Economic contribution of PGP

A cost-benefit analysis of potential impacts

NZIER report to the Ministry for Primary Industries

May 2014

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Authorship

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Key points

The estimated economic impacts reported on the Primary Growth Partnership website and by individual programmes tend to represent *the overall outcomes of the primary sector R&D investment by both the taxpayer and the private sector if each programme performed according to aspirations*. We estimate that this overall economic impact of PGP from current and future programmes will be $11.1 billion per annum in 2025, with ongoing benefits into the future. This economic impact is roughly equivalent to increased export earnings or primary sector revenue.

To further investigate this overall outcome, we used a cost-benefit analysis framework to decompose the overall outcome. The decomposition allowed us to discuss several different elements of the original business cases. The estimate was derived from assessing the business cases of existing programmes, interviewing key informants in the primary sector, reviewing funding information for PGP as a whole and conducting sensitivity analysis around key assumptions. From our research, we concluded that existing programmes will make positive contributions to the primary sector and the New Zealand economy. The economic contribution will be an increase in export value and volume, primary sector output and GDP. Overall, we estimated positive net benefit and benefit-cost ratios (BCRs) from government funding of existing PGP programmes. We used those findings to estimate the potential impacts of the full PGP.

The decomposition provides a clearer picture of the sources of economic impacts and the assumptions used in their calculation. The annual estimate of $11.1 billion in 2025 can be roughly decomposed in the following way:

- $2.2 billion (20%) is the increase in Gross Domestic Product (GDP) that can be attributed to the government investment in PGP. It is net value produced by PGP in the form of additional economic growth, and is a key number that may be compared with the GDP impact of other government initiatives
- $4.2 billion (38%) is value from industry investment, and is also an increase in GDP. It is the increase in economic activity that we have attributed to the industry's contribution to PGP. It includes several elements: the matching contributions of industries to their programmes, an adjustment to account for business as usual improvements attributed to the programmes, and the structure of returns to investment
- $2.2 billion (20%) of the increase arises from assuming successful R&D. By modifying that assumption, we have estimated the additional value of improved R&D success. Also, decomposing the total impact ($11.1 billion) in this way has allowed us to make the more cautious estimates of government and industry GDP impacts, above
- $1.1 billion (10%) is the estimated value of the aspirational stretch described by the programmes. Applicants were asked to be aspirational in their programme goals; this estimate provides a measure of the stretch. It also allowed us to produce a more cautious estimate of net impacts, particularly when a more detailed estimate of expenditures and uptake were not possible

- $0.6 billion (5%) is an estimate of the operating and set-up expenditures required to implement the innovations developed through programmes
- $0.8 billion (7%) represents an adjustment to uptake levels from the aspirational stretch of programmes to levels of uptake of innovations more commonly demonstrated. By adjusting uptake rates to more conservative levels, we have estimated the potential benefit of improved uptake rates and provided a more cautious estimate of economic impacts.

The benefit cost ratio (BCR) of the net benefit from government investment compared to the amount of investment is 32. This BCR is relatively high, but well within the range of international assessments of BCRs of agricultural R&D. The range of results for existing programmes suggests that all programmes are expected to produce positive net benefits.

Non-quantified benefits are also a significant output of PGP programmes. Programmes are leading to reduced erosion in hill country, less nutrient loss into waterways, lower impacts on fishing stocks, and other social, cultural and environmental improvements. PGP is also fostering improved communication and co-operation within industries as part of the process of organising programmes and co-funding.

The report also provides suggestions for future assessments of PGP proposals and programmes. The suggestions are based around a cost-benefit analysis framework, and chiefly aim toward obtaining more detailed information and consistent measures of impacts. Possible metrics are discussed, with a focus on SMART metrics and the R&D process from research to economic impact.

More broadly, an evaluation of the whole PGP portfolio over time should start with its stated aims: improving sector output and productivity. Assessing the impacts of PGP should therefore focus on growth in total output from the primary sectors, improvements in wages and salaries, increased investment or returns to investment, increased land prices, greater product diversity, greater diversity of markets and improved unit prices. Non-market impacts could be losses due to slips or erosion, numbers of worker injuries or deaths, improved quality of streams and rivers, or other appropriate metrics. The changes would have to be assessed against some baseline. Possible baselines are historical trends, base year measures or the experiences of industries that have not participated in PGP.

Contents

Appendices

Figures

Tables

1. Introduction

1.1. Description of the project

This report provides the findings from an investigation into the economic impacts of the Primary Growth Partnership (PGP) at the Ministry for Primary Industries. The goal of the research was to understand the economic impacts for PGP that have been discussed in other places (most notably on the MPI website) and provide a robust analysis of potential export growth, GDP growth, and other economic measures. The project investigated most of the existing PGP programmes, and has made extrapolations about potential future (i.e., as yet unknown) programmes.

As with all research, this project has some caveats. This project concerns innovation and research and development (R&D). These are uncertain and risky processes. They can lead to success or failure, but they can also lead in unexpected directions. With these uncertainties, it is impossible to predict the future. We can only make our best assessment, given the information available. In addition, this is an economic analysis of the programmes and our best estimate of future programmes. We have not attempted to review the science in the programmes to determine whether it is appropriate or achievable. Our assessment starts from the point of view that the science is sound.

1.2. Context of the Primary Growth Partnership

The PGP was established as a 2009 Budget initiative to drive substantial gains in economic growth and sustainability in the primary and food sectors, including pastoral and arable production, horticulture, seafood and aquaculture, forestry and wood products, and food processing. PGP was intended to work by creating investment partnerships between government and primary sector and food industries based in New Zealand. The focus is on innovation and enhancement across the entire value chain, from primary inputs to final consumer markets.

The PGP programmes are now part of the Government's Business Growth Agenda. In particular, they are expected to assist in the strategy to increase exports from 30% to 40% of Gross Domestic Product by 2025.

Primary industries are important to the strategy because the sectors make an important contribution to the New Zealand economy. They produce over half the country's merchandise exports, which in turn account for around three-quarters of total exports of goods and services. The recent expansion in output and value in many primary sector industries has capitalised upon past research and development, with on-farm productivity growth outstripping that of the rest of the economy, but the pace of that growth is slowing.

The PGP initiative reflects the need for government and industry to work together to achieve higher rates of growth through innovation that will increase the yield, quality and market fit of primary products, create added-value uses for by-products, and lead to more sustainable and environmentally friendly farming and harvest methods.

Among the PGP objectives mandated by Cabinet are the following:

- Investment programmes should be aligned with, but additional to, existing initiatives and work programmes
- Investment programmes should comprise a suite of complementary and mutually supporting projects, targeted at a range of points along the value chain
- Co-investors must at least match the financial contribution of the government, over the life of the programme
- Investment programmes are expected to deliver measurable economic benefits to the co-investors, as well as economic growth to their industry sector and the country.

This assessment has focused on the current impacts of the programmes, the quality of the information and the potential contribution to the Business Growth Agenda. It also makes an assessment of potential PGP programmes.

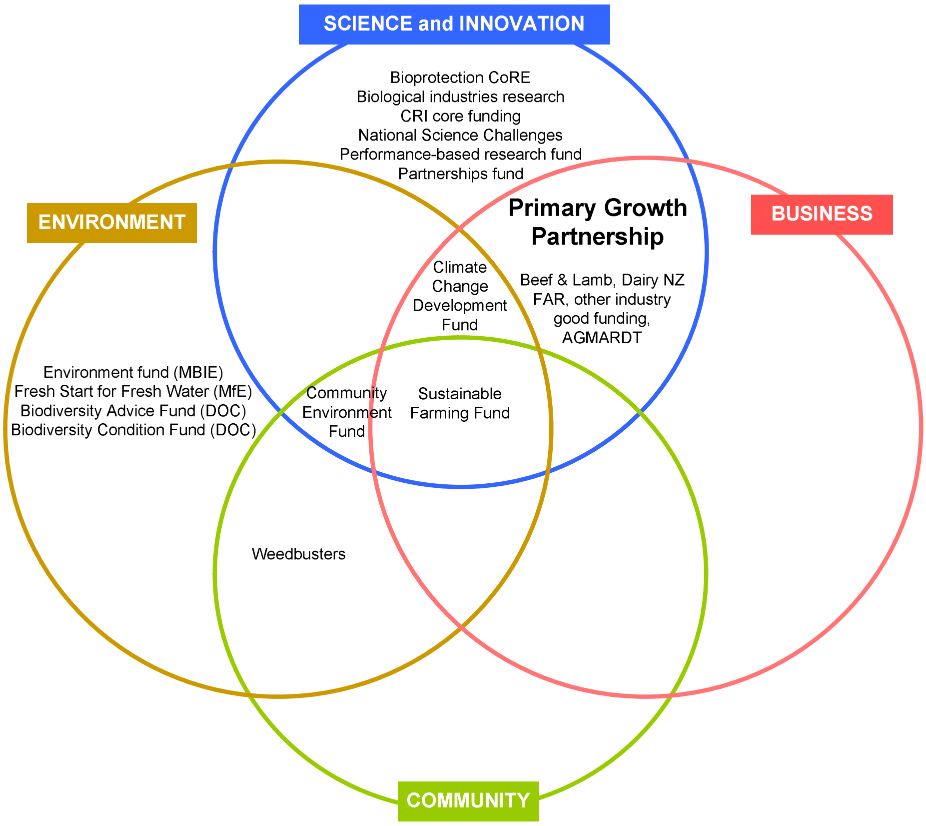
The Primary Growth Partnership is one of a number of initiatives that have been taken to encourage and support the growth and development of the primary sector. Some initiatives are supported through:

- industry good bodies,[1]
- funding provided by Ministry for Primary Industries' budget appropriations,
- funding from other ministries (including DoC, MBIE and MfE),
- funding of science programs and research organisations
- funding from community resources (wholly or partly).

Figure 1 sets out the funding context of the Primary Growth Partnership. The PGP is strongly anchored at the intersection of the Science and Innovation and Primary Sector Business circles of influence. The PGP also reflects environmental issues in its sustainability objective, especially as it provides the primary government funding for the Centre for Agricultural Greenhouse Gas Research, but PGP does not derive its funding from the environmental and conservation votes. The PGP also engages with the community through its on-farm program components, but does not derive programme funding from community sources.

[1] Industry good bodies are funded through compulsory levies. Their function in the PGP process has been to coordinate the research activity.

Figure 1 Primary Growth Partnership in context of other initiatives



Source: Kinnect Group, adapted by NZIER

1.3. Description of this report

This report does three things. First, it describes the methods used for the different stages of the project, and how the information from each stage informed the findings. Secondly, it presents the findings for the project. The findings include our best-informed estimates of the potential impacts of PGP programmes. Thirdly, it makes some estimates of potential returns from future PGP programmes..

The report has a straightforward structure. Chapter 1 provides an introduction. Chapter 2 describes the process of the assessment, including the three main elements of the analysis. Chapters 3, 4 and 5 present results from the documentary review, interviews and results of the quantitative analysis, respectively. Chapter 6 is a benchmarking exercise, relating the findings to the domestic and international literature. The final chapter provides a conclusion to the report.

2. Assessment process

2.1. Introduction

The assessment process had several parts to it, and they are discussed in this chapter. The parts were:

- document review – review written information about the programmes and the intended impacts
- initial quantitative analysis – a CBA and sensitivity analysis to establish the method and identify key variables in the analysis
- interviews with stakeholders – semi-structured interviews with a number of key informants on PGP programmes to explore the key variables
- estimates of impacts – final CBA, informed by the interviews and sensitivity analysis.

Each of these parts is discussed in detail in this chapter.

2.2. Document review

Criteria for review

The document review required the development of criteria relating to the goals and objectives of the PGP. The criteria were made up of the following parts:

- Programme **description.** The business case sets out the opportunity and the proposed solution and identifies the information required in developing the benefit estimates and identifies who the Crown is partnering with
- Programme **context**. The business case identifies the industry, sets out the size of the industry, and describes the opportunity (assuming success) and relevant demand and supply factors
- The **counterfactual** (or business as usual scenario). What would happen without the PGP funding? This is an important part of the analysis since this provides the basis by which the benefits are measured against
- The **analytical method**(s). What are the methods used to illustrate how the benefits are calculated is required? This could include direct and indirect impacts and spillovers
- The **extent of the impact**. Are the benefits quantified and how big are the expected benefits?
- **Risk and uncertainty**. Have the risks and uncertainties been identified and how are they incorporated into the analysis e.g. are they described qualitatively and has that detail been used to quantitatively set out expected returns?
- **Progress**. Has progress been reported?
- **Discounting**. Has discounting been used to show the benefits in today's dollars?

- **Support for results**. Does the business case provide consistent and sufficient information to justify the statements of economic benefits?
- **Benefit number**. What is the economic impact estimated?
- **Total benefit**. Are there other significant unquantified benefits, in particular non-market benefits?

Assumptions about the audience

The following assumptions were made when assessing the business cases:

- The audience for the business cases is the informed reader. This person is not a technical expert but is able to understand non-technical language and find their way around a well-structured document
- Stakeholders and interested parties are typically busy, so they value concise summaries that allow them to minimise time spent reading. Business cases should be appropriately presented
- The important issues should be up front in documents, particularly the assumptions that drive the benefit analysis.

2.3. Initial quantitative analysis

We used a cost-benefit analysis framework to decompose the various 'value creation' elements of the PGP.

It is important to note that while we have followed the NZIER cost-benefit framework to review the PGP, we have not undertaken first hand CBA assessments. Rather we have used the existing data from the original business cases supplied to estimate likely net benefits. As a result, should updated information on programme performance become available the results may need to be revisited.

NZIER's standard process for undertaking a CBA is outlined in the table below. We have focused on defining the opportunities and specifying the baseline or 'counterfactual' for defining the benefits, and the justification of the assumptions on uptake of the research outputs.

NZIER's 10-step cost-benefit analysis framework
1. Define the problem / opportunity 2. Decide whose **benefits and costs count** (standing) 3. Select options and specify the **baseline** (i.e. the 'without') scenario 4. **Classify** the kinds of benefits and costs and select the measurement indicators 5. **Quantify** the consequences (via the measurement indicators) over the life of the options 6. **Value** (attach dollar values to) the benefits and costs 7. Discount future benefits and costs to obtain present values at 8% 8. Calculate decision criteria 9. Analyse **uncertainty and sensitivity** of the results to assumptions (ideally including Monte Carlo simulation) 10. Make a **recommendation** and document the assessment.

For each of the current programmes (as at March 2014) we have considered the following points:

- the economic impacts relative to baseline (without the PGP programme) whilst managing the risk of double counting benefits and costs
- distinctions between private and other benefits (or costs)
- ensuring that annual impacts, timing, and discounting to present value use the Treasury mandated discount rate (8% real)
- Monte Carlo sensitivity assessment of each programmes's CBA, in particular focusing on the impact of assumptions around the probability of science success and commercialisation
- the impacts on export targets for 2025.

A limitation of the using CBA framework of individual programmes is that it does not accommodate inter-relationships between the risk profiles of the individual programmes that make up the PGP investment portfolio. Thus the mid-point estimate of value should not be aggregated to estimate a total programme or portfolio return. To do this would require the application of portfolio theory approach to assess how the portfolio of PGP investments (those currently being undertaken and projected) collectively lowers or enhances the risk of achieving the outcomes sought by the PGP overall.

