 out of every 10 years. At a cost of $400 p.a. each year mechanical shaking provides an expected value of $2,768 per hectare.

Table 2 Expected value of mechanical shaking

Per annum, per ha

Mechanical shaking for botrytis	Value
Hand thinning bunches/vines and cost of lost crop	-$3,960
80% change of occurrence	80%
Expected losses	**-$3,168**
Cost of mechanical shaking	-$400
Expected savings from mechanical shaking[7]	$3,168
Expected value of mechanical shaking[8]	**$2,768**

Source: Preece, 2015

[7] The risk of crop loss is accounted for. The author mentions that 'Mechanical thinning can reduce botrytis risk without reducing crop loads'.

[8] This is the value in comparison with hand thinning.

We assume uptake rates of 50 percent for Gisborne, 10 percent for Hawke's Bay, 50 percent for Marlborough, 40 percent for Nelson and 5 percent for Central Otago.[9] Applying these uptake rates on vineyards yields over the last 10 years, we estimate **a (total factor) productivity of 1.5 percent from mechanical shaking**.[10]

2.2 Timing of pruning (NZW levy funded)

Confirmation that pruning could be done early without loss to next season's yield enables an earlier start to pruning. Earlier pruning spreads the workload over a longer period, which increases the hectares able to be pruned in a labour-shortage situation.

With the results derived from the timing-of-pruning research, we expect the timing of pruning to extend by 1 month. That is equal to a 20 percent increase in the chance of pruning. The impact of timing of pruning can be more significant in unexpected situations such as the lockdown of COVID-19 that may lead to a shortage of seasonal workers, which, if that occurred would likely lead to significant loss of crops.

If growers did not start pruning earlier, due to the labour constraint, they may need to change their pruning type from 4 cane Vertical Shoot Positioned (VSP) to 2 cane VSP, 2 arm cordon or 4 arm cordon. Calculations from BRI and NZIER suggest that this will lead to a loss in income of between $11,300 and $3,800 per hectare. We take a conservative approach and assume that this change is only applicable to one-fifth of the annual yield.[11] That is equal to a total value between $19 million and $56.5 million for the Marlborough region. Therefore, **the (total factor) productivity gain will be between 1.04 and 3.1 percent.**[12]

2.3 Trunk disease – vineyard longevity[13] (NZW levy funded)

Eutypa and *botryosphaeria* dieback (ED and BD), caused by fungal species of the *Diatrypaceae* and *Botryosphaeriaceae*, respectively, are major grapevine trunk diseases (GTD) worldwide, causing significant yield and quality reduction. They threaten the sustainability of the New Zealand wine industry and are becoming more prevalent as vineyards age (Sosnowski, Mundy and Jong, 2020). In many wine regions of Australia, up to 100 percent of vines in older vineyards are diseased, and yield losses of 1500 kg/ha have been reported (Wicks and Davies, 1999).

In California, the cost of trunk diseases to the industry has been estimated at $US260 million per annum (Siebert, 2001). In New Zealand, GTD threatens the entire national crop which is equal to 38,680 hectares in 2019 (NZ Winegrowers, 2012) and has been estimated to cause **14 percent reduction in vineyard profitability** (Mundy and Manning, 2007) with 54 percent and 68 percent of surveyed vineyards recorded with species that cause ED and BD, respectively (Mundy et al. 2009).

9 Uptake rate assumptions provided by field experts.

10 The productivity gains for the growers that adopt the mechanical shaking is 5.1–11.2% p.a.

For this calculation, we have applied the uptake rates to the total harvest area in different regions. This provides us with the number of hectares that have adopted the mechanical shaking techniques. We multiplied this by the per hectare savings from adopting mechanical shaking. This provided us with the dollar value of increased production (from less loss of crop). This increased production as a ratio of total GDP of the wine sector is equal to the (total factor) productivity gain of 1.5%.

11 That is because we assume the change will only be applicable to the 1 month extra time derived from the timing of pruning research.

12 For the estimation of the productivity gain, we have assumed the gains will only be limited to the Marlborough region and have estimated the productivity gains at national level.

