ACIL ALLEN CONSULTING

REPORT TO
TIMOR GAP, E.P.

3 JUNE 2017

ECONOMIC IMPACT OF GREATER SUNRISE:

IMPACTS OF THE DEVELOPMENT AND OPERATION OF THE GREATER SUNRISE GAS FIELD TO THE TIMOR-LESTE ECONOMY

ACIL ALLEN CONSULTING PTY LTD
ABN 68 102 652 148

LEVEL NINE
60 COLLINS STREET
MELBOURNE VIC 3000
AUSTRALIA
T+61 3 8650 6000
F+61 3 9654 6363

LEVEL ONE
50 PITT STREET
SYDNEY NSW 2000
AUSTRALIA
T+61 2 8272 5100
F+61 2 9247 2455

LEVEL FIFTEEN
127 CREEK STREET
BRISBANE QLD 4000
AUSTRALIA
T+61 7 3009 8700
F+61 7 3009 8799

LEVEL ONE
15 LONDON CIRCUIT
CANBERRA ACT 2600
AUSTRALIA
T+61 2 6103 8200
F+61 2 6103 8233

LEVEL TWELVE, BGC CENTRE
28 THE ESPLANADE
PERTH WA 6000
AUSTRALIA
T+61 8 9449 9600
F+61 8 9322 3955

P.O. BOX 546
HOBART TAS 7001
AUSTRALIA
T+61 3 8650 6000
F+61 3 9654 6363

161 WAKEFIELD STREET
ADELAIDE SA 5000
AUSTRALIA
T +61 8 8122 4965

ACILALLEN.COM.AU

SUGGESTED CITATION FOR THIS REPORT

ACIL ALLEN CONSULTING (2017), ECONOMIC IMPACT OF GREATER SUNRISE: IMPACTS OF THE DEVELOPMENT AND OPERATION OF THE GREATER SUNRISE GAS FIELDS TO THE TIMOR-LESTE ECONOMY, MAY 2017.

FOR INFORMATION ON THIS REPORT PLEASE CONTACT:

GUY JAKEMAN

C O N T E N T S

INTRODUCTION 1

ACIL Allen Consulting (ACIL Allen) has been commissioned by TIMOR GAP, E.P. to estimate the economic benefit that the development and operations of the Greater Sunrise Field could provide to the Timor-Leste economy under alternative scenarios.

The Greater Sunrise fields comprise the Sunrise and Troubadour gas and condensate fields. They are located approximately 150 kilometres south-east of Timor-Leste and 450 kilometres north-west of Darwin, Northern Territory.

Production from the field is pending the delimitation of the maritime boundary between Timor-leste and Australia, although the field is currently under two Production sharing contracts issued under the Timor Sea Treaty and 2 Retention Leases issued by Australian Authorities.

In undertaking this analysis, ACIL Allen has relied on a range of detailed analysis of the project economics undertaken by TIMOR GAP, E.P.

1.1 Cases

Two Cases have been modelled in this analysis reflecting different equity shares and alternative locations of downstream infrastructure:

— Case 1: 100 per cent of the Greater Sunrise field is deemed to be owned and controlled by the Timor-Leste Government with the LNG facility located on-shore in Timor-Leste.

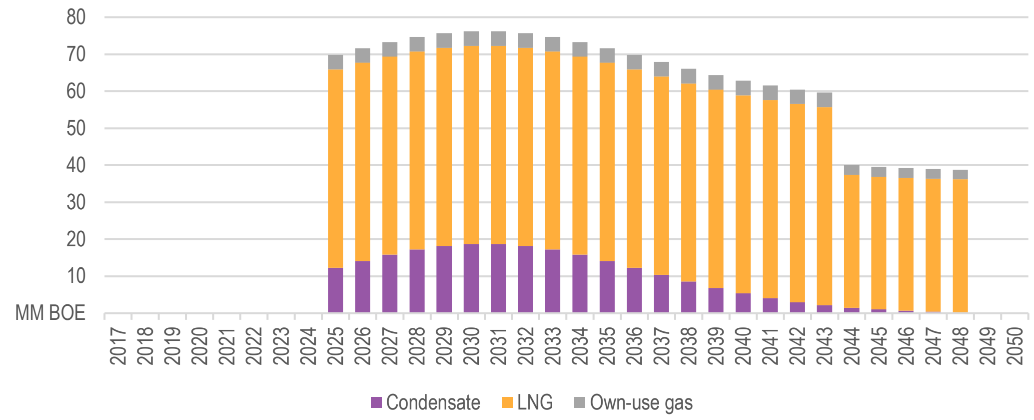
— Case 2: The Two Government agreed to split the revenue both upstream and downstream in 50:50 Split with the LNG facility located on-shore in Australia (backfilling the Darwin LNG facility).

DIRECT IMPACTS 2

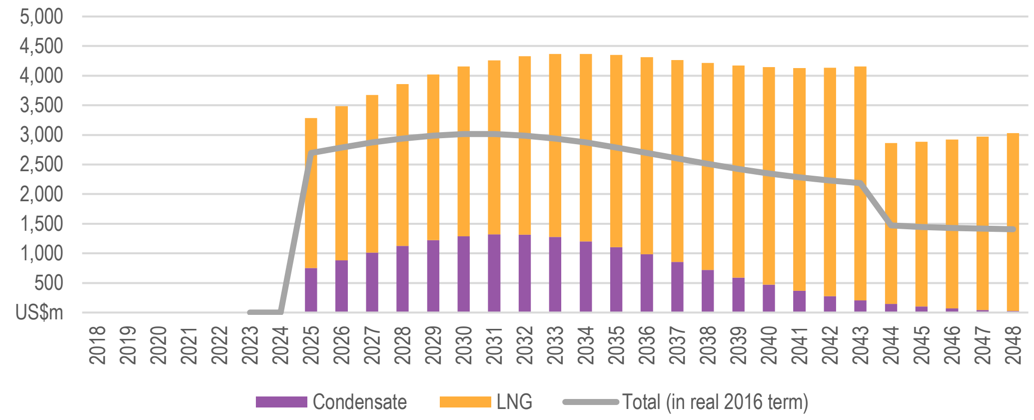
Total forecast revenues from the development of the Greater Sunrise field (including downstream LNG production) are estimated to be US$92.4 billion (US$58.4 billion in real 2016 terms). This is based on an assumed real condensate price of US$50/bbl and a real LNG price of US$7.0/MMbtu (and annual CPI of 2.5 per cent). In total, over the life of the project 237 MM BOE of condensate and 1,285 MM BOE of natural gas is expected to be produced. Annual production and revenues from the different product streams are presented in **Figure 2.1**.

FIGURE 2.1 PROJECTED PRODUCTION AND REVENUES BY PROJECT ELEMENT (BOTH CASES)

A. Production



B. Nominal and real revenues



SOURCE: TIMOR GAP, E.P. AND ACIL ALLEN CONSULTING

While total production and revenues are projected to be the same under both cases, there are significant differences in the Timorese local content as well as the gross returns to Timor-Leste.

In particular, over the period **2020** to **2048,** under **Case 1**:

— Total capital expenditure over the forecast period is US$11 billion with Timor-Leste's share of total capital expenditure estimated to be US$1.1 billion (approximately 10 per cent).

— Total operating expenditures over the forecast period is US$11.4 billion with Timor-Leste's share of total capital expenditure estimated to be US$6.8 billion (approximately 60 per cent).

— Net cash flow by the Timor-Leste Government (and through TIMOR GAP, E.P.) is projected to be US$49.2 billion (US$29.7 billion in real 2016 terms).

— Approximately 38,000 FTE direct jobs for Timor-Leste residents are estimated to be created.

Under **Case 2**, over the period **2020** to **2048:**

— Timor-Leste's share of total capital expenditure is estimated to be US$765 million (with the difference compared to Case 1 due to the LNG facility being located in Australia).

— Timor-Leste's share of total operating expenditures is estimated to be US$2.5 billion.

