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Predicting the Impacts of Road Investment on Gross State Product and Employment

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Abstract

There is a vast literature concerning the effects of public investment on productivity and growth of transport infrastructure A review of the literature highlights considerable controversy regarding the usefulness of particular modelling approaches and the validity of conclusions attributed to various econometric and general equilibrium methodologies

While social benefit-cost analysis provides information concerning the welfare effects of alternative road proposals, governments and road planners are often interested in the impacts of infrastructure investment in terms of other outcomes. A methodology is proposed which can predict within reasonable limits the impacts of road projects on Gross State Product and employment, and as a by-product, regional output and employment. The information provided by the model complements that provided by social benefit-cost analysis The proposed methodology is an integrated input-output/ econometric model

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Introduction

The micro-economic reform process in Australia has focussed attention on a wide range of issues concerning the efficient use and provision of investment in both public and private sectors. In the roads sector standard issues concern the efficient pricing of roads; road funding arrangements; and the "optimal" size and efficient allocation of budgets.

Interest in the investment problem has also given rise to discussion and empirical work concerning beneficial impacts of investment in road infrastructure beyond those that accrue directly to road users. There are various reasons for this interest. Some are concerned solely with efficiency issues while others include an interest in such matters as employment and equity effects.

An interest in employment and equity impacts of road infrastructure investment can be viewed as part of the utility function of road authorities required to assist their respective state governments achieve employment objectives and consistent with the "public benefit" test linked with micro-economic reform and Australia's new competition policy.

This paper is concerned with modelling the impacts of state road authority investment on gross state product and employment. The remainder of the paper is divided into 5 sections. The first section provides a background statement of issues concerning, inter-alia, the arguments for adoption of a methodology which predicts output and employment impacts of alternative road investment strategies, to be used along with the traditional social benefit-social cost (SBCA) technique.

The second section provides an outline of the modelling procedures that can be used to predict impacts of alternative road investment programs on Gross State Product (GSP) and employment over a planning period of say, ten years. A non-technical description of the models are presented. The approach recommended is a dynamic model, which requires econometric modelling, combined with input-output analysis

The penultimate section identifies the data requirements of the model. The final section provides a conclusion.

Background

There is a vast literature directed to the broad subject of evaluation of public investment in infrastructure. In recent years much of this attention has focussed on impacts of public infrastructure investment on productivity and growth, and not surprisingly, on the impacts of transport infrastructure investment, especially roads (Gillen, 1994). The issues examined include the effects of road investment on private sector productivity, regional development, export industry competitiveness and regional growth and employment.

The analysis of these issues has also given rise to considerable debate regarding the usefulness of particular modelling approaches and the validity of the conclusions which have been attributed to various econometric and general equilibrium approaches, especially to estimates of rates-of-return on investment It is not our intention to review this literature here However, some technical matters concerning modelling procedures, which this literature raises, would need to be addressed should these procedures be implemented.

One important methodological issue that does require brief mention here concerns the limits of social benefit-social cost analysis as a guide to investment planning and the role of other methodologies in assisting policy making.

Often mentioned limitations of SBCA include problems associated with the measurement of benefits and costs for which markets do not exist (e.g. environmental effects), problems associated with measuring the efficiency impacts of large projects on related sectors of the economy and issues concerning income distribution effects of projects.

Suffice it to say that a properly constructed and applied SBCA framework for roadwork evaluation is of paramount importance for determining the effects of alternative road programs on economic efficiency It is clearly important for road authorities to keep abreast of improvements in the use of the technique and especially of developments in the treatment of risk and uncertainty, and the valuation of environmental impacts and other externality and spillover effects Where welfare effects cannot be assigned a monetary value (or acceptable values estimated) and income distribution consequences are important for policy makers, other approaches may need to be adopted to identify and record these outcomes. Thus some commentators would argue that benefit-cost analysis should be confined to an analysis of all project-related effects which can be measured in monetary terms in an unambiguous manner.

Aside from problems of valuation of various benefits and costs, the SBCA methodology has been subject to scrutiny and critical comment on other grounds. These criticisms also provide a rationale for the use of other methodologies along with benefit-cost analysis to assist in public policy decision making.