13 https://issuu.com/winepressmagazine/docs/winepress_-_june_2019

Recent New Zealand Wine research develops more practical and efficient methods for the protection of pruning wounds against infection by identifying effective fungicides that can be applied with tractor-driven sprayers (Sosnowski and Mundy, 2019). If this could become a routine practice in New Zealand vineyards, it has the potential to increase production by up to an extra $20 million each year. Furthermore, the use of remedial surgery could produce a further $20 million annually (Sosnowski and McCarthy, 2017). Based on our estimation, the outcomes of the trunk disease research will lead to **a total of 1.6 percent improvement in (total factor) productivity**.

3 Literature review

NZIER conducted a literature review of the impact of R&D in the agriculture sector, including the horticulture and the viticulture sectors, on (total factor) productivity.[14] This gives us an understanding of the impact of $1 spent on R&D in the wine sector on production. A summary of the most relevant studies is presented in Table 3.

The literature suggests a very wide range of productivity gains from R&D in agriculture. One possible factor is that the productivity gains from R&D are sensitive to the stage of development of the sector and the region. The number of studies in New Zealand is limited. Hall & Scobie (2006) estimated the impact of R&D in New Zealand and concluded that while R&D plays a significant role in productivity of the agriculture sector, as a small, open economy New Zealand depends on the knowledge flow from overseas.[15] One of the key models in Hall & Scobie (2006) estimated that domestic R&D produced an annual rate of return of 17 percent.

The most relevant study on the impact of research in agriculture in New Zealand is Greer & Kaye-Blake (2017). They estimated the impact of research on five primary industries: apple, avocado, kiwifruit, seafood and wine. The methodology used for their estimates consisted of a range of expert workshops to understand the key influences on productivity growth of the industries and estimation of the GDP impact from the key influences for each industry. Their results suggested that the research contribution to economic growth of the industries was between 20 and 25 percent.

We use the estimated productivity gains as an input to our CGE model, which is outlined in Appendix C. NZIER's regional CGE model specifically models the Marlborough economy and the interlinkages among the different Marlborough industries, and demonstrates how the Marlborough economy both drives the wider New Zealand economy and is connected to other regional economies.[16]

14 While the impact on viticulture sector is more relevant to the topic of our study, because of the limitations in the literature, we also included studies on the agriculture industry as a whole in our review of the literature.

15 Another important reason for differences in findings of different studies of the impact of R&D is their methodology. For more details see Greer and Kaye-Blake (2017).

16 Our model is highly detailed, incorporating 106 industries, 201 commodities, as well as specific modelling of the household, government and export sectors in Marlborough and across New Zealand.

Table 3 Literature review of the impact of R&D on productivity

For agriculture industry including wine sector

Date	Title	Author(s)	Industry	Region	Productivity impact pa
2020	Assessing the long-term impact of agricultural research on productivity: Evidence from France	Lemarié et al.	Agriculture	France	0.15%
2013	Impacts of Public, Private, and R&D Investments on Total Factor Productivity Growth in Tunisian Agriculture	Boubaker Dhehibi, Roberto Telleria, Aden Aw-Hassan	Agriculture	Tunisia	0.50%
2012	Role of Agricultural Research and Extension in Enhancing Agricultural productivity in Punjab, Pakistan	Nadeem and Mushtaq	Agriculture	Punjab, Pakistan	0.57%
2006	Trends in Research, Productivity Growth and Competitiveness in Agriculture in New Zealand and Australia	J.D. Mullen , G. M. Scobie and J. Crean	Agriculture	Australia	1.20%
2011	Research and productivity in Thai agriculture	Waleerat Suphannachart and Peter Warr	Agriculture	Thailand	5.9–6.7%
2009	Productivity growth and the effects of R&D in African agriculture	Alene, Arega D.	Agriculture	Africa	4.00%

As shown in Table 4, a wide range of literature provided information on the return on investment from R&D in agriculture. As illustrated, the return on investment ranges between 15 and 20 percent for most of the investments (with some exceptionally high numbers).

Table 4 Literature review of return on investment from R&D

Date	Title	Author(s)	Industry	Region	Return on Investment
2017	The impacts of research in an era of more stringent performance evaluation	Glen Greer and Bill Kaye-Blake	Agriculture	New Zealand	21% of industry growth
2010	The Benefits from Agricultural Research and Development, Innovation, and Productivity Growth, OECD Food, Agriculture and Fisheries Papers, No. 31, OECD Publishing, Paris.	Julian M. Alston	Agriculture	Various	20–80% p.a.
2009	Agricultural research: Implications for productivity in New Zealand and Australia	J.D. Mullen,G. M. Scobie & J. Crean	Agriculture	New Zealand and Australia	15–20% p.a.
2006	The Role of R&D in Productivity Growth: The Case of Agriculture in New Zealand:1927 to 2001 (WP 06/01)	Hall, Julia Scobie, Grant M Treasury NZ	Agriculture	New Zealand	17% p.a.