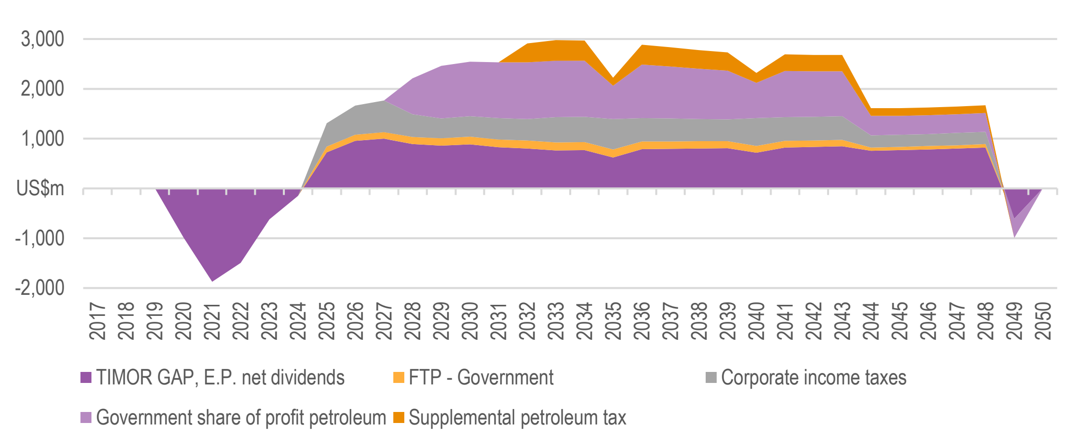
— Net cash flow by the Timor-Leste Government (or through TIMOR GAP, E.P.) is projected to be US$28.7 billion (US$15.9 billion in real 2016 terms). In line with the lower equity ownership, net outflows of cash during the initial construction period are lower compared to Case 1 but net inflows from the project during the operations phase are also lower.

— Approximately 16,400 FTE direct jobs for Timor-Leste residents are estimated to be created. This is less than half of those estimated under Case 1, and is principally due to the LNG facility being located in Australia rather than Timor-Leste, thereby giving negligible opportunities for Timorese citizens to be employed in downstream construction or operations.

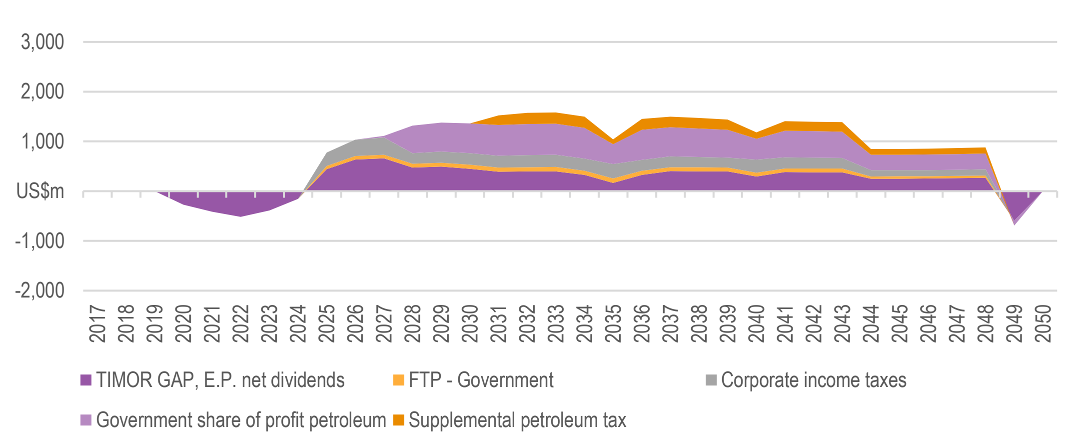
Figure 2.2 presents the projected revenue components that accrue to the Timor-Leste Government under both cases, including the net dividends payable to TIMOR GAP, E.P. Under Case 1, US$35.5 billion is accrued through taxes and royalties over the life of the project with a further US$13.7 billion accrued through TIMOR GAP, E.P. (total equals US$49.2 billion). Under Case 2, the Timor-Leste Government is projected to accrue US$22.0 billion through taxes and royalties with a further US$6.7 billion accrued through TIMOR GAP, E.P. (total equals US$28.7 billion).

FIGURE 2.2 TIMOR-LESTE GOVERNMENT REVENUES COMPONENTS (NOMINAL TERMS)

A. Timor-Leste revenue sources – Case 1



B. Timor-Leste revenue sources – Case 2



Note: FTP = first tranche petroleum

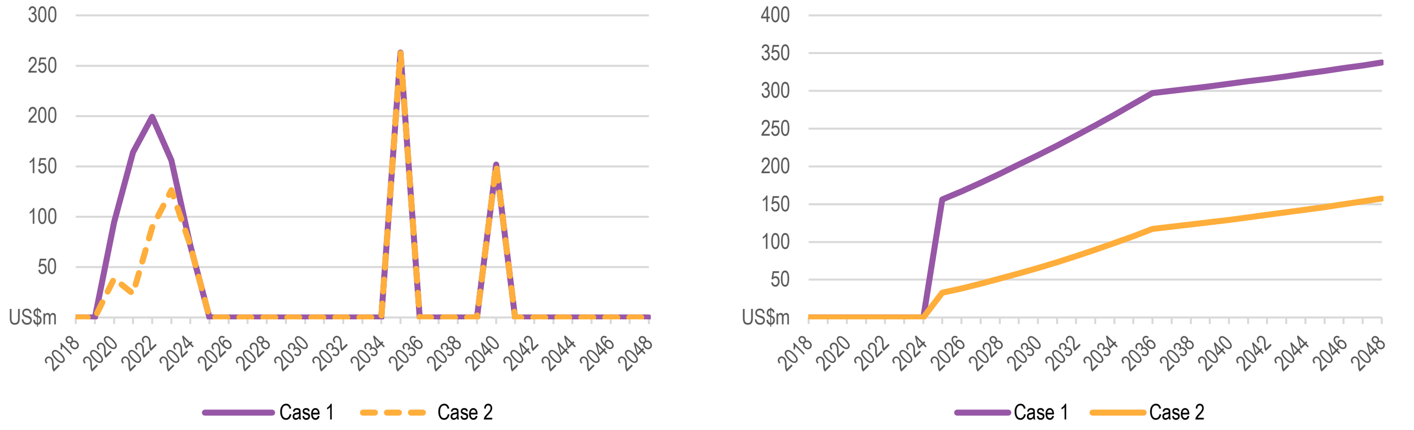
SOURCE: TIMOR GAP, E.P. AND ACIL ALLEN CONSULTING

Figure 2.3 presents the projected year on year local Timor-Leste content under both cases while **Figure 2.4** presents the annual direct employment and net cash flow for Timor-Leste.

FIGURE 2.3 TIMOR-LESTE CONTENT OF CAPITAL AND OPERATING EXPENDITURES UNDER EACH CASE

A. Capital expenditure (local Timor-Leste content)

B. Operating expenditure (local Timor-Leste content)



SOURCE: TIMOR GAP, E.P. AND ACIL ALLEN CONSULTING

FIGURE 2.4 DIRECT EMPLOYMENT OF TIMOR-LESTE RESIDENTS AND NET TIMOR-LESTE CASH FLOWS UNDER EACH CASE

A. Direct employment of Timor-Leste citizens

B. Net Timor-Leste cash flows

Note: FTE = full-time equivalent. Net cash flows include any expenditure or investment undertaken by TIMOR GAP, E.P.

SOURCE: TIMOR GAP, E.P. AND ACIL ALLEN CONSULTING

MODELLING METHODOLOGY 3

3.1 Estimating indirect impacts

Large, complex resource and infrastructure projects such as the development of the Greater Sunrise field can be expected to have indirect economic impacts that are felt throughout the host economy. These economic impacts arise because the various sectors of the economy are interrelated: that is, the output of one economic sector provides inputs to other economic sectors. These interrelationships can be represented in what are referred to as “input-output tables”. The inputs of labour and capital required to undertake a major infrastructure project will tend to draw resources away from some sectors of the economy, while providing growth opportunities for other supporting sectors. Hence it is usual to find that some economic sectors benefit from the development while other economic sectors may experience adverse changes.

The macroeconomic impacts of a policy, project or other activity can be estimated using a variety of economic analysis tools. The most common methods utilised are input-output (I-O) multiplier analysis and computable general equilibrium (CGE) modelling. The selection of the right tool is critical to the accuracy of the estimated impacts and depends upon the characteristics of the project/industry. Sometimes more than one tool may be required to provide a full picture of economic consequences.

By their nature, I-O multipliers and CGE models focus on “market impacts” across the economy (that is, impacts on activities with observed market prices). Analysis of various “non-market impacts”, such as property right infringements, potential loss of biodiversity, changes in air quality or greenhouse gas emissions, social justice implications and so forth may also be relevant in assessing the full implications of a project or policy, but are not captured within I-O multipliers and CGE models.

