POSITION PAPER - EVALUATION METHODS AND TECHNIQUES

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Glossary of terms

CGE modelling	Computable general equilibrium modelling – a computer based model of a national and/or global economy.
Consumer surplus	The difference between what a buyer is willing to pay for a good or a service and the amount that the buyer has to pay in the market
Demand curve	The curve showing the amount of a good or service that consumers are willing to purchase over a range of prices.
Non- use values	The value of services that are not used directly by the consumer such as valuing the existence of a remote area of high conservation value that the consumer never visits or the value of a bequest
Option	An option is the right to acquire something at some time in the future but not the obligation to do so. Investing in basic R&D is equivalent to purchasing an option to develop any discovery that might eventuate
Price elasticity of demand	The ratio of the change in quantity demanded of a good or service to the change in its price
Producer surplus	The difference between the price received by a producer for a unit of production and the cost of producing the unit of production
Supply curve	The curve relating the amount of a good or service that firms are willing to supply over a range of prices
Use values	The value of a good or service that is used directly by a consumer. Includes tangible and intangible benefits.
Value added	The difference between the revenue received by a firm for production less the cost of inputs, It is the return to labour and capital.

Abstract

This paper reviews methodologies in economics for valuing the benefits of geospatial data and services; including the value of open data.

Section 2 explores the meaning of socioeconomic value and reviews the methodologies underpinning value assessment. It explains the theoretical background to economic welfare analysis, total turnover analysis and value added analysis. The use of different methods for economic impact assessment is then outlined. The methods include benefit cost analysis, multiplier analysis and Computable General Equilibrium (CGE) modelling[1]. This section also outlines the background to value chain analysis and real options analysis.

Examples of the application of these techniques are discussed. They include the application of earth observation to agricultural and water resource management and the use of mapping to improve decision making in areas such as emergency management, managing endangered species, conducting property tax assessments and verifying insurance claims. These examples illustrate the potential for geospatial data to deliver value over a wide and growing range of applications.

Section 3 addresses the issues that arise in applying these techniques. It points out that the methodology selected must address the questions being asked by policy makers and/or users of geospatial data. In the current defensive fiscal environment experienced by governments in many OECD countries, it is important that the valuation method links the use of geospatial data services to a clearly defined and quantifiable outcome. There needs to be a 'line of sight' between application of geospatial data services and the benefits that are identified. The paper suggests that evaluations should clearly outline such relationships and suggests a hierarchy of methods that can be applied in such circumstances. The methods include cost effectiveness analysis, benefit cost analysis and regional and economy wide economic modelling.

Section 4 comments on the issues that arise draws some conclusions and raises some questions for discussion. It concludes that there is a need to: align methodology to the decision maker's needs; develop better evidence based economic assessments; adopt more structured approaches to addressing the rapid evolution in the use and application of geospatial data; develop greater capability in building better business cases; and reaching a consensus on internationally recognised methodologies. It also raises the possibility of greater international collaboration and research into building better business cases and establishing a community of experts to help advance the discipline of socioeconomic evaluation as applied to geospatial data and services.

[1] A CGE model is an economic model of the economy that can be used to calculate the impact on metrics such as Gross Domestic Product, Income, Investment and employment of changes in productivity in specific sectors.

1. Introduction

This paper reviews the methodologies that have been applied to the socio economic valuation of geospatial information including open data. Section 2 explores the current state of the art in economic approaches to valuation. It explores welfare economics, benefit cost analysis, value-added techniques, computable general equilibrium (CGE) modelling, real options and value chain analysis. It also discusses approaches to valuing intangible benefits.

Section 3 discusses issues arising with the application of these techniques. It explores the issues facing policy makers and the questions they are asking when considering policy or investment decisions in geospatial data and systems.

Section 4 outlines possible future directions for consideration. It discusses approaches to matching methodology with the issue at hand. Finally it suggests issues for further consideration in the development of valuation techniques.

2. Current state of the art

In this section we review the approaches that have been applied to assessing the value of geospatial information from the view point of its intrinsic value as well as the value that it creates for other areas of economic and social activity. A summary of studies is provided at Attachment A.

2.1. The meaning of value

Assessing the value of a good or a service such as geospatial information is a complex problem. Valuing the contribution made by open geospatial data is even more complex because there is not a fully functioning market for it.

A starting point in estimating a value for provision of geospatial data is to clarify what is meant by the term “value”. Fundamental geospatial data is an intermediate good and an enabler of other activities through value added services. To understand its value we need to explore the value that suppliers and users draw from the data.

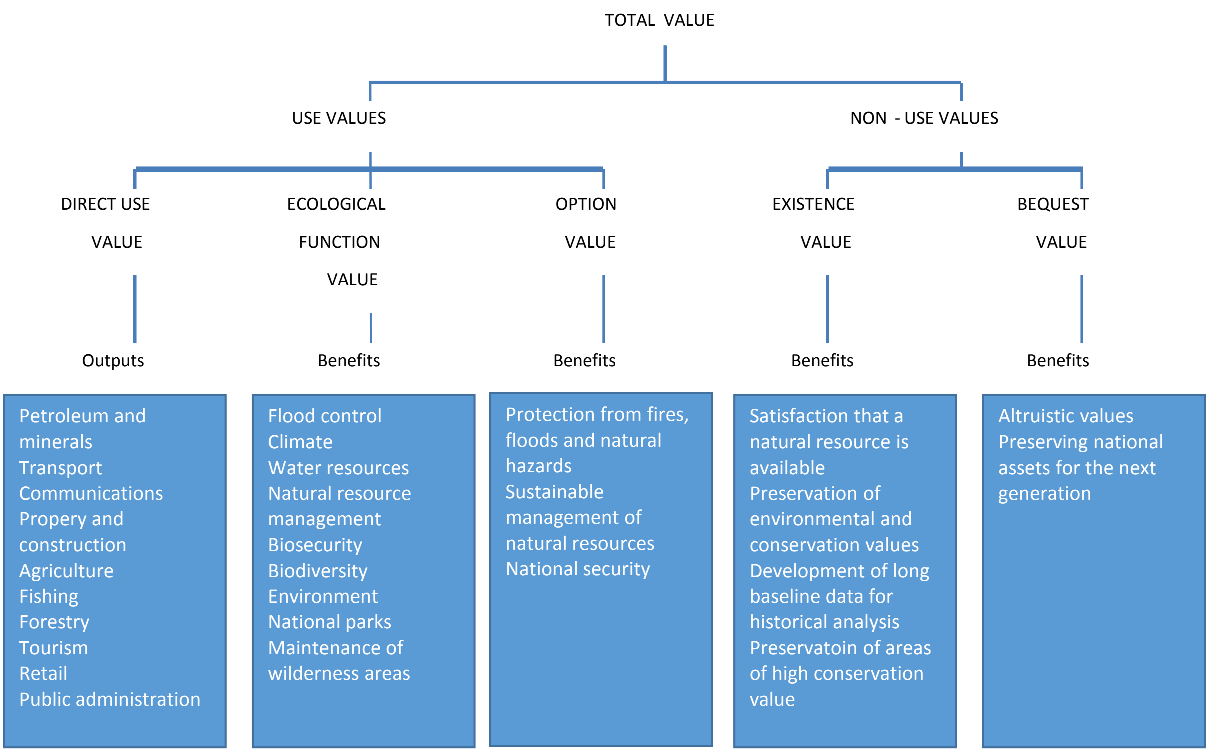
The answer to this question depends on the view point of the person asking the questions. For a government custodian it could be as narrow as the financial benefit to government (for example realised future savings) less the cost of the investment in acquiring the data. For a policy decision maker it could be as wide as the expected benefits that would accrue to society as whole from the use of the data less its costs.

A suggested framework for considering different concepts of value is provided in Figure 1. In this figure, value is divided into use values and non-use values. Use values are those goods and services that people consume. Use values comprise direct use values (such as the value of goods and services), ecological values (such as biodiversity or sustainable rivers and streams) and option values (such insurance against the costs of natural disasters).

Non-use values can be considered as existence values (valuing the existence of a coral reef but never diving on it) and bequest values (preserving the value of assets for later generations). While non-use values are conceptual, they are real in the minds of many in society and potentially become policy issues for this reason.

In theory, total socioeconomic value is the sum of the use and non-use values.

Figure 1**The nature of socio-economic value**



Source: ACIL Allen Consulting based on work by Professor Mike Young, University of Adelaide.

Most studies undertaken in the past decade or so have focused on the direct use values for which economic value is amenable to quantification. However, there is a long history of economic evaluation of intangible benefits in the literature and some of these methods can be applied with respect to the use of geospatial data.