4 Description of R&D and the wine sector

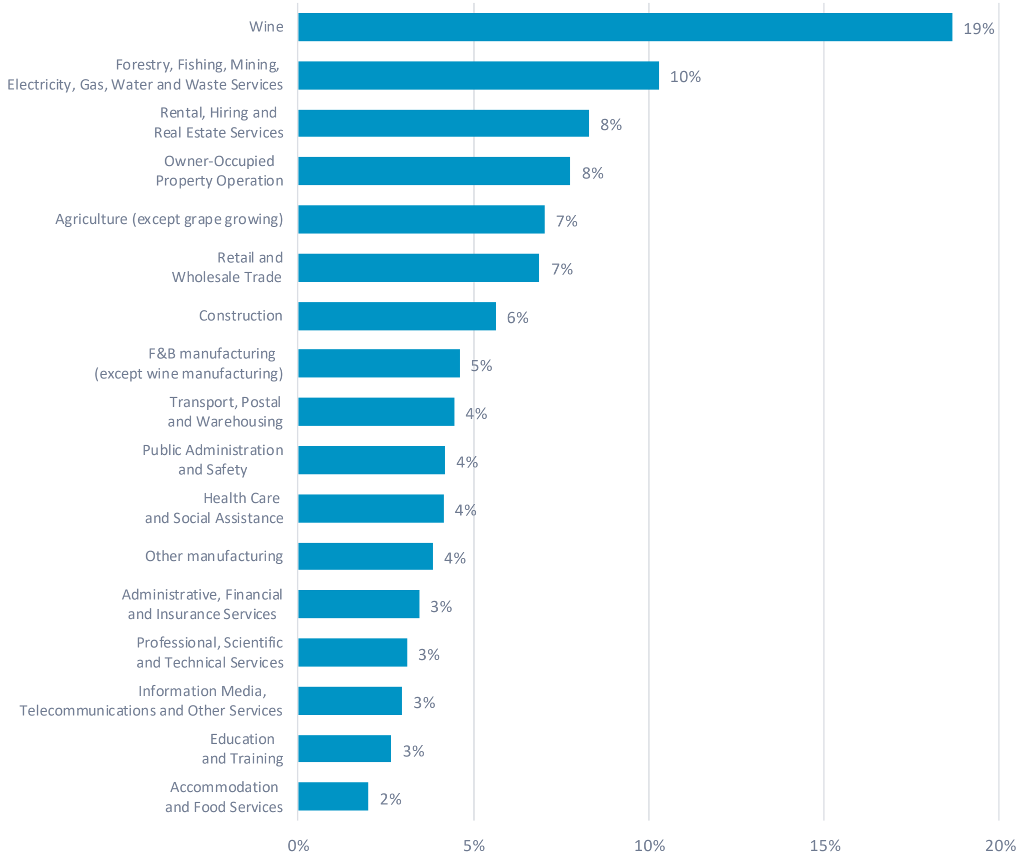
With a total export value of $1.83 billion, the wine sector contributed 2.2 percent of New Zealand's exports in 2019. The average export price of wine increased by 1 percent, compared to 2018, to $6.74 per litre. As a major factor of production, there is still commercially viable land available and the sector will not reach its supply capacity until 2028 (NZ Winegrowers, 2019).

The total expenditure of R&D in the wine sector is unclear. Based on Statistics NZ's R&D survey, the total amount of R&D investment in 'beverage and tobacco manufacturing', including 'wine and other alcoholic beverage manufacturing', in 2018 was $9 million. Based on our review of the literature and expert advice, the Statistics NZ figure significantly under-reports the R&D expenditure in the wine industry. Jordan & McCarthy (2016) provided an example for 5 companies' expenditure on R&D that summed up to a total of $6.02 million, whereas the figure reported in the Statistics NZ's R&D survey for the same companies was $48,000.

BRI has received a total funding of $12.5 million from the Ministry of Business, Innovation and Employment over 5 years. Between 2018 and 2022, BRI manages total value of $22 million research funded by NZ Winegrowers and government R&D funds. On average, BRI spends $4.5 million on own research activity per year. This is in addition to $1.3 million in external spend on research contracted to other organisations within the next four years.