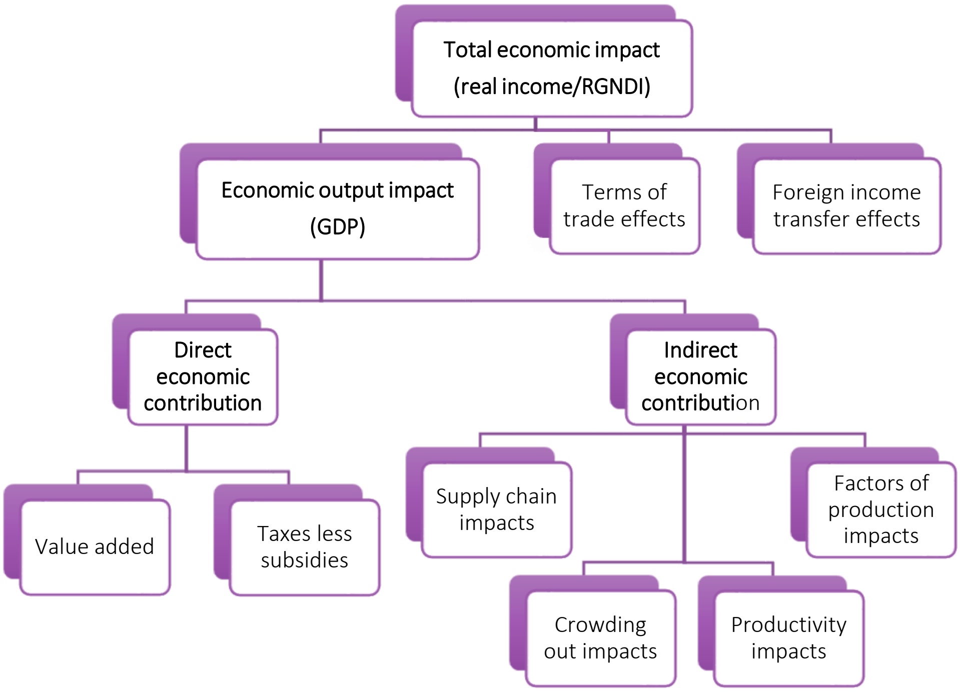
Fundamentally, although various aspects of a policy or project are of relevance to particular stakeholders—for example, the number of jobs created or the size of the investment expenditure—the key aggregate measure of the macroeconomic impact of a project or policy is the extent to which the ***total income of the economy*** has changed as a result of that policy or project. Typically, this is measured in terms of the change in real gross national disposable income (RGNDI), although real gross domestic product (GDP) and consumer surplus can also be important aggregate measures depending on the nature of the policy or project being analysed.

The main factors that need to be considered when analysing the macroeconomic impacts of a project or policy include:

— the direct and indirect contribution to the economy as a result of the activities associated with the project or policy
— any crowding out implications as resources are potentially diverted away from other productive activities to undertake the project or policy being analysed
— any productivity effects generated as a direct result of the policy or project activities – particularly any enduring productivity changes or productivity impacts on other activities not directly associated with the project or policy
— any changes to the factors of production in the economy
— any implications associated with changes in terms of trade or foreign income transfers
— the extent of any dynamic element to the size of any of the above effects (for example, associated with different phases of the project).

Figure 3.1 shows these components graphically. Some of these effects may have negligible impact while others may be very significant and an understanding of the relative size of these effects helps determine the most appropriate tool(s) for the analysis.

FIGURE 3.1 ESTIMATING THE ECONOMIC IMPACT OF A PROJECT OR POLICY



SOURCE: ACIL ALLEN CONSULTING

For many projects, static estimates of the direct economic contribution and supply chain implications can be obtained through the use of I-O multipliers. Estimating the size of other components using multiplier techniques is either not possible or very complex, as is estimating the economic impacts through time. In contrast, most CGE models are able to estimate all of the components shown in **Figure 3.1**, with dynamic CGE models able to estimate the impacts through time. The greater complexity of CGE models enables a much broader range of economic impacts to be considered within a single framework provided the necessary data inputs are available.

3.2 The *Tasman Global* CGE model

For this project ACIL Allen has used the Tasman Global CGE model in which Timor-Leste has been explicitly represented in the economic databases.

Tasman Global is a large scale, dynamic CGE model of the world economy that has been developed in-house by ACIL Allen Consulting. *Tasman Global* is a powerful and effective tool for undertaking economic analysis at the regional, national and global levels. This model has been used for numerous similar economic impact assessments of major petroleum projects in Australia (and overseas) including for the development of the Icthys, Gorgon, Scarborough, Prelude, Browse, Northwest Shelf, Gippsland Basin, Bayu-Undan, P'nyang and Pasca A fields and any associated downstream LNG, refining or domestic gas activities. Tasman Global is one of the few CGE models that has the capacity to model Timor-Leste's economy. The Timor-Leste database was constructed and used for an assessment of the potential economic impacts of the Tasi Mane project on the Timor-Leste economy in 2015-16. More detail of the Tasman Global model is provided in Appendix A.

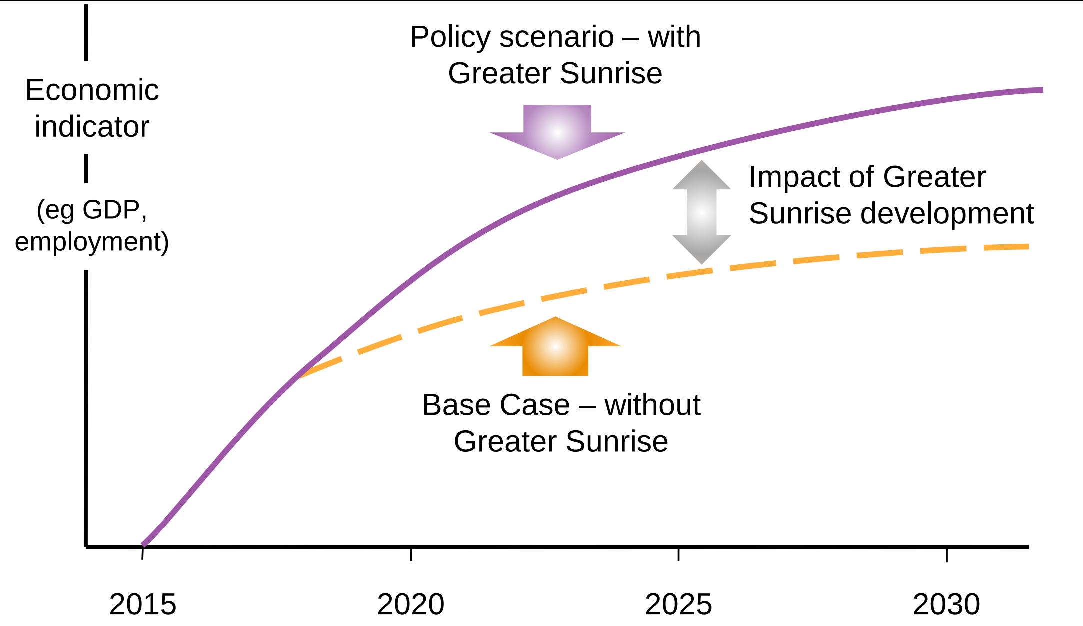
CGE models mimic the workings of the economy through a system of interdependent behavioural and accounting equations which are linked to an I-O database. These models provide a representation of the whole economy, set in a national and international trading context, starting with individual markets, producers and consumers and building up the system via demands and production from each component. When an economic "shock" or disturbance is applied to a model, each of the markets adjusts according to a set of behavioural parameters which are underpinned by economic theory. The generalised nature of CGE models enable a much broader range of analysis to be undertaken (generally in a more robust manner) compared to I-O multiplier techniques.

A dynamic model

Tasman Global is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before a policy change and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues where both the timing of impacts and the adjustment path that economies follow are relevant in the analysis.

In the current application of the *Tasman Global* model, a Base Case simulation provides a 'business-as-usual' scenario against which to compare the results of various simulations. The Base Case provides projections of growth in the absence of the project. It therefore provides the base line projections of GDP, population, labour supply, industry output, and other relevant measures, and provides projections of endogenous variables such as productivity changes and consumer preferences. The Policy scenario assumes all productivity improvements, tax rates and consumer preferences change as per the Base Case projections but also includes the proposed Project. The two scenarios result in two different projections of the economy, and the net impacts of the project can be calculated as the differences, for each relevant measure, between the Policy scenario and the Base Case. This is illustrated schematically in see **Figure 3.2**.

FIGURE 3.2 ILLUSTRATIVE SCENARIO ANALYSIS USING *TASMAN GLOBAL*



Note: In reality impacts could be negative, positive, neutral or a mixture.

SOURCE: ACIL ALLEN CONSULTING

Micro-industry approach

To accurately assess the economic impacts or economic contribution of a major project such as the development of Greater Sunrise, it is necessary to represent the project in the model's database. An accurate representation can be achieved by establishing the proposed project as a new 'micro-industry' in the database.

The micro-industry approach is so called because it involves the creation of one or more new, initially very small, industries in the *Tasman Global* database. The specifications of each of the micro-industry's costs and sales structures are directly derived from the financial data for the project to be analysed. At the outset, the new industry is necessarily very small so that its existence in the *Tasman*

Global database does not affect the database balance or the "business-as-usual" Base Case outcomes.

Besides having a separate cost structure for the project of interest, a further challenge is to faithfully represent the time profile of the individual cost items. This is particularly important for the investment phase where there are typically large changes in demands for machinery, labour and imported components year on year. This challenge is met in *Tasman Global* by incorporating detailed year on year input changes by source.

Using the micro-industry approach for project evaluations is the most accurate way to capture the detailed economic linkages between the project and the other industries in the economy. This approach has been developed by ACIL Allen because each project is unique relative to the more aggregated industries in the *Tasman Global* database.

Consequently, in addition to the standard industries, the database also identifies the construction and operation phases of the Greater Sunrise project as separate micro-industries with their own input cost structure, sales, employment, tax revenues and greenhouse gas emissions based on detailed information generated as part of the project analysis.

Another important aspect in the CGE modelling approach used for this analysis is to have separate identification of the capital stock created as part of the project's investment phase and isolating it until the capital is available for use, thereby preventing the economy gaining false benefits from, say, half a bridge.

The model has the ability to account explicitly for the repatriation of profits (for example through foreign ownership of capital or through the use of fly-in, fly-out workers) for each industry in each region. For this project, the net taxation and equity returns to the Timor-Leste Government as derived from the financial modelling have been incorporated explicitly with all other net profits assumed to be repatriated to foreign residents. As with any asset, the share of domestic versus foreign ownership is not guaranteed to remain the same in the future, but in the absence of other information has been assumed to remain constant over the life of the project.

3.3 Measures of macroeconomic impacts

Before reporting the economic impacts of the modelling, it is important to understand what they mean. One of the most commonly quoted macroeconomic variables at a national level is real GDP, which is a measure of the aggregate output generated by an economy over a given period of time (typically a year).

GDP may be calculated in different ways.

— On the expenditure side by adding together total private and government consumption, investment and net trade.

— On the income side as the sum of returns to the primary factors (labour, capital and natural resources) employed in the national economy plus indirect tax revenue.

Measuring the impact of a policy or project using just real GDP may disguise investments or policy changes that are not beneficial in the overall economic welfare sense. This is because it is possible for real GDP to increase while at the same time consumers may be worse off as measured in terms of real income. In such circumstances people and households would be worse off despite economic growth.

This leads to a preference for considering real income effects. Real income is a measure of the ability to purchase goods and services, adjusted for inflation. A rise in real income indicates a rise in the capacity for current consumption, but also an increased ability to accumulate wealth in the form of financial and other assets. The change in real income from a development is a measure of the change in welfare of the people in an economy. The change in real income at a national or regional level is a measure of real economic output plus external income transfers and the nation's or region's terms of trade (which measures the purchasing power of the nation's or region's exports relative to its imports).

The change in a region's real income as a result of a policy change or investment (often referred to by economists as a policy 'shock') is therefore the change in the region's real GDP plus the change in net external income transfers plus the change in the region's terms of trade. As many people have experienced first-hand in recent years, changes in the terms of trade can have a substantial impact on residents' welfare independently of changes in real economic output.

In global CGE models such as *Tasman Global*, the change in real income is equivalent to the change in consumer welfare using the equivalent variation measure of welfare change resulting from exogenous shocks. Hence, it is valid to say that the projected change in real income (from *Tasman Global*) is also the projected change in consumer welfare.

Real GDP versus real income under Case 1 and 2

As mentioned in Section 2 above, a key difference between Case 1 and Case 2 is whether or not the LNG facility is located in Timor-Leste or in Australia. This assumption makes a significant difference to the projected macroeconomic impacts.

In both Cases the LNG facility is *adding considerable value to the raw gas produced and it is the value-adding that impacts on real GDP*. Under Case 1, the value adding is counted as being part of the Timor-Leste economy while under Case 2 it is counted a part of the Australian economy. Hence, irrespective of any differences in equity ownership or local content, it would be expected that the real GDP of Timor-Leste will be noticeably higher under Case 1 compared with Case 2.

As mentioned in the previous section, income transfers, however, offset the difference in the accounting for where the value added is being created. That is, under Case 1, a significant portion of the value added (or real GDP) is counted in Timor-Leste but then Timor-Leste remits part of the income back to the other investors. Consequently, all else equal, the impact of the project on real income under Case 1 will be *smaller* than the projected impact on real GDP.

In contrast, under Case 2, a significant portion of the value-added (or real GDP) is counted in Australia but then Australia remits part of the income back to the Timor-Leste Government. Consequently, all else equal, the impact of the project on real income under Case 2 will be *greater* than the projected impact on real GDP.

4 TOTAL ECONOMIC IMPACTS (DIRECT PLUS INDIRECT)

Figure 4.1 presents the year on year impacts on Timor-Leste's real GDP, real income and employment under each case while **Table 4.1** presents a decomposition of the total projected change in real GDP and real income. The projected changes are based on the assumption that the revenues generated by the project are used judiciously by the Timorese Government and/or private sector to bring unskilled and low skilled workers out of the subsistence economy into the formal economy. In terms of economic modelling, this has the effect of formalising (or monetising) the economic value of currently unpaid labour rather than creating work and value per se. Such a transition and monetisation is important, however, in achieving longer term development via division of labour and trade.

In undertaking the modelling in Tasman Global, Timor-Leste has been placed in a currency union with the United States and the share of real income going to savings versus current consumption is assumed to reflect current rates, thereby maintaining the current legislated policy of building a sovereign wealth fund from short-term petroleum revenues for long-term sustainable development (the Petroleum Fund of Timor-Leste).

4.1 Case 1

Over the period **2020** to **2048**, it is estimated that, in total, the development of the Greater Sunrise field under **Case 1** will:

— Add **US$92.1 billion** to the Gross Domestic Product (GDP) of Timor-Leste (**US$3.1 billion** per year) in 2016 terms.
— Increase the real incomes (or economic welfare)[1] of Timor-Leste residents by more than **US$84.4 billion** (or **US$2.9 billion** per year) in 2016 terms.
— Stimulate nearly **390,000** full time equivalent (FTE) job years of employment throughout Timor-Leste (or an average of **13,440** FTE jobs per year).

Based on the reference case projection of population growing to 1.54 million by 2030 and 2.10 million by 2048, the projected increase in real income as a result of the development of the Greater Sunrise field under **Case 1** is equal to an average increase of just over US$1,600 per person for every year between 2020 and 2048. This is a substantial boost to Timorese incomes.

4.2 Case 2

Over the period **2020** to **2048**, it is estimated that, in total, the development of the Greater Sunrise field under **Case 2** will:

— Add **US$26.7 billion** to the Gross Domestic Product (GDP) of Timor-Leste (**US$922 million** per year) in 2016 terms.
— Increase the real incomes (or economic welfare) of Timor-Leste residents by more than **US$55.4 billion** (or **US$1.7 billion** per year) in 2016 terms.
— Stimulate approximately **238,300** full time equivalent (FTE) job years of employment throughout Timor-Leste (or an average of **8,220** FTE jobs per year).

The projected increase in real income as a result of the development of the Greater Sunrise field under **Case 2** is equal to an average increase of US$1,100 per person for every year between 2020 and 2048. Although a significant boost to Timorese incomes, this is just over US$500 per person per year less than the projected impacts under Case 1.

TABLE 4.1 PROJECTED IMPACT OF GREATER SUNRISE DEVELOPMENT ON TIMOR-LESTE ECONOMY UNDER ALTERNATIVE CASES (IN REAL 2016 TERMS)

	Case 1	Case 2	Difference (Case 1 minus Case 2)
	US$m	US$m	US$m
Private and Government real consumption	26,710	18,267	
Real investment	12,005	6,444	
Net foreign trade	53,392	2,013	
– Real exports	71,086	11,231	
– Contribution of real imports	–17,694	–9,219	
Real GDP	**92,107**	**26,724**	**65,383**
Terms of trade	–253	–1,815	
Net income transfers	–7,435	30,524	
Real income	**84,418**	**55,433**	**28,985**

SOURCE: ACIL ALLEN CONSULTING

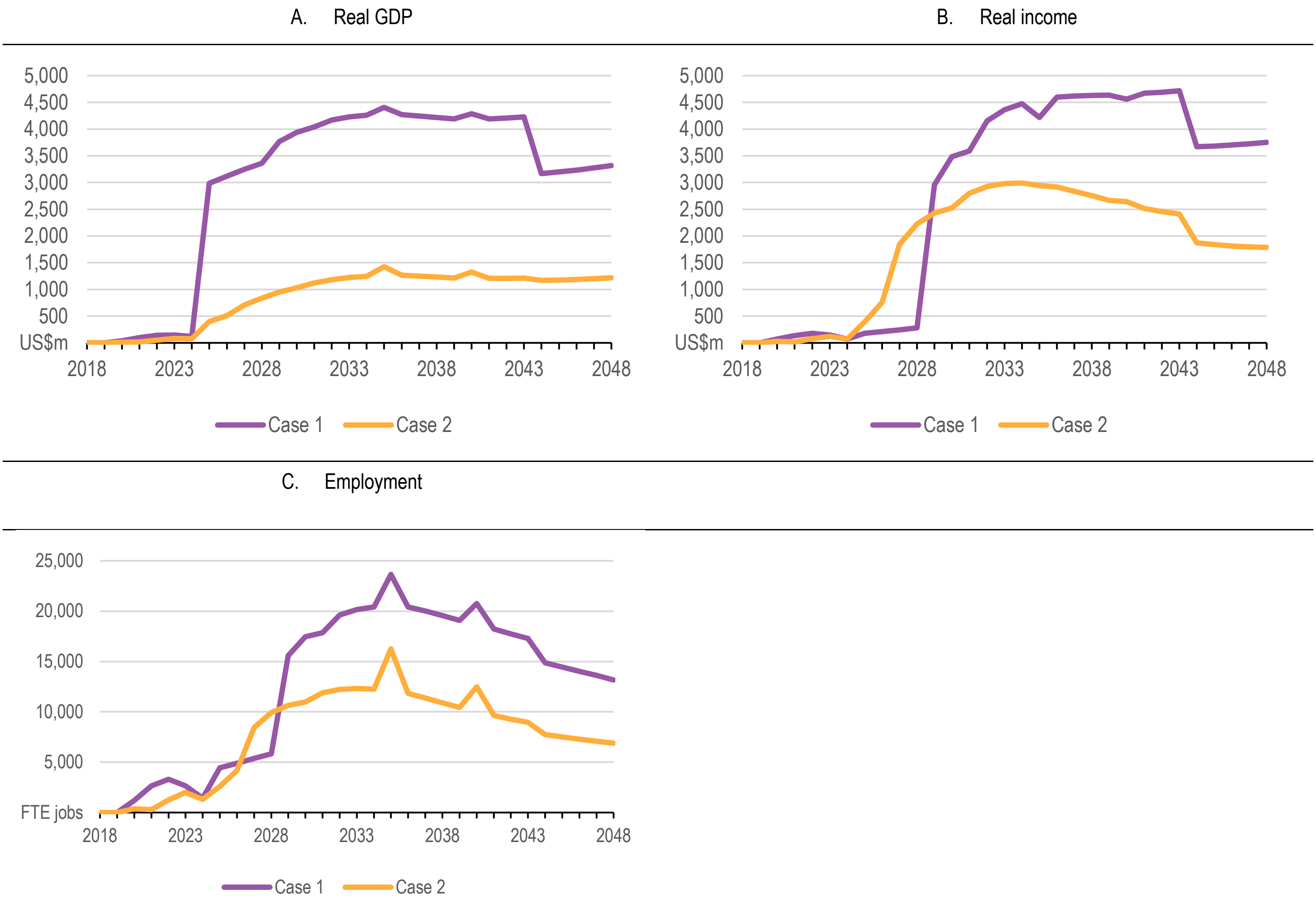
Although real income is the most appropriate measure of economic welfare of Timor-Leste as a whole, current consumption (private and government) is also a practical measure of welfare as it reflects the level of aggregate real incomes that flows through to residents. The large difference between the two is due to the assumption that the revenues from the Greater Sunrise project are directed into the Petroleum Fund (i.e. there is a large increase in real savings which provides the opportunity for future residents to share in the economic welfare generated by the project). Real consumption over the

[1] See 3.3 for a discussion of the difference between real GDP and real income.

period **2020** to **2048** is projected to increase by **US$26.7 billion under Case 1** and **US$18.3 billion under Case 2** (Table 4.1).

Real investment in Timor-Leste is projected to increase by US$12.0 billion under Case 1 versus US$6.4 billion under Case 2, with the majority of this directly related to the Greater Sunrise development. (Non-project related real investment is projected to increase by US$934 million under Case 1 and US$541 under Case 2.) Similarly, the majority of the projected growth in real exports is due to the direct exports associated with the Greater Sunrise development. (Under Case 1 the change in real exports not associated with Greater Sunrise is projected to be US$12.7 billion versus US$2.9 billion under Case 2.)

FIGURE 4.1 ECONOMIC IMPACT OF GREATER SUNRISE PROJECT ON THE TIMOR-LESTE ECONOMY (IN 2016 US$)



SOURCE: ACIL ALLEN CONSULTING

4.3 Other considerations

In analysing these results it is important to consider the underlying modelling framework and implied assumptions. Importantly, the analysis has been undertaken using an "all else being equal" assumption. Although this allows the impact of the Greater Sunrise project to be isolated it does not allow a range of other possible indirect impacts to be included unless they are specifically assumed as part of the analysis. In particular, a key assumption is that the underlying productivity of all factors and production technologies remain the same with and without the Greater Sunrise project (although people can change between different skilled occupations based on the relative changes in demand). In reality the large income streams that will be generated by the project could be used for many beneficial developments that could improve other areas of the Timor-Leste economy. For example, investment in transportation infrastructure may enable substantial reductions in the cost of transport while at the same time improving reliability of market-based supplies to parts of the Timor-Leste economy encouraging a movement away from subsistence lifestyles. Such “co-investment” can induce substantial improvements in the underlying economy relative to the Reference Case (that is, without the Greater Sunrise project).

Similarly, increased real income and the potential for knowledge spill-overs from the foreign investment could result in a more rapid improvement in the education and skills of the local workforce relative to the Reference Case, opening up a range of new opportunities for the development of local enterprises. Indeed, it is easy to imagine that trade-exposed manufacturing industries could actually benefit as a result of the project rather than suffer any “Dutch disease” effects.

OVERVIEW OF TASMAN GLOBAL A

Tasman Global is a dynamic, global computable general equilibrium (CGE) model that has been developed by ACIL Allen for the purpose of undertaking economic impact analysis at the regional, state, national and global level.

A CGE model captures the interlinkages between the markets of all commodities and factors, taking into account resource constraints, to find a simultaneous equilibrium in all markets. A global CGE model extends this interdependence of the markets across world regions and finds simultaneous equilibrium globally. A dynamic model adds onto this the interconnection of equilibrium economies across time periods. For example, investments made today are going to determine the capital stocks of tomorrow and hence future equilibrium outcomes depend on today's equilibrium outcome, and so on.

Thus a dynamic global CGE model, such as *Tasman Global*, has the capability of addressing total, sectoral, spatial and temporal efficiency of resource allocation as it connects markets globally and over time. Being a recursively dynamic model, however, its ability to address temporal issues is limited. In particular, *Tasman Global* cannot typically address issues requiring partial or perfect foresight, however, as documented in Jakeman et al (2001), it is possible to introduce partial or perfect foresight in certain markets using algorithmic approaches. Notwithstanding this, the model does have the capability to project the economic impacts over time of given changes in policies, tastes and technologies in any region of the world economy on all sectors and agents of all regions of the world economy.

Tasman Global was developed out of the 2001 version of the Global Trade and Environment Model (GTEM) developed by ABARE (Pant 2001), and has been evolving ever since. In turn, GTEM was developed out of the MEGABARE model (ABARE 1996), which contained significant advancements over the GTAP model of that time (Hertel 1997).

A.1 A dynamic model

Tasman Global is a model that estimates relationships between variables at different points in time. This is in contrast to comparative static models, which compare two equilibriums (one before a policy change and one following). A dynamic model such as *Tasman Global* is beneficial when analysing issues where both the timing of and the adjustment path that economies follow are relevant in the analysis.

A.2 The database

A key advantage of *Tasman Global* is the level of detail in the database underpinning the model. The database used for this analysis is derived from the Global Trade Analysis Project (GTAP) database (version 9.1). This database is a fully documented, publicly available global data base which contains complete bilateral trade information, transport and protection linkages among regions for all GTAP commodities. It is the detailed database of its type in the world.

Tasman Global builds on the GTAP database by adding the following important features:

– a detailed population and labour market database
– detailed technology representation within key industries (such as electricity generation and iron and steel production)
– disaggregation of a range of major commodities including iron ore, bauxite, alumina, primary aluminium, brown coal, black coal and LNG
– the ability to repatriate labour and capital income
– explicit representation of the states and territories of a nation

– the capacity to explicitly represent multiple regions within the states and territories of a nation.

Nominally, version 9.1 of the *Tasman Global* database divides the world economy into 150 regions (142 international regions – including Timor-Leste – plus the 8 states and territories of Australia) although in reality the regions are frequently disaggregated further. ACIL Allen regularly models Australian or international projects or policies at the regional level including at the provincial level for Papua New Guinea and Canada.

The *Tasman Global* database also contains a wealth of sectoral detail currently identifying up to 72 industries (**Table A.1**). The foundation of this information is the input-output tables that underpin the database. The input-output tables account for the distribution of industry production to satisfy industry and final demands. Industry demands, so-called intermediate usage, are the demands from each industry for inputs.

For example, electricity is an input into the production of communications. In other words, the communications industry uses electricity as an intermediate input. Final demands are those made by households, governments, investors and foreigners (export demand). These final demands, as the name suggests, represent the demand for finished goods and services. To continue the example, electricity is used by households – their consumption of electricity is a final demand.

Each sector in the economy is typically assumed to produce one commodity, although in *Tasman Global*, the electricity, transport and iron and steel sectors are modelled using a 'technology bundle' approach. With this approach, different known production methods are used to generate a homogeneous output for the 'technology bundle' industry. For example, electricity can be generated using brown coal, black coal, petroleum, base load gas, peak load gas, nuclear, hydro, geothermal, biomass, wind, solar or other renewable based technologies – each of which have their own cost structure.

TABLE A.1 SECTORS IN THE *TASMAN GLOBAL* DATABASE

Sector		Sector	
1	Paddy rice	**37**	Wood products
2	Wheat	**38**	Paper products, publishing
3	Cereal grains nec	**39**	Diesel (incl. nonconventional diesel)
4	Vegetables, fruit, nuts	**40**	Other petroleum, coal products
5	Oil seeds	**41**	Chemical, rubber, plastic products
6	Sugar cane, sugar beef	**42**	Iron ore
7	Plant- based fibres	**43**	Bauxite
8	Crops nec	**44**	Mineral products nec
9	Bovine cattle, sheep, goats, horses	**45**	Ferrous metals
10	Pigs	**46**	Alumina
11	Animal products nec	**47**	Primary aluminium
12	Raw milk	**48**	Metals nec
13	Wool, silk worm cocoons	**49**	Metal products
14	Forestry	**50**	Motor vehicle and parts
15	Fishing	**51**	Transport equipment nec
16	Brown coal	**52**	Electronic equipment
17	Black coal	**53**	Machinery and equipment nec
18	Oil	**54**	Manufactures nec
19	Liquefied natural gas (LNG)	**55**	Electricity generation
20	Other natural gas	**56**	Electricity transmission and distribution
21	Minerals nec	**57**	Gas manufacture, distribution
22	Bovine meat products	**58**	Water
23	Pig meat products	**59**	Construction
24	Meat products nec	**60**	Trade
25	Vegetables oils and fats	**61**	Road transport
26	Dairy products	**62**	Rail and pipeline transport
27	Processed rice	**63**	Water transport
28	Sugar	**64**	Air transport
29	Food products nec	**65**	Transport nec
30	Wine	**66**	Communication
31	Beer	**67**	Financial services nec
32	Spirits and RTDs	**68**	Insurance
33	Other beverages and tobacco products	**69**	Business services nec
34	Textiles	**70**	Recreational and other services
35	Wearing apparel	**71**	Public Administration, Defence, Education, Health
36	Leather products	**72**	Dwellings

NOTE: NEC = NOT ELSEWHERE CLASSIFIED

The other key feature of the database is that the cost structure of each industry is also represented in detail. Each industry purchases intermediate inputs (from domestic and imported sources) primary factors (labour, capital, land and natural resources) as well as paying taxes or receiving subsidies.

A.3 Model structure

Given its heritage, the structure of the *Tasman Global* model closely follows that of the GTAP and GTEM models and interested readers are encouraged to refer to the documentation of these models for more detail (namely Hertel 1997 and Pant 2001, respectively). In summary:

- The model divides the world into a variety of regions and international waters.
  - Each region is fully represented with its own 'bottom-up' social accounting matrix and could be a local community, an LGA, state, country or a group of countries. The number of regions in a given simulation depends on the database aggregation. Each region consists of households, a government with a tax system, production sectors, investors, traders and finance brokers.
  - 'International waters' are a hypothetical region where global traders operate and use international shipping services to ship goods from one region to the other. It also houses an international finance 'clearing house' that pools global savings and allocates the fund to investors located in every region.
  - Each region has a 'regional household'[2] that collects all factor payments, taxes, net foreign borrowings, net repatriation of factor incomes due to foreign ownership and any net income from trading of emission permits.
- The income of the regional household is allocated across private consumption, government consumption and savings according to a Cobb-Douglas utility function, which, in practice, means that the share of income going to each component is assumed to remain constant in nominal terms.
- Private consumption of each commodity is determined by maximising utility subject to a Constant Difference of Elasticities (CDE) function which includes both price and income elasticities.
- Government consumption of each commodity is determined by maximising utility subject to a Cobb-Douglas utility function.
- Each region has *n* production sectors, each producing single products using various production functions where they aim to maximise profits (or minimise costs) and take all prices as given. The nature of the production functions chosen in the model means that producers exhibit constant returns to scale.
  - In general, each producer supplies consumption goods by combining an aggregate energy-primary factor bundle with other intermediate inputs and according to a Leontief production function (which in practice means that the quantity shares remain in fixed proportions). Within the aggregate energy-primary factor bundle, the individual energy commodities and primary factors are combined using a nested-CES (Constant Elasticity of Substitution) production function, in which energy and primary factor aggregates substitute according to a CES function with the individual energy commodities and individual primary factors substituting with their respective aggregates according to further CES production functions.
  - Exceptions to the above include the electricity generation, iron and steel and road transport sectors. These sectors employ the 'technology bundle' approach developed by ABARE (1996) in which non-homogenous technologies are employed to produce a homogenous output with the choice of technology governed by minimising costs according to a modified-CRESH production function. For example, electricity may be generated from a variety of technologies (including brown coal, black coal, gas, nuclear, hydro, solar etc.), iron and steel may be produced from blast furnace or electric arc technologies while road transport services may be supplied using a range of different vehicle technologies. The 'modified-CRESH' function differs from the traditional CRESH function by also imposing the condition that the quantity units are homogenous.
- There are four primary factors (land, labour, mobile capital and fixed capital). While labour and mobile capital are used by all production sectors, land is only used by agricultural sectors while the fixed capital is typically employed in industries with natural resources (such as fishing, forestry and mining) or in selected industries built by ACIL Allen.

[2] The term "regional household" was devised for the GTAP model. In essence it is an agent that aggregates all incomes attributable to the residents of a given region before distributing the funds to the various types of regional consumption (including savings).

  - Land supply in each region is typically assumed to remain fixed through time with the allocation of land between sectors occurring to maximise returns subject to a Constant Elasticity of Transformation (CET) utility function.
  - Mobile capital accumulates as a result of net investment. It is implicitly assumed in *Tasman Global* that it takes one year for capital to be installed. Hence, supply of capital in the current period depends on the last year's capital stock and investments made during the previous year.
  - Labour supply in each year is determined by endogenous changes in population, given participation rates and a given unemployment rate. In policy scenarios, the supply of labour is positively influenced by movements in the real wage rate governed by the elasticity of supply. For countries where sub-regions have been specified (such as Australia, Canada, PNG etc), migration between regions is induced by changes in relative real wages with the constraint that net interregional migration equals zero. For regions where the labour market has been disaggregated to include occupations, there is limited substitution allowed between occupations by individuals supplying labour (according to a CET utility function) and by firms demanding labour (according to a CES production function) based on movements in relative real wages.
  - The supply of fixed capital is given for each sector in each region.

  The model has the option for these assumptions to be changed at the time of model application if alternative factor supply behaviours are considered more relevant.

- It is assumed that labour (by occupation) and mobile capital are fully mobile across production sectors implying that, in equilibrium, wage rates (by occupation) and rental rates on capital are equalised across all sectors within each region. To a lesser extent, labour and capital are mobile between regions through international financial investment and migration, but this sort of mobility is sluggish and does not equalise rates of return across regions.
- For most international regions, each consumer (private, government, industries and the local investment sector), consumption goods can be sourced either from domestic or imported sources. In any country which has disaggregated regions (such as Australia, Canada, PNG etc), consumption goods can also be sourced from other intrastate or interstate regions. In all cases, the source of non-domestically produced consumption goods is determined by minimising costs subject to a Constant Ratios of Elasticities of Substitution, Homothetic (CRESH) utility function. Like most other CGE models, a CES demand function is used to model the relative demand for domestically-produced commodities versus non-domestically produced commodities. The elasticities chosen for the CES and CRESH demand functions mean that consumers in each region have a higher preference for domestically produced commodities than non-domestic and a higher preference for intrastate or interstate produced commodities versus foreign.
- The capital account in *Tasman Global* is open. Domestic savers in each region purchase 'bonds' in the global financial market through local 'brokers' while investors in each region sell bonds to the global financial market to raise investible funds. A flexible global interest rate clears the global financial market.
- It is assumed that regions may differ in their risk characteristics and policy configurations. As a result, rates of return on money invested in physical capital may differ between regions and therefore may be different from the global cost of funds. Any difference between the local rates of return on capital and the global cost of borrowing is treated as the result of the existence of a risk premium and policy imperfections in the international capital market. It is maintained that the equilibrium allocation of investment requires the equalisation of changes in (as opposed to the absolute levels of) rates of return over the base year rates of return.
- Any excess of investment over domestic savings in a given region causes an increase in the net debt of that region. It is assumed that debtors service the debt at the interest rate that clears the global financial market. Similarly, regions that are net savers gives rise to interest receipts from the global financial market at the same interest rate.
- Investment in each region is used by the regional investor to purchase a suite of intermediate goods according to a Leontief production function to construct capital stock with the regional investor cost minimising by choosing between domestic, interstate and imported sources of each intermediate good via the CRESH production function. The regional cost of creating new capital stock versus the local rates of return on mobile capital is what determines the regional rate of return on new investment.

— In equilibrium, exports of a good from one region to the rest of world are equal to the import demand for that good in the remaining regions. Together with the merchandise trade balance, the net payments on foreign debt add up to the current account balance. *Tasman Global* does not require that the current account be in balance every year. It allows the capital account to move in a compensatory direction to maintain the balance of payments. The exchange rate provides the flexibility to keep the balance of payments in balance.

— Emissions of six anthropogenic greenhouse gases (namely, carbon dioxide, methane, nitrous oxide, HFCs, PFCs and SF_6) associated with economic activity are tracked in the model. Almost all sources and sectors are represented; emissions from agricultural residues and land-use change and forestry activities are not explicitly modelled but can be accounted for externally. Prices can be applied to emissions which are converted to industry-specific production taxes or commodity-specific sales taxes that impact on demand. Abatement technologies similar to those adopted in Australian Government (2008) are available and emission quotas can be set globally or by region along with allocation schemes that enable emissions to be traded between regions.

More detail regarding specific elements of the model structure are discussed in the following sections.

A.4 Population growth and labour supply

Population growth is an important determinant of economic growth through the supply of labour and the demand for final goods and services. Population growth for each region represented in the *Tasman Global* database is projected using ACIL Allen's in-house demographic model. The demographic model projects how the population in each region grows and how age and gender composition changes over time and is an important tool for determining the changes in regional labour supply and total population over the projection period.

For each of region, the model projects the changes in age-specific birth, mortality and net migration rates by gender for 101 age cohorts (0-99 and 100+). The demographic model also projects changes in participation rates by gender by age for each region, and, when combined with the age and gender composition of the population, endogenously projects the future supply of labour in each region. Changes in life expectancy are a function of income per person as well as assumed technical progress on lowering mortality rates for a given income (for example, reducing malaria-related mortality through better medicines, education, governance etc.). Participation rates are a function of life expectancy as well as expected changes in higher education rates, fertility rates and changes in the work force as a share of the total population.

Labour supply is derived from the combination of the projected regional population by age by gender and the projected regional participation rates by age by gender. Over the projection period labour supply in most developed economies is projected to grow slower than total population as a result of ageing population effects.

For the Australian states and territories, the projected aggregate labour supply from ACIL Allen's demographics module is used as the base level potential workforce for the detailed Australian labour market module, which is described in the next section.

A.4.1 The Australian labour market

Tasman Global has a detailed representation of the Australian labour market which has been designed to capture:

— different occupations

— changes to participation rates (or average hours worked) due to changes in real wages

— changes to unemployment rates due to changes in labour demand

— limited substitution between occupations by the firms demanding labour and by the individuals supplying labour, and

— limited labour mobility between states and regions within each state.

Tasman Global recognises 97 different occupations within Australia – although the exact number of occupations depends on the aggregation. The firms who hire labour are provided with some limited scope to change between these 97 labour types as the relative real wage between them changes. Similarly, the individuals supplying labour have a limited ability to change occupations in response to the changing relative real wage between occupations. Finally, as the real wage for a given occupation rises in one state relative to other states, workers are given some ability to respond by shifting their location. The model produces results at the 97 3-digit ANZSCO (Australian New Zealand Standard Classification of Occupations) level which are presented in Table A.2.

The labour market structure of *Tasman Global* is thus designed to capture the reality of labour markets in Australia, where supply and demand at the occupational level do adjust, but within limits.

Labour supply in *Tasman Global* is presented as a three stage process:

1. labour makes itself available to the workforce based on movements in the real wage and the unemployment rate;
2. labour chooses between occupations in a state based on relative real wages within the state; and
3. labour of a given occupation chooses in which state to locate based on movements in the relative real wage for that occupation between states.

By default, *Tasman Global*, like all CGE models, assumes that markets clear. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model).

TABLE A.2 OCCUPATIONS IN THE *TASMAN GLOBAL* DATABASE, ANZSCO 3-DIGIT LEVEL (MINOR GROUPS)

ANZSCO code, Description
1. MANAGERS
111 Chief Executives, General Managers and Legislators
121 Farmers and Farm Managers
131 Advertising and Sales Managers
132 Business Administration Managers
133 Construction, Distribution and Production Managers
134 Education, Health and Welfare Services Managers
135 ICT Managers
139 Miscellaneous Specialist Managers
141 Accommodation and Hospitality Managers
142 Retail Managers
149 Miscellaneous Hospitality, Retail and Service Managers
2. PROFESSIONALS
211 Arts Professionals
212 Media Professionals
221 Accountants, Auditors and Company Secretaries
222 Financial Brokers and Dealers, and Investment Advisers
223 Human Resource and Training Professionals
224 Information and Organisation Professionals
225 Sales, Marketing and Public Relations Professionals
231 Air and Marine Transport Professionals
232 Architects, Designers, Planners and Surveyors
233 Engineering Professionals
234 Natural and Physical Science Professionals
241 School Teachers
242 Tertiary Education Teachers
249 Miscellaneous Education Professionals
251 Health Diagnostic and Promotion Professionals
252 Health Therapy Professionals
253 Medical Practitioners
254 Midwifery and Nursing Professionals
261 Business and Systems Analysts, and Programmers
262 Database and Systems Administrators, and ICT Security Specialists
263 ICT Network and Support Professionals
271 Legal Professionals
272 Social and Welfare Professionals
3. TECHNICIANS & TRADES WORKERS
311 Agricultural, Medical and Science Technicians
312 Building and Engineering Technicians
313 ICT and Telecommunications Technicians
321 Automotive Electricians and Mechanics
322 Fabrication Engineering Trades Workers
323 Mechanical Engineering Trades Workers
324 Panelbeaters, and Vehicle Body Builders, Trimmers and Painters
331 Bricklayers, and Carpenters and Joiners
332 Floor Finishers and Painting Trades Workers
333 Glaziers, Plasterers and Tilers
334 Plumbers
341 Electricians
342 Electronics and Telecommunications Trades Workers
351 Food Trades Workers
361 Animal Attendants and Trainers, and Shearers
362 Horticultural Trades Workers
391 Hairdressers
392 Printing Trades Workers
393 Textile, Clothing and Footwear Trades Workers
394 Wood Trades Workers
399 Miscellaneous Technicians and Trades Workers
4. COMMUNITY & PERSONAL SERVICE
411 Health and Welfare Support Workers
421 Child Carers
422 Education Aides
423 Personal Carers and Assistants
431 Hospitality Workers
441 Defence Force Members, Fire Fighters and Police
442 Prison and Security Officers
451 Personal Service and Travel Workers
452 Sports and Fitness Workers
5. CLERICAL & ADMINISTRATIVE
511 Contract, Program and Project Administrators
512 Office and Practice Managers
521 Personal Assistants and Secretaries
531 General Clerks
532 Keyboard Operators
541 Call or Contact Centre Information Clerks
542 Receptionists
551 Accounting Clerks and Bookkeepers
552 Financial and Insurance Clerks
561 Clerical and Office Support Workers
591 Logistics Clerks
599 Miscellaneous Clerical and Administrative Workers
6. SALES WORKERS
611 Insurance Agents and Sales Representatives
612 Real Estate Sales Agents
621 Sales Assistants and Salespersons
631 Checkout Operators and Office Cashiers
639 Miscellaneous Sales Support Workers
7. MACHINERY OPERATORS & DRIVERS
711 Machine Operators
712 Stationary Plant Operators
721 Mobile Plant Operators
731 Automobile, Bus and Rail Drivers
732 Delivery Drivers
733 Truck Drivers
741 Storepersons
8. LABOURERS
811 Cleaners and Laundry Workers
821 Construction and Mining Labourers
831 Food Process Workers
832 Packers and Product Assemblers
839 Miscellaneous Factory Process Workers
841 Farm, Forestry and Garden Workers
851 Food Preparation Assistants
891 Freight Handlers and Shelf Fillers
899 Miscellaneous Labourers

SOURCE: ABS (2009), ANZSCO – AUSTRALIAN AND NEW ZEALAND STANDARD CLASSIFICATIONS OF OCCUPATIONS, FIRST EDITION, REVISION 1, ABS CATALOGUE NO. 1220.0.

Labour market database

The *Tasman Global* database includes a detailed representation of the Australian labour market which has been designed to capture the supply and demand for different skills and occupations by industry. To achieve this, the Australian workforce is characterised by detailed supply and demand matrices.

On the supply side, the Australian population is characterised by a five dimensional matrix consisting of:

- 7 post-school qualification levels
- 12 main qualification fields of highest educational attainment
- 97 occupations
- 101 age groups (namely 0 to 99 and 100+)
- 2 genders.

The data for this matrix is measured in persons and was sourced from the ABS 2011 Census. As the skills elements of the database and model structure have not been used for this project, it will be ignored in this discussion.

The 97 occupations are those specified at the 3-digit level (or Minor Groups) under the Australian New Zealand Standard Classification of Occupations (ANZSCO) (see **Table A.2**).

On the demand side, each industry demands a particular mix of occupations. This matrix is specified in units of full-time equivalent (FTE) jobs where an FTE employee works an average of 37.5 hours per week. Consistent with the labour supply matrix, the data for FTE jobs by occupation by industry was also sourced from the ABS 2011 Census and updated using the latest labour force statistics.

Matching the demand and supply side matrices means that there is the implicit assumption that the average hours per worker are constant, but it is noted that mathematically changes in participation rates have the same effect as changes in average hours worked.

A.4.2 Labour market model structure

In the model, the underlying growth of each industry in the Australian economy results in a growth in demand for a particular set of skills and occupations. In contrast, the supply of each set of skills and occupations in a given year is primarily driven by the underlying demographics of the resident population. This creates a market for each skill by occupation that (unless specified otherwise) needs to clear at the start and end of each time period.[3] The labour markets clear by a combination of different prices (i.e. wages) for each labour type and by allowing a range of demand and supply substitution possibilities, including:

- changes in firms demand for labour driven by changes in the underlying production technology:
  - for technology bundle industries (electricity, iron and steel and road transportation) this occurs due to changes between explicitly identified alternative technologies
  - for non-technology bundle industries this includes substitution between factors (such as labour for capital) or energy for factors
- changes to participation rates (or average hours worked) due to changes in real wages
- changes in the occupations of a person due to changes in relative real wages
- substitution between occupations by the firms demanding labour due to changes in the relative costs
- changes to unemployment rates due to changes in labour demand, and
- limited labour mobility between states due to changes in relative real wages.

All of the labour supply substitution functions are modified-CET functions in which people supply their skills, occupation and rates of participation as a positive function of relative wages. However, unlike a

[3] For example, at the start and end of each week for this analysis. *Tasman Global* can be run with different steps in time, such as quarterly or bi-annually in which case the markets would clear at the start and end of these time points.

standard CET (or CES) function, the functions are 'modified' to enforce an additional constraint that the number of people is maintained before and after substitution.[4]

Although technically solved simultaneously, the labour market in *Tasman Global* can be thought of as a five stage process:

1. labour makes itself available to the workforce based on movements in the real wage (i.e. it actively participates with a certain average hours worked per week)
2. the age, gender and occupations of the underlying population combined with the participation rate by gender by age implies a given supply of labour (the potentially available workforce)
3. a portion of the potentially available workforce is unemployed implying a given available labour force
4. labour chooses to move between occupations based on relative real wages
5. industries alter their demands for labour as a whole and for specific occupations based on the relative cost of labour to other inputs and the relative cost of each occupation.

By default, *Tasman Global*, like all CGE models, assumes that markets clear at the start and end of each period. Therefore, overall, supply and demand for different occupations will equate (as is the case in other markets in the model). In principle, (subject to zero starting values) people of any age and gender can move between any of the 97 occupations while industries can produce their output with any mix of occupations. However, in practice the combination of the initial database, the functional forms, low elasticities and moderate changes in relative prices for skills, occupations etc. means that there is only low to moderate change induced by these functions. Thus the changes are sufficient to clear the markets, but not enough to radically change the structure of the workforce in the timeframe of this analysis.

Factor-factor substitution elasticities in non-technology bundle industries are industry specific and are the same as those specified in the GTAP version 8.1 database[5], while the fuel-factor and technology bundle elasticities are the same as those specified in GTEM.[6] The detailed labour market elasticities are ACIL Allen assumptions, previously calibrated in the context of the model framework to replicate the historical change in the observed Australian labour market over a five year period[7]. More specifically, all labour market elasticities are neutral across industries, regions, age and gender with each responding to changes in relative wages with the ability to change occupations having an elasticity of 0.1, the ability to migrate between different regions of Australia having an elasticity of 0.025, the ability to alter hours worked/participation rate having an elasticity of 0.000375. The unemployment rate function in the policy scenarios is a non-linear function of the change in the labour demand relative to the reference case with the elasticity being a function of the unemployment rate (ie the lower the unemployment rate the lower the elasticity and the higher the unemployment rate the higher the elasticity).

A.5 Detailed energy sector and linkage to *PowerMark* and *GasMark*

Tasman Global contains a detailed representation of the energy sector, particularly in relation to the interstate (trade in electricity and gas) and international linkages across the regions represented. To allow for more detailed electricity sector analysis, and to aid in linkages to bottom-up models such as ACIL Allen's *GasMark* and *PowerMark* models electricity generation is separated from transmission and distribution in the model. In addition, the electricity sector in the model employs a 'technology bundle' approach that separately identifies up to twelve different electricity generation technologies:

[4] As discussed in Dixon et al (1997), a standard CES/CET function is defined in terms of *effective units*. Quantitatively this means that, when substituting between, say, X_1 and X_2 to form a total quantity X using a CET function a simple summation generally does not actually equal X. Use of these functions is common practice in CGE models when substituting between substantially different units (such as labour versus capital or imported versus domestic services) but was not deemed appropriate when tracking the physical number of people. Such 'modified' functions have long been employed in the technology bundles of *Tasman Global* and GTEM. The Productivity Commission have proposed alternatives to the standard CES to overcome similar and other weaknesses when applied to internationally traded commodities.

[5] Narayanan et al. (2012).

[6] Pant (2007).

[7] This method is a common way of calibrating the economic relationships assumed in CGE models to those observed in the economy. See for example Dixon and Rimmer (2002).

1. brown coal (with and without carbon capture and storage)
2. black coal (with and without carbon capture and storage)
3. petroleum
4. base load gas (with and without carbon capture and storage)
5. peak load gas
6. hydro
7. geothermal
8. nuclear
9. biomass
10. wind
11. solar
12. other renewables.

To enable more accurate linking to *PowerMark* the generation cost of each technology is assumed to be equal to their long run marginal cost (LRMC) while the sales price in each region is matched to the average annual dispatch weighted prices projected by *PowerMark* – with any difference being returned as an economic rent to electricity generators. Fuel use and emissions factors by each technology are also matched to those projected in *PowerMark*. This representation enables the highly detailed market based projections from *PowerMark* to be incorporated as accurately as possible into *Tasman Global*.

A.6 References

Australian Government (2008), *Australia's Low Pollution Future: the economics of climate change mitigation*, Australian Government, Canberra.

Dixon, Parmenter, Sutton, & Vincent (1997), ORANI: A Multisectoral Model of the Australian Economy.

Dixon, P.B. and Rimmer, M.T. (2002), *Dynamic general equilibrium modelling for forecasting and policy*. Contributions to Economic Analysis 256, North Holland, Amsterdam

Hertel, T. (1997), *Global Trade Analysis: modelling and applications*, Cambridge University Press, Cambridge.

Jakeman, G., Heyhoe, E., Pant, H., Woffenden, K. and Fisher, B.S. (2001), The Kyoto Protocol: economic impacts under the terms of the Bonn agreement. ABARE paper presented to the International Petroleum Industry Environmental Conservation Association conference, 'Long Term Carbon and Energy Management - Issues and Approaches', Cambridge, Massachusetts, 15-16 October.

Narayanan, G., Badri, Angel Aguiar and Robert McDougall, Eds. (2012). *Global Trade, Assistance, and Production: The GTAP 8 Data Base*, Center for Global Trade Analysis, Purdue University.

Pant, H.M. (2007), *GTEM: Global Trade and Environment Model*, ABARE Technical Report, Canberra, June

ACIL ALLEN CONSULTING PTY LTD
ABN 68 102 652 148

ACILALLEN.COM.AU

ABOUT ACIL ALLEN CONSULTING

ACIL ALLEN CONSULTING IS ONE OF THE LARGEST INDEPENDENT, ECONOMIC, PUBLIC POLICY, AND PUBLIC AFFAIRS MANAGEMENT CONSULTING FIRMS IN AUSTRALIA.

WE ADVISE COMPANIES, INSTITUTIONS AND GOVERNMENTS ON ECONOMICS, POLICY AND CORPORATE PUBLIC AFFAIRS MANAGEMENT.

WE PROVIDE SENIOR ADVISORY SERVICES THAT BRING UNPARALLELED STRATEGIC THINKING AND REAL WORLD EXPERIENCE TO BEAR ON PROBLEM SOLVING AND STRATEGY FORMULATION.