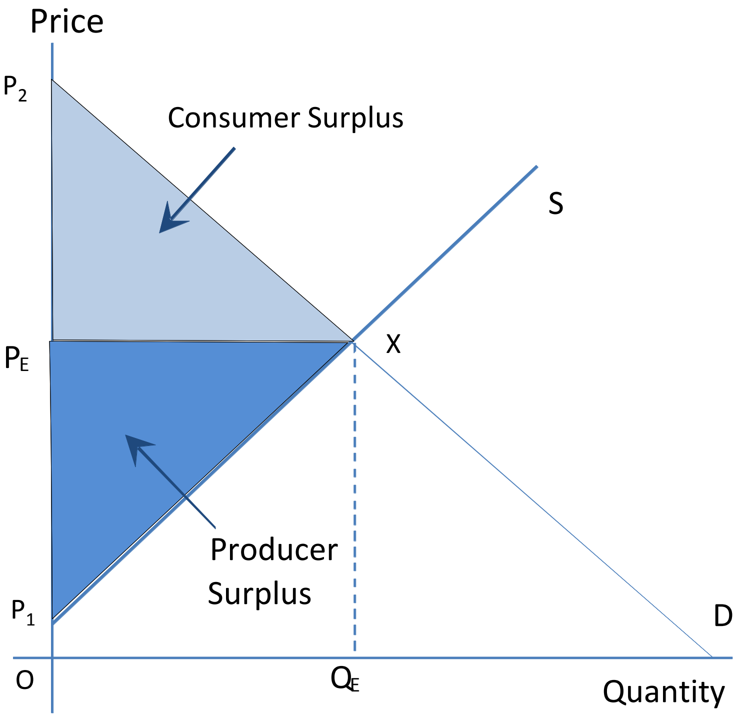
There has been limited use of options valuation in assessing the value of geospatial applications although there has been considerable work in areas such as astronomy and research and development in Australia.

A number of techniques have been developed and applied over the past 15 years or so to estimate the value of geospatial information. A representative sample of these approaches is discussed in the following sections.

2.2 Welfare analysis

Welfare analysis is a theoretical conceptual economic model for describing the total economic value of a good or a service. It is one way of looking at total socio economic value. In a fully operating market, the economic welfare of society is measured by consumer and producer surplus. The conceptual base for consumer and producer surplus is the supply and demand or market model depicted in Figure 2.

FIGURE 2 STANDARD CONCEPTS OF PRODUCER AND CONSUMER SURPLUS



Source: ACIL Allen

The market supply curve (which comprises the summation of individual firm supply curves) indicates the costs of extra production i.e. the costs to society of producing an extra unit of a good or service. Firms aim to operate on the upward sloping part of their marginal cost curve above the minimum average variable cost. The upward slope reflects diminishing returns to factor inputs, and hence it costs more to produce each additional unit of output[2]. The area under the supply curve is the total cost of production.

The market demand curve (which comprises the summation of individual demand curves) indicates the maximum amount that consumers are willing to pay for incremental increases in the quantity of the good or services. The demand curve is normally downward sloping because the more someone consumes of a good, the less they are willing to pay for more. This concept is generally known as diminishing marginal utility. The area under the demand curve is the total willingness to pay for a good.

The interaction of demand and supply determines the market price (P_E) for a good and the quantity that is produced in any given time period (Q_E).

This market model provides the basis for identifying and estimating the net economic value to consumers and the net economic value to producers, referred to as consumer surplus and producer surplus, respectively.

Consumer surplus is the difference between what an individual would be willing to pay (demand) for a good or service (the total benefit to the consumer) and what they have to pay (the cost to the consumer i.e. consumer expenditure (price times quantity). In Figure 2 it is the area between the demand curve and the price line (P_2xP_E).

[2] Provided the marginal cost of producing an extra unit of output is less than the market price then it is still profitable to produce.

Producer surplus is the difference between the revenue (consumer expenditure) received for a good or service (total benefit to producers) and the costs (supply) of the inputs used in the provision of the good or service (economic cost to producers). In practical terms, it is the net revenue (before tax) that is earned by a producer of goods and services. In Figure 2 it is the area between the price line and the supply curve (P_1XP_E).

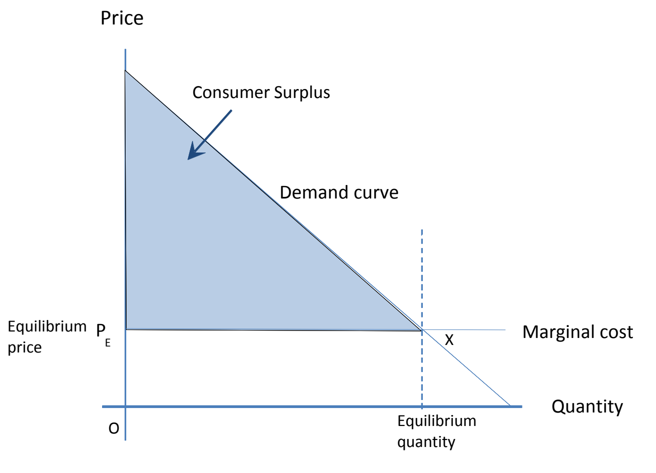
If the diagram is specified in annual terms, the sum of the shaded areas will represent the annual value to society of the product. The consumer surplus area represents the amount consumers obtain in excess of what they actually pay. Equivalently, producer surplus represents returns in excess of costs obtained by producers at the prevailing price P_E.

2.2.1 Application to fundamental geospatial data

The application of the theory of welfare analysis to empirical analysis of the value of data is a big jump from the textbook model requiring lots of assumptions to be made about the real nature of the markets under examination. Its application to the decision to support investment in geospatial data must recognise two important differences to a fully functioning market. Firstly, the custodian of the data is generally a government organisation where the price for access is set by a policy decision - not by the market. Secondly, the data exhibits characteristics of a public good which has implications for the value that is generated for society depending on the price set by government.

Under an ideal open data policy the price would be set at the marginal cost, which is close or equal to zero when supplied through the internet. This is illustrated in in Figure 3. The value to consumers of this arrangement is the consumer surplus shown as the shaded area in the diagram.

FIGURE 3 DEMAND AND SUPPLY CURVES IN THE CASE OF FUNDAMENTAL GEOSPATIAL DATA



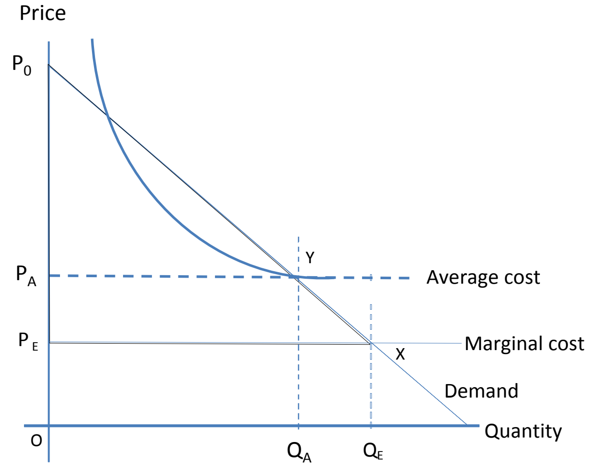
Source: ACIL Allen

Welfare analysis has been used on a number of occasions to estimate both the value of geospatial data services in general and the relative economic benefits of different pricing policies.

A study published in 2008 by Cambridge University estimated the value of moving from average cost pricing to marginal cost. (Pollock et al, 26 February 2008). The theoretical framework used by Pollock is illustrated in Figure 4.

FIGURE 4 DEMAND AND SUPPLY CURVES IN THE CASE OF FUNDAMENTAL GEOSPATIAL DATA

Diagram including average cost



Source: ACIL Allen

The average cost curve is the convex upward curved line identified in the diagram. Average cost includes the original cost of acquiring the data and the annual cost of maintaining and supplying data. The marginal cost is the horizontal line P_EX. For open data the short run marginal cost of supply is constant and close to zero for web based applications. This outcome is a special case that arises for government-supplied public goods where governments have a supply monopoly[3]. The value of changing from average cost pricing to marginal cost pricing is the increase in consumer surplus (area P_AYXP_E) less the decrease in producer surplus (area P_AYZP_{EP} minus ZXQ_EQ_A) which is represented by the area YXZ.

There is no functioning market for foundation geospatial data held by government and hence no observable price-quantity trade-off that would enable one to estimate the demand curve. The Cambridge study used evidence from the UK as well as evidence from the literature to estimate the price elasticity of demand for geospatial data[4]. Using comparative studies the report assumes a price elasticity of demand for Ordnance survey data to be 2 – that is, a 1 percent reduction in price would produce a 2 percent change in the volume of data demanded by consumers.

The study made other adjustments for innovation, for the cost of government funds and an adjustment for the time delay in realising the benefits. The most important of these was the adjustment for innovation to recognise the fact that welfare analysis is a static analysis and does not take into account the dynamic effects of innovation by users. To address this the study applied a multiplier of 3 to the results.

With these assumptions the Cambridge study estimated the value of moving from average cost pricing to marginal cost pricing to be £168 million while the net cost to government would be around £12 million – a net benefit to society of £156 million.

A subsequent study for the Australian and New Zealand Land Information Council in 2010 used a similar conceptual model to estimate the economic value of different pricing policies for foundation data (ANZLIC, 2010). In this case a willingness to pay approach was used to estimate price elasticities

[3] Public goods exhibit market failure because they are non – rival (consumption by one consumer does not exclude consumption by another) and non-excludable (the consumer cannot be excluded from acquiring the good or service and hence there functioning market).

[4] The price elasticity of demand of a good or service is the ratio of the percentage change in quantity demanded and the percentage change in price.

of demand for selected foundation data sets. Users of selected data products were interviewed to assess the value they placed on data and their likely response to different price points.

This study assumed that the demand curve was linear (as with the Pollock study) and used a price elasticity of 1 and a multiplier of 1. Using these assumptions, this study estimated that the value of moving from average cost to marginal cost was A$3.3 million for Victorian topographic data, A$1.4 million for Western Australian topographic data (Landgate), A$1 million for Western Australian aerial photography (Landgate) and A$4.7 million for national topographic data (Geoscience Australia) (ANZLIC, 2010).