Figure 4 shows an aggregated industry-level snapshot of the Marlborough economy extracted from our CGE database. It shows that **the wine sector accounts for 19 percent of Marlborough's economy**.

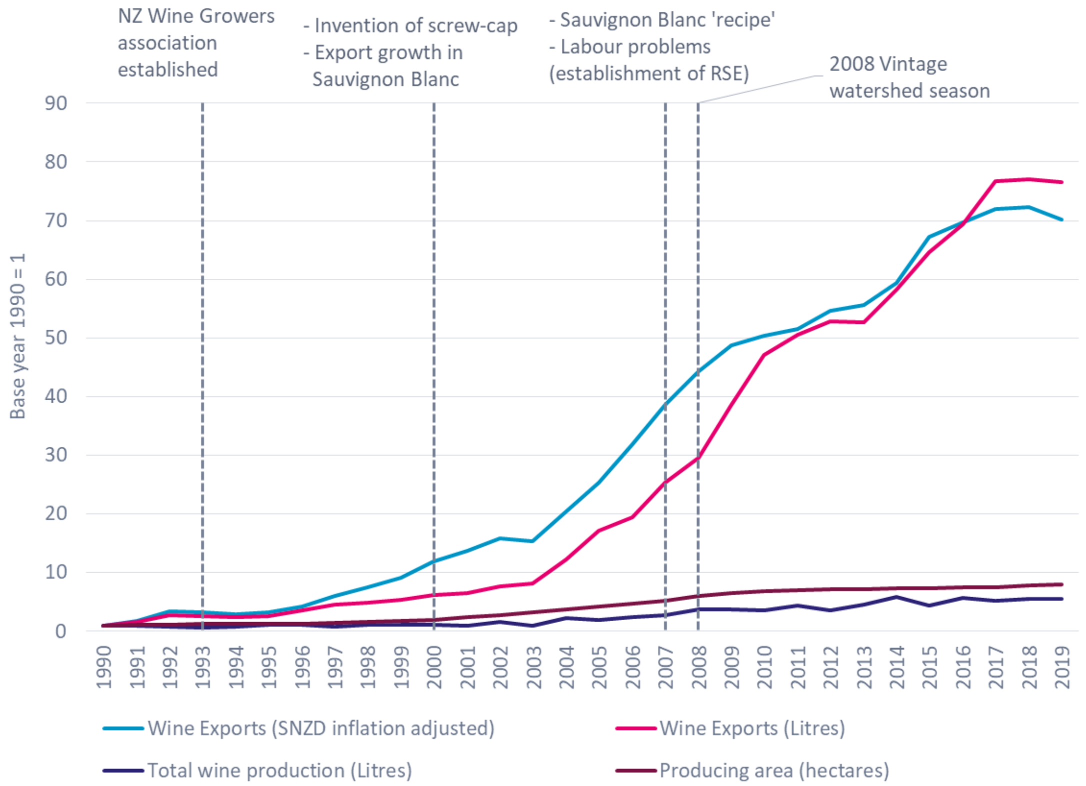
Figure 4 Marlborough economy snapshot



Source: NZIER (2017), Statistics NZ, NZ Wine

Figure 5 provides a description of the changes in the wine production and exports over time. The significant events are highlighted in the graph.

Figure 5 High level trends in the wine sector[17]



Source: NZIER, Statistics NZ, NZ Wine, RBNZ, Greer and Kaye-Blake (2017)

5 Results

As discussed in Section 3, we used the results from Greer and Kaye-Blake (2017) to estimate the productivity gains for the wine sector. This is equal to a 1.17 percent increase in the (total factor) productivity of the wine sector. This figure is slightly less than the productivity gains that we calculated in the three case studies of industry funded research in Sections 2.1, 2.2 and 2.3 above.

The outcomes of R&D are available to be applied throughout New Zealand industries. We have used our CGE model of the New Zealand economy to estimate the economic impact of the estimated productivity gains from research in wine – for technical details of our CGE modelling see Appendix C. The national and regional impacts are shown in Table 5. Our results suggest that **each year,** wine R&D leads to:

- an increase in exports by $41 million
- an increase in the size of the national economy by $64.5 million
- a boost in household consumption by $37.2 million
- and 258 new jobs for the economy.