Applying a CBA framework

The CBA framework provided several benefits to this assessment:

- a framework for organising the data from the business cases
- a consistent approach to identifying benefits and costs
- a robust method for considering the baseline or 'business as usual' (BAU) scenario – without the Government investment

Each of these elements affected the decomposition of the estimates of economic impacts. For example, the business cases were inconsistent in the metrics used to measure impacts and the baselines against which they measured the impact of PGP investments. We have used the CBA framework to create consistency in the estimates by being clear about the baseline for each assessment:

- investigating the impacts of probability assumption
- assigning additionality, or the additional impact from the government's share of the investment.
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We also need to consider the degree of uncertainty and risk involved in the research. For example where there is highly applied incremental research arguably government investment has displaced or inappropriately extended the level of private investment. Whereas, the same conclusion might not be drawn if the research being supported is more risky and uncertain. Clearly significant subjective judgement is required to make this call.

Figure 2 illustrates the impact of different assumptions. The largest reported benefits arise from measuring current performance (or no change over time) against aspirational outcomes for PGP. The reported benefits become smaller when a different baseline is used, or different assumptions are used about the probability of success or impacts. Achieving greater consistency across the estimates required:

- being clear about the baseline for each assessment
- investigating the impacts of probability assumption
- assigning additionality, or the additional impact from the Government's share of the investment.

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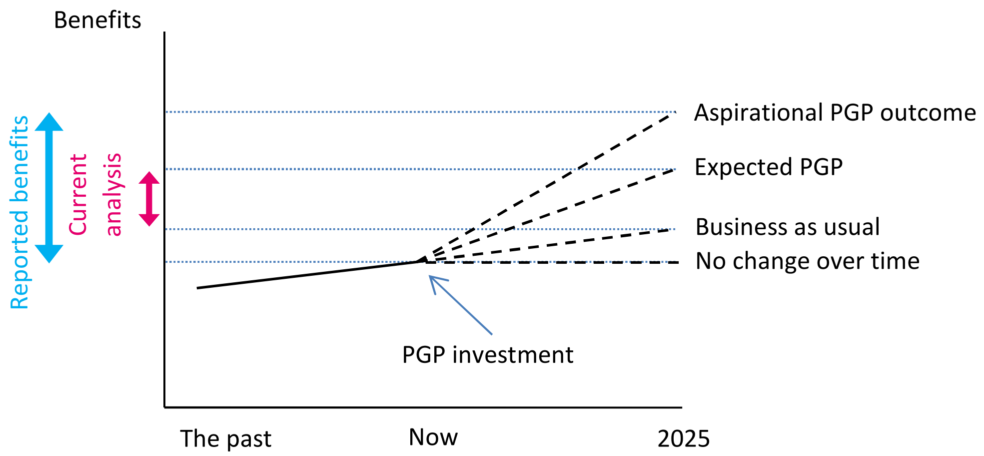
Figure 2 Illustration of the CBA process

Illustration of setting out PGP benefits, with focus on PGP expected outcomes vs BAU counterfactual within the relevant appraisal year



Source: NZIER

Our assessment considered the following dimensions of each business case; they are explained more fully in the next section:

- probability of success of R&D and commercialisation
- the initial benefit number
- uptake of the new and improved products, processes & services
- extent of improvement that would have occurred in the counterfactual
- operating and set-up costs, and prices charged
- appraisal period and benefit growth.

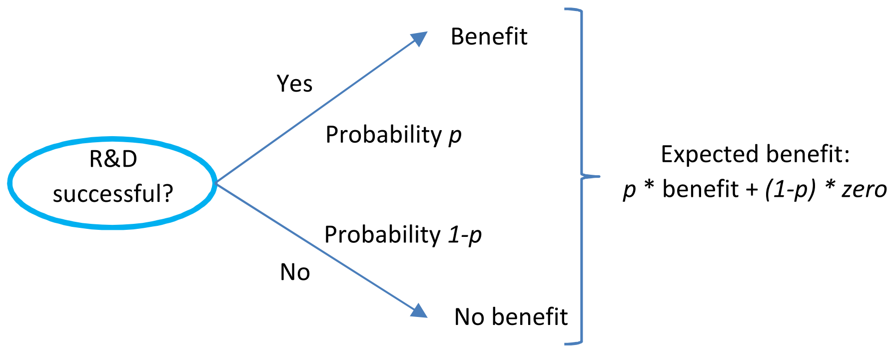
CBA elements considered for project evaluation

Probability of success of R&D and commercialisation

In the proposals firms and industries were asked to be aspirational. Proposals are based on the certainty of R&D success as well as bringing the innovation to market. For instance, the reported benefits in the PGP relate to the top-right result in the 'decision tree' of Figure 3. However, by its very nature innovation is uncertain. An adjustment is needed to represent the reported benefit number as a probability-weighted expected value. Our assessment used sensitivity analysis to estimate the impact of assumption around R&D success, using a central probability (the *p* in Figure 3) of 0.75 and a range from 0.50 to 1.00.[2]

Figure 3 Adjusting for the chance of R&D success

Stylised 'decision tree'



Source: NZIER

Value of benefit – mid-point or upper range?

The original benefit value reported sometimes differs between an upper limit, or aspirational outcome, and that of a probability-weighted expected (or 'average') outcome. Sometimes the original reported benefit figures are optimistic, because of assumed high uptake rates or associated costs were excluded. Some PGP programmes were conservative in reporting their value. We made some adjustments if the logic of the business cases warranted it. For instance, the full benefits of the PGP on annual industry growth rates should apply after the programme is complete, rather than from when the proramme starts.

Uptake of the new and improved products and processes

Uptake is a crucial issue when considering the benefits of a new product, process or service. It is the actual use of innovation that leads to economic impacts. In some cases this is not really an issue, because the private partner(s) comprise the majority of industry that would be the primary user. But in other cases the research partner needs others (such as farmers, customers, sometimes even competitors) to adopt and take up the new product, process or service before the full benefits are realised.

Extent of improvement that would have occurred in counterfactual

Economic assessment places a heavy emphasis on the 'counterfactual' scenario, which is what the state of the world would likely be if the initiative were not done. The impact of the analysis is considered as a comparison between the factual (the

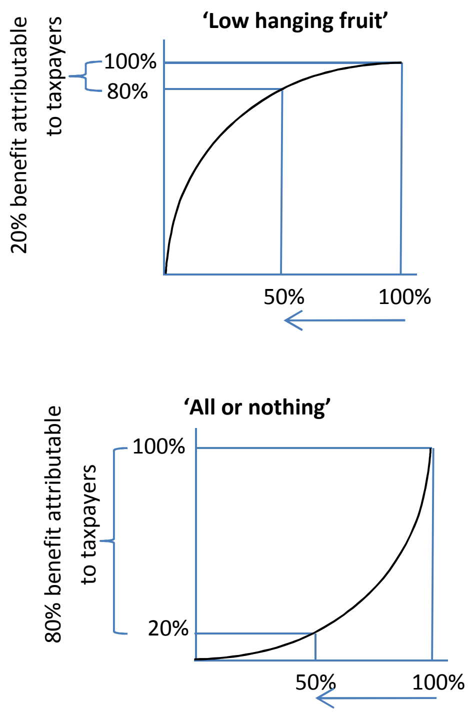
[2] The analysis used a triangle distribution, which is so called because it looks like a triangle on a graph. It is a bounded distribution (it does not go to infinity, like the Normal distribution) and symmetric around its mid-point.

world with the initiative) and the counterfactual in each time period. Analysts will spend as much time and effort considering the counterfactual as they do the factual. Questions asked when reviewing each PGP programme business case and supporting documentation included:

- would productivity improvements continue to occur over time anyway?
- what is the 'public policy' problem that prevents what seems to be profitable exercises from being done anyway by the private sector?
- what is the nature of the 'R&D production function' (the relationship between inputs and outputs), as shown in Figure 4?

Figure 4 Thinking through the counterfactual

Illustrations of (respectively) decreasing, constant, and increasing returns to scale R&D 'production functions', whereby removing the up to 50% Crown contribution may have a small, equally proportional, or large detriment to claimed benefits



Source: NZIER

Operating costs and prices charged

New and improved products, processes and services will usually be associated with variable operating costs ('opex') and/or set-up costs (in addition to the original PGP investment cost). For instance, trying to get farmers to change their practices would require material effort to train and encourage uptake, which is a costly. Alternatively planting new types of crops developed comes at the opportunity cost of not planting traditional crops. These operating costs and other set-up costs need to be netted off if one is to distinguish between a gross benefit and a net benefit.

Appraisal period and benefit growth

An 8% 'social opportunity cost' discount rate is used because it is Treasury policy. We acknowledge there are grounds to use a lower 'consumption' discount rate ('social rate of time preference') to consumption impacts when estimated using a CGE model, because the impacts on savings and investments would already be implicit in the analysis. The reason we do not, however, is because cost of taxpayer funds for the original investment would need to be adjusted upward to account for the extent of displaced private investment.

2.4. Interviews

As part of reviewing the assessment of benefits we have conducted a number of interviews with those participating in the PGP process. The aim was to elicit a high level understanding of the programmes from the participants' point of view.

As part of this process we interviewed 17 respondents from 15 of the current PGP programmes from a list of key contacts given to us by MPI. These were a combination of face-to-face and telephone interviews lasting around 20-40 minutes each.

A standard set of questions (see Appendix B) were developed to further understand the aim of the PGP programmes, the baselines used to measure the benefits, and the critical factors that drive the benefits to further understand the approaches taken. Below we set out a summary of the main findings.

2.5. Final assessment

The final stage of the project was to re-evaluate the quantitative CBA using the new information gained from the interviews. The interviews provided information about some of the key variables in the CBA, as identified earlier in the project. Some of those key variables were:

- industry investment in the counterfactual situation
- uptake rates
- R&D success probabilities
- operating costs
- process for assessing potential benefits.

By incorporating the new information in the CBA, we have been able to estimate the economic impacts of PGP using both qualitative and quantitative information. The results are a more robust assessment of the potential impacts of PGP.

3. Results of document review

3.1. Introduction

The PGP is associated with two economic goals. One is the goal set by Cabinet to create investment programmes additional to existing initiatives, thereby increasing the amount of investment in the primary sector. The second goal is grounded in the Business Growth Agenda, with its target of doubling exports by 2025. The two goals are apparent in the programmes' plans. They contain both aspirational goals of 'step changes' and transformations, as well as discussion of how industries can double exports between 2009 and 2025.

Most innovation is incremental and occurs at the margin and 'step changes' in growth, for example those that arose from the development of the transistor, occur infrequently and typically unexpectedly. The chances of major breakthroughs in any particular industry are not high, but they are still possible. The benefit calculations should be seen in this light, as a mix of aspirational but possible goals on the one hand, and more sedate plans for contributing to exports on the other.

3.2. Economic metrics for the programmes

One of the main tasks has been to understand how the benefits were calculated and what they are measuring. Business cases may present gross outputs, export growth, net economic impacts, GDP impacts, EBIT and/or job growth, calculated with financial analysis, cost-benefit analysis, multiplier analysis, CGE or unspecified methods. By bringing some consistency to the estimates, we are able to form a better view of the aggregate impacts of PGP (for current and future programmes).

Gross output figures and gross export figures are higher than the net benefit to New Zealand. Gross figures do not account for costs, which need to be deducted to arrive at net economic benefit. While the amount of investment or spending required to produce results varies from industry to industry, in some cases the investment required is substantial, e.g. the costs in the dairy industry are forecast to rise by 1.8 billion by 2020 (fuel and expansion of milk supply) to meet the Transforming of the Dairy Value Chain programme goals.

Some measures of economic impact

The business cases use a number of measures of economic impact. The main ones are:

- export growth – the value of exports is the amount of revenue gained from selling products overseas. The sales revenues pay for both the materials used (the *cost of goods sold* or *intermediate products*) and the value created by employees, machinery and plant, investment capital, land, and other factors of production
- gross output – gross output is the value of products and services at their average prices. Export growth increases gross output directly. However, gross output is a revenue number rather than a measure of value added
- GDP impact – Gross Domestic Product (GDP) is a measure of how much economic value the economy creates in a year. Importantly, it is about the value added or created. It is therefore smaller than gross output or export growth, because the costs of intermediate products are subtracted
- financial impact – financial modelling considers impacts at a business level – will the project be commercially successful for a business? Importantly, labour is a cost for financial analysis, while increased labour income is a benefit from the perspective of GDP
- economic impact – this phrase does not have a precise meaning. Further explanation can clarify whether it refers to gross output or GDP impact.

PGP programmes target the improvement in efficiency, quality, and quantity of production irrespective of export potential. An example is honey: because of its medical uses, 10% of that product will find its way on to the domestic market. Low-calorie and low-alcohol wine is also likely to be sold domestically as well.

We have had to make conversions between gross impacts and net benefits. We have adopted a rule of thumb for this review, that GDP increases by $0.50 for every $1.00 increase in exports or gross output. This ratio is based on our experience with trade modelling and gross margins in the agricultural sector, but needs to be investigated further.

3.3. Resource limitations

Some projects are focused on increasing the value within the existing resource base of the industry (e.g. Precision Seafood Harvesting). However, in many cases, the analysis assumes that success involves taking resources from other sectors at current prices. For example, the Manuka honey business case compares returns for honey to forestry and sheep and beef, suggesting that it will need between 30,000 and 50,000 hectares of sheep and beef or forestry land to reach its target benefits. Each of those industries also has PGP work that attempts to boost returns to that sector, increasing the prices of land, capital and labour that supports the industry. A further example is the dairy industry which forecasts that it will increase its land in dairy by 16%. This will be taken from existing sheep and beef properties and possibly forestry. Other programmes seek to use under-utilised marginal land.

Success of a research project will mean factors of production (land, labour and capital) will rise in price and the ability to bid away land from other sectors is limited.

So if, for example, forestry and sheep and beef programmes are successful, both Manuka plantations and dairy will find it increasingly difficult to bid away land from those activities. There are limits to growth since success in one sector will have impacts on other sectors both positive and negative. The successes and failures, risks and uncertainties are not independent for each programme, so the potential value is not strictly additive.

3.4. Assessments using the criteria

Description and context

The focus of the description and context sections is on the machinery of the business cases: opportunity, solutions and general state of the industries in questions.

In all business cases there are good descriptions of what the opportunity was, how they were going to fix it and general state of the industry.

Counterfactual

The business cases generally do not have a good description of the counterfactual (i.e. what would happen in the absence of Crown funding).[3] One issue to note is that they often appear to assume a static future with no improvements in R&D without the PGP programme. It is against this baseline that business cases measure the benefits from the PGP programme. The suitability of this baseline depends on the impact being measured. If the goal is to measure a doubling in export growth, then a 2009 or 2010 baseline is likely to be correct. On the other hand, it may not be the correct baseline for measuring additionality of the programme. Some cases studies do assert that this research will not have happened otherwise 'without' the PGP funding e.g. the Seed Nutrition Technology PGP programme.

These claims were later investigated in the interviews, and the information obtained was incorporated in the final assessment.

Analytical method

A variety of methods are used to calculate the benefits. Most start with a financial analysis that sets out the direct benefit from the industry. Typically this is well explained.

Some business cases then use CGE analysis to demonstrate how the research will then benefit the country beyond the farm gate (e.g. the Farm IQ and Precision Seafood Harvesting Business Cases). These report GDP impacts, trade balances and impacts on the domestic economy among other impacts.