One frequently cited objection to total reliance on SBCA is that the methodology does not capture all of the effects of proposed investment programs In economists' jargon, SBCA usually employs a partial equilibrium framework In some cases large projects have significant impacts on resource use in other sectors of the economy. In principle a general equilibrium model is required to measure the welfare (efficiency) effects on these sectors. How well this can be done depends on many factors, not least of which is data availability and the ingenuity of the model builder

In addition to the above difficulties, decision-makers are likely to be interested in an even wider approach and the adoption of other methodologies that meet that requirement. While SBCA provides information concerning the implications of adoption of different road programs for efficiency in resource use, governments and road planners are often interested in the impacts of infrastructure investment in terms of other outcomes These outcomes include the impacts of different road investment programs on state product and employment, and regional output, employment and income. Put another way, decision-makers may wish to have a wider test of "public benefit" than is provided by application of SBCA alone, and irrespective of whether a partial or general equilibrium framework is adopted in the application of SBCA.

The development of a methodology which can predict within reasonable limits the impacts of alternative road investment programs on GSP and employment and, as a by-product, regional output and employment, would clearly provide valuable information to complement that provided by SBCA.

How that information is used depends on the objectives of policy. A few brief comments are made. It is assumed that the relevant authority bases its road expenditure decisions on the achievement of multiple objectives. Accordingly, the application of a model designed to predict the employment and output impacts of alternative road investment programs by size and by location (e.g., rural and urban) may assist road-planning decisions in a number of respects. Some of these are noted as follows:

- Information on the impacts of road investment on GSP and employment may assist the authority in obtaining additional funding allocations. However, it is noted that the models described later in this paper do not enable a comparison of the impacts of road investment on GSP and employment to be made with the impacts, on such variables, of alternative forms of government expenditure, eg. health. This would require a more complex modelling approach and that is something a State Treasury, for example, might wish to investigate and develop.
- There may be conflict between the results obtained by SBCA appraisal of projects and the employment implications of alternative road projects. For example, a project with a low B/C ratio might generate high levels of employment, at least in the short run. In other word, employment can be generated by upgrading and expanding sections of the road network even though the efficiency benefits as measured using SBCA may be very small or negative. Application of SBCA within a wider modelling framework can thus help to identify opportunity costs where choices have to be made between conflicting policy goals.
- Various projects may have different impacts on regional development. The differences in regional development may not match differences in B/C ratios
- Expansion of road investment in one region may result in contractions in employment in other regions.
- Road investment programs intended to promote GSP may not be consistent with short-term employment objectives
- Different road projects (by size and location) may have different impacts on internationally traded and non-traded goods sectors of the state economy with different implications for state product and employment

As indicated, the point of listing some of the possible outcomes of alternative road expenditure programs is to highlight the importance of developing macroeconomic type models of the type discussed later in this paper. The complementary nature of the SBCA methodology and state/regional (macroeconomic) model of the relationship between infrastructure expenditure and GSP and employment may assist road planners and government to estimate the trade off between conflicting outcomes where these arise.

Such procedures should enable improved decision making in the context of a wider test of "public benefit".

Impact assessment methodologies

There are two main macroeconomic modelling approaches, in addition to SBCA, which are relevant to the objectives of road planners. These are: (1) applied general equilibrium (AGE) models, and (2) integrated input-output/econometric (IOEC) models.

The debate has raged for some time about the pros and cons of the two approached (see, eg, Beaumont, 1990; West, 1995), and does not appear to be abating (and in all likelihood will continue for some time yet). Yet it seems that in some respects, the methodologies are slowly merging, even it the extent they can produce similar results (Dixon and Peter, 1996).

This section briefly describes the underlying differences between these two modelling approaches, firstly in terms of their structures and secondly in terms of their philosophies.