[17] The Sauvignon Blanc 'recipe' refers to the research programmes that have informed vineyard and winery practices that help winegrowers optimize quality recipe for Sauvignon Blanc and have led to an increase in sales of Sauvignon Blanc.

The impact is larger for Auckland, Marlborough and Wellington, but all regions are positively affected.

Table 5 National and regional GDP impacts

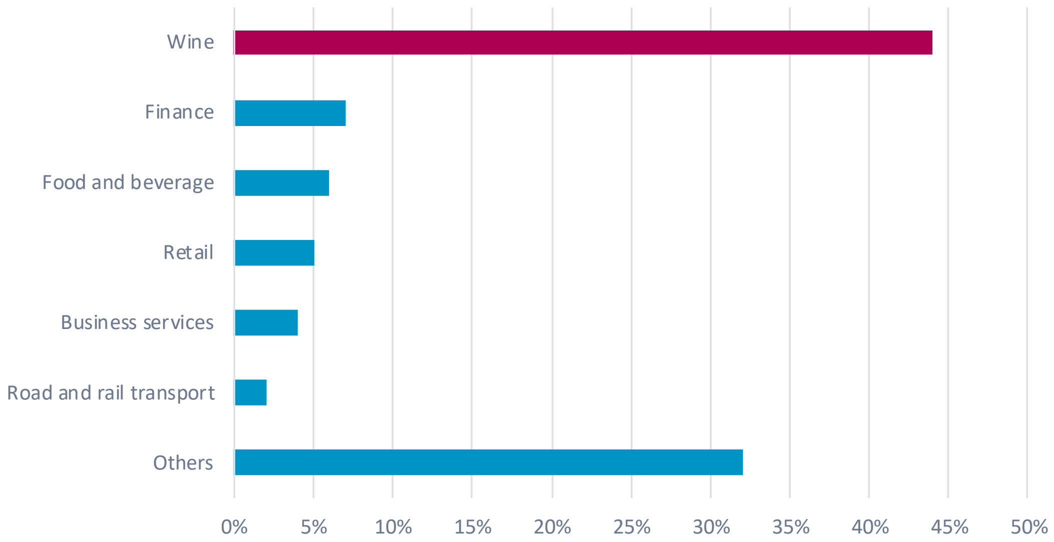
Region	GDP $ millions	Export $ millions	Wages $ millions	Household consumption $ millions	Employment (number)
Auckland	22.2	11.56	5.27	12.69	80
Bay of Plenty	2.9	1.51	0.66	1.96	14
Hawke's Bay	4.2	3.74	0.77	2.03	16
Wellington	6.17	3.33	1.54	4.09	26
Tasman / Nelson	1.95	1.67	0.4	1.06	10
Marlborough	8.99	8.39	1.51	2.43	17
Canterbury	6.5	3.82	1.54	4.27	31
Otago	2.99	2.04	0.7	1.89	12
Other	8.6	4.99	1.87	6.74	51
New Zealand	**64.5**	**41.05**	**14.26**	**37.16**	**258**

Source: NZIER

The positive impact of R&D in the wine sector goes beyond the initial gains for the wine sector. As illustrated in Figure 6, a wide range of industries, such as finance services, food and beverage, retail, business services and transport, are positively affected by the outcomes from improvements in the wine sector.

With 1,100 employees, Auckland has the second largest employment in the wine sector after Marlborough (1,350 employees). There is also a wide range of other services relevant to the wine sector located in Auckland. An improvement in the wine sector's production will benefit all the relevant sectors, such as food and beverage, retail and road and rail transport. Therefore, Auckland benefits from both the direct boost to production of its wine sector and from the boost to other relevant services as illustrated in Table 6.

Figure 6 Share of impact of R&D in wine by industry



Source: NZIER

Table 6 Regional GDP by industry

$ millions

Region	Wine	Retail	Food and beverage	Road and rail transport	Finance services	Business services	Other industries	Total
Auckland	9.1	1.5	1.5	0.3	2.3	1.3	6.2	22.2
Hawke's Bay	3.3	0.1	0.1	0.0	0.1	0.1	0.5	4.2
Wellington	1.0	0.3	0.6	0.1	1.1	0.4	2.7	6.2
Marlborough	8.5	0.0	0.1	0.0	0.0	0.0	0.4	9.0
Canterbury	1.4	0.5	0.5	0.1	0.4	0.3	3.2	6.5
Other	4.8	0.9	1.3	0.3	0.8	0.5	7.8	16.5

Source: NZIER

6 Discussion

The wine sector will be competing with other primary sectors over factors of production, particularly labour. Our expert advice is that the only solution for the wine sector in the medium term will be to improve the productivity of labour, land and capital.