Others use multiplier analysis (e.g. Marbled grass-fed beef business case). While it gives an indicator of the contribution from various sectors and general macroeconomic indicators, multiplier analysis is not used in public policy. The main reasons for this are:

- Supply is unconstrained. Inputs such as labour, capital and land are always available for the expanding sectors and available at constant prices

3 One of the reasons for this is that many if not all private sector business cases do not have a counterfactual.

- Wages are held constant even in the sectors that are growing
- There is no substitution between factors of production or on the demand side i.e. as incomes rise the consumption of different goods remains constant

As a consequence the multipliers used tend to systematically overestimate the true impact and provide an unjustifiably rosy view of the economic impact

Extent of impacts

Depending on the method of analysis used, most business cases report benefit results in a clear and concise fashion. In most approaches, the assumptions that drive the impacts also are clear e.g. the Pioneering to Precision fertiliser business case has a particular clear set of assumptions on uptake rates, the impact of variable rate fertiliser application, and application costs.

Many of the programmes have significant positive spillovers, particularly environmental benefits. Potentially, these benefits will have major impacts for all New Zealanders e.g. the variable application of fertiliser (Pioneering to Precision Business Case), more efficient use of nitrogen (Transform the Dairy Value Chain Business Case) and increased planting of Manuka (High Performance Manuka Plantations) all will contribute to cleaner water.

Indirectly, they will also contribute to the durability of farming, including farmers' licence to farm.

Risk and uncertainty

Many of the business cases set out in a detailed descriptive way the various risks and uncertainties of the marketing, supply chain management, up-take rates by farmers and research success.

Only in a few cases are the risks shown in quantitative form to give a range of benefit estimates. This is a major failing of most business cases since some linkage is required between the critical (success) assumptions and modelling risk. One exception is Pioneering to Precision Business Case which sets out lower adoption rates, increased costs of aerial application, lower adoption rates and higher costs, and other scenarios (AGFIRST Economic Analysis p5).

Progress

Progress is reported on the Ministry's website. This is useful for tracking progress and performance.

Support for results

The support for results is highly dependent on the type of analysis that has been developed. This is dependent on the:

- Description and context which is well developed in all business cases
- The counterfactual analysis which is neglected in most business cases
- The type of analytical tools used to estimate the extent of the benefits. In most cases, a part from where multipliers have been used, the direct

benefit estimation is clear and concise. In some cases CGE models have been used to illustrate the wider economic benefit

- Other factors such as discounting and accounting for risk and uncertainty are variable in the business cases. Discounting is only done in a few cases while risk and uncertainty is qualitatively assessed in most cases but only in a few cases is it assessed quantitatively.

Therefore, the support for the results is variable and in most cases more work is required to understand how the analysis has been put together. Also, more work is required to understand the nature of those risks and whether the benefit claims can be substantiated.

Benefits

The documents provided initial benefits numbers, and these were also compared to information on PGP on the MPI website. The final assessment of the size of the economic benefit was conducted in the last part of this research project.

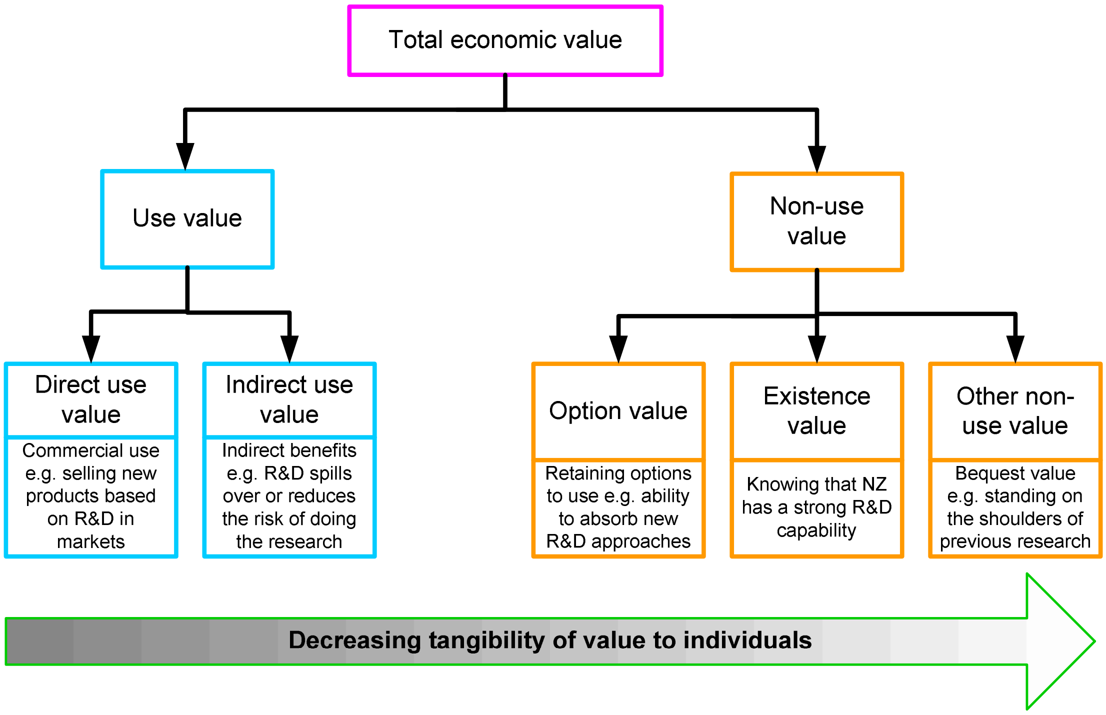
Total benefits

There are many significant benefits that have not been quantified. Specifically, the environmental benefits associated with the reduction in sediment loss, cleaner water and support for farmers' license to farm. These should not be underestimated since they contribute to the durability of the primary industries. This is examined more closely in the next section.

3.5. Non-quantified benefits

Many of the PGP programmes have substantial non-quantified benefits. To examine these issues we often use the total economic value framework. This framework is a standard economic tool for categorising and exploring the different sources of value. It provides a way to capture all the ways that people value natural resources. The framework is set out in Figure 5.

Figure 5 Total economic value



Source: Adapted from Serageldin, 1999

One way that people derive value from natural resources is by using them (use value in Figure 7). The commercial value has been estimated by this report and reflects the dollars being invested by industry and government in research and the aspirational outcomes.

The PGP programmes also provide what is called non-use value. Non-use value is something that people derive from the R&D without actually using it, either directly or indirectly. The non-use values are the benefits to the environment, social benefits from better performing primary industries, and the impact of the PGP on other innovation and the willingness of firms to engage in further innovation programme.

As we move from commercial, direct use of R&D to non-use values, particularly things like preserving environmental outcomes, we move from more tangible values to less tangible. More tangible values tend to be easier to quantify.

PGP programmes have a mix of expected non-use values. In the Transforming the Dairy Value Chain programme researchers have identified a raft of non-quantified benefits from reducing nitrogen run off on farms and more efficient use of natural resources per cow through to better health and animal welfare practices and building rural advisory capability that can be leveraged to other rural industries.

Similarly, the High Performance Manuka Plantations programme aims to convert class six and seven land into Manuka plantations. By doing so it is likely to have a very large environmental benefit in terms of erosion prevention and land stabilisation.

The Clearview Innovations programme aims to reduce nitrogen losses by developing improved land management and mitigating tools that reduce nitrogen losses at point source. This is likely to reduce nitrogen losses both in waterways and into the atmosphere (reducing greenhouse emissions).

The Precision Seafood Harvesting programme looks to deliver enduring environmental benefits for the fishing industry that are very large. The benefits revolve around:

- harvesting only selected species that are sought in the market at the time. This involves reducing the incidental catch of undesired fish species, reducing any potential for discarding of undesirable fish at sea
- harvesting only the desired size of the target species. This reduces juvenile mortality and conserve the stock and potentially leads to increases of the stock as the juveniles on-grow and reproduce
- matching product characteristics to market demand. This enables harvesting of seafood species only and not other marine biota of any type and minimising impact on the marine environment.

The Steepland Harvesting programme through mechanisation is aimed at reducing erosion and flood damage, improving the protection of forest land and waterways, building capability in the harvesting equipment sector, and improving worker safety.

Other innovation benefits from programmes are less tangible, such as the value of bring researchers together who previously haven't cooperated and the creation of larger innovation programmes with a better chance of success (relative to a succession of smaller projects done over a longer time frame). In programmes such as the red meat sector this type of benefit should not be understated.

All PGP programmes mention the wider economic and social benefits of success. If a programme is successful it will generate economic activity in the wider rural community and further afield. From this increased economic prosperity, communities will benefit through increased employment and higher wages.

The benefits from use and non-use values are all equally important and as far as possible the assessment considers not only the more easily obtainable costs but the more intangible benefits. Further many of the non-use values are likely to become more important as times goes on – therefore there value is likely to increase.

We believe that more work could be done to illustrate the more readily identifiable dollar values of non-use values within the PGP programmes as they gather momentum and targets are reached, particularly for non-use values that are seen to be important.

4. Learnings from interviews

4.1. Introduction

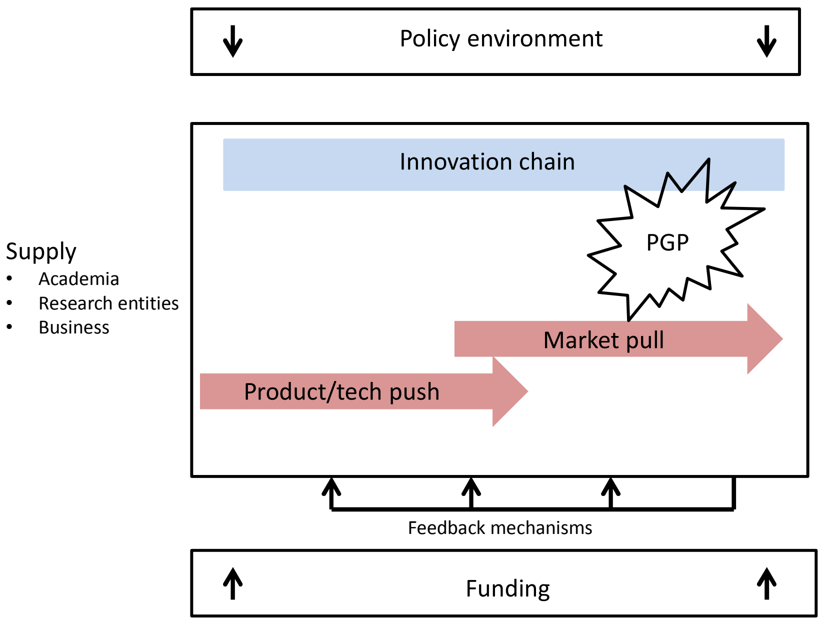
The interviews provided a richer, more detailed picture of the PGP programmes than we could obtain just from the documents. The initial quantitative assessment helped identify the key drivers of economic results, which were then the main topics for the interviews. This chapter reviews our findings for those main topics.

4.2. Aspirational goals

All participants had a strong understanding about what they wanted to achieve from the various programmes and could articulate that vision succinctly. The 'vision' drove the investment from industry and they were focused on achieving that vision through the PGP process.

In all instances, the PGP programmes were 'market pull' i.e. industry had focused the research on specific goals and objectives that are intended to deliver commercial outcomes. This is a major strength of the PGP process because of the clear focus on delivery. Participants see the process as filling a necessary gap in the primary sector funding approach by government (see Figure 6).[4] Respondents saw a need for an industry focused market pull approach to funding in the primary sector.

Figure 6 Simplified innovation funding system



Source: NZIER

4 While there are other parts of the science system that require 50% funding by industry most are not exclusively focused on the primary sector.

All participants were also well aware of the risks and uncertainties associated with R&D and appreciated that there was no guarantee of success.

4.3. Deciding on research priorities

The impact of the 'market pull' approach is clearly felt in the way that the innovation priorities have been developed. In some cases the research agenda was obvious (e.g. Manuka Research Partnership, NZSTX, SPATSnz and Future Forests had a clear goal from the outset). In others, the industry, its research partners, and MPI have engaged in a process that has taken some time to work through the research priorities[5] (e.g. Stump to Pump, Lifestyle Wines, and New Vision for Pastoral Agriculture) or were part of the industry research objectives (e.g. Transforming the Dairy Value Chain ensured that its PGP programme focused on the industry goals).

In some instances, the priorities have been re-ordered (e.g. Red Meat Profit Partnership and Marbled Grass-fed beef). This is a signal that the research process is not static and that incremental changes to the research process are required that involve grappling with the uncertainties of the R&D process. This is a positive signal since it shows that PGP programmes are prepared to move their research priorities to ensure they maximise the chances of success in the face of uncertainty.

4.4. Baseline measurement

A crucial part of the analysis is further understanding what each PGP programme is using as its baseline to measure progress i.e. what would occur 'without' PGP. This is important since it acts as baseline to measure benefits and costs against.

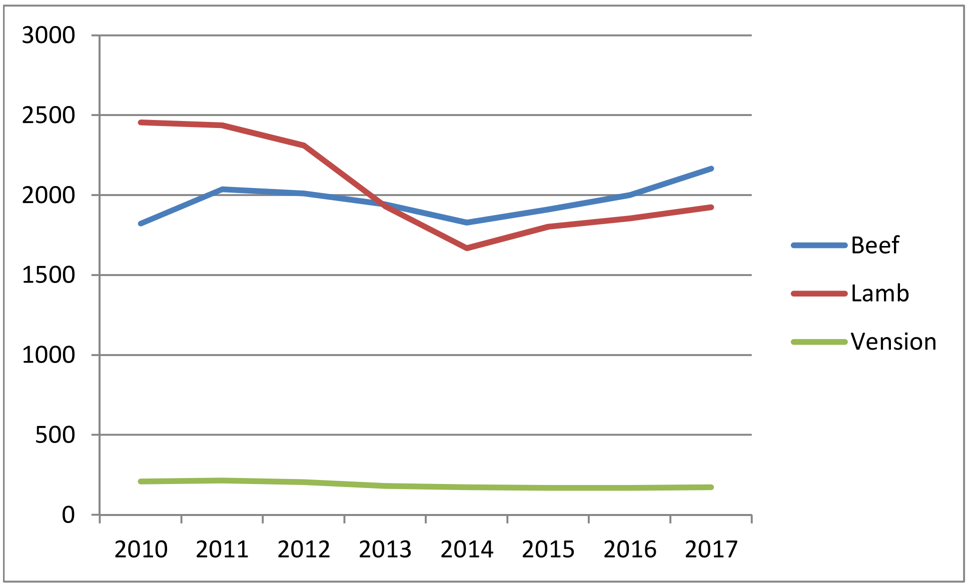
This is problematic since asking industry about what they would have done otherwise is likely to get a predictable response. The incentives on industry to paint a picture of a lack of a coordinated research without the PGP funding are very high. Therefore, these are industry reported answers. However, in most cases the industries did have credible answers that suggest that PGP will provide tangible impetus to the innovation effort.

All of the red meat sector participants (FoodPlus, Farm IQ, Grass-fed Wagyu, NZSTX, and Red Meat Profit Partnership) said that the PGP programme would not have gone ahead without government funding. A good reason to believe this response is the poor performance of the red meat sector over the ten to twenty years (see Figure 7 for current values and MPI forecasts). Poor performance means that it is less likely that research money will be made available by the industry to develop such comprehensive PGP type innovation programmes.

[5] Particularly, if the innovation priorities duplicated other PGP programme priorities.

Figure 7 Red meat: current and forecast export value

Export Value $ millions



Source: SOPI MPI

Programmes such as the Steepland Harvesting programme also are unlikely to have been funded because most research into forestry harvesting had stopped 10 years prior to the PGP process. Forestry harvesting research was seen as something for the contractors to undertake. Most forestry contractors were more concerned with the day-to-day running of their businesses and less concerned with medium to longer term research priorities. At the time that the PGP funding proposal was developed no research attempts were being undertaken into mechanised steepland haversting.

All participants emphasised the de-risking that government funding offered them. Some such as the dairy industry suggested that they would have attempted some of the projects but not all of them. The impact of this was that:

- they would undertake the PGP innovation sooner than otherwise would have occurred and arrive at research outcomes faster
- the scale of the projects reduced the risk of failure of their whole PGP programme of work for each industry. The number of projects being undertaken in each PGP programme means that projects could be turned on and off depending on the outcomes. Failure of one project is unlikely to jeopardise the success of the total programme of work undertaken in each PGP programme.

The issue of risk dictates the attitudes of each sector towards the level of research. This includes:

- the degree of risk of an R&D project from an economy-wide point of view may be lower than that perceived by private firms
- the degree of risk aversion by private investors may be such that the private rate of return is higher than the social rate of return. As a result, the market may provide for too little risk taking in R&D, and hence government support would encourage firms to take more R&D risks.

Even large entities such as the dairy industry were not prepared to undertake the sort of portfolio of projects developed under PGP. Therefore, participants believed there is a case for encouraging more R&D risk-taking by all firms involved in the export related industries.

4.5. Assumptions that drive the benefits

4.5.1. Take up rates

In some PGP programmes there was a strong connection between those undertaking the research and take-up rates (e.g. Transforming the Dairy Value Chain, FoodPlus, SPATSnz, Precision seafood harvesting, and Future Forestry Research). Typically, those doing the research are also involved in up-take or are very closely integrated with entities responsible for up-take. In other PGP programmes, those doing the research are more loosely connected with those who will up-take the R&D (i.e. farmers would need to be encouraged to take up the R&D if successful). In these cases, the assumptions around take-up rates that drive benefits need to be examined closely (e.g. this occurs in most red meat proposals[6] and the Manuka Research Partnership).

Some industries are more likely to take-up technology given the profile of the industry (e.g. younger managers/owners, asset rich businesses, and history of adoption rates). Dairy and wine programmes, for example, fit this profile whereas red meat does not. We would expect lower take-up rates in nutrient management programmes e.g. in the Precision Application of Fertiliser in Hill Country PGP programme take-up rates over the period to 2025 are roughly 42%. Other take-up rates are more ambitious (e.g. NZSTX), however the impact of the benefits is expected over a much longer timeframe.

We found that take-up rates were crucial in driving the benefits in each programme. The higher the adoption rates, the higher benefits stream. The largest take-up rates were those where the innovation was tightly integrated with those who will take-up the technologies developed in the PGP programme.

4.5.2. Capital requirements

Some programmes require additional capital to ensure successful research results are implemented e.g. Transforming the Dairy Value Chain, Manuka Research Partnership, Precision Seafood Harvesting, and Future Forests Research.

Participants argue that if the R&D proves to be successful then the capital will follow. All participants were less concerned with capital constraints than other requirements (e.g. it was less important than take-up rates).

[6] Except the FoodPlus programme.

4.5.3. Monitoring of research outputs and outcomes

One of the strengths of the PGP is that it is a partnership between business and government. The project priorities have been determined mainly by the endusers – since they are providing at least half the funding.

This means that there is unlikely to be research provider capture i.e. those doing the research deviating from the set project goals for their own ends. This is a particular problem with fully-funded government programmes where it is difficult to monitor success or failure and where endusers have less influence on outcomes. Evidence of close monitoring is apparent as some PGP programmes have re-ordered their research priorities (e.g. Red Meat Profit Partnership and Grass-fed Wagyu).

This has the potential internalises the monitoring problem (relative to other fully-funded government programmes). Industry is likely to closely monitor progress, switching on and off sub projects that show promise or otherwise. This has the impact of improving the innovation focus of the programmes(s).

We found that this was one of most important advantages of the PGP programme since it solved the monitoring problem that other fully-funded government programmes have continual issues with.

4.5.4. Intellectual property

Where ever government money is involved in R&D intellectual property outputs are an issue. When partnerships between government and the private sector occur it can become a source of friction. Government have an interest in making R&D available as widely among New Zealand industry as possible (in the jargon ensuring that R&D spillovers reach all New Zealand stakeholders for maximum efficiency). Firms would like to keep the R&D protected as long as possible to maintain a competitive advantage, recoup investment and make a profit on that investment.

Tension exists between government wanting to disperse R&D as widely as possible within New Zealand and firms wanting to protect their investment in R&D.

This will not be easily resolved and will require on-going goodwill (covered within the PGP contracts) on both sides before a feasible solution can be reached in each case. A number of comments can be made:

- if the research entity is part of an industry wide coalition which includes most industry participants then government can be reasonably happy that the R&D benefits can 'spillover'. For example:
  - Red Meat Profit Partnership and Lifestyle Wines show a commitment to specific industries by involving the entities that represent the total industry
  - Transforming the Dairy Value Chain and Future Forest Research both have the majority or a significant amount of the industry involved the projects

- some PGP programmes may find that there are other ways of protecting their intellectual property through trade secrets (e.g. this may be the route that SPATnz takes)
- in a number of cases the government will need to weigh up the costs and benefits of allowing firms to apply for patents.

We found that IP issues were on-going i.e. what is considered a reasonable time frame for IP protection and how IP will be made available to other entities within the industry. As anticipated by MPI, PGP participants and MPI will have to spend more time working through the IP issues before a satisfactory resolution can be reached in each case (contracts specify this in many cases).

4.6. Benefit life

Whether the research will continue to reap benefits after 2025 depends on the type of innovation being undertaken.

For each PGP programme the benefit streams are likely to be very different. For example the NZSTX programme is aimed at changing the type of sheep grown. This type of innovation is unlikely to deliver the majority of benefits until after 2025. Other research is expected to produce results much sooner. The FoodPlus programme is already developing a plan to commercialise innovation from PGP. Other projects are hitting their research milestones and are likely to capitalise on R&D sooner rather than later (possibly Steepland Harvesting and High Performance Manuka Plantations).

The innovation process is also uncertain. Therefore, there will be surprises and disappointments during the research phase. From the interviews we have found that participants generally expect innovation that is aimed at changing the type of animal being prepared for market will take longer to have an impact than 'near market' research.

4.7. Non-quantified benefits

Many of the PGP programmes have substantial non-quantified benefits. These are set out in Section 3.5. While most are indirect benefits some are central to the programmes' success. For example, the Transforming the Dairy Value Chain programme relies on reducing nitrogen; High Performance Manuka Plantations will benefit land that is highly vulnerable erosion prone land; and Precision Seafood Harvesting will assist in developing a sustainable fishery.

PGP participants pointed to these non-use values as having an important bearing on the success or otherwise of programmes.

4.8. Impact on the analysis

The interviews have been used to further develop the quantified analysis. Specifically, they have been used to further understand the expected additionality of the PGP programmes, the impact of take-up rates, the requirement for further capital to realise benefits, and likely full success.

5. Results of quantitative analysis

5.1. Decomposing the economic impacts

After reviewing the programme documents and interviewing key informants, we analysed the potential economic impacts of the existing portfolio of programmes. We estimated that these programmes will make positive contributions to the primary sector and the New Zealand economy. The economic contribution will be an increase in export value and volume, primary sector output and GDP. Part of the increase GDP can be attributed to government investment in PGP, and a larger portion can be attributed to industry co-funding that is included in PGP programmes. We also found that some of the expected benefits of PGP are related to aspirational or stretch goals of the programmes, both in terms of research success and commercial adoption. Overall, we estimated positive net benefit and benefit-cost ratios (BCRs) from government funding of existing PGP programmes.

Using these existing programmes as examples of the potential impacts of PGP as a whole, we further estimated the likely increase in annual gross revenue for the primary sector in 2025. This figure roughly aligns with the expected increase in exports, although it also includes some domestic revenue. The impacts are based on a government investment of approximately $450 million to $500 million over several years and multiple programmes (including as yet unknown future programmes). We have then decomposed the annual gross revenue figure into several components. A graph of the decomposition is given in Figure 8, and a detailed discussion is provided in the next section. A summary of the results is as follows:

- $11.1 billion is the value of overall PGP outcomes of the primary sector R&D investment by both the taxpayer and the private sector in 2025. This value assumes that the programmes are successful and able to achieve their aspirational or stretch goals
- $2.2 billion (20%) is the increase in Gross Domestic Product (GDP) that can be attributed to the government investment in PGP. It is net value produced by PGP in the form of additional economic growth, and is a key number that may be compared with the GDP impact of other government initiatives
- $4.2 billion (38%) is value from industry investment. This is the increase in economic activity that we have attributed to the industry's contribution to PGP. It includes several elements: the matching contributions of industries to their programmes, an adjustment to account for business as usual improvements attributed to the programmes, and the structure of returns to investment (see section 5.2.2, below)
- $2.2 billion (20%) of the increase arises from assuming successful R&D. By modifying that assumption, we have estimated the additional value of improved R&D success and provided a more cautious estimate of the net GDP impact from government investment

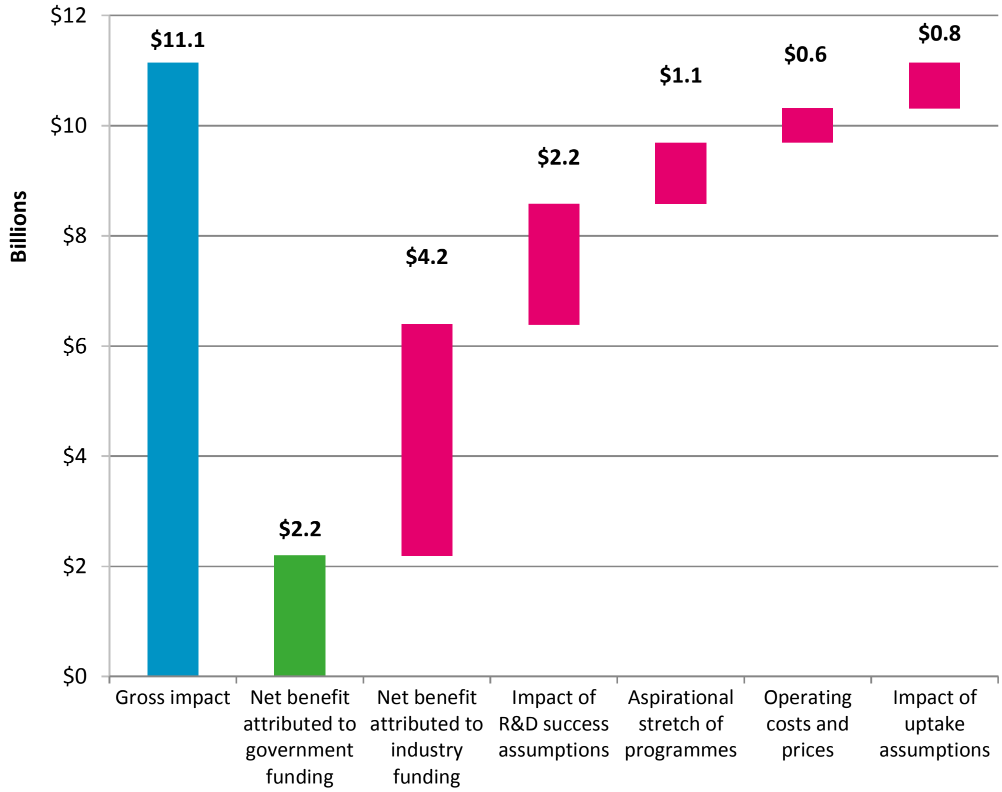
- $1.1 billion (10%) is the estimated value of the aspirational stretch described by the programmes. Applicants were asked to be aspirational in their programme goals; this estimate provides a measure of the stretch. It also allowed us to produce a more cautious estimate of net impacts, particularly when a more detailed estimate of expenditures and uptake were not possible
- $0.6 billion (5%) is an estimate of the operating and set-up expenditures required to implement the innovations developed through programmes
- $0.8 billion (7%) represents an adjustment to uptake levels from the aspirational stretch of programmes to levels of uptake of innovations more commonly demonstrated. By adjusting uptake rates to more conservative levels, we have estimated the potential benefit of improved uptake rates and provided a more cautious estimate of economic impacts.

Some aspects of some programmes had considerable uncertainty, but the assumptions made by NZIER represent our view if we were 'forced to choose', based on how convinced we were by the respective business case. These assumptions have been part of discussions with key informants from the programmes, with whom we tested our thinking. Individual programmes differed in the decomposition of the various components; the figures reported above and in Figure 8 represent PGP as a whole.

Figure 8 presents this decomposition graphically. The first column is the total estimated economic impact, the $11.1 billion. The elements of the decomposition follow, so that this figure shows how the total economic impact is broken down. Part of the economic value is made up of the operating expenses or intermediates. Part of the projected economic value relies on aspirational targets for R&D and commercialisation success. Once those elements are accounted for, the net GDP impact is identified and apportioned to the government and industry shares of funding. These are specifically the second and third items (columns) on Figure 8: net benefit or GDP impact of government investment ($2.2 billion), and net benefit or GDP impact of industry investment ($4.4 billion).

Figure 8 Decomposition of economic impacts

Annual impacts in 2025, based on experience of existing programmes and final size of PGP



Source: NZIER

5.2. Discussion of the components of economic impact

The decomposition of total economic impacts into several components was described briefly above. This section provides more detail on the individual components and how they were developed from the business cases and the interview with key informants.

5.2.1. Net benefit attributed to government

We estimate that 20% of the annual increase in gross output from PGP can be described as net growth in GDP attributed to the government investment. When this net benefit is assessed over 30 years[7] and compared to the government investment in PGP, the resulting benefit-cost ratio indicates that the investment is economically worthwhile.

Table 1 presents our estimates of the BCRs for PGP. For the BCRs, the top-line 'benefit' number is the present value of the net benefits over 30 years (i.e., the green item in Figure 8, labelled 'Net benefit attributed to government funding'), discounted

[7] CBA methodology, including that used by the New Zealand Transport Agency, typically focuses on impacts over 30 years when a discount rate of 8% is used.

at 8% (real). The cost (bottom-line) number is the simple (undiscounted) lump sum of taxpayer investment. The estimated BCR for PGP as a whole is 32, that is, the benefits are expected to be 32 times the costs of PGP.

Table 1 also provides BCRs based on most existing programmes. All these BCRs are good, and some are quite high. They have been adjusted for industry investment, costs of innovations, aspirational stretch for science and uptake, and more. They range from 6 to 142, with a median value (that is, the middle-performing progamme) of 27.