Model structures

Input-output/econometric: Integrated models acknowledge that each model type displays a unique set of characteristics, both good and bad, and attempts to splice the different modelling approaches in such a way so as to enhance the strengths and minimise the weaknesses. Both input-output (IO) and econometric (EC) models have strengths and weaknesses. The strength of IO lies in the detailed interindustry accounts, the weaknesses are first-degree homogeneity, constant technology, and unlimited capacity. Econometric models, on the other hand, are generally dynamic with the parameters specified as elasticities, but lack industry detail. The perceived advantages of integrating these two methodologies is to construct a model which produces a dynamic, non-linear picture of economic change in a detailed interindustry framework.

How the input-output and econometric models are integrated depends to a large extent on the modeller's objectives. Rey (1998) recently reviewed a number of integrated IOEC models and suggests a taxonomy of integration strategies; coupling, embedding and linking. The coupling strategy is the most comprehensive requiring the development of a full set of final demand accounts that permits a high degree of model closure and interaction between the IO and EC components. Embedding utilises prior information from an IO model to achieve parsimony in the specification of the EC model without the specification of a full set of final demand accounts. In the linking strategy, the output from one module provides the input into the other module in a recursive fashion. In this paper, it is taken that the IOEC models of interest are of the coupled variety.

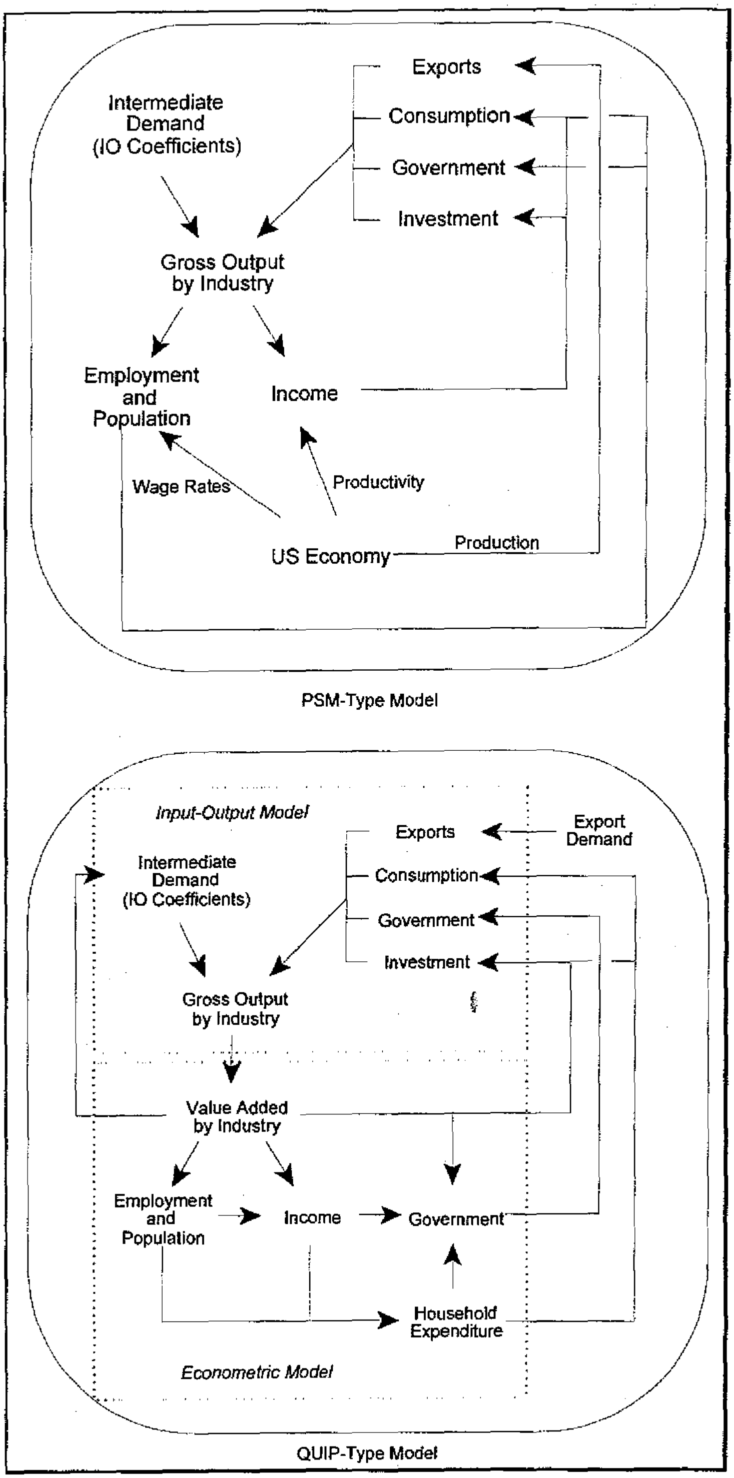

Figure 1. Schematic Overview of Input-Output/Econometric Model

Within the coupled classification, it is possible to identify two basic approaches. In the United States, the most widely implemented framework is that established by Conway (1979, 1990), and adopted by the other organisations, e.g. Regional Economic Applications Laboratory, in the early 1990s, as a means of providing an impacts and forecasting capability with a strong regional flavour (see, e.g. Israilevich *et al.*, 1994). Similar models have been constructed for the States of Washington, Illinois, Iowa and Ohio, and metropolitan areas including Chicago, Cincinnati and Columbus. Collectively, this classification of model is referred to here by the generic term Projection and Simulation Model (PSM).

The IO table does not exist as a separate entity within the PSM model. Rather, the IO coefficients only exist indirectly in the form of parameters of a subset of econometric equations. The PSM is therefore similar to more conventional regional econometric models, both in terms of overall structure and in terms of individual equation specification. Thus, in common with other regional EC models, the PSM is primarily a forecasting tool.