The research we reviewed involved different types of changes to vineyard production. Vine shaking substitutes mechanised work for hand labour, a classic example of labour-saving innovation. Other research is associated with lower losses, which enables increased output for the resources used. The three specific projects did not involve innovative products or increased value for wine. The $64.5 million in GDP growth entails a combination of increased labour in the industry (the 258 new jobs) and increased output due to mechanisation and reduced losses. Given the current size of the industry, we believe that the increased output is within the current capacity of the industry.

It is also important to understand that R&D adds to the stock of knowledge in the industry. Research has a shelf-life; it goes stale and loses its impact (Hall & Scobie, 2006). Our recent study of the impact of a range of Provincial Growth Fund investment in Māori economic development highlighted the importance of increasing productivity of Viticulture and Horticulture sectors to maintain their growth (Torshizian et al., 2020). The industry must expect to continue with its R&D in order to maintain its prior gains and make new ones. In our analysis, we have assumed the current level of performance as a baseline. Alternative assumptions could also be applied, including scenarios in which a lack of R&D leads to poorer performance.

Over time, the industry will face new challenges. For example, the potential risk to the industry from lack of seasonal workers during the pruning season is partly mitigated by the research on the timing of pruning. The challenges to the industry vary over time and innovative solutions will be required. The risk management aspect of R&D will require proactive and preventative research to ensure that the capability to extend the shelf-life of research will be maintained and grow.

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Appendix A List of relevant BRI studies

Table 7 A list of wine industry and BRI funded research leading to productivity gains for the wine sector

Research	Benefits	Category of work
Impacts of nitrogen in vineyard and winery	Improvement of flavours, efficiency of fermentation process.	Winemaking, Viticulture
Yeasts for different flavours	Improvement of flavours, efficiency of fermentation process, quality consistency.	Winemaking
Volatile sulphur compounds	Avoiding faults.	Winemaking
Sauvignon Blanc programme	Understanding of impacts of interventions and processes to deliver preferred style of wine.	Winemaking, Viticulture
Powdery mildew	Improvement of mitigation against powdery mildew on wine grapes - reducing crop loss.	Viticulture
Mechanical Shaking 2011–2014	Reduction of botrytis infection of wine bunches.	Viticulture
Virus elimination project 2009	Reduction of leafroll 3 virus infection of wine bunches.	Viticulture
Trunk disease - vineyard longevity	Extended lifecycle of crops.	Viticulture
Spray Sensor	Consistent watering of crops (coverage).	Viticulture
Leaf plucking using sheep	Cost savings to crop management.	Viticulture
Organic focus soils project	Improvement to brand value and sustainability.	Viticulture
Herbicide reduction trials	Reduction of reliance on herbicides and improvement to brand value.	Viticulture
Irrigation reduction trials	Reduction of water usage and subsequent cost savings.	Viticulture
Timing of pruning	Improved understanding of labour requirements and timings reducing labour shortages.	Viticulture
MPI Annual benchmarking	Greater understanding of vineyard performance and when to mitigate for underperformance.	Viticulture

Source: BRI

Appendix B Supplementary literature of returns from R&D

Table 8 Additional literature on returns to agriculture R&D

Date	Title	Author(s)	Industry	Region	Return on Investment
2011	The Economic Returns to Public Agricultural Research in Uruguay	José E. Bervejillo, Julian M. Alston, and Kabir P. Tumber	Agriculture	Uruguay	Internal rate of return was very stable, ranging from 23% per annum to 27% per annum.
2009	Measuring the benefits from R&D investment beyond the farm gate: the case of the WA wine industry	Manju Radhakrishnan, Nazrul Islam and Glynn Ward	Wine	Western Australia	The benefits per dollar of R&D investment are found to be $2.8 at the farm level compared to $14.9 when flow-on benefits are taken into account.
2007	The Rate of Return to New Zealand Research and Development Investment	Robin Johnson	Agriculture	New Zealand	Private R&D 61.2%
2002	Research returns redux: a meta-analysis of the returns to agricultural R&D	Julian M. Alston Michele C. Marra Philip G. Pardey T. J. Wyatt	Agriculture	Various	Across 1128 observations the estimated annual rates of return averaged 65 per cent overall — 80 per cent for research only, 80 per cent for extension only, and 47 per cent for research and extension combined.

Appendix C Description of NZIER's CGE model

We used our NZ-TERM ('The Enormous Regional Model') CGE model of the New Zealand economy and its regions for this economic impact analysis.

NZIER's NZ-TERM has been built in consultation with CGE experts at the Centre of Policy Studies (COPS) which is now based at Victoria University, Melbourne. COPS is well-regarded internationally and recognised as a world leader in CGE modelling. For more details, see their website.

The TERM model includes 106 industries, 201 commodities and 15 regions. We usually aggregate the industries and commodity groups to broader groups depending on the focus of the study.

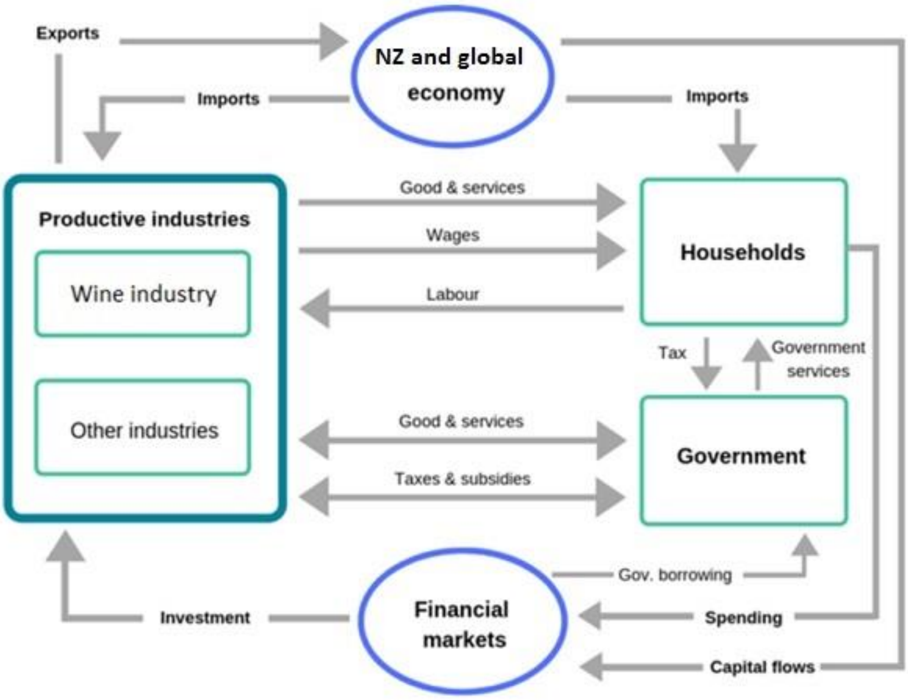
NZ-TERM is a bottom-up regional CGE model which treats each region as a separate economy. All regions are linked via inter-regional trade in commodities and movements in labour and capital. The model captures the various inter-linkages between sectors, as well as their links to households (via the labour market), the government sector, capital markets and the global economy (via imports and exports). 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.
- Within each region, any changes to the economy have multiple direct and indirect (flow-on) impacts, including beyond the sectors initially affected. So, for example, changes to the Waikato economy due to changes in land use patterns will flow on to other regions.
- Price changes (e.g. wage increases, shifts in the exchange rate) as a result of a change to the regional economy in one sector also affect all other sectors, both within the region and across the rest of the country.

A visual representation of NZ-TERM is shown in Figure 7 It highlights the complex and multidirectional relationships between the various parts of each regional economy and how they interact with other New Zealand regions and rest of the world.

Figure 7 CGE models show the whole economy



Source: NZIER

1.1 Closure

As we noted above, 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.

1.1.1 Short run closure

We have used a static CGE model, but with a short run closure. Since BRI recently started doing research in wine industry, therefore there was not enough time for investment decisions to affect capital stocks in other sectors. However, time is long enough in a way that price changes transmit through the economy and price-induced substitution to take place.

The Short run closures[18] include:

- **Labour market adjustment** – we hold national real wage fixed to base levels but allow for employment to vary by industry and region via adjustment in national employment.
- **Capital mobility** – Short term is not long enough for investment decisions to greatly affect the useful size of the sectoral capital stocks. For example, new buildings take time to be made.

[18] In this section variables being fixed to base levels means relative to future pre-simulation levels.