Table 1 Benefit-cost ratios from PGP

Discounted benefits over 30 years divided by lump-sum cost of the government's investment in programmes

	BCR
PGP as a whole	32
Median	27
Minimum	6
Maximum	142

Source: NZIER

These BCR estimates are high relative to investments in other areas of government. There are a number of possible reasons for high BCRs. One possible reason is that the investment being evaluated concerns R&D in the agricultural sector, which tends to produce high *ex ante* return estimates. Comparable international and domestic assessments of returns to R&D investments are discussed in the next chapter. A second possible reason for the high BCRs concerns the method of the assessment. Each of the components of the decomposition involved making judgements about the likelihood of events occurring in the future and the relevant counterfactual. The judgements were subjected to sensitivity analysis using a Monte Carlo simulation. If those judgements are changed, then the net result changes. The research team determined that additional analysis of potential futures and counterfactuals would not provide sufficient additional information to warrant the exercise. It is important to note that favourable BCR estimates do raise a question as to whether the investments would proceed without a government contribution to funding, an issue discussed with key informants as reported in section 4.4.

5.2.2. Net benefit attributed to industry

The partnership approach used in the PGP programmes requires an approximately equal investment share between the state and industry. The additional benefits attributable to the private partners' contributions are about 38% of gross output value. This is higher than the government attribution because some PGP programmes seemed to include some business as usual growth and development too, that can be attributed directly back to them. The analysis also took into account the impact of additionality in terms of the relationship between investment spend and R&D impact, as shown in Figure 4, page 13. R&D may be focused on low hanging fruit, so that there are sizeable early gains. Alternatively, the ratio of effort to reward may be linear, so that gains are proportional to investment. Finally, the relationship can be non-linear such that the largest portion of the rewards can be attributed to the last tranche of investment.

5.2.3. Impact of R&D assumptions

The decomposition also reviewed the assumptions about R&D success. The programmes tended to present business cases conditional on high rates of success with R&D. We estimate that this assumption contributed about 20% to the gross value of the programmes.

To maximise the chances of achieving success requires:

- adapting overseas R&D to New Zealand – Hall and Scobie (2006) show a strong link between imported technology and its adaption to New Zealand. They found that '*foreign knowledge is consistently an important factor in explaining the growth of productivity. It appears that the agricultural sector relies heavily on drawing on the foreign stock of knowledge generated off-shore*' (page i). This means that projects focused on adapting foreign technology in the New Zealand production system are more likely to succeed than others. These projects should receive priority
- developing systems that allow for fast failure – This requires the development of a metric (plus context) that details what success/failure looks like. By managing failure, the PGP programme can learn from its errors more quickly and therefore redirect investments into projects or parts of the project that are likely to be more successful.

5.2.4. Aspirational stretch of programmes

The PGP applications were intended to be aspirational, to promote step-change within the participating industries. The aspirational nature of the proposals encouraged to industry to set out their calculations on what success would look like if the project achieved its goals. As a result, the programmes include lofty goals that could be achieved, but do not form part of a more cautious assessment of likely economic impacts from government funding. We have assessed this additional component at 10% of the gross impact.

5.2.5. Operating expenses required

A number of programmes will require further investment and operating costs by industry to make the innovation strategy vision set out in the proposals to be fulfilled. This component makes up approximately 5% of the contribution towards programme gross value. Proposals in the future may need to be more explicit about the additional costs, how those costs will be raised, and how that affects the uptake and benefits, and the likelihood of realisation.

5.2.6. Impact of uptake assumptions

As with the R&D success and programme goals, programme uptake rates include a level of aspiration. The vision set out in some proposals is for near total take-up of the specific innovation. We have estimated the proportion of gross impacts that can be attributed to the assumption of high uptake rates, by adjusting to more restricted uptake rates and estimating the change in economic impacts. This component accounts for 7% of the gross economic impacts.

We do note that the uptake analysis reported here is based on a static analysis. There is the possibility for dynamic improvement in uptake rates with successful innovations. That is, companies that can work out how to improve take-up after an innovation has occurred are likely to be more successful. This is why the most successful companies are those that can leverage their scale and avoid making the mistakes of the innovators (Chandler 1990).[8]

5.3. Summary of quantitative analysis

This assessment used information from the business cases and interviews with key informants to develop a Monte Carlo analysis of the outcomes from the programmes. The gross economic impact was estimated at $11.1 billion, of which $2.2 billion was a robust assessment of the likely impact on GDP that could be attributed to the government's contribution to PGP funding. Other components included in the analysis were the impacts of industry funding, the impact of aspirational stretch and assumptions about science success and uptake rates.

8 Known second mover advantage at scale. Chandler A (1990) Scale and Scope: The Dynamics of Industrial Capitalism, Harvard University Press.

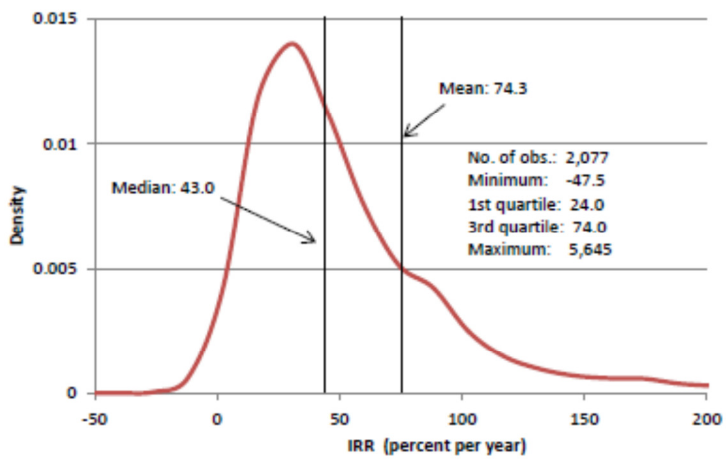
6. Benchmarking

One way to test the robustness of the estimates in this report is to compare them to similar research elsewhere, a process known as benchmarking. Estimating the costs and benefits of science has been going on for over 50 years, using a number of approaches. The seminal piece of research is Griliches (1958), which reported internal rate of return (IRR) and benefit cost ratio (BCR) results for research into hybrid corn in the US.

One of the most recent pieces of research is a meta-study of the returns to agricultural research and development (Hurley, Pardey, & Rao, 2013), and it provides an excellent guide to CBA results. The authors reviewed 359 studies published from 1958 to 2011, and from them obtained 2,186 estimates of IRR. The results focused on IRRs, rather than BCRs.[9] IRRs indicate the return on investment in percentage terms, taking into account the costs of the project and the stream of benefits over time. In their report, they provide a simple distribution of the IRR estimates. The graph (Figure 9) shows that most estimates were positive, the median estimate was 43.0% (with a peak or mode around 20%), and the mean or average result was 74.3%. The mean is noticeably higher than the median because of a number of estimates over 100% and even 150%.

Figure 9 Returns to food and agricultural R&D: IRRs

Distribution of internal rates of return (IRRs)



Source: (Hurley et al., 2013; Rao, Hurley, & Pardey, 2012)
Note: Vertical axis represents relative frequency

The meta-study also provided detail on the results by commodity and type of research (basic vs applied). The key figures relevant to the present analysis are provided in Table 2. The median result by type of research varied, with basic research having a relatively low estimated IRR and livestock having a relatively high result. The

9 We have used BCRs, and Griliches (1958) reported both BCR and IRR. 'Griliches expressed a preference for the BCR' (citation, p 3), as do CBA handbooks. Nevertheless, IRRs appear to be more commonly reported in this literature.

ranges of estimates from the database were also reported as the 5th and 95th percentile estimates. The range covered a couple of orders of magnitude, from 7% to 191% for all studies.

Table 2 IRRs for agricultural R&D studies

Data are % rates of return

Study scope	Median result	5% result	95% result
All	43.0	7.0	191
Basic	22.2	-1.3	110
Applied	46.0	18.7	325
Research and extension	43.3	8.3	196
Fruit, vegetables and nuts	33.7	4.3	92
Beef and dairy	50.0	8.2	118
Sheep and goats	24.4	5.0	69
All livestock	60.0	11.0	99

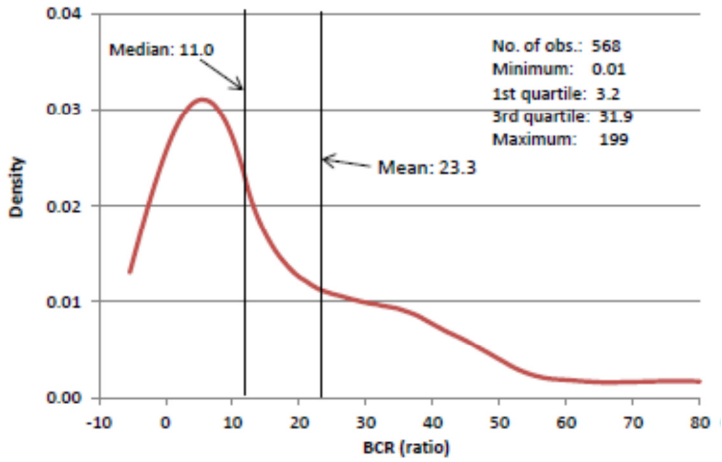
Source:

Because the report used the IRR metric, its results are not directly comparable to those reported here. The mathematical relationship between BCRs and IRRs is not straightforward (as an example, two hypothetical flows of costs and benefits that yield the same IRR but different BCRs are provided in Appendix C). Although there is not a simple conversion of IRR to BCR, the median IRR of 43% is consistent with double-digit BCRs. The cut-off for the lowest 5% of projects was a 7% IRR, which is nearly the Treasury discount rate of 8%. This result suggests that nearly 95% of estimates would meet the standard Treasury criterion of a positive net benefit with an 8% discount rate.

The same authors also published results of a meta-analysis of BCRs, using the same database (Rao et al., 2012). That analysis had fewer data points: 569 estimates of BCR and did not report the results in as much detail. However, the authors did provide a distribution of the BCRs from the database. The graph (Figure 10) shows a peak (mode) around a BCR of 7, with a median value of 11.0 and a mean of 23.3. One-quarter of the estimated BCRs were above 31.9.

Figure 10 Returns to food and agricultural R&D: BCRs

Distribution of benefit cost ratios (BCRs)



Source: (Rao et al., 2012)

Note: This graph is a kernel density estimate. The authors did not discuss the data that led to negative BCRs, which are unusual: the benefit in the benefit-cost ratio would have to be a negative gross benefit.

These meta-studies are very important for understanding past estimates of returns to investments in R&D. The BCR meta-analysis shows that over half of estimates are in the double digits, which indicate very large benefits from investment in R&D. It also suggests that BCRs over 5.0 or 3.0, which are generally considered 'good' BCRs from CBA, are extremely common. The IRR meta-analysis provides some detail about the returns to different types of research. Applied research and extension research tend to have higher rates of return that basic research. Whether this is a result of methodology or actual R&D experience is an open question.

Methodologically, it is easier to link costs to benefits for applied and extension research, while the benefits of basic research by their nature tend to be diffuse. However, one description of research is 'going up alleys to see if they are blind'. If that is the case, we would expect a lower proportion of successes with basic research, with applied research and extension focusing on areas more likely to succeed. Finallly, livestock research tends to do at least as well as the average, although the 'sheep and goat' category in the database did not.

6.1. New Zealand examples

Estimates of the value of research in New Zealand have used a number of methods. An example of a CBA is a study by Nixon (2003) on the value of a solution for carrot rot. The author reviewed three possible methods for valuing the benefits of research on carrots, and their associated problems:

- estimating the profitability of the carrot business as a measure of the direct benefit of the R&D innovation (there were confidentiality concerns with this approach)
- determining the difference between the value of carrots and the next best alternative crop (there was difficulty in identifying a counterfactual)

- estimating the insurance payments made to clients for storage losses, and considering them equivalent to the benefit of the research.

On the cost side, Nixon (2003) attributed some of the research costs over several decades and across several crops to the particular solution found to carrot rot. The final result was a BCR of 2.38.

Much of the other research on returns to agricultural R&D as used a different method, and comparable analysis has been conducted overseas. The method is a top-down analysis of macroeconomics data, and it estimates the improvement in productivity compared to the investment in research. One example is Scobie and Eveleens (1986), who used a total factor productivity (TFP) index, which is outputs divided by inputs. The variables in their model were:

- weather conditions in the previous year, captured by soil moisture deficit
- level of spending on extension services;
- number of graduates and diplomats trained in the agricultural sciences over the past 15 years
- economic conditions of the agricultural sector, measured by deviation from long-term trends
- real spending on agricultural research, in both the current period and the prior 30 years.

Scobie and Eveleens (1986) showed that productivity can be measured in a number of ways, but the analytical result is generally similar. They concluded, ‘a $1 investment generates total benefits of $8.55. However, these benefits come over a 23 year period. Discounting them at a real rate of 10 percent means they are worth $2.81; i.e. a benefit cost ratio for agricultural research of 2.8 to 1.’ Updating their analysis to the current Treasury discount rate of 8% yields a BCR of 3.5.

Johnson (2000) undertook a similar analysis, using data from 1962 onwards. A two step-process was used to derive the estimation. First, a TFP index was calculated for different industries based on GDP, employment, capital stock and factor shares. This index was then subsequently regressed against four variables of interest (private, public and external stocks of R&D, as well as education). He found that the returns to private investment in agriculture were high, but that the returns to public investment were negative. Johnson, Razzak, & Stillman (2005) found similar results using a panel of nine industries. This result suggested that there might have been overinvestment in public research in agriculture. It does support a view, however, that private investment in R&D is likely to yield a good return.

Hall and Scobie (2006) developed a further model to generate estimates of the impact of R&D on productivity growth in the agricultural sector within New Zealand. They used a TFP calculation with the variables of weather, extension, a constructed human capital index, domestic R&D (expenditure) and foreign R&D (patents). This was then regressed using a lagged and cointegration approach to the dependent variables due to the time series nature of the model. They estimated a number of models, which had different variables and different specifications. The overall conclusion was that the preferred model showed a rate of return on domestic investment in R&D of 17%. They also note, ‘The key message that can be drawn from these results is that the estimates of the contribution of domestic R&D are very sensitive to the method and specification adopted, and that even with lengthy time series data it is not easy to isolate the effect' (p. 33).

The New Zealand research is inconclusive. It suggests that BCRs generated from case-by-case analysis show that some research projects contribute economic value: their benefits are higher than their costs. The overall record of public investment in R&D is less clear. Some research has found little to no contribution of public investment to productivity in the economy. However, the results appear to depend on the way the modelling is done, so that the actual returns may be positive and valuable (Hall & Scobie, 2006).

6.2. International examples

The meta-analyses discussed at the beginning of the chapter cover are the best sources for international estimates of returns to research. Some other studies are also worth a mention.

An earlier meta-analysis investigated 292 studies to determine the return to investment in agricultural R&D (Alston, Chang-Kang, Marra, Pardey, & Wyatt, 2000). They found an average rate of return of 64.7%. They used a regression approach to decompose this average, regressing the rate of return against a set of independent variables about the studies:

- measures: real or nominal rate of return; marginal or average rate of return; private or social rate of return; ex ante or ex post rate of return; rate of return to research only, extension only or both estimated; and rate of return imputed from a benefit-cost ratio;
- analyst: first author's place of employment; and self-evaluation or independent assessment;
- research: government versus other research performers; commodity focus of research; research type; developed or developing country research performer; and time period in which research benefits occur; and
- research evaluation: date of evaluation publication; single project versus programme or institution-wide evaluation; evaluation published in a refereed journal or other outlet; supply shift estimated econometrically or not; form of research-induced supply shift; experimental industry data used to calculate supply shift; length of gestation lag; short or long benefit lag assumed; adjustment for research spillovers; and adjustment for market distortions.

The meta-analysis provided three key findings. First, research conducted on commodities appears to produce a lower rate of return. Secondly, the type of research being analysed appears to have an impact on the calculated rate of return. That is, lower returns are observed for research where the scope is broader. Finally, it is concluded that 'the rate of return literature and the numerous rate of return estimates in that literature have a low signal-to-noise ratio that does not lend them to meaningful analysis by ad hoc inspection' (Alston et al., 2000, p. x). For that reason, statistical meta-analysis can provide a better understanding of returns.

Fuglie & Heisey (2007) summarised 35 economic studies from 1965 to 2005 that had produced a rate of return. Although the study was not as statistically rigorous as the

Alston et al. (2000) research, it nevertheless produced similar results. Fuglie & Heisey (2007) also suggested similar problems associated with measuring the economic value of research, namely lags, spillovers and attribution. The rates of return varied, but the bulk of estimates ranged between 20% and 60%.

Research in the US investigated the impact of spill-over from state to state (Alston, Andersen, James, & Pardey, 2011). It found that spill-overs were economically important, and that rates of return to research depended on whether the models accounted for them. The average of own-state BCRs was 21.0, while accounting for spill-overs raised the average of BCRs to 32.0. The result demonstrates the difficulty of drawing boundaries around the impacts of research and the importance of drawing them as widely as possible.

There have been a number of more focused pieces of research. Barkley, Nalley, & Crespi (2008) investigated the CIMMYT wheat breeding to analyse the impacts on on Mexican wheat producers and consumers. They found a BCR of 14.99. Bervejillo, Alston, & Tumber (2011) assessed public agricultural research in Uruguay from 1961 to 2010, and estimated a BCR of 48.2. The estimates varied across the models used, in particular by the way that the time lags in impacts were modelled. Finally, a review of the Australian Centre for International Agricultural Research fruit fly research estimated a BCR of 5 (Lindner, McLeod, & Australian Centre for International Agricultural Research, 2008).

6.3. Methodological issues

There are a number of methodological issues discussed in these studies. Factors that influence the variation in the reported rates of return the final rate of return calculated include (Alston et al., 2000; Hall & Scobie, 2006; Raitzer & Kelley, 2008; Rao et al., 2012):

- apportioning costs and benefits: Identifying and apportioning all relevant costs and benefits is difficult if not impossible. For example, individual scientists may be involved in multiple activities (e.g., research and teaching), and the benefits often produce spill-over impacts that might not be measured
- selection bias: Some research tends to focus on successful projects only, if only for reasons of survival bias. These biases need to be avoided, especially if the rate of return of successful projects is misrepresented as being the rate of return for all projects
- measuring reduction in production costs from research: Errors may occur moving from an estimate of productivity change that applies in one context to an industry-level supply shift
- model specification choices: The above research used many different models, and it is clear that modelling choices affect the estimates of rates of return
- lag distributions: The number and type of lags can be either endogenous to the model or exogenously imposed. Lags are usually not longer than 30 years. Using an inappropriate lag is likely to bias the result

- environmental and non-market impacts: These impacts are difficult to capture in conventional measures of benefits from R&D, and yet they are some of the benefits most of interest to publicly funded research
- inflated IRR estimates: The standard method for estimating IRR results in inflated estimates because of the assumption about reinvestment. Modifying this assumption produces lower IRR estimates, although they still suggest large positive returns to investment in agriculture and food R&D.

6.4. Conclusion

The literature suggests that investment the agricultural R&D is worthwhile, whether the impacts are measured with IRRs or BCRs. There is still some question as to the optimal level of public investment in R&D in New Zealand. Case-by-case analysis finds positive returns, while macroeconomic analysis is less conclusive. The distribution of IRRs shows that impacts vary widely, with applied research doing better than basic research, and livestock research being relatively valuable. Meta-analysis of BCRs found a median of 11.0 and mean of 23.0. By comparison, the results for the analysis of PGP found a mean BCR of 32 and a median BCR of 27. While the results of the analysis of PGP projects are somewhat higher than average, they are well within the observed range.

7. Assessing PGP

7.1. Assessing individual programmes

Individual programmes will need to be assessed, at the proposal stage, while operating and after completion. For the assessment reported here, we have used a CBA framework, and we would recommend it for any assessment or evaluation. It provides a step-by-step recipe for identifying and valuing actual or potential impacts. A detailed discussion is provided in Appendix A.

Briefly, however, the idea of CBA is the following:

- determine which impacts matter – what is important? what is the focus? what do we want to value?
- describe the 'with' and 'without' scenarios – this is a process of describing the primary industry with the PGP programme, and what would happen without it, focusing on the impacts identified above
- describe the difference – the core of CBA is the difference between the two scenarios: that is the effect of the programme
- assign a value (probably a dollar value) to the difference – the process of assigning dollar values can be difficult, but there are sources for market and non-market values.

Ideally, assessment is part of the research and dissemination of the programme. Along the way, stakeholders would decide what is important and collect data on those aspects. Assigning a value can still be tricky, but good data on impacts – physical impacts – is an important first step.

7.2. Assessing the PGP portfolio

There are essentially two ways to measure something as large and complex as the full PGP initiative: bottom-up and top-down.

- A bottom-up approach starts with the programme-level impacts and adds them up. It relies on good CBAs of the individual programmes, and also relies on a certain measure of consistency across those assessments
- A top-down approach looks at the primary sector or even the economy as a whole, and then estimates the change in the sector overall as a result of PGP. This approach will capture more of the interactions between industries, any synergies or competition for resources and possibly even flow-on effects.

The bottom-up approach would focus on the metrics identified by each programme. Metrics might be number of new products or services, number of new contracts, number of employees, increase in gross margin, or number of business adopting innovation. More metrics are provided in Appendix A. However, if different programmes are targeting different changes in industries, these metrics might be hard to combine into an overall measure.

A top-down may be appropriate. One aim of PGP is better economic performance of the primary sector overall: higher exports and greater contribution to GDP. Success would mean increased output and increased productivity. Increased productivity would be measured by greater output per worker, per land area and per capital investment, as well as a combination of all three (multi-factor productivity). Because this increased performance is a main aim of PGP, it makes sense to consider estimating it directly.

The top-down approach would use econometrics to estimate the observed impact of PGP. The approach would investigate the changes in primary sector output as a function of changes in inputs, and would estimate how productivity had changed as a result of PGP investment. This work has been done several times in New Zealand, most recently by Hall & Scobie (2006). The method and historical trends are well established, so it would be a matter of building on the prior work to estimate changes in productivity corresponding to PGP funding.

The top-down approach has some weaknesses. Unfortunately, it is less likely to observe smaller impacts (impacts that are small relative to the size of the sector, particular relative to the variability in the sector). Changes in productivity are also observed over time, so it is less useful for short time periods (under five years). It would also need to be adapted to consider non-market impacts. However, it is a robust and well-understood method of valuing changes in productivity.

The two methods can also be combined. A bottom-up approach can identify the specific impacts of individual PGP programmes, essentially creating a map of where to look for macro impacts and estimates of their sizes. The top-down approach can then determine whether the impacts are observable at the scale of the sector or the economy. The combination would provide a robust and detailed view of the impacts of PGP.

8. Conclusion

Industries and firms are asked to produce PGP proposals that are ambitious and unlock future growth and profitability. Successful proposals have done this by detailing how they are going to overcome the R&D challenges, unlock value, and grow their respective industries. They have also provided calculations detailing the value of those aspirational goals.

Another important aspect of the PGP is how it fits into and contributes to the Business Growth Agenda, which includes the goal of growing exports from 30% to 40% of GDP by 2025. Given the government's interest in investing in R&D, the economy's heavy reliance on agricultural exports and the likelihood that innovation will translate into export dollars, the agricultural marketing chain is an appropriate area for R&D investment. The MPI export double goal suggests one possible measure of the impact of PGP, which is the contribution to export growth between the present and 2025.

Investment optimism does need to be tempered somewhat by the uncertain nature of the R&D process. Aspirational goals, willingness to invest and New Zealand's heavy reliance on agricultural exports by themselves does not guarantee success. Therefore, different stakeholders need to know how the estimates have been developed and the likely returns.

We have estimated the impact of a fully developed PGP portfolio. To do this, we relied on a study of existing programmes, interviews with stakeholders in the primary sector, and quantitative analysis of business plans and potential PGP funding. The analysis suggests that the gross economic output from PGP will be $11.1 billion in 2025. This gross impact estimate is made up of several components, which we have also estimated. The growth in GDP that can be attributed to government funding of PGP is $2.2 billion. The portion that can be attributed to industry investment in PGP is $4.2 billion. The impact of assumptions about R&D success, uptake rates, and aspirational stretch make up most of the rest of the gross impact estimate.

The impact of these adjustments suggests that there may be ways to improve the value derived from PGP. The probability of science success has a major impact on the total benefit calculated from PGP. Ways of improving science success include incremental innovation, applying overseas research to local conditions and enabling fast failure in the application of science. The uptake rate for innovations is another major factor in the overall impact of PGP. Measures to improve uptake, such as linking science to end-users and encouraging extension activities, could have a large impact on the final value of PGP.

The estimated impact on GDP suggests that PGP has a high benefit-cost ratio, which indicates that PGP is a worthwhile investment of government funds.

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Appendix A Guidance on evaluating PGP programmes

A.1 Introduction

This appendix is prepared to assist Ministry for Primary Industries (MPI) staff with the economic *ex ante* appraisals of new PGP business cases and of the *ex post* evaluations of the performance of completed PGP programmes. We also expect that MPI might draw from elements of this document when providing its own guidance to future PGP submitters.

Economic appraisals are one component of a project evaluation framework, such as Treasury's 'Better Business Cases', and are complemented by other considerations. For instance, economic appraisals do not themselves place higher benefits on projects that align strongly to government/industry strategies. However, an economic appraisal that follows the 10-step process outlined in this document usually covers off the bulk of issues of importance to public officials.

Research, science and technology (R&D) projects span a spectrum from the highly uncertain and speculative, to relatively straightforward adaptations of existing processes. PGP programmes tend to be at the applied end, sometimes building upon many years of more 'basic' research funded through the likes of the government's previous Foundation for Research, Science and Technology. The bulk of the net-benefits of these more applied projects can be reasonably well estimated, as has been done to date.

Some PGP programmes are more ambitious and foundational, such as the New Zealand Sheep Industry Transformation Programme. Cost-benefit appraisals (CBAs) are more problematic because the cause and effect chains are uncertain and difficult to value.

However difficult an appraisal is, it is nevertheless useful to run the rule of a CBA procedure on the investment proposition. Describing market failures and counterfactuals, the plausible ranges of productivity impacts, factors that influence uptake rates, etc. are still key to appraising investment proposals.

A.2 Introduction to some basic concepts

Prior to drilling into the process for a CBA, it could be helpful to clarify some underpinning economic concepts.

PGP programmes have a range of potential sources of benefit, such as:

- creating new products and services for users
- reducing costs to industry
- improving capabilities, say of farmers, in the aim of lifting poorer performers towards that of higher performers

- establishing or maintaining a general purpose industry wide R&D capability that may create any number of innovations further in future.

The two underpinning concepts are *efficiency* and *opportunity cost*. It is useful to clarify these concepts. Knowing what they are is very useful when reviewing the problems or opportunities that are the foundations for investment cases.

A.2.1 Efficiency

'Efficiency' is an economic concept that relates to society's overall wellbeing, and includes the benefits of 'consuming' non-market resources such as biodiversity and clean waterways. The specific concepts are as follows:

- *productive efficiency* occurs when it is not possible to create more of one kind of commodity without producing less of another
- *allocative efficiency* occurs when goods and services are produced and allocated to where the marginal benefits to consumers are equal the marginal cost of production
- *dynamic efficiency* occurs when people have the capability, are incentivised, and are appropriately confident and informed to invest, innovate, and adapt technologies over time to create new products, processes and services demanded by consumers (which includes non-market as well as market commodities).

Dynamic efficiency is thought to be the most important of these items, but it is the most speculative and the most difficult to incrementally measure even if it could be foreseen. These concepts are illustrated below.

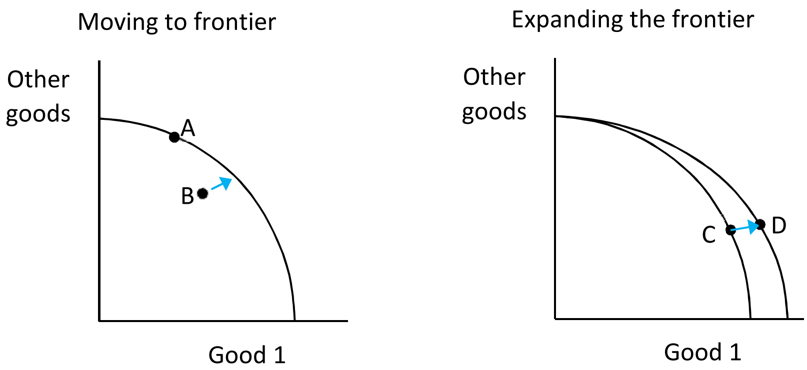
Productive efficiency

The left item in Figure 11 below relates to PGP programmes that seek to improve the performance of the low end of the market. An example is the *Red Meat Profit Partnership*, which aims to improve the capability of poorer performing sheep and beef farms by developing, teaching and coaching farmers about best practice. Point A represents a case of no wastage, whereas at point B there are benefits to be had from producers better using existing techniques and resources.

The right item relates to PGP programmes that seek to create new tools and techniques to increase what is possible to produce. For instance *SPATnz* aims to create ways to breed spat (baby mussels), rather than rely on the vagaries of fishing the open seas. The improvements expand the range of outcomes that would otherwise be possible, and one could move from point C to D.

Figure 11 The production possibility frontier

Two types of impacts on 'productive efficiency'



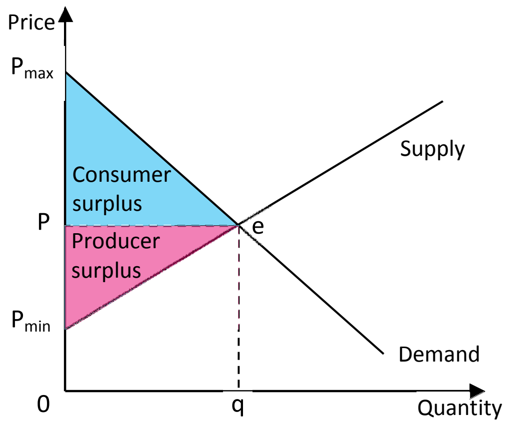
Source: NZIER

Allocative efficiency

A supply and demand graph is useful to explain allocative efficiency. In a single-market case the benefits provided by a commodity are made up of two key components, which when added together are called *social surplus*:

- *consumer surplus*, which is the amount consumers are willing to pay (area $0qeP_{max}$ in Figure 12) in excess of what they do pay (area *0qeP*)
- *producer surplus*, which is the amount of revenue producers receive (area *0qeP*) in excess of their immediate *opportunity costs*[10] to operate (area $0qeP_{min}$).