An alternative formulation of a coupled IOEC model is the Queensland Impact and Projection Model (QUIP) (West, 1994). In contrast with the PSM specification, QUIP retains the explicit structure of the IO model and its classical output solution, $\boldsymbol{X} = (\boldsymbol{I} - \boldsymbol{A})^{-1}$, with the econometric relationships integrated into the primary input and final demand components. The QUIP model thus retains the character of a conventional IO model. An overview of the two model structures is given in Figure 1. A more detailed comparison of these two models is provided in West and Jackson (1999).

Applied general equilibrium: Equilibrium implies a balance between economic variables, such as income and expenditure, or demand and supply. While IO represents a simplified form of equilibrium (it has been demonstrated that, particularly under 'small region' assumptions, the AGE solution converges to the IO solution; see, e.g. McGregor and Swales, 1994), applied general equilibrium models are intended to capture a wider set of equilibrium relationships than the IO or IOEC models. In short, they provide an alternative closure mechanism to the IOEC model. This is achieved through endogenising prices. See, e.g. Dixon, *et al.* (1992) and Shoven and Whalley (1992) for a detailed exposition of AGE models.

The starting point for the AGE model is the IO table. Each transactions flow is disaggregated into its two components, price and quantity. Because real prices are rarely known, one possibility is to set the benchmark price level at one. This means that the AGE model assumes that the benchmark IO table is a physical quantities table measured in unit prices. Then any exogenous shock will produce price changes measured as relative price changes from unity.

Each producer in a regional industry chooses its inputs so as to minimise its costs of production subject to a multi-layered production function, as shown in Figure 2. At the first level, there are two broad categories of inputs, intermediate and primary, which are used in fixed proportions to output, i.e. using Leontief technology. This is due to the structure of the IO table, which is constructed on the assumption that inputs are homogeneous and non-substitutable, e.g. one does not normally substitute food products for steel products.

The inputs at the first level are composite goods which in turn consist of sub-inputs, i.e., bundles of commodities which make up the broader category. The second level production function allows for the non-linear substitution between sub-inputs. At this level, a CES function is commonly used, although other functions can easily be specified. Thus, for example, intermediate inputs consist of both locally produced commodities and imported commodities, which are combined in the cost minimising manner. In other words, the relative quantities of imported to locally produced commodities used depends on the relative prices and the elasticity of substitution. This is often referred to as the Armington (1969) model.

Similarly, primary inputs, consisting of labour and capital, would be combined so as to minimise cost, depending on the elasticity of substitution between labour and capital. This can be extended further by breaking down capital into imported and local, and labour could be disaggregated into different skill categories in a similar manner.

The closure of an AGE model has both an accounting dimension and a behavioural dimension. Firstly, there are zero pure profit equations which ensure that revenue from the sale of goods and services equals their costs, and secondly, there are the market clearing equations in which demand and supply are equated for each commodity produced. These equations imply that total income equals total revenue in the region. There are also additional accounting equations required to handle international trade and the balance of payments.

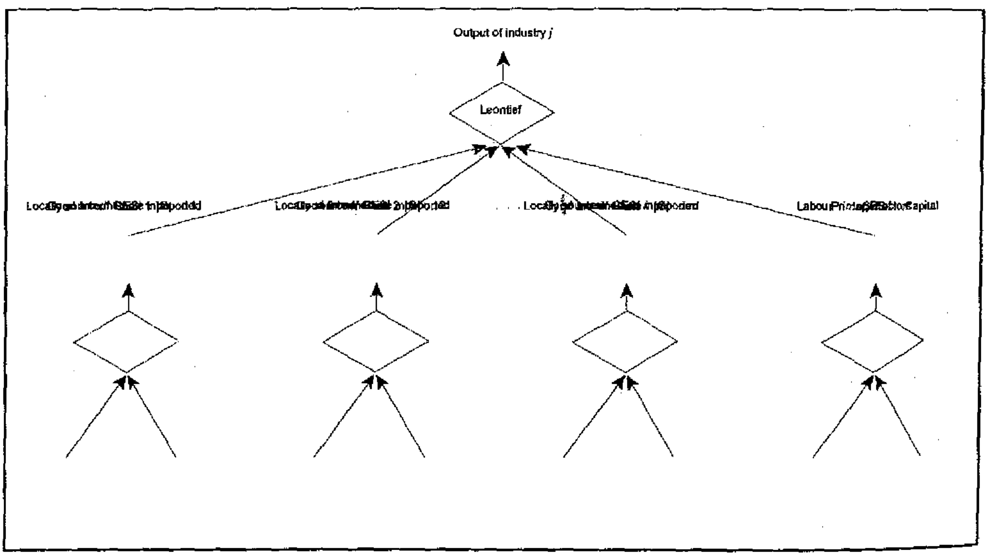

Figure 2. AGE Production Technology

Solving the AGE model can be a complex affair. They are highly non-linear which, when combined with the size scale of the models (the MONASH model of the Australian economy contains several million equations; Dixon *et al.*, 1982), can result in the need for complex solution techniques. One possibility is to attempt to solve the equations using numerical optimisation methods, another is to transform the equations into a linear, percentage-change form and solve using matrix inversion.

Comparison of the models

From the above exposition, it is now possible to clarify and summarise the differences between the two modelling approaches. These differences are substantial and arise more from two diametrically opposed philosophies than anything else. In this section, these differences are compared and summarised.

Structural differences: The major difference between IOEC and AGE is the estimation of the parameters of the structural equations defining primary factors and final demands and the closure mechanism. In the IOEC formulation, dynamics plays a major part. The dynamic structure of the IOEC model enables the temporal adjustments of economic change to be analysed. They attempt to track the time path of the economy, including business cycles, rather than simply providing a comparative static picture. For this purpose, they are commonly linked into national forecasting models. Because they use variable coefficient IO tables, they are ideal for capturing the marginal adjustments over time, and both impact (short-run) multipliers and dynamic (long-run) multipliers can be calculated and the cumulative effects of dynamic impacts which occur over several years can be analysed.

Philosophical differences: The second major distinction of the AGE and IOEC models is the fundamental philosophical difference between the methodologies. The AGE model relies heavily on neoclassical theory and all that implies; perfect competition where markets operate without friction, full capacity and full market clearing of all goods and services, and perfect or near-perfect knowledge. Equilibrium generally does not occur in the real world, but this does not necessarily make general equilibrium analysis invalid. The aim is to provide an insight into the interaction between the micro and macro economic processes under perfect or near-perfect competition. Being comparative static, they provide an indication of the 'optimal' reallocation of resources after the economy is subjected to an exogenous shock.

Advocates of IOEC-type models shy away from the neoclassical paradigm in favour of partial-or non-equilibrium market behaviour. Production can operate at less than full capacity and without market clearing. They would argue that the market never reaches full-equilibrium; at any point in time it may be moving towards an equilibrium but that point is never reached before it veers off in a different direction due to continual unforseen shocks, both within and external to the economy. They see the actual time path as being more important than ideology.

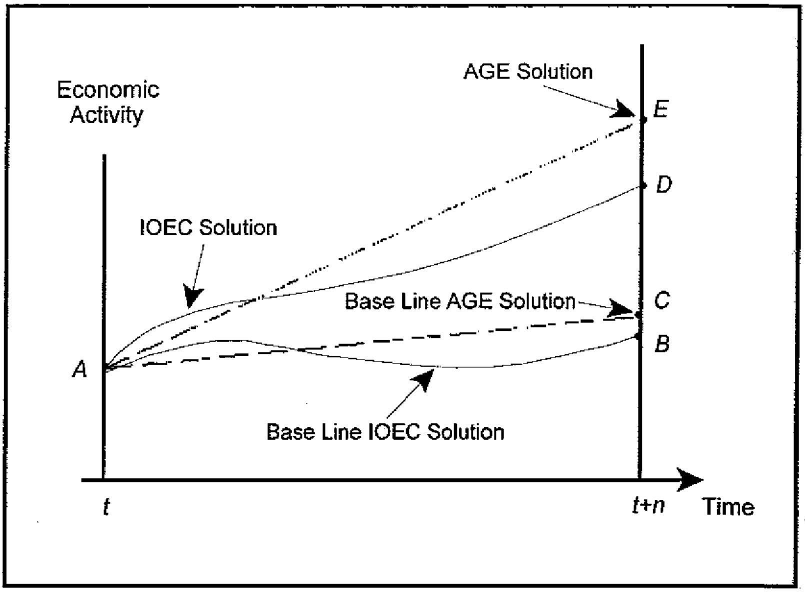

Figure 3. AGE and IOEC Solution Paths

This distinction is highlighted by Figure 3. At time *t*, the economy is at point A. The AGE model calculates the (base-line) economy will be at point C after time *n*, whereas the IOEC model tracks the time path of the economy to point B. Now suppose the economy at time *t* experienced an exogenous shock. Point E represents the new 'optimal' solution as given by the neoclassical assumptions. This is normally expressed as the percentage change in economic activity, (E-C)/C*100, which is why it is called a comparative-static model, but does not tell us anything about the path taken to get to E. The IOEC model, on the other hand, tries to plot the path taken to get to the new solution D, which, theoretically, should be closer to the actual (although perhaps non-equilibrium) solution.

Small region considerations: How the region of interest interacts with the surrounding regions and nation as a whole effects the model specification. It will impact on the region in two main ways; through prices and through interregional trade. If the region is small, this can greatly simplify the specification.

Generally, the main link with the outside world is prices, i.e. local prices relative to foreign (external) prices. In the small region assumption, it is assumed that the region on its own is too small to affect the terms of trade; in other words, the region is a price taker so external prices become exogenous. Local supply and demand still interact and determine relative local prices, but these prices will gravitate to the given external prices, subject, of course, to transport and other margins.

Note the similarity with the IO model. The IO model is an equilibrium model in the sense that demand and supply are forced to equate to each other. From the dual problem, it is possible to calculate relative prices, but there is no feed-back mechanism back to quantities, i.e. local prices are assumed to have no effect on local production. But local prices will adjust to the external prices if imports are perfect substitutes for local commodities. This is called the strong small country assumption, i.e. where local prices are set equal to the given (predetermined) world prices (This implies that there is a question of aggregation involved. If there is some product differentiation between local and imported commodities, the strong small country assumption may not be suitable). This implies that (a) local demand does not affect the foreign prices for imports, i.e. the extra-regional supply curves are infinitely elastic, