Evaluating economic models to forecast regional socioeconomic impacts generated by unconventional fossil fuel extraction

Economic Assessment and Forecasting Project (Milestone #4 Report)
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Executive summary

This summary report was prepared as part of the GISERA Economic Assessment and Forecasting Project. It presents the outcome of a review of available techniques for modelling future local economic effects of the CSG industry during the expansion and ongoing operations phase. The report builds on an earlier milestone which presented a synthesis of past economic research on the initial construction phase of the CSG industry in southern Queensland. The objective of this report is to explain and assess the different modelling approaches which have been identified and discussed by the research team to forecast local socioeconomic impacts of the upstream CSG industry in coming decades. These three approaches are:

1. Input-Output tables

2. Computable General Equilibrium modelling

3. Econometric approaches.

Each of these modelling options has empirical strengths and weaknesses, which we briefly discuss in this report. Each modelling approach was considered in relation to the following factors:

- Appropriate scale
- Data availability/salience
- Modelling timeframe
- Ability to tailor to Project Reference Group (PRG) priorities
- Value for money.

In developing the report, the project team drew on the experience and input of the Project Reference Group to ensure that the modelling approach selected is best suited to the needs of key GISERA stakeholders, which include academia, industry, state government and federal government. In addition, the consultation process involved direct input from GISERA representatives who are in direct contact with communities living in close proximity to the industry, so that the needs of local services and businesses could be considered when deciding which framework was most appropriate.

Each of the modelling options has different potential and limitations to forecast impacts across regions. After considering the needs of diverse stakeholders, the project team found the econometric modelling approach to be most appropriate. The principal advantage of econometrics over other modelling approaches was that it could be tailored to the region and customised to ensure the most locally relevant results. The second most useful approach was found to be computable general equilibrium (CGE), but this is better suited to forecasting outcomes at the state scale, with limited potential to tailor modelling to the region. The least appropriate option was found to be input-output modelling. Input-output models have several empirical limitations – such as the inability to account for negative spillovers or changes in industry innovation over time – that could result in misleading forecasting results in the context of this research.

1 Introduction

As the unconventional fossil fuel (UFF) industry grows rapidly across the world, an increasing number of researchers have addressed its diverse implications for local economies (Fleming et al., 2015a). In many places the industry is entering into a phase of maturity. Construction activities and large initial investments are decreasing, so questions arise as to how the industry will contribute to economic activity across the regions where it operates once it becomes fully operational in coming years. Given the lack of studies looking at future projections for regions hosting UFF activity, in this report we synthesise and discuss the potential for, and limitations of, different economic tools to estimate likely future impacts of UFF activity in local economies.

The main research question that this project attempts to answer is given by '*What are the likely effects of the CSG industry, and its transition from construction to operational phase, on different socioeconomic indicators such as direct employment, indirect employment and income, in the Surat region from 2016-2036?'* The socioeconomic effects to analyse will depend heavily on internal and external factors that are likely to affect the evolution of the CSG industry in the Surat Basin. Among the factors affecting the industry, important issues include: (1) changes in international commodity (gas) prices, (2) the degree to which workforces reside locally compared with commuting workforces, and (3) technological changes which decrease the number of well pads per unit of area. This report summarises the usefulness of economic models for this type of forecasting exercise and expands on the alternative of using a bottom-up approach that could include factors affecting the behaviour of the CSG industry in the medium to long term, aiming to better capture the consequent socioeconomic effects on regional areas of Queensland based on different scenarios.

1.1 Report outline

This paper is structured as follows. The next section is subdivided into three components analysing three common approaches to modelling economic activity and making projections: input-output tables, computable general equilibrium models and econometric approaches. These are discussed, assessing their usefulness and limitations when forecasting regional impacts. Section three discusses the three economic model options in the context of the CSG development in southern Queensland and evaluates their usefulness using a ranking system and five different selection criteria. Section four summarises and concludes.

2 Forecasting regional economic activity: three potential approaches

This section discusses the potential and limitations of three commonly used economic models: input-output (I-O) tables, computable general equilibrium (CGE) and econometrics.

2.1 Input-Output tables

I-O tables record interdependency across sectors in an economy (Gretton, 2013). They track flows of labour, capital, resources and immediate commodities, both domestic and imported, which are used by individual industries; as well as sales of products to other producers and consumers, both local and foreign (see Table 1). Therefore they can be used to estimate the primary impact of exogenous interventions on an industry's production, employment and value-added, the secondary impact on its upstream (supplying) industries, and the tertiary impact on all industries along the supply chain.

		Processing Sector						Final Demand					
	Outputs[1] → / Inputs[2] ↓	(1) A	(2) B	(3) C	(4) D	(5) E	(6) F	(7) Gross inventory accumulation (+)	(8) Exports to foreign countries	(9) Government purchases	(10) Gross private capital formation	(11) Households	(12) Total Gross Output
Industry Producing: Processing Sector	(1) Industry A	10	15	1	2	5	6	2	5	1	3	14	64
	(2) Industry B	5	4	7	1	3	8	1	6	3	4	17	59
	(3) Industry C	7	2	8	1	5	3	2	3	1	3	5	40
	(4) Industry D	11	1	2	8	6	4	0	0	1	2	4	39
	(5) Industry E	4	0	1	14	3	2	1	2	1	3	9	40
	(6) Industry F	2	6	7	6	2	6	2	4	2	1	8	46
Payments Sector	(7) Gross inventory depletion (−)	1	2	1	0	2	1	0	1	0	0	0	8
	(8) Imports	2	1	3	0	3	2	0	0	0	0	2	13
	(9) Payments to government	2	3	2	2	1	2	3	2	1	2	12	32
	(10) Depreciation allowances	1	2	1	0	1	0	0	0	0	0	0	5
	(11) Households	19	23	7	5	9	12	1	0	8	0	1	85
	(12) Total Gross Outlays	64	59	40	39	40	46	12	23	18	18	72	431

[1]Sales to industries and sectors along the top of the table from the industry listed in each row at the left of the table.
[2]Purchases from industries and sectors at the left of the table by the industry listed at the top of each column.

Figure 1. A Hypothetical Input-Output table. *Source*: Miernyk (1965)

This modelling technique is easy to use and relatively inexpensive to complete with software packages such as IMPLAN in the US. Therefore, it has long been a widely-used analytical tool in consulting, industry and government. I-O models are generally employed by industry and governments to measure job spillovers or multipliers from a particular industry.

Although a common way to appraise ex-ante local multipliers of particular programs, policies or industry expansions in local economies, several economic studies have claimed that I-O models are unlikely to generate meaningful results. The I-O approach relies on several assumptions that generally jeopardise its usefulness (Gretton, 2013). One important issue with I-O models is that they rely on the strong assumption that each industry maintains a fixed input structure. In other words, inside the model a producer cannot substitute among inputs in response to technological and/or price changes (ACARP, 2014). I-O models also assume that regional factor supplies (including labour) are perfectly elastic (Weber, 2012), which is usually untrue. In other words, the I-O approach assumes that there is unlimited labour and capital available at fixed prices, so changes in demand for products will not induce any change in their cost. A third important assumption is that I-O assumes away all resource and budget constraints on producers and households, which is untrue and generally leads to unrealistic results (Kinnaman, 2011). A fourth limitation of I-O is that they are based on identity equations that define contemporaneous relationships, limiting their usefulness to predict changes over time and to understand causal relations during expansion and ongoing operations phases (Kilkenny and Partridge, 2008).