Figure 12 Supply and demand for a good or service



Source: NZIER

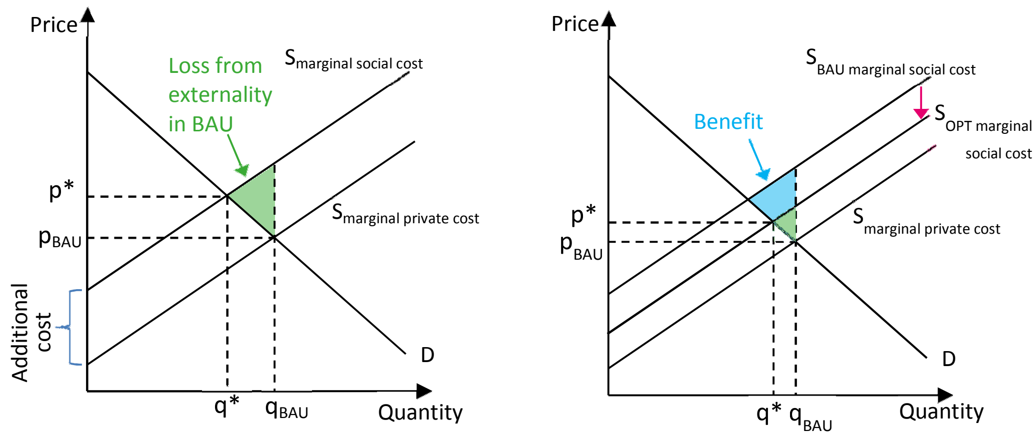
With allocative efficiency, these surpluses are maximised. The goal is therefore to get commodities to the best markets – those that demand the highest premium.

10 More on this below in section A.2.2.

Allocative efficiency can also be used to explain externalities. If a PGP programme reduces negative environmental externalities, it benefits because the marginal costs are brought closer to the marginal benefits. Many PGP programme have associated environmental benefits from reducing fertiliser run-off (e.g. *Clearview Innovations*), land erosion (*e.g. Steeplands Harvesting*), and the degradation of natural environments (e.g. *Precision Seafood Harvesting*).

The left item in Figure 13 relates to the business as usual presence of a negative externality. The social cost exceeds the private cost by the green shaded area; if quantity reduced back to *q**, the cost savings would exceed the benefit losses.

Figure 13 Reducing negative environmental externalities



Source: NZIER

Dynamic efficiency

Programmes such as *The New Zealand Sheep Industry Transformation Programme* aim to increase the focus of the sheep supply chain towards the needs of consumers. The aim is to improve the transmission of consumer demands for new and improved goods and services throughout the supply chain. This in turn is hoped to lead to dynamic efficiencies by enhancing the innate ability of industry to create new and improved products, processes and services demanded by consumers.

The number of such innovations is not limited, and as such higher growth rates over the years and decades to come can be sustained. This is why the dynamic efficiency concept is more important to economic development than static notions of productive and allocative efficiency.

Other than the inherent inability to forecast innovation (because novelty by definition cannot be foreseen), practically measuring the change in total social surplus across multiple interrelated markets is difficult.[11] Practical appraisals tend to use ad hoc higher productivity growth rates[12], which is a fraught practice.

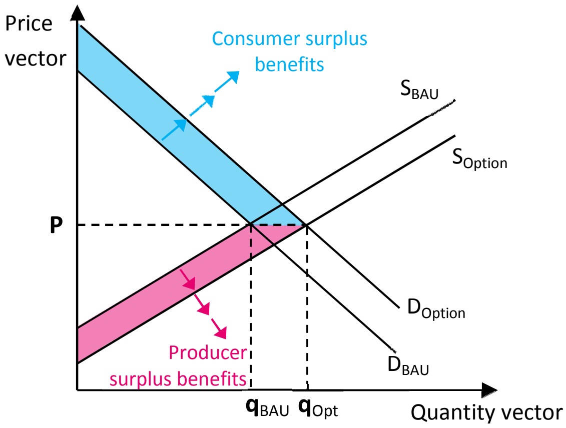
Figure 14 below is an attempt to illustrate dynamic efficiency with aggregate supply and demand curves. An aggregate demand curve that spans all the markets in the

[11] See for instance NZIER (2013) *Appraising transport strategies that induce land use changes*, NZIER public good paper 2013/4

[12] For instance, the Electricity Authority's recent cost-benefit appraisal of a different way for Transpower to charge for the national electricity transmission grid.

economy moves up and to the right, representing the increased value of product and service innovations. An aggregate supply curve moves down and to the, representing process innovations that lead to efficiencies in production. Very broadly speaking, the benefits are the entire shaded area.

Figure 14 Dynamic efficiency: unspecific ongoing innovations



Source: NZIER

A.2.2 Opportunity cost

If you use a resources for one purpose, it is not available for another. This is *opportunity cost*, or what is forgone when using a resource for a particular purpose. For instance, if a PGP programme leads to a type of plant being commercial viable to farm, then the opportunity cost is not using the land available to farm what would have otherwise been planted. If the new cultivar is only equally as profitable as the status quo, then the opportunity cost may well be close to, if not, 100%, and there may be minimal net economic benefits all else equal. (Of course there may be benefits from more planting options being open to farmers and investors, but the point is that the outcome may be marginal rather than transformational.)

A further concept relevant to some PGP programmes is whether more employment opportunities may accrue in rural isolated areas with high unemployment (e.g. *Steepland Harvesting*). In that case, the costs and wages paid exceed the opportunity cost of people's time and the resources used, and the lower actual costs lifts net-benefits.

A.3 10-step process for a CBA

Introduction

The following set of steps are usually undertaken in a cost-benefit appraisal.[13]

[13] For instance, refer to: Boardman et al (2006) Chapter 1; Australian Government (2010) Appendix E. See also Treasury CBA Primer.

NZIER's 10-step cost-benefit appraisal process

1. Define the problem / opportunity
2. Decide whose **benefits and costs count** (standing)
3. Select options and specify the **baseline** (i.e. the 'without') scenario
4. **Classify** the kinds of benefits and costs and select the measurement indicators
5. **Quantify** the consequences (via the measurement indicators) over the life of the options
6. **Value** (attach dollar values to) the benefits and costs
7. Discount future benefits and costs to obtain present values at 8%
8. Calculate decision criteria
9. Analyse **uncertainty and sensitivity** of the results to assumptions (ideally including Monte Carlo simulation)
10. Make a **recommendation** and document the assessment.

Even if MPI officials will not be conducting a CBA themselves, knowing how they are done is useful for reviewing those received, and for providing directions on what is expected.

A.3.1 Step 1. Define the problem / opportunity

The problem definition or opportunity statement explains why a supposedly beneficial initiative would either not happen, or be delayed, or be inferior if taxpayer support was not forthcoming. After all — New Zealand is a relatively free economy; if something is of benefit, then what exactly is preventing it? The things that prevent beneficial initiatives are called either *market failures* or *government failures*.

This is also called a 'first principles analysis', which establishes if there is a justification for government assistance and to cross-check claims over the need of investment co-funding, and whether the proposed project is an 'all or nothing' proposal. If relevant market or government failures do not exist, then it is questionable whether any benefit could arise from a public intervention. Is there evidence to confirm both the causes and impacts of the problem? If there are market or government failures, then the initiative should then target the work to address these failures.

There is a tension in this analysis. Programmes that appear better and more worthwhile also raise the question of whether public funding is necessary; they perhaps would be done anyway.

Treasury's Better Business Case 'Strategic Assessment' document (August 2012) says:

> *In addition to clearly stating the problem, further context is also needed to describe the nature and size of the problem. The causes and effects of the problem should be identified. The root cause of the problem should be identified, not just the presenting symptoms. The costs and risks of not investing should be explained, supported by evidence.*

Typical reasons for market and government failures to arise include[14]:

- externalities (effects of decisions, both costs and benefits, that fall on external third parties)

14 Refer to the Green Book Annex I; Boardman et al (2006) Chapter 6; DFA (2006) pp 30–31.

- public goods (i.e. a good or service where people cannot be excluded from consuming it (non-excludable), and consuming it does not forgo someone else from consuming it either (non-rival); free-riding problems are similar)
- coordination problems (such as convincing industry stakeholders to collaborate; the *NZ Wine; finding the sweet spot* may be a good example) 'asymmetric information' (where some people know more than others)
- excessive unemployment, usually of labour, where the shadow price is lower than market prices or wages
- monopoly, abuse of market power, natural monopoly (for PGP, a dominant position of an investment proposer could suggest that if they did not do the R&D project, then nobody else would)
- inefficient existing restrictions on activities, prices, taxes and subsidies ('government failure').

A.3.2 Step 2. Decide whose benefits and costs count (standing)

A cost-benefit appraisal is a normative analysis, which means value judgements cannot be avoided. CBAs should clarify these judgements and to distinguish them from the associated descriptive analysis. The key ones[15] are:

- Is the relevant perspective from the local industry, national industry, New Zealand as a whole, or the global community?
- Should equal weighting be given to the impacts on gainers and losers? Should this differ depending on: the fairness and equity of the outcomes? By the wealth of the stakeholders? By the property rights of the stakeholders? By the foreign ownership of firms? By the social acceptability of preferences (or lack thereof)?

Usually CBAs take a national perspective[16], and weight the monetary impacts to gainers and losers equally. Regardless, all judgements should be made clear.

A.3.3 Step 3. Select options and specify the baseline

A CBA should consider all feasible and realistic options, but a process should be undertaken to minimise the options analysed in detail. Too few options may:

- bias results for 'favourite' – overlook potentially better alternative(s)
- seem to limit choices available to decision-makers.

A PGP proposal may warrant splitting out the sub-components if there are markedly different attributes such as costs, benefits, risks, or problem definitions.

A credible and well thought through *baseline* (*counterfactual*, *business as usual*, *do nothing*) needs to be established with which to compare options against. Note that the baseline is not a before vs. after comparison; one needs to compare two or more mutually exclusive states of the world, one with the proposed programme and one without it which may nevertheless be different from 'before' because of non-policy related changes (like continued industry growth or productivity improvement).

[15] Eg refer to Chapter 2 of Boardman et al 2006, pp 36–39, and to Chapter 18.

[16] Treasury's expectation in their Cost Benefit Primer (p11) 'is that cost benefit analysis will be undertaken from a national perspective rather than a government or departmental perspective wherever possible… Put another way, economic CBA seeks to capture all benefits and costs regardless of to whom they accrue.'

If a CBA shows positive net benefits but there are no market or government failures, then it is likely that the baseline was misspecified.

Some further guidance on specifying options and baselines can be found here:

- Treasury Regulatory Impact Analysis Handbook (Nov 2009) section 2.6
- The UK Green Book (July 2011 pp 17–19)
- Boardman et al (2006 pp7–9).

A.3.4 Step 4. Classify benefits and costs and select measurement indicators

Before one can classify the kinds of costs and benefits that would result from an intervention, one needs to know what they are intervening in. What is 'the thing' that is primarily affected by the intervention that one should conceive demand and supply curves? This is called the *primary market*.[17]

All other goods and services that people are willing to pay for (i.e. markets with demand curves) that are only indirectly affected are called *secondary markets*.[18] Making this distinction is important to help ensure benefits and costs are not double-counted.

The classic textbook example is when a new or improved road increases the prices of houses that are made more accessible. One could count the travel time savings (the primary market), or could measure the house price lift (the secondary market), but not both. The latter is merely a different manifestation of the primary market benefits.

Unless the secondary markets have market or government failures, there are no additional benefits as impacts ripple through them. This is one of several key reasons why policy makers prefer CBA over multiplier-type studies.[19]

The issue of how narrow to focus on costs and benefits is one of the hardest parts of any CBA. It is better that a PGP investment proposal errs on a narrower focus, concentrating on the first-round impacts, unless suitably resourced computable general equilibrium analysis is available to support the proposal.

To help in specifying the cost and benefit categories one should also specify the types of gainers and losers, and the reasons why they may gain or lose. This can help when different groups of people view an impact in opposite ways. For instance, a PGP programme might lead to the expansion of the sheep industry, but may create more pollution for users of the neighbouring rivers. It is usually more useful to classify opposing views of the same impact as different impact categories.

When classifying costs and benefits one should consider:

- intended and side effects
- tangible and intangible effects
- whether effects differ in the short run versus the long run

[17] Boardman et al (2006) Chapter 4.

[18] Boardman et al (2006) Chapter 5.

[19] The use of multiplier studies and input-output studies may provide insights into the activity of the wider economy, but they do not directly provide insights into what the net-benefits are.

- whether effects are temporary, lasting, or permanent (for all intents and purposes).

For each class of cost and benefit measurement indicators should be specified wherever possible. This could be the number of hectares farmed, the quantity of livestock per hectare, the value per animal, the number of plant variants, the quantity of runoff, etc.

A.3.5 Step 5. Quantify the impact on measurement indicators over the life of options

The next stage of a cost-benefit appraisal is to estimate what will happen in quantified terms in each of the alternative scenarios (including the baseline):

- quantitative evidence on the cause-and-effect relationships should be drawn upon where available. Try to avoid confusing correlation with causation
- this part of the analysis should be descriptive, not prescriptive. The focus should be on what people *would* do, not what the analyst thinks they *should* do
- take account of offsetting behaviours. For instance, if a new product is put on the market, then competitors may respond, say by cutting prices and developing similar products
- take account of pricing and operating cost effects. The proponent may have higher operating costs once the new product, process or service is commissioned, which will often be paid for by customers. Furthermore, customers may have their own set-up costs and higher operating costs. These all need to be considered before any estimate of uptake rate can be reliably established
- when making predictions, account for the uncertainty in scientific knowledge, particularly relating to environmental systems. Refer to the section on 'sensitivity analysis' below for more
- if certain impacts are difficult to quantify, still construct the analysis as though it can be quantified. It is still possible to test plausible 'what if' scenarios to see how the issue could impact on benefits, or use the [presumably spreadsheet] model to back-calculate to establish thresholds, assess materiality, and sense-check against other plausible benchmarks[20].

Valuing future impacts needs to consider a range of factors, such as:

- the appropriate appraisal period length is an important judgement. Cost-benefit appraisal textbooks advise to make this as long as costs and benefits relative to the baseline are reasonably expected to be sustained. For PGP, consistency is important so that one project does not appear more beneficial than another merely because its appraisal period was longer

[20] For instance, NZIER could not robustly determine how a bridge form of Additional Waitemata Harbour Crossing (rather than a tunnel) might have affected property values of houses that were within view of the new crossing. A range of plausible impacts were assessed to understand how material the issue of visual detriment was to the case for a tunnel. NZIER and PwC (2010) *Economic Benefits and Funding Options Report*, Report to NZTA, *awhc.nzta.govt.nz*

A.3.6 Step 6. Value the benefits and costs

After the consequences have been quantified relative to the baseline, they then get multiplied by unit values. Chapter A.2 provides guidance on how to measure and value impacts.

The unit values should either all include general price inflation (usually about 2% p.a.), or all exclude it. The term 'real prices' is used for the latter case. For PGP we recommend all prices are in real terms (which appears to already be the norm).

The unit values do not need to be held fixed over the appraisal period. If the analyst expects any significant changes in real unit values (such as willingness to pay increasing at a faster rate than general price inflation) then these should be incorporated[21].

Establishing the unit values can be difficult for an appraisal if they have not been researched and standardised beforehand. For PGP this would usually be the case for environmental externalities. The process of simply using values from previous studies is called 'value transfer' (or 'benefit transfer'). When it is not appropriate to perform value transfer, or if preliminary value transfer indicates that effects are substantial, then a primary valuation may be required. It is not expected that any one PGP proposal would conduct such primary research.

It would be useful if MPI could provide guidance on the value of non-market impacts. This would require further understanding how communities valued these impacts. The more that approximate values can be used, the more likely that it will improve the quality of funding decisions more generally. This may help target any possible government-funded research in future into valuing particular non-market impacts.