Houghton (2011) applied welfare analysis to data on increases in downloads of geospatial data released by Geoscience Australia following the introduction of new pricing policies which made online spatial data free over the internet (Houghton, 2011). This analysis included agency and user transaction related cost savings. Houghton estimated the price elasticity of demand for scheduled data sets to be 1.3. Using this estimate along with download data and estimates of agency and user cost savings, the paper estimated the total increase in consumer surplus of moving from cost-recovery to freely available data to be A$60.2 million over the period from 2001-02 to 2005-06.

2.2.2 Issues with welfare analysis

Welfare analysis is generally best suited to evaluating a single product or service that is uniform in quality and availability. The product or service must be clearly defined for consumers. This is not a major drawback for consideration of a defined data set such as addresses or topography. However it is less useful for analysing the socio-economic value of a package of fundamental data sets.

The form of the demand curve is critical to the examination of consumer and producer surplus. The estimates of the demand curve also rely on estimates of elasticity of demand that are generally based on two price-quantity observations with little evidence of the shape of the demand curve between or beyond of those observations.

Welfare analysis is a static analysis. It does not take into account changes in demand patterns, innovation, competition, changes in industry patterns, changes in data quality, or of resource shifts in the economy resulting from changes in the use of the data. To some extent this can be addressed through the use of multipliers. However estimating multipliers can be highly subjective.

Welfare analysis is very useful for comparing changes in socio-economic impacts of different pricing policies providing the range of change along the demand curve is not large. It is less helpful when estimating socio-economic value along the total demand curve because of difficulties in estimating the shape of the demand curve.

2.3. Estimates of turnover

Some studies in recent years have used total turnover to show the size and hence value of the geospatial sector. However this can be challenging. The treatment of the geospatial sector in standard industry classifications in the national accounts is, in most cases, inadequate for the purpose of estimating its turnover. The sector is generally allocated partly into professional services and partly into the IT sectors in many cases. Extracting a realistic estimate of the total revenue for the sector from national accounts requires considerable judgement for which there is little data.

Such an approach formed part of the analysis undertaken by Oxera in their report for Google on the value of geospatial services released in January 2013 (Oxera, 2013). Oxera estimated that the global geo services sector generated around $150 billion to $250 billion in revenue in 2012. This number was compared with estimates of revenues from other industries such as the global airline industry which it estimates generates total revenues of $ 594 billion.

Such revenue estimates indicate the size of the transactions being generated by the industry but, as the report notes, they do not indicate the full economic contribution of the industry. An alternate and more rigorous approach is to estimate gross value added.

2.4. Value added approaches

Gross value added of an industry represents the total revenue generated less the cost of inputs incurred. In practice it reflects the returns to capital (profits) accruing to geospatial service providers and salaries and wages paid to those working for them. Gross value added makes up the bulk of Gross Domestic Product (GDP)[5]. GDP is an important economic indicator for economists and policy makers.

The Oxera report estimated that the gross value added of the geo-services sector was $113 billion compared with a gross value added of the global economy of $70 trillion, suggesting that geo services account for roughly 0.2 per cent of global GDP. Such comparisons can help place the contribution of each sector in context. Gross value added approaches are far more rigorous than general descriptions of market size when issues of economic impact are concerned. However, taken in isolation they are less helpful in estimating economic value.

A key problem with value added approaches lies in the fact that geospatial data is an intermediate good. It is an enabler of economic activities along value chains rather than a final good. Tracking the value added therefore requires an understanding of how geospatial data supports productivity along supply chains rather than in its direct use.

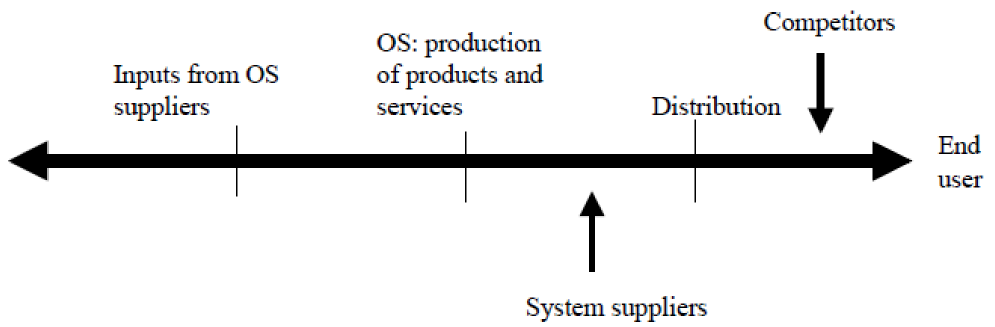
2.3.3. Value added along supply chains

Value added analysis can be undertaken along a supply chain to enrich the analysis of value added contributions from geospatial information. This extends the estimate of the value added beyond that immediately associated with the geospatial sector. Such an approach and can provide a more realistic estimate of the wider contribution of geospatial systems as part of the supply chain.

This approach was adopted in a study undertaken by Oxera in 1999 to estimate the economic contribution of Ordnance Survey in the United Kingdom (Oxera, 1999). The supply chain adopted in the study is shown in Figure 5.

[5] The other components are subsidies and taxes. GDP comprises the sum of gross value added plus taxes less subsidies.

FIGURE 5 SUPPLY CHAIN ASSUMED BY OXERA



Source: (Oxera, 1999)

The study estimated the proportion of value added by each sector along the supply chain that could be attributed to the use of Ordnance Surveys geospatial products. The results were a total GVA in Great Britain of between £79 billion to £136 billion or 12 to 20 per cent of GDP at the time. Of this £28-38 billion was attributable to local government, £23-29 billion attributable to utilities, and £14-12 billion to the transport sector, and so on.

The Allen Consulting Group estimated the value added along the supply chain that could be attributed to spatial information and systems in Australia to be around $12.5 billion in 2010, with this mainly occurring in the areas of government administration, property and business services, construction and mining. This amounted to around 1 per cent of GDP at the time. For New Zealand, the estimate of gross value added along the supply chain was $1.6 billion or around 1.4 per cent of GDP at the time (ACIL Tasman, 2010).

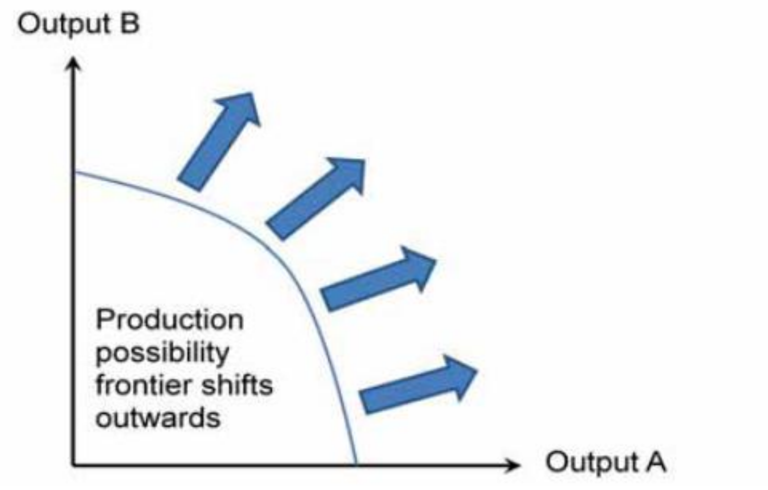
Such approaches provide information about the size of the footprint of the geospatial sector in an economy, but they are dependent on judgements on the proportion of each sectors' value added that can be attributed to geospatial information systems. There is little data in published statistics to support such judgements.

2.5. Economic impact analysis

While welfare theory and value added approaches are useful economic concepts, they require considerable work to translate the theory into empirical evidence to support evidence based decision making. Prospective decisions that require estimates of the economic impacts of different policy or program options require a framework within which different options can be assessed. The framework for such an assessment starts with understanding how geospatial data and services affects total output in a sector or in the economy overall.

The effect of introducing geospatial data and services to the economy can be summarised as the ability to deliver more output for a given combination of resources. This idea is summarised in Figure 6 which shows an economy's so called 'production possibility frontier' shifting outward as a result of the use of geospatial data services.

FIGURE 6 GEOSPATIAL INFORMATION AND THE ECONOMY'S PRODUCTIVE CAPACITY



Source: ACIL Allen Consulting

As discussed, geospatial information services are enabling technologies that improve the productivity of a range of industries or government services. In many cases these services create applications and markets that would not possible without them, resulting in extra value for the economy. An example of the application of this concept is contained in the paper prepared by Bernknopf and Shapiro for this Workshop (Bernknopf and Shapiro, 2014).

This 'extra value' may come in several forms:

- cost savings in doing the same things more efficiently
- delivery of new products or services producing greater value in the use of the resources required to deliver them
- dynamic savings within and across sectors of the economy creating new value not previously possible
- lower costs for governments and regulators in managing environmental, health and social services
- better environmental, health and social outcomes with the resources available.

Economic impact assessment attempts to estimate this extra value that has arisen or is expected to arise in the future. To do this, the analysis must establish two scenarios:

- a reference case representing the situation with geospatial data services that is to be assessed
- a counterfactual representing the situation without the geospatial data services.

As discussed in Houghton's paper submitted for this workshop, the counterfactual should represent the next best option that would be available in the absence of the geospatial data services being evaluated.

These concepts are drawn on in an analysis of the benefits of the use of satellite imagery to support better management of agricultural production and regulation of ground water quality (Department of the Interior, 2012). This paper demonstrates the need for careful structuring of assumptions for the reference case and the counterfactual to ensure that the results are appropriate for decision making purposes.

In the following sections, different approaches to undertaking economic impact analysis are discussed. These include:

- Benefit cost analysis
- Multiplier analysis
- Computable general equilibrium analysis
- Value chain analysis
- Real options analysis.

2.6. Benefit cost analysis

Benefit cost analysis is an approach to an empirical form of welfare analysis. It can be applied to investment analysis as well as policy change.

For purpose of analysis benefits represent the additional value that is produced as a result of an investment or policy change. In other words, the additional value that is created under the reference case when compared to the value that is created under the counterfactual.

Simply put, an investment or policy change is considered justified on economic grounds when the net benefit (total benefit less total cost) is equal to or greater than zero.

Benefit cost analysis involves laying out a time series of costs and benefits and using discounting techniques to account for the time value of money. In economic parlance, the discount rate reflects the opportunity cost of money over time. Cash flows are discounted back to a reference year (usually the date of evaluation or the commencement of a project) and the discounted cash flows are summed.

Discounting is a method of bringing future benefits and costs back to their value in a base year; referred to as the present value of benefits or costs. The present value of a monetary value *A* accruing in a future year *n* is discounted according to the following formula:

$$Present\ value\ of\ A(n) = \frac{A(n)}{(1+r)^{n-1}}$$

Where r = discount rate

Net present value can be calculated with the following formula:

$$Net\ present\ value = \sum_{1}^{n} \frac{B(n)}{(1+r)^{n-1}} - \sum_{1}^{n} \frac{C(n)}{(1+r)^{n-1}}$$

Where

B(n) = benefit in year *n*

C(n) = benefit in year *n*

The results can be expressed as either a net present value, a benefit cost ratio or a return on investment (ROI). The ROI is the discount rate that equates the present value of benefits to the present value of costs. It is a popular metric and is well recognised. However it also exhibits some technical limitations and needs to be treated with care[6].

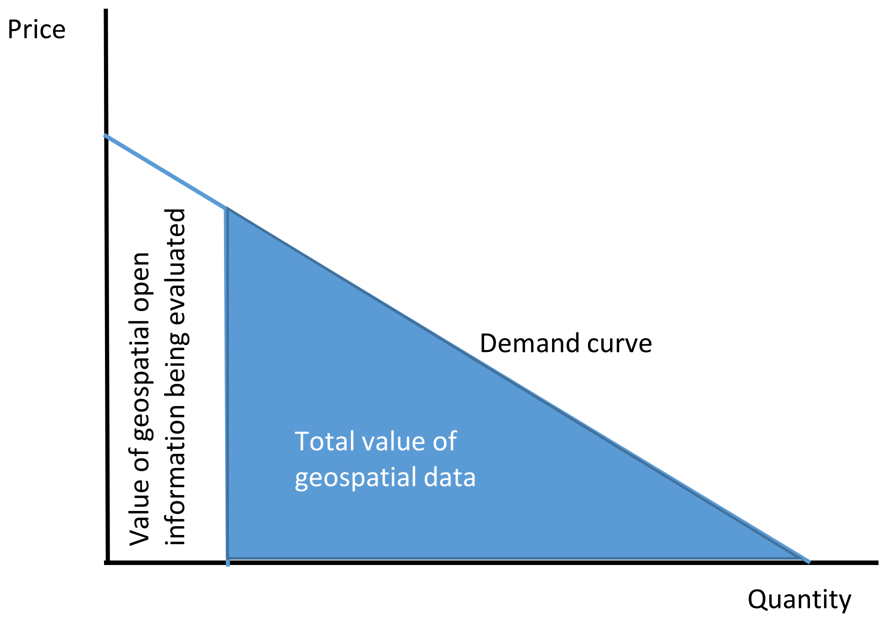
A key challenge in benefit cost analysis is defining the counterfactual – that is the situation against which the proposed investment or policy change is being assessed. The counterfactual is the next best outcome without the proposed investment or policy change. Common mistakes in this type of analysis are to assume that without the investment or policy change, nothing happens. This is rarely the case. Other solutions to found but they are usually less effective or deliver delayed benefits. To be credible a benefit cost analysis must have a credible counterfactual.

A further challenge is arriving at realistic estimates of benefits that are an indirect outcome from the use or application of geospatial data. Benefit cost analysis can require complex calculations and careful treatment of uncertainty.

An excellent primer for undertaking benefit cost analysis has been issued by NASA (NASA, 2013). This sets out the steps and approaches required for earth observation from space which also has more general application to assessing socioeconomic value of geospatial services.

Benefit cost analysis generally focusses on a specific uses rather than attempting to estimate the benefit delivered across all uses. The relationship between the total benefits and a subset of benefits subject that are typically subject to benefit cost analysis is illustrated in Figure 7.

FIGURE 7 VALUE OF OPEN GEOSPATIAL DATA



Source: After Raunikar (2011)

The figure assumes that the data is supplied free as it would be under a full open data policy. The total value of the data is the area under the demand curve. However for practical purposes benefit cost analysis generally focuses on a defined subset of the total data use shown as the unshaded area in Figure 7. In such cases the results obtained from the selected subset are likely to capture a lower bound estimate of the total benefits that accrue across all users.

[6] The ROI can have more than one solution where cash flows switch between positive and negative over time. It also assumes that the borrowing and lending rate is equal to the ROI. This is unrealistic where the ROI departs from the borrowing and lending rate. There are methods of addressing these problems that are beyond the scope of this paper.

An early example of a benefit cost analysis can be found in a 2004 cost benefit analysis of the National Map (Halsing, 2004). This report compares the state of the world with the National Map and without it (the counterfactual). It allows for the fact that uses of spatial data are likely to increase over time, in part as a function of the National Map, and accounts for variation in the ability of customers to use the National Map data. It also assesses three scenarios: two with different levels of implementation of the National Map; and the counterfactual.

Benefits were estimated as the net present value of a user's ability to improve a decision's effectiveness/efficiency with the use of spatial information or to use spatial information in a way that would not otherwise be feasible. Examples of applications included:

- Creating an emergency evacuation plan
- Designating critical habitat for an endangered species
- Conducting property tax assessments
- Researching land cover change and deforestation
- Verifying insurance claims

An average improvement in net benefit per application was calculated and a model built to estimate distribution of total values and a mean total value. The total value could be updated as information on the use of an application of the National Map evolved. This ability to do post implementation analysis is an important aspect of this work.

The study estimated that the National Map could have a net present value (NPV) of $2.045 billion dollars. Sensitivity testing was done to assess the robustness of the findings. The testing showed that net benefits remained positive in all tested scenarios and identified those scenarios that did the most damage to the NPV. Such analysis is critical for policy formulation under uncertainty.

An example of a complex benefit cost analysis can be found in the aforementioned benefit cost analysis of the use of remote sensing information from Landsat in the application of agricultural production and at the same time maintaining groundwater quality (Department of the Interior, 2012). In this study, the value of information from the satellite remote sensing (reference case) was realised through better informed decisions based on remote sensing from Landsat leading to higher net crop production without sacrificing water quality in aquifers. Data from Landsat was compared to ground based methods. In this case ground based methods represented the counterfactual.

The study found that the expected additional net present value accruing from increased production with remote sensing from Landsat was $38.1 billion. This represents the net benefit that is derived in this case from the use of Landsat remote sensing data

For most valuations in the use and application of geospatial systems the benefits arise downstream in the sectors that utilise them. This presents challenges in defining the envelope of benefits and costs so that, in addition to estimating the immediate costs and benefits associated with, say, a new geospatial data service, the analyst also must estimate the costs and benefits that arise in downstream industry sectors.

Benefit cost analysis is a fundamental tool for the development of business cases. It has many uses beyond simple assessment of benefits and costs. Sensitivity analysis can provide information to better manage downside risk as well as prioritise options.

There are two issues that require care in benefit cost analysis. The first arises in highly uncertain environments. Benefit cost analysis assumes that all costs are locked in over the full project period.

This does not allow for the possibility of adaptive management approaches to investment decisions over time.

The second is the possibility of portfolio approaches to investment. In some circumstances, optimal outcomes exist through the management of a portfolio of investment options. In such circumstances it is necessary to undertake benefit cost analysis of different portfolios of investments. There is little evident literature of such approaches in the valuation of spatial information systems.

2.6.1 Valuation of tangible benefits

Tangible benefits are those that can be quantified in some way. They can be described in terms of monetary value or physical values such as productivity levels, employment or even time saved by citizens though better use of operating systems. However for estimates of economic value it is necessary to express these benefits in monetary terms. For revenue assessments, the value will require an estimate of the market price or a suitable proxy as well as changes in quantity sold. Approaches have been developed for assessing both direct and indirect benefits.

Direct benefits

Direct benefits are the value in each year of the benefits with reference to market outcomes. Increases in outputs or reductions in costs are quantified with market prices. Market prices may need to be adjusted for subsidies, tax differences or to allow for the effects of monopoly pricing.

Many examples in the use of geospatial data present major challenges in quantification of benefits arising in user sectors. The benefits arise in terms of the value of information as a key input to decision making.

Indirect benefits - defensive expenditure or substitute cost approaches

In some cases, benefits can also be quantified in terms of as time saved, complaints reduced, clients serviced or reduction in exposure to natural hazards. While many such benefits can be difficult to price, they can often be estimated in monetary terms, using substitute costs as a proxy for value. For example the value of improved flood control could be estimated as the reduction in the expected annual average damage from future flood events.

An example of direct benefits that are realised through better use of information by users is contained in a benefit cost assessment of geological maps undertaken for the US geological survey in 2004 (Bernknopf, 2004).

The report noted that information from mapping data is important for

- better management of water quality,
- mapping of groundwater,
- managing natural hazards such as landslides or volcanic activity.

In each case, the value of the information contained in geological maps lies in reducing the probability of environmental or other damage costs through better decision making. The report used two case studies to prove the point. The first case study was concerned with decisions on the location of landfill sites. Information on permeability of soils was cited as providing regulators with more accurate information on the potential for contamination of soils around landfill sites. This would allow regulators to be more precise about areas of environmental sensitivity. The value was identified as being the reduced loss of property values as a result of more effective location of landfill sites.

The second case study addressed the use of mapping data to better locate the Washington By-Pass, a new arterial highway. Mapping data enabled better prediction of land slide potential and hence reduced the mitigation costs for slope failures. This benefit was estimated in the study and represented the benefits of the mapping information for planning highway alignment.

Another approach can be found in changes in defensive expenditure. Such an approach was used in an assessment of the value of earth observation from space in Australia undertaken in 2010 ((ACIL Tasman, 2010). In this study, the reduction in average annual damage from floods, fires, cyclones and extreme weather was estimated to be $100-335 million.

These methods assume that the cost of avoided expenditure or damage costs match the benefit. There are many academic and other studies of the cost of incidents such as fires, floods and earthquakes that can provide useful data for such studies. A problem with using estimates from established studies is that circumstances may have changed so that the average annual damage costs are no longer representative of the current or future situation.

2.6.2 Valuation of intangible benefits

The public good nature of geospatial data services means that many of the national economic benefits that accrue from their use are intangible. Intangible benefits typically include wider societal benefits, environmental benefits and increased national security. There is generally no market price for these services.

However, this does not mean that they cannot be quantified and economic techniques have been developed to do just that. The approaches tend to fall into three categories:

- stated preference testing
- revealed preference
- benefits transfer.

Stated preference

Stated preference seeks to estimate a consumer's willingness to pay for a good or a service or willingness to accept compensation to tolerate a negative or bad economic outcome. Willingness to pay surveys provide an estimate of the demand curve for a good or a service which is then used to calculate the value of consumer surplus associated with that good or service.

Shadow prices for goods or services that have no market price can be estimated by surveys to test peoples willingness to pay or alternatively to test their willingness to accept a negative outcome. Such an approach was used by ACIL Tasman in 2004 to estimate the consumer surplus associated with the Western Australian Land Information System (WALIS) (ACIL Tasman, 2004). In this case users were asked what they would be willing to pay for the services that WALIS provided. The result estimated the value to consumers to be $15 million at that time.

One of the problems with willingness to pay approaches is estimating the shape of the demand curve as discussed in Section 2.2. In addition, there is significant potential for bias in responses. There can be an incentive to overstate the price people would be willing to pay.

Revealed preference

Revealed preference seeks to estimate the value of a good or a service by estimating the trade-off that people are prepared to concede in exchange for a benefit. The most common approaches to estimating revealed preference are discussed below.

Travel cost method

This is mainly applied in recreation and tourism. The recreational value of a site is calculated from the expenditure that people would spend on reaching the site. People at different distances from the recreational site are surveyed to estimate a proxy demand curve from which consumer surplus can be estimated.

This technique can result in overestimates if the reasons for travel are multi-objective. This method is also data intensive.

Hedonic pricing

This method is used when environmental conditions influence the price of marketed goods. For example the value of river tours may be higher in more attractive parts of the river or the value of real estate may be higher in safer communities.

This method only captures willingness to pay for perceived benefits. If people are not aware of the links between amenity and location, the value will not be reflected in the price.

This method can also data intensive.

Choice Modelling

Choice modelling estimates the values based on asking people to make a trade-off between sets of intangible options such as environmental services or socio-economic outcomes.

It can also model a variety of simultaneous trade-offs that include cost attributes. It addresses some of the bias problems of contingent valuation. It is again very data intensive.

2.6.3 Benefits transfer

This method is often used in evaluating the benefits accruing to ecosystems and recreational uses. It uses existing benefits from studies already completed in comparable situations and locations to estimate benefits in the case in question.

This can be very cost effective and avoids the need for major surveys or research. However it can only be as accurate as the initial study and is only useful in similar situations.

For example, the Canadian-run Environmental Valuation Reference Inventory (EVRI) provides a comprehensive database of over 2,000 international studies. These studies provide values, methodologies, techniques and various theories on environmental valuation. EVRI facilitates worldwide development and promotion of environmental valuation by employing the benefits transfer approach. Access is free to citizens of all member countries, which include: Australia, France, New Zealand, Canada, the UK and USA[7].

2.7. Productivity and value added analysis

An alternative approach to estimating the benefits of new technologies is to estimate the economic impact on the economy in terms of the changes they deliver to value added. Value added is the core component of Gross Domestic Product (GDP) and Gross National Product (GNP)[8]. Changes in these measures can also indicate the economic impact of the use and application of new technologies.

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7 https://www.evri.ca/Global/HomeAnonymous.aspx

8 Value added by an enterprise is the difference between the value of final goods and services sold and the cost of inputs required to provide those goods and services.

Depending on the approach taken, the results can be expressed in terms of GDP, income, investment, trade or employment. There are two main approaches to estimating the economy wide effects of such value changes:

- Input output multiplier analysis
- computable general equilibrium (CGE) modelling.

These are discussed in turn below.

2.8. Input-output multiplier analysis

An input-output model is a quantitative economic technique that represents the interdependencies between different branches of a national economy or different regional economies. The modelling recognises the impact of inter industry transactions involved in the production of a specific good or service.

Input-output analysis draws on tables of interdependencies that are available in the economic accounts of most advanced nations. An input-output approach estimates how many goods and services from other sectors are needed (*inputs*) to produce each dollar of *output* for the sector in question. These tables can be used to develop multipliers that represent the total amount of a good or service that must be produced to meet a final demand of that good or service. These multipliers can then be used to estimate regional or national impacts of an increase in output from a specific sector.

Input output tables can be generated from national accounts. In some circumstances economic and research agencies produce national and even regional input output models. The US Bureau for Economic Analysis produces a Regional Input-Output Modelling System that includes regional multipliers that can be used to assess wider regional impacts of a change in one sector (Ambargis, 2011).

Input-output models provide a comprehensive picture of the inter-industry structure of regional and national economies as well as a more robust means of estimating multipliers. However the models are unconstrained and care needs to be exercised when estimating national impacts where resource transfers are involved.

Input-output analysis does not appear to have been used in estimating the economic impacts of geospatial systems.

2.9. Computable General Equilibrium (CGE) Modelling

There will always be winners and losers from shifts in technology and services – some tasks or jobs may, for example, become redundant – but the question is whether, overall, society can produce more and better outputs with the same inputs. This means that the productivity of the economy as a whole is greater.

Computable General Equilibrium (CGE) models provide the capability to model economy wide impacts of technology shifts such as the introduction of new geospatial information technologies ('what-if' or 'with-and-without' scenarios). CGE models can produce estimates of impacts on:

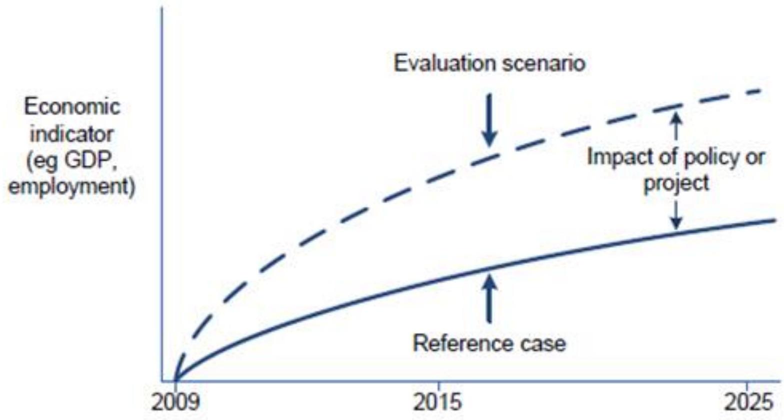
- GDP and GNP
- incomes
- trade
- consumption

- investment
- employment

The impact of improvements in productivity or revenues in specific sectors can be translated into national and regional benefits via CGE modeling. A CGE model is a representation of all markets in an economy. The model solves a suite of prices by commodity and factor in order to clear all markets (balance supply and demand). Most CGE models will be based on social accounting matrices based on national accounts. The number of sectors is typically around 60 depending on the model. These are generally aggregated to around 30 or 40 sectors to improve computational run time. A typical accounting matrix is the Global Trade Analysis Project developed at Purdue University.

Such models provide the capability to analyse the impacts of changes in the different sectors of the economy and compare the impacts of these changes for economic aggregates such as GDP, consumption, employment and investment. This is illustrated in Figure 8.

FIGURE 8 ECONOMIC INDICATORS WITH AND WITHOUT GEOSPATIAL INFORMATION SERVICES



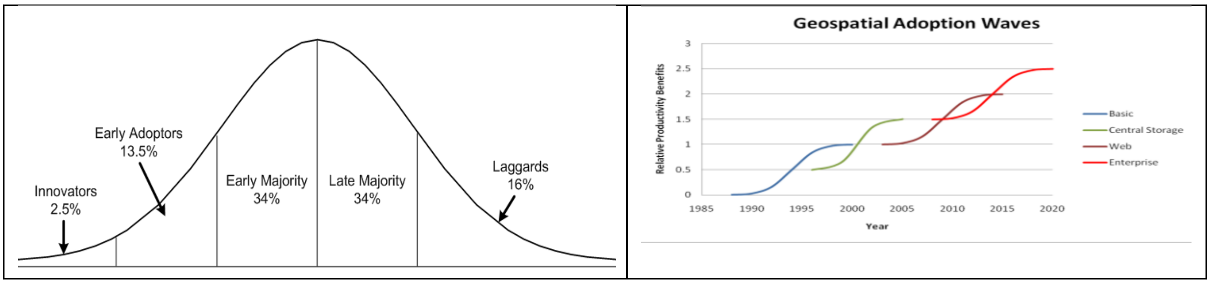
Source: ACIL Allen Consulting.

Thus it is possible to compare the accumulated impacts of geospatial services on the economic aggregates between two scenarios representing different levels of impact that access to geospatial information and services would have on sectors of the economy.

In order to produce an accurate CGE analysis, it is necessary to first estimate the likely improvement in performance of sectors of the economy that are affected by the use and application of geospatial information. This can be modelled in different ways but generally involves estimating the productivity impacts of specific applications from case studies. Productivity impacts can be improvements in productivity of capital or labour or of any input in the production function for the sector.

These case studies are then augmented with studies of levels of adoption across the sector in question. A typical adoption profile is shown in the left hand chart of Figure 9. This curve is based on work done by Rogers (2003) and illustrates the early to mid-level adoption phase followed by the late adopters (Rogers, 2003). It is necessary to assess at what stage the adoption phases are for each application. In practice geospatial systems frequently come in waves of adoption as technologies merge. An example of adoption waves is shown in the right hand diagram based on work undertaken in England and Wales for local government (Consultingwhere and ACIL Tasman, 2010)

FIGURE 9 ADOPTION CURVES



Source: (Rogers, 2003), (Consultingwhere and ACIL Tasman, 2010)

Estimates of the productivity impacts for an application and the level of adoption are combined to provide productivity shocks for a sector. An example of a table of productivity shocks for the use of geospatial systems in New Zealand is provided at Attachment B. This data is then entered into the CGE model which produces a new equilibrium showing the impacts on macro-economic aggregates such as GDP, Consumption, Trade, Investment and Employment. An example of results for Australia in 2008 are shown in Table 1.

TABLE 1 ECONOMIC IMPACTS OF TWO SCENARIOS FOR AUSTRALIA (2008)

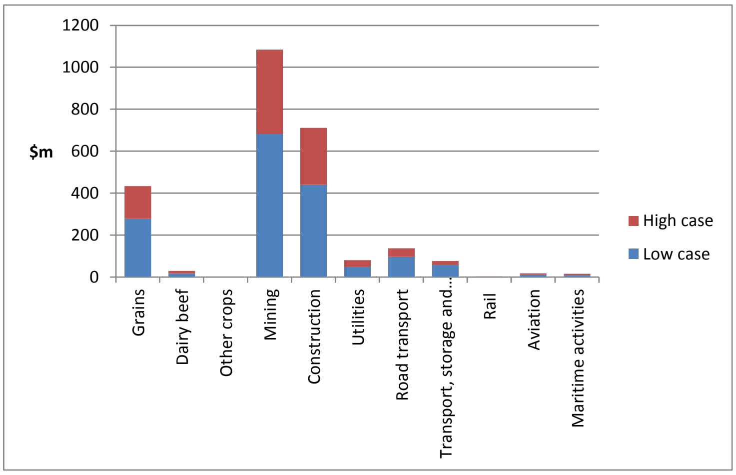
	Scenario 1				Scenario 2			
	Productivity only		Productivity plus resources		Productivity only		Productivity plus resources	
	Per cent	A$ billion	Per cent	A$ billion	Per cent	A$ billion	Per cent	A$ billion
GDP	0.51	5.31	0.61	6.43	0.99	10.31	1.20	12.57
Household consumption	0.50	2.89	0.61	3.57	0.93	5.39	1.16	6.78
Investment	0.51	1.43	0.61	1.73	0.98	2.78	1.20	3.39
Capital stock	0.56	-	0.72	-	1.05	-	1.38	-
Exports	0.45	0.98	0.58	1.26	0.80	1.73	1.07	2.30
Imports	0.39	0.89	0.52	1.18	0.72	1.64	1.98	2.23
Wages	0.50	-	0.60	-	0.92	-	1.12	-

Source: (ACIL Tasman, 2008)

This study estimated that the value of spatial information across the Australian economy ranged from $6.43 billion to $12.57 billion. The first estimate was based on observed applications that could be quantified in case studies and the second based on examples that had been provided but were estimated on the basis of evidence.

Results can also be reported by sector as shown from a study on the value of precise GNSS positioning technologies.

FIGURE 10 EXAMPLE OF OUTPUT CHANGE BY SECTOR FROM CGE MODELLING – USE OF PRECISE POSITIONING IN AUSTRALIA (2012)



Source: (ACIL Tasman, 2012)

CGE analysis has been applied in Australia, New Zealand, England and Wales and is currently being applied in Canada.

Its strength is its ability to manage resource shifts in the economy, while overcoming the lack of resource constraints in multiplier analysis. However the result is only as robust as the comprehensiveness of the case studies that have been undertaken for the work. It requires extensive case studies to build credible results (Ordnance Survey, 2013).

2.10. Value chain analysis

Assessing the impact of disruptive technologies such as potentially the case with most geospatial services, introduces the possibility of further efficiency gains arising from fundamental changes in value chains and clusters of supporting industries. The latter have been identified by many analysts as being the source of fundamental improvements in international competitiveness (Porter, 1998)

While this phenomenon (sometimes referred to as X factor productivity by economists) is quite difficult to quantify or model, its effects can be understood though value chain analysis.

The purpose of value chain analysis is to break down the business processes in a particular market to provide greater insight into where the opportunities can be found for adding value and thereby generating growth in the economy.

Figure 11 shows a simplified value chain derived from property data. One of the major effects of providing better foundation property data is disintermediation. While in the past consumers obtained mapping and other data through traditional sources, particularly lawyers or planning consultants, consumers will be able to obtain property data directly from the source as improved foundation property data is provided by Government.

FIGURE 11 EXAMPLE OF A VALUE CHAIN WITH REFERENCE TO PROPERTY DATA

Source: Based on past work by ACIL Allen.

This is creating the potential for a new range of activities that both improve the efficiency of the value chain and create new, more efficient service providers. These new, more efficient industries provide inputs to other economic activities as well. The overall effect is to achieve a significant step change in the efficiency of economic activities that rely on these clusters of supporting industries.

Such analyses can, in some cases, reveal new insights into productivity and employment impacts. In doing so, it is also important to take into account the decline of existing, less efficient support industry activities. Providing this is done, value chain analysis can assist in assessing the wider impacts of new services such as geospatial information.

2.11. Real Options

An important issue for assessing the value of investment in geospatial information is the fact that it will almost certainly yield access to growing volumes of information where only some of its potential applications and value can currently be scripted. Like many R&D investments, investments in geospatial information can be expected to lead to growing time series of data whose future value is necessarily highly speculative. These time series will embed options for future applications, including in ways not currently envisaged[9]. It would seem reasonable and appropriate to recognise that these options – as 'cream on top' of the immediately planned applications of the observation data add value. Failure to recognise this could be expected to imply systematic bias towards undervaluing the investments – and could well result in underinvestment.

This approach – of recognising 'option value' on top of planned use value – is worth considering if there is to be appropriate balance in planning whether to invest, and the level and form of investment in these systems. It may not be necessary to attempt any precision in quantifying the option value, but recognition of the existence of this extra value, and some characterisation of whether and how it could prove important over time, would seem critical to a sound approach to planning and justifying forward investment strategy.

A further characteristic of the emerging use of geospatial information systems is the impact of exogenous technological change on its use. These external changes are difficult to predict but history has shown that they can find future valuable uses as other technologies emerge. One example of the

[9] The potential value of data that might not be immediately recognised is discussed in Houghton's paper also issued at this Workshop (Houghton, 2011)

use of geospatial systems has been the development of autonomous mining vehicles and robotic mining which has emerged through the convergence of GIS, vehicle control systems and precise GNSS.

Real options thinking can help in deciding whether or not there is value in preserving an option for the use of data at a later date. It can also help with decisions of how long to preserve the option and when the cost of preserving that option should be curtailed.

There is no evidence in the literature of real options approaches to valuing geospatial information. However it has been used in Australia for valuing investments in R&D including the Square Kilometre Array telescope in Western Australia and in research into geoscience and marine science in Australia.

3. Issues

3.3. The audience?

There is a general need in most OECD countries to provide meaningful estimates of the value of geospatial data services to support decision making by government. This has become critical as governments consider the introduction of open data policies with pricing at marginal cost. While economists have long argued that this maximises economic welfare, it also creates a funding requirement for the responsible government agencies as their average costs will no longer be recovered from sales.

Governments are also faced with decisions on future investments including in spatial data and infrastructure, data aggregation and maintenance as well as in large investments in things like earth observation satellites.

Developing the case for such investments will require robust methodologies for estimating net benefits of government funding decisions.

Recent experience in Australia has outlined several key messages:

- agencies investing in spatial data or spatial data infrastructure are facing a defensive fiscal environment. This has created the need for agencies to identify very specific returns to both government and/or specific industry sectors to support the case for further investment.
- Some of the more generalised assessments of grossed up revenue and consumer benefits are viewed with scepticism. The main problem seems to be in lack of a clear “line of sight” between proposed investments in geospatial data or infrastructure and tangible socio-economic benefits.

Anecdotal evidence suggests that this is a relatively common view in many OECD countries.

This is not to say that estimates of economy wide net benefits are not important. The message is that the methodologies used to assess socio-economic values should be matched to the specific needs of the audience.

A tight fiscal climate is likely to mean that the priority for government decision makers will be firmly on quantifiable “use” values in the diagram supplied in Figure 1 above. General estimates of wider economic benefits are not going to be sufficient on their own to support future business cases to Governments.

Macaulay (2005) also notes that the need for evidence of the value of spatial information varies depending on the cost of wrong decisions and the range of actions available to act on the information services that are being evaluated (Macauley, 2005). Requirements for valuation methodology will also vary according the costs involved and the significance of the technologies under consideration to economic and social outcomes.

There is potentially a wide audience for socio economic benefit assessments. The principal party however will be government. This is likely include data custodians as well as agencies responsible for natural and mineral resources, environment, agriculture, health, transport, planning, infrastructure and national security. Over time this could also extend to other areas such as finance and economic policy, as the use and application of geospatial systems penetrates wider sectors of the economy.

Industry is another audience for valuation studies. From time to time Industries need to explain the importance of the geospatial industry for advocacy purposes as well as for developing business cases for investment decisions.

Non-government organisations (NGOs) are another but less likely audience for such studies.

3.4. Methodologies and decision support

From discussions with policy makers in Australia it is evident that whatever methodology is applied, it is important that linkages between the use and application of geospatial data services and the benefits described are clearly articulated. Policy makers are looking for the “line of sight” between investment and benefit.

Cost effectiveness analysis and benefit cost analysis is appropriate to support specific policy proposals or investment decisions. Quantifiable results (both cost effectiveness and benefit cost) are highly desirable in these circumstances. These may be reinforced with qualitative assessment of intangible benefits. However intangible benefits on their own are likely to be less compelling in the current fiscal environment.

Where wider economic benefits are important, productivity analysis using either multiplier analysis or CGE modelling is more appropriate. The latter deals with resource constraints and resource shifts more effectively than the former and is likely to be more credible to decision makers providing the data can be obtained to support estimates of the direct sectoral productivity effects.

A possible matching of decision support and possible methodologies along these lines is provided in Table 2. This table is put forward for consideration and discussion.

TABLE 2 AUDIENCE AND METHODOLOGIES

Audience	Decision support	Possible methodologies
Data custodians	To meet known standards To set standards	Cost effectiveness analysis Specifically targeted BCAs
Government agencies responsible for aggregation and maintenance of spatial data and infrastructure	To meet known regulatory and policy requirements To decide on additions to data sets or assess policy changes For broad policy decisions on industry policy	Cost effectiveness analysis Cost effectiveness analysis within government BCAs of specific down-stream industries Consideration of option values Value added analysis including CGE modelling with economic and employment outcomes reported
Government policy and line agencies (resources, planning, environment etc)	For specific regulatory requirements For broader policy decisions	Cost effectiveness analysis Willingness to pay analysis Ecological value analysis. Value added and CGE analysis Value chain analysis for more competiveness and industry development
Private sector	For investment decisions For broader policy advocacy	BCA analysis on specific sectors Value added analysis and CGE analysis Value chain analysis Option value analysis
NGOs	Social and environmental issues	Targeted BCA analysis possibly with focus ecological and societal benefits.

3.5. Summary comments on methods

3.5.1 Cost effectiveness analysis verses benefit cost analysis

Cost effectiveness analysis is likely to be more powerful where the valuation question involves how to best meet a defined regulatory standard or deliver a defined level of service provision. In such cases the objective function is clearly defined in legislation or regulation and the question is how best to meet the regulatory objective.

However if the investment is aimed at changing regulatory standards or levels of service provision, benefit cost analysis is warranted. The benefits of increased standards or services will need to be taken into account in order that a true picture of the net benefits of different options are considered.

In such cases, it is also likely that it will be necessary to quantify both tangible and intangible benefits. Whatever the nature of the benefit, it will be important to be specific about the nature of the benefits and who benefits from the higher standards.

3.5.2 Derived benefits

Derived benefits are those that accrue to users of geospatial data, usually from use of value added services. From an economic viewpoint, the value in derived benefits will be found in direct use values where financial and employment estimates can be clearly identified. These can be estimated from case studies of productivity impacts and adoption estimates. The economic model may be a simple benefit cost analysis, or a more comprehensive value added approach such as CGE modelling. The latter can provide sector by sector outputs as well as the impact on national economic aggregates.

Intangible benefits may be estimated from stated preference or revealed preference techniques. It would be desirable to assign a monetary value to these benefits if possible. However if this is not possible, specific quantitative benefits such as improvements in water quality or preservation of areas of high environmental value should be clearly identified.

3.5.3 Economy wide benefits

Economy wide benefits are best drawn from value added approaches such as CGE modelling. However, this requires good evidence of productivity impacts and levels of adoption across sectors to provide robust results. Presentation of the results in terms of impacts on macroeconomic aggregates such as GDP, income, investment and employment is desirable.

It would also be highly desirable to identify sectoral impacts and, where necessary, regional impacts to provide a full value picture for the decision maker.

3.5.4 Competitiveness benefits

Maintaining international competitiveness is an important policy objective for most developed economies. Geospatial information is an important enabler of competitiveness both in terms of the productivity effects that accrue from its use by other industries, and in terms of its impacts on related and supporting industries. The latter are important drivers of international competitiveness (Porter, 1998).

Value chain analysis may be a useful adjunct to benefit cost analysis or CGE modelling if international competitiveness is an important factor in the decision makers mind. While it can be very time intensive, identifying the capacity of related and supporting industries can provide insights into the more dynamic aspects of industry development arising out of the use of value added geospatial information services.

3.5.5 Options value in spatial information

The options value in spatial information should not be ignored. The high probability of exogenous technological change, disruptive technologies and innovation by downstream users, suggests that spatial data may have an option value that is not fully apparent at the time of assessment. Real options thinking can provide insights into how to take such potential values into account.

This does not necessarily mean adding additional value to the more traditional benefit cost or other approaches. Rather it means ensuring that potentially valuable options are not extinguished before judgements can be made on whether those potential opportunities might be realised. It has the potential to provide decision support for adaptive management of investment in the provision of spatial information over time.

3.6. Summary comments on methods

While welfare analysis has a strong basis in neo classical economics, the assumptions that lie behind it are not robust in the real world. Turning economic theory into results based on empirical evidence requires careful structuring of assumptions about the reference case and the counterfactual.

Estimating the demand curve from a limited number of price-quantity pairs is only valid for small changes in price assumptions. Traditional welfare analysis is useful for assessing the impact of price changes for specified product groups. For more complex decisions other approaches are more appropriate.

For specific assessment of investment proposals or policy change, benefit cost analysis is likely to be the most useful, provided there are no significant resource shifts in the economy. Where major resource shifts are possible, more comprehensive analysis such as CGE modelling is warranted - provided that the case studies and data can be found to provide inputs to the models.

Evaluation of intangible benefits is always likely to be subject to some scepticism. Willingness to pay surveys are effective but costly and may not be warranted for decisions involving smaller investments. However if willingness to pay surveys are undertaken, considerable attention needs to be given to eliminating bias from surveys to preserve credibility of the results.

Finally consideration might be given to options values and a portfolio approach to investment in geospatial data services. Portfolio approaches still require benefit estimate techniques. However a portfolio approach can potentially deliver a more optimal investment path over time than considering related geospatial projects in isolation.

4. Comments, conclusions and questions for consideration

The purpose of this paper has been describe approaches to socioeconomic valuation as applied to geospatial data and services and to provide ideas on how application might be improved and targeted in order to address the questions that policy makers and users are asking.

This discussion occurs at a time when production and accessibility of geospatial information is growing while at the same time we are experiencing rapid technological change and growth in user participation. Technology advances have changed the way that geospatial data is produced and accessed. This is delivering more efficient processes and greater accessibility. Improved technology is also creating opportunities for greater participation by users in the gathering and interpretation of data through crowdsourcing and other forms of user participation.

This presents challenges for those involved in estimating socioeconomic value in support of better and more informed policy and decision making. The following observations and conclusions are submitted to promote discussion of valuation methods.

4.1. Valuation methodologies that address the needs of the audience

It is considered critical that the methodologies adopted are tailored to the needs of the policy makers and users alike. This means that for many decisions made by government agencies, specific benefits must be identified and quantified where possible.

Regardless of whether the evaluation is sector specific or economy wide, policy makers need to see a direct “line of sight” between the geospatial data service being assessed and the benefits delivered.

4.2. More evidence based economics

Traditional welfare analysis as described in Section 2.1 is deductive. It start with a neoclassical economic model and estimate parameters that can be fed into the valuation model. However the equilibrium and market assumptions underlying neoclassical economics are not always met in the rapidly changing world of spatial information technologies.

It is worth considering an inductive model. That is one that builds the analysis from the bottom up using case studies to assemble evidence of productivity changes and levels of adoption. Such an approach is highly workable for cost effectiveness studies, benefit cost analyses and value added analyses such as CGE modelling.

There may be value in further integration of physical modelling and economic modelling to better capture the value created through the use of spatial information.

4.3. Dealing with the rapid evolution in the use and application of geospatial data

Data from earth observations and other contemporary geospatial services, are providing new ways of addressing policy questions in areas such as management of natural resources, the environment and natural disasters. With far more spatiotemporal data becoming available, such policy decisions will be able to be made with greater certainty.