Given its assumptions and linear nature, I-O models always produce positive multipliers, which is critical when evaluating its usefulness for assessing the impact of labour demand changes exogenously generated in local economies (like those resulting from mining activity). Thus, this approach would neglect potential employment effects in tradable goods sectors that, based on local resource curse theory, can be negatively affected by labour crowding-out – that is, out-migration of labour from manufacturing and agriculture to mining sectors. Thus, they overlook potential job losses in the tradable goods sector caused by increases in labour costs, and any jobs gained by agglomeration economies (Moretti, 2010). In addition to these limitations, the I-O approach is also constrained by the availability of data at an appropriate scale.

2.2 CGE models

The development of computable general equilibrium (CGE) was intended to overcome some of the aforementioned limitations of I-O tables (Miller and Blair, 2009). CGE models conceptualise the basic I-O table as a competitive equilibrium of the commodity and factor markets, so that producers minimise their costs by optimising the input bundle while households maximise their utility by optimising the consumption bundle. The optimisation process is guided by the change of market prices, the 'invisible hand', as well as technological progress, given the resource and budget constraints (see Figure 1). As such, CGE models extend the I-O tables to account for the price and technology induced substitution of inputs in production as well as of commodities in consumption. Moreover, CGE models preserve the cost linkage between inputs and outputs, and therefore offer a systematic framework to evaluate the impacts of government interventions, such as income taxes and the redistribution of resource windfalls. This allows the approach to capture the wider and longer-term economy wide effects. Among its usefulness, CGE models can provide a channel to quantify the interaction between the socioeconomic system and biophysical systems (see Figure 1). This is an important feature to allow integrated assessment of the impacts of UFF.

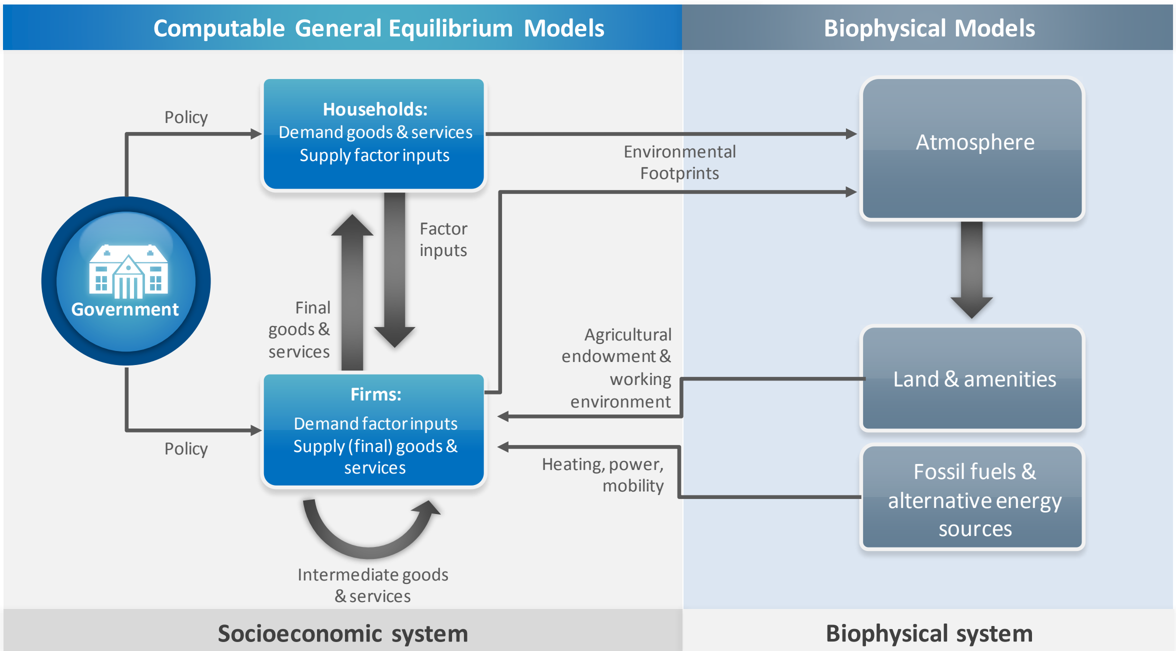

Figure 2. The CGE framework Source: Adapted from Cai et al. (2015)

However, CGE models also have their limitations. First, CGE models are built upon a large system of structural equations, which predict behaviours of producers and households across regional contexts. This requires a host of parameters, for instance, on local migration elasticities, commuting elasticities, and firm elasticities with respect to changes in input prices (Partridge and Rickman, 1998). Second, CGE models are based on data from I-O tables. Therefore, they are subject to the same problem of data availability as the I-O approach, which makes them hard to implement in regional contexts where detailed industry and input price data are generally scarce. This adds to the difficulty and cost of applying cross-regional CGE models, which explains its most common use in national (or state) level economic analyses. Thus, in general, CGE are more suitable when decision makers are interested in the impact of a project/program/policy at a higher level (e.g. state or national scale) rather than at local/regional economy level (ACARP, 2014).

2.3 Econometric approaches

Econometrics is perhaps the most common empirical method employed by academic and research economists. This is due mainly to its straightforward and relatively inexpensive use compared to CGE. Econometric modelling does not require a large set of equations and many statistical packages can produce estimates for complex modelling specifications. Econometric models are also flexible to use, as many indicators and parameters can be estimated as long as models follow economic theory and empirically coherent assumptions.

Econometric models are also widely used for impact evaluation, where researchers evaluate the impact of certain policies or interventions in affected regions (treatment areas) compared to a set of regions that have not received the evaluated intervention (control areas). In this domain several techniques exist to overcome sampling issues (for instance when researchers only observe a handful of units receiving treatment) and other empirical considerations. In other words, many alternatives exist within econometric modelling approaches to overcome limitations given by data, small samples and other empirical concerns.

One disadvantage of using econometric specifications is that forecasting ability is limited by time series trends and extrapolation. In other words, the forecasting capacity of econometric methods is given by the estimation of parameters using real (ex-post) data, which are then used to simulate impacts given particular future scenarios. Another disadvantage is that econometric approaches will not track the interaction between multiple industries as CGEs and I-O models formally include every industry, clustered into sectors, and consider how changes in one sector influence another sector usually at a state or national scale. Conversely, econometric approaches will generally go deeper on a smaller number of selected key industries, allowing the ability to focus on the effects of a particular industry and at an appropriate scale.

On the other hand, one main advantage of econometrics is its flexibility to predict changes in different indicators (different dependent variables can be analysed) and the several techniques that exist to overcome data and sample limitations in cross-regional contexts. Another advantage is that, given its flexibility and relative low opportunity cost to use, econometrics can easily be tested as background modelling for bottom-up approaches based on scenarios and/or projections given by experts, industry, government or other stakeholders. In other words, econometric specifications can be tailored in order to analyse indicators of interest and obtain specific parameters that can later be used to model data obtained from expert consultation, industry/government projections and similar future scenarios. Thus, given the difficulty of obtaining detailed industry and input data at regional scale, the flexibility of econometric models takes advantage of any available data to support the estimation of parameters to inform a bottom-up approach.

3 Application of forecasting tools for the upstream CSG industry

The regional economic effects of the construction phase of CSG have received special attention in different research (Fleming et al., 2015b). However, the continuous expansion and progressive shift from the construction phase to the operational phase of the CSG industry holds many uncertainties in the medium to long terms, including potential new business opportunities, declines in some economic sectors and shifting demographics. All of these require careful planning based on the best available information. This project attempts to address these gaps by providing an economic tool to forecast potential local socioeconomic impacts of the upstream CSG industry operations phase.

It is not an easy task to obtain a reliable economic forecast. Forecasts will always have some degree of uncertainty as certain parameters can change unpredictably (other non-modelled sectors of the economy can change, affecting forecasting estimates) and assumptions may be violated. The process is even more complex when the desired forecasting is applied to regional non-urban contexts shaped by resource extraction activity and limited data are available.

In Australia I-O tables are conventionally produced only down to state level, though in some cases regional planners have their own input-output data, but these differ in quality and availability, time and sectoral coverage, making it difficult to harmonise data from different regions. As a result, I-O models are likely to present limitations when used for economic impact analysis of projects across many small sub-state regions such as statistical local areas. As discussed above, I-O models are also unreliable in this project's context as the exogenous nature of CSG extraction activity (or mining in general) affects key assumptions of the model, therefore making it very likely to produce misleading forecasting outcomes (Kilkenny and Partridge, 2009; Kinnaman, 2011; Weber, 2012).

There exists an Australian multi-regional CGE model called the Monash Multi-Regional Forecasting Model (MMRF) (Adams et al., 2010). This model distinguishes up to eight Australian regions, six States and two Territories, but relies on a simple downscaling facility to calculate output and value-added at the statistical division level. Another version is The Enormous Regional Model (TERM), which adds to MMRF by providing finer regional divisions (Horridge, 2011). However, the regional data are derived based on a crude assumption that 'industry technologies do not vary by region'. The downscaling facility of MMRF and the homogeneity assumption of TERM cast shadows on the precision of applying CGE models for regional studies, especially for a relatively new industry spread across different small regions, such as CSG upstream activity.

Econometric methods have been used to evaluate the economic impacts that upstream CSG activity has had in local extractive regions (Measham and Fleming, 2014; Fleming and Measham, 2015). Although these studies present 'ex-post' analyses, their approach can be modified to obtain parameters for use in forecasting. In other words, econometric specifications can be tailored in such a way as to generate parameters of key economic indicators to use in quantitative analysis of scenarios and/or projections to estimate cross-regional forecasting of CSG local economic impacts. However, as with I-O and CGE, econometrics will also present limited options to forecast structural changes at regional level; i.e. because of data limitations econometric will also have restricted capacity to forecast economic effects given by changes in the operation of a new industry such as the CSG. However, given its modelling flexibility, an econometric panel model can be tailored more so than I-O or CGE to support a 'bottom-up' approach that could capture changes in the CSG industry based on companies' reports and scenarios on different factors affecting industry decisions and investment (see section 3.2. below for more detail on the bottom-up approach).

3.1 Assessment of options based on identified criteria

In the following section important aspects of each model, as previously discussed, are summarised in terms of the five different selection criteria used in this project.

Scale:

- Input-Output modelling can be suitable where project impacts are localised and the simplifying assumption of an I-O model can realistically be accepted.
- CGE modelling is better suited to higher scales (state or nation).
- Econometric assessments are the most flexible for customising to different scales.

Data availability/salience:

- Although I-O tables exist for several sub-state regions, some key variables for CGE analysis, such as 'sectoral capital use', are not available.
- By employing linear regression models, econometric reduced form models can use different regional data to estimate impacts, not constrained by the more formal structures of I-O, CGE and microsimulation modelling approaches. The project team conducted a preliminary review of available data and concluded that the data available at a regional level appears to be reasonably diverse for trying different econometric estimations.

Modelling timeframe:

- The most appropriate timeframe is to match the 20 years timeframe used in industry projections (e.g. Energy Skills Queensland, 2014).
- Considering their forecasting limitations, each of the three approaches can provide results, although the dynamic components of CGE allow more consistent simulations over the long term. I-O would provide the least consistent projections as initial model parameters are generally not dynamic.

Value for money:

- CGE is the most expensive option due to its complexity and size.
- Econometric modelling is the least expensive option because it is easy to run using inexpensive software and there exists a vast literature on options to model natural gas impacts on local economies (Fleming et al., 2015a).