A.3.7 Step 7. Discount future benefits and costs to obtain present values

The concept of discounting

People tend to regard costs and benefits that are closer in time as more relevant to decisions than those that are further out in time. That is, people discount the future. Cost-benefit appraisals need to account for this to compare:

- costs incurred now with benefits in the future
- benefits forgone now for benefits later
- different speed options (e.g. high cost rapid programme vs. lower cost slower programme).

The process of discounting

Cost-benefit appraisals model this discounting in the same way as interest compounds on bank accounts. Where a dollar saved now can grow exponentially large in future with even a moderate sized interest rate, one dollar in future is shrunk exponentially smaller to a present value term.

[21] For more, refer to chapter 5, page 25 of The Green Book

The formula for discounting a future cost or benefit is as follows, where r is the discount rate, B_t and C_t is the value of the benefit and cost respectively in year t, and there are T years in the appraisal period:

$$Present\ value\ of\ benefits = \frac{B_1}{1+r} + \frac{B_2}{(1+r)^2} + \cdots + \frac{B_t}{(1+r)^t} + \cdots + \frac{B_T}{(1+r)^T}$$

$$PV(B) = \sum_{t=1}^{T} \frac{B_t}{(1+r)^t}$$

$$Present\ value\ of\ costs = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

This is relatively easy to do in a spreadsheet in MS Excel.

A higher discount rate means a shorter-term focus, which means a weaker investment case because benefits typically follow costs.

The choice of discount rate

The challenge is to determine the appropriate discount rate. This is one of the most contentious areas in economics and philosophy.[22] It is so difficult because there are many confounding issues that have their roots in different fields of economics.

The Treasury (2008) suggests a default discount rate is 8% (real), based on analysis of the New Zealand share market. This makes $1 of cost or benefit in fifteen years' time worth $0.32 now, and in 25 years' time $0.15. This approach is called the *social opportunity cost* discount rate, and represents the return on investment in the private sector. From July 2013 the NZ Transport Agency (which allocates ~$4b of public funds annually) reduced the social opportunity cost discount rate it uses from 8% real to 6% real.

The specialist CBA literature actually provides a fairly clear steer on the conceptual approach to setting a discount rate. NZIER (2013)[23] found that eight out of nine specialist cost-benefit textbooks advise that a *social rate of time preference* be used.[24] This concept reflects what an independent policy maker judges to be the rate of growth in annual consumption that society is indifferent between. This is a value judgement. This is the approach that is becoming commonplace across most developed economies. It is not for an economist to specify what this value is, but it often is something like 3%–4% real, and not higher than the real rate of foreign borrowing for the government (a long-term average of some 4%).

For PGP the Treasury approach will likely prevail. Sensitivity assessments with different discount rates are never a bad thing, but it would be useful for all proposals to be consistent in how they go about that (for instance advise that they use both 4% and 8%).

22 For an overview of some issues see NZIER (2011) *Economics like there's no tomorrow* - NZIER Insight 32. *nzier.org.nz/publications/economics-like-there's-no-tomorrow-nzier-insight-32*

23 Refer to NZIER (2013) *Advice on Auckland's social discount rate policy*. NZIER report to Auckland Council, 24 May 2013

24 A further two textbooks stopped short of advising a specific approach to use.

A.3.8 Step 8. Calculate decision criteria

The simplest way to complete the analysis is to sum the present value costs and benefits and determine if benefits exceed costs. This is called the 'net present value'.

$$NPV = PV(B) - PV(C)$$

A programme should be rejected on efficiency grounds if its NPV is less than zero (unless there were additional benefits likely that were excluded). The NPV can be compared across all alternatives straightforwardly to determine which has the largest positive NPV and is thus 'most efficient'.

Another common measure is the benefit-cost ratio (BCR), expressed as present value benefits over present value costs, with the requirement that it exceeds 1:

$$BCR = \frac{PV(B)}{PV(C)}$$

This latter approach should be used if the option involves costs relating to a constrained resource, such as the government's overall PGP budget. It is also useful for allowing for a hurdle cut-off, such as 2, 3, 4 say, that is unrelated to myopia like using a higher discount rate is.

Other methods such as the 'payback period' and the 'internal rate of return' are in many respects inferior to the above.

Reporting the NPV is a minimum requirement.

A.3.9 Step 9. Sensitivity analysis

Cost benefit appraisals usually contain many judgements that may or may not matter to the results. For instance, the analyst may be unsure of how what uptake will be. The purpose of sensitivity analysis is to test how sensitive the results are to those judgements.

Some changes in assumptions flow through extremely easy in an analysis, whereas others will require entirely new model runs (like CGE) to be undertaken, which can be costly.

When undertaking sensitivity analysis use 'best estimates' of uncertain values (e.g. mean, mode, most likely, consensus opinion). The analyst can vary uncertain values up and down across the range of estimates. This becomes problematic when there are lots of variables that warrant testing. That is because it is (by definition) improbable for a variable to be at its low value, and highly improbable for two to be at their minimum. It is extremely improbable for several to all be at their lowest value. In this case 'Monte Carlo' assessment becomes very useful[25]. It is an MS Excel add-on such as '@RISK', which is relatively easy to use. This can test multiple probability distributions at the same time to give an overall spread of outcomes to provide decision makers with added assurance as to the robustness of the findings.

Sensitivity analysis can help identify the key features that are most material to the analysis. It can be used to investigate:

- how much results change if adopt different values

[25] Treasury 2006 CBA Primer Annex 1.

- at what critical values would findings differ
- to which uncertain coefficients/variables the results are most sensitive
- where additional information or research would be most useful.

A.3.10 Step 10. Recommendations and document assessment

The analysis should be documented and reported as per the process outlined above. Enough information should be provided so as to allow interested parties to fully contribute on an informed basis.

Ideally, enough information should be provided so as to allow a third party to broadly copy the approach to see if they can get similar outcomes. However, sometimes confidential data, specific modelling capabilities, or specialist skills prevent this from being able to be done to its full extent.

A.4 Metrics for assessing PGP programmes

Success of PGP programmes is uncertain. There are several aspects to PGP that improve its chances of success – industry co-funding, co-operation with producers, focus on communication and extension – it is nevertheless an R&D initiative and thus entails some risk.

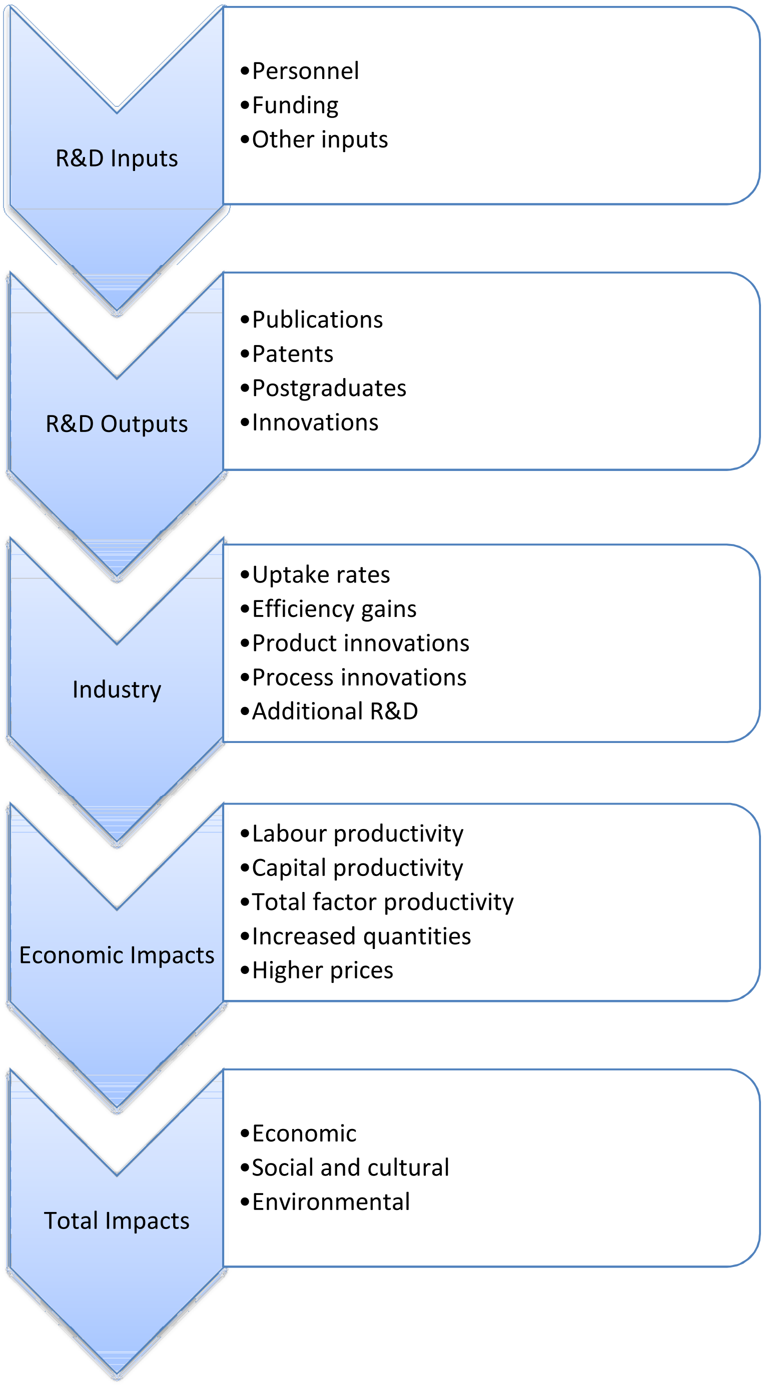
One way to reduce the overall performance risk is to monitor progress and look for early warning signs. To do this, it is important to have something to measure – metrics. These metrics should be SMART:

- Specific – who, what, where, why, when and how?
- Measurable – what will you measure and how?
- Achievable – but also 'Aspirational'
- Relevant – measure the right thing
- Time-bound – stop/go points, final project goals.

Before moving to specific suggestions for metrics, it is important to think about the process being measured. PGP is an innovation process that uses public and industry funding to develop R&D plans, pursue them, produce innovations, create change in their industries and finally produce economic value and other improved well beings. This process is depicted in Figure 15.

Figure 15 PGP innovation process

From R&D to total impacts



Source: NZIER

The goal of a metric is to measure activity within any of the steps along the way and from one step to the next. For example, one measure of successful activity in producing research is the number of publications from the programme. More publications can be taken as a marker of more successful research. However, it does not necessarily translate into impacts at the industry level. At the industry level, success might mean high labour productivity – more output for a given level of employees, perhaps as a result of research described in an academic publication.

With that background in mind, here are some possible metrics, mainly focusing on the industry and economic impacts parts of Figure 15:

- To identify innovation within companies:
  - number of products, stock-keeping units (SKUs)
  - number of services offered
  - number of process changes
- To measure the progress of new business ideas:
  - stage of development of new ideas – discussion, planning, pre-production, etc.
  - amount of private investment
  - number of employees working on development
  - contracts signed or in pipeline
- To measure progress with farmers/producers:
  - number of farmers testing innovation
  - number of farmers using innovation
  - number of hectares/production units using innovation
  - investment in required equipment
  - prices received by individual farmers
  - sizes of herds/flocks
- Other metrics:
  - number of copycat products or processes
  - volume of total production
  - volume of production of new products
  - prices in the industry, both level and variation
  - changes in measures of quality, both level and variation
  - amount of inputs sold (e.g., grapevines, manuka plants, milk vats).

These metrics can then be further described using the SMART scheme. For example:

- Metric: number of contracts
  - Specific: contracts must be for consultation services in relation to the innovation
  - Measureable: we will record the number of contracts and their dollar value
  - Achievable and Aspirational: we will aim for 10 contracts, and try to stretch for 15
  - Relevant: farmers are willing to pay a consultant once they have decided that the innovation is worthwhile, so a consulting contract indicates that they are serious about the innovation

– Time-bound: we will record contracts for services in the last calendar year and next calendar year.

The metrics will vary from programme to programme, and indeed across projects in the programmes. Importantly, they must demonstrate that producers in the primary sector are actually doing what the programme is targeting. The question should be, are there commercial producers actually using this technology, process or innovation? If the innovation is still in its early stages, before it is ready for commercial use, then the questions should centre on two things. First, there needs to be demonstrated progress within the current stage of R&D. The progress could be experiments completed, papers presented, processes tested, etc. Secondly, there needs to be progress towards moving through the R&D process, from the current stage to the next. Indication of progress might be moving from lab trials to field trials, or field trials to on-farm test paddocks.

A possible approach would be for PGP applicants to start the process of identifying appropriate (Relevant) metrics that they propose to use to measure progress. As part of the funding process, MPI can agree on a suite of metrics. Ideally, they would measureable several parts of the R&D process. One might focus on measuring science progress, another on industry uptake, and a third on improved output quality. These agreed metrics would then form part of the programme's reporting and would be tracked over time.

A.5 References

Australian Government (2010) *Best Practice Regulation Handbook*, Canberra

Boardman, E.A., Greenberg, D.H., Vining, A.R. and Weimer, D.L. (2006) *Cost-Benefit Analysis Concepts and Practice*, 3rd edition, Pearson Prentice Hall.

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Appendix B : Questions for PGP participants

1. Can you tell us about what the programme was intended to achieve? (The aspirational rationale for the programme?)
2. How and why did you decide on the approach to the R&D given there is always competing options demanding R&D attention? What road block it was intended to remove?
3. How did you decide upon the baseline (or business as usual scenario)? i.e. was it performance over the past five years?)
4. What are the crucial assumptions that drive the benefits?
    a. take-up rates
    b. injection of new capital
    c. the go/no go points that determine research success
    d. IP and its treatment i.e. if successful, how long will the project stakeholders hold on to IP rights?
5. Do you expect that the full benefit will occur by 2025? (given the time lags in R&D research)
6. What consideration has been given to non-quantitative benefits? How important are they to the success of the programme?
7. What is your general approach to risk and uncertainty?

Appendix C Comparison of IRR and BCR

A discussion of the mathematical relationship between IRR and BCR is available in Rao, Hurley, & Pardey (2012). Projects with the same IRR can have different BCRs, and vice versa. As a simple demonstration, Table 3 shows the flow of costs and benefits from two hypothetical projects. They have the same IRR, but different BCRs.

Table 3 Comparison of BCR and IRR

Two example projects with different results

Year	Example 1		Example 2	
	Costs	Benefits	Costs	Benefits
1	1,000	0	1,000	0
2	1,000	0	1,000	0
3	1,000	0	1,000	0
4	1,000	0	1,000	0
5	1,000	0	1,000	0
6	0	513	1,000	586
7	0	1,477	1,000	1,688
8	0	3,235	1,000	3,697
9	0	5,782	1,000	6,608
10	0	8,891	0	10,161
11	0	12,229	0	13,976
12	0	15,486	0	17,698
13	0	18,446	0	21,081
14	0	20,998	0	23,998
15	0	23,114	0	26,416
16	0	24,818	0	28,363
17	0	26,161	0	29,898
18	0	27,202	0	31,088
19	0	28,000	0	32,000
20	0	28,000	0	32,000
Present value	$3,993	$76,173	$6,247	$87,055
BCR	**19.1**		**13.9**	
IRR	**43%**		**43%**	

Source: NZIER