Exogenous technological developments also offer the prospect of new and innovative applications of geospatial data. Such developments are likely to new ways of creating value both in policy decision making and in commercial applications.

Valuing as yet untested possibilities requires a sound framework. Thought might be given to incorporating options value thinking in such circumstances. Options frameworks can provide additional insights into valuing new applications. They can also be useful in supporting adaptive management approaches to investment in data services.

4.4. Building business case capability

Many organisations today are faced with making complex decisions on the creation and maintenance of foundation spatial data and the supporting infrastructure. These organisations range from local government to departments of state and other national agencies of government. Building better business cases is important but many smaller organisations do not have the resources or capacity to undertake major benefit cost analysis.

Establishing a repository of case studies and examples may be one way of lowering the costs developing business cases for smaller organisations. A working group has commenced the assembly of such a data base. The question arises as to whether this should be enhanced by establishing an international library of case studies to inform future evaluations. An example of such a repository is mentioned in the Canadian-run Environmental Valuation Reference Inventory discussed in Section 2.6.3.

The role of research should not be overlooked in this discussion. There may be a case for examining funding priorities for research into evaluation techniques and in their application to policy formulation and investment in acquisition and sharing of open geospatial data.

4.5. Developing internationally recognised methodologies

The case for reaching international consensus (and standardised methodologies) on the use and application of valuation methodologies should be considered. Many organisations face the same set of questions on the value of spatial data, including the value of open data. Technology and uses are evolving rapidly and there is a lot to be learned from the experience of others. Is it worth capturing this evolving experience to lower the cost of future evaluations?

Again the question arises as to the role of research in developing and refining methodologies. Consideration might also be given to how well research into this area is coordinated and whether there is a case for fostering a community of experts to progress valuation techniques.

Attachment A Past studies

TABLE 3 PAST STUDIES

Organisation/Author	Date	Topic	Approach	Findings
Larisa, Serbina and Miller	2014	Landsat and Water - case studies of the uses and benefits of Landsat Imagery in Water Resources	Case studies identifying mainly qualitative benefits from improved water and land management and reductions in average damage costs from flood mitigation	Qualitative benefits
Friedl et al	2013	Applications of earth observation to fisheries management, Poster and paper the fall meeting of the American Geophysical Union	Estimated savings from 17 per cent reduction in stock size uncertainty	NPV of $25.4 million across three fish categories.
NASA	2013	Measuring the Socio-economic impacts of earth observations	A primer providing guidance on case study analysis, cost benefit analysis and use and non-use values.	Guide to analysis
Oxera Consulting Ltd for Google	2013	What is the economic impact of GEO Services	Revenue estimates, Gross value added, consumer impacts	GEO Global Services revenues around $150 -270 billion per year. Gross value added of $133 billion globally Consumer benefits of around $34 billion in fuel savings and education Welfare effects totalling around $45 billion globally
Forney, Rauniker, Bernknopf	2012	An economic value of remote sensing information	Traditional benefits from improvements in agricultural production from improved water management	Increased production from the use of Landsat imagery was estimated to be $38.1 billion.
Space tec partners for OECD	2012	Assessing the economic value of Copernicus	A market study of the impact on downstream markets using multiplier analysis and coefficients of employment.	Market study
OECD	2012	OECD handbook for measuring the space economy	Provides a review of the nature of the benefits both direct and indirect, local and regional and new markets	Guide for analysis
USGS	2011	What is the economic value of satellite imagery	Traditional benefits from improvements in agricultural production from improved land and water management	Estimated that a 1 per cent improvement in public sector efficiency would lead to a €25 billion benefit in terms of direct value added. Tentative conclusion that improved address data could have added 0.5 per cent to European GDP or around €63 million.
Miller, Sexton, Koonitz	2011	The uses, uses and value of Landsat and other moderate resolution satellite imagery	Traditional benefits from improvements in agricultural production	
Borzacchiello, M, Craglia M	2011	Socio Economic Benefits from the use of Earth Observation	Reviews different approaches to benefit assessment including willingness to pay for imagery, reductions in average annual damage costs, measurement of transactions costs and CGE modelling.	Review of approaches
Houghton, J	2011	Costs and Benefits of Data Provision	Welfare analysis approach extended to include agency and user cost savings	Increase in consumer surplus associated with introduction of free access to spatial data from Geoscience Australia on the internet in 2001 estimated to be $60 million over four years.

ACIL Tasman	2010	The value of earth observation from space	Used case studies to assess economy wide economic impacts both tangible and intangible	Value estimated to be $3.3 billion in 2008-09
ACIL Tasman	2010	The value of spatial information in New Zealand	Used case studies and CGE modelling to estimate the value of geospatial information in the New Zealand Economy.	Value estimated to be $1.2 billion in 2010 and $1.6 billion with barriers removed.
ANZLIC/PWC)	2010	Economic assessment of spatial information pricing and access	Welfare analysis of selected topographic and aerial photography data sets.	The value of moving from average cost to marginal cost was $3.3 million for Victorian topographic data, $1.4 million for Western Australian topographic data (Landgate), $1 million for Western Australian aerial photography (Landgate) and $4.7 million for national topographic data(Geoscience Australia)
Oxford Economics	2009	The case for space – the impact of space derived services and data	Examines direct and indirect impacts, induced impacts and wider benefits from catalytic effects.	
ConsultingWhere and ACILTasman	2009	The value of geospatial information used in Local Government in England and Wales	Used case studies and CGE modelling to estimate the value of geospatial information used by local government in England and Wales.	Value estimated to be £230 *million in* 2010
Lievin Quoidbach, Michael Nicholson and Christian Fisher (EURADIN, 15 May 2009)	2009	Euradin - Social and economic benefits of better addressing	Used a high level survey of users to estimate benefits to different sectors and extrapolated across the EU countries	Estimated that a 1 per cent improvement in public sector efficiency would lead to a €25 billion benefit in terms of direct value added. Tentative conclusion that improved address data could have added 0.5 per cent to European GDP or around €63 million.
ACIL Tasman	2008	The value of spatial information	Used case studies and CGE modelling to estimate the value of spatial information to the Australian economy in 2008	Value estimated to range between $6 billion and $12 billion in 2008. Around 0.6 per cent to 1 per cent of GDP Estimated that reducing barriers could result in values around 7 per cent higher
Pollock et al Cambridge University	2008	Models of public sector information provision via trading funds	Welfare analysis of Ordnance Survey Geospatial data	The value of moving from average cost pricing to marginal cost pricing was estimated to be £168 million while the net cost to government would be around £12 million – a net benefit to society of £156 million
Bernknopf R, Wein A, St Onge, N and Lucas,S	2007	Analysis of improved government geological map information in Canada	Uses a constrained optimisation model to estimate benefits under different scenarios of old and updated maps	On southern Baffin Island, the economic value of the updated map ranges from CAN$2.28million to CAN$15.21million, which can be compared to the CAN$1.86 million that it cost to produce the map (a multiplier effect of up to eight).
Halsing, Theissen and Bernknopf	2004	Cost benefit analysis of the National Map	Benefits estimated as the present value of a user's ability to improve decision making.	NPV of $2 billion
McCauley, M	2004	The value of information,	A background paper on measuring the value of space derived earth science data to natural resource management	Background paper
Halsing	2004	Economic value of the National Map	Benefits estimated as the Net Present Value of users' ability to improve decision making effectiveness	NPV of $2 billion estimated.
Oxera Consulting Ltd	1999	The economic contribution of Ordnance Survey GB	Gross value added analysis along the supply chain	Gross value added along the supply chain estimated to be between £79 billion to £136 billion or 12 to 20 per cent of GDP

Attachment B: Example of sector inputs to a CGE model

TABLE 4 DIRECT IMPACT OF SPATIAL INFORMATION ON PRODUCTIVITY AND RESOURCE AVAILABILITY AUSTRALIA (2008)

	Type of shock applied	Quantifiable scenario	Estimated scenario
Productivity shocks			
Grains (specialist growers)	Total productivity	0.93%	1.08%
Mixed (grain & sheep/cattle)	Total productivity	1.35%	1.50%
Sugar cane	Total productivity	0.11%	0.26%
Cotton	Total productivity	0.07%	0.22%
Other agriculture	Total productivity	0.00%	0.15%
Forestry	Labour productivity	1.93%	1.93%
Fisheries	Total factor productivity	4.00%	5.14%
Construction	Total productivity	0.25%	0.50%
Business services	Labour productivity	0.50%	0.70%
Coal	Total factor productivity	0.21%	0.36%
Metal ores	Total factor productivity	0.16%	0.31%
Oil & Gas	Total factor productivity	0.15%	0.27%
Government	Labour productivity	0.34%	1.05%
Road Transport	Total productivity	1.40%	1.58%
Rail Transport	Total productivity	0.00%	0.45%
Air Transport	Total productivity	0.84%	1.04%
Other transport	Total productivity	0.00%	0.30%
Electricity/gas/water	Total productivity	0.73%	1.25%
Communications	Total productivity	0.98%	1.32%
Trade	Total productivity	0.00%	0.08%
Manufacturing	Total productivity	0.00%	0.02%
Other	Total productivity	0.00%	0.02%
Resource availability shocks			
Oil	Resource availability	3%	6%
Gas	Resource availability	5%	10%
Minerals nec	Resource availability	7%	14%
Coal	Resource availability	0.93%	1.08%

Data source: (ACIL Tasman, 2008)

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