Ability to tailor to PRG priorities:

At the Project Reference Group (PRG) meeting (26 October 2015), the project team were asked to consider how well each modelling approach was capable of incorporating the following stakeholder-defined priorities:

- if the oil price moves outside of the range for which gas production remains profitable
- the relative mix of resident/commuting workforces, and
- the potential application of multi-well pad technology which would reduce the total number of well pads for the same number of wells.

No model presents the perfect situation to address these priorities; however, its flexibility and relative low opportunity costs supports the use of econometrics as a background economic tool to generate inputs (parameters) to a bottom-up approach to forecast likely effects of the industry across regional Queensland considering the priorities of the stakeholders (see section 3.2). Table 1 summarises the advantages and disadvantages of using I-O, CGE and econometrics in the context of forecasting local economic impacts of upstream CSG activity in coming decades be assigning ranking values.

Table 1. Ranking of assessment criteria by model option

Assessment criteria	Input-Output	CGE	Econometric
Appropriate scale	Equal 1	3	Equal 1
Data availability/salience	2	3	1
Modelling timeframe	3	1	2
Ability to tailor to PRG priorities	3	2	1
Value for money	2	3	1
Overall rank	2	3	1

3.2 A bottom-up approach to forecast economic impacts from a changing CSG industry

The main aim of this research project is to provide insights and a better understanding of how the dynamics of the CSG industry will affect local economies in coming decades. Thus, given the complex nature of the behaviour of the industry (heavily dependent on factors such as the international price of gas), the most practical approach to forecast CSG industry activity in the medium to long term would be based on companies' reports and projections, especially on labour demand changes such as the ones reported by Energy Skills Queensland (2014). These industry data, plus projections for different scenarios that may include international gas prices, industry projections for drilling activity, structural costs and labour use for well servicing, well pad technology, drilling and maintenance, and other scenarios (and assumptions) for factors such as water use/supply projections given by CSG activity and the use of long distance commuting work forces, will be put together in a cross-regional bottom-up approach model that, supported by modelled economic estimates and regional data, will produce quantitative scenarios (forecasts) of likely socioeconomic impacts of CSG development.

Given the limitations of I-O and CGE to obtain meaningful results for impacts across small local economies in regional Queensland, and the less expensive nature and flexibility of using ex-post econometrics methods to inform regional parameters, we propose that the best approach to provide an insightful forecast of economic impacts is given by integrating the cross-regional bottom-up approach model to an econometric specification that can include parameters on different socioeconomic changes due to CSG activity in regions of Queensland.

One key issue to address in the cross-regional bottom-up approach model is the differentiated socioeconomic effects that the construction phase of the CSG industry could have in comparison to its operational phase. To capture these differences, it is proposed to take advantage of past data showing well activity and employment to differentiate the socioeconomic impact that the industry has had in the last decade (2001–2014) across early and recent intervened regions. Thus, using panel econometric models, it will be attempted to measure the different socioeconomic impacts of the industry (given, for example, by different parameters of job multipliers) based on the time the CSG extraction has been present in a region – the earlier the presence of the industry, the more fully operational it will be. The parameters will be then used in the cross-regional bottom-up approach model to produce the scenarios to forecast and thus provide information on the potential socioeconomic effects of the industry across regions in 20 years time.

4 Summary and conclusion

Each of the modelling approaches considered has strengths and weaknesses. However, after considering the needs of diverse stakeholders, the project team found econometric modelling to be the most appropriate. The principal advantage of econometric modelling over other approaches was that it could be tailored to the region and customised to ensure the most locally relevant results. A review of the available data indicated that this strength could be readily utilised. The second most useful approach was found to be CGE, however, this is better suited to forecasting outcomes at the state scale, with limited potential to tailor the modelling to a region and address specific questions raised by the Project Reference Group. The least appropriate option was found to be input-output modelling, which has fundamental limitations, such as an inability to account for negative spillovers or changes in industry's inputs use (substitutability) over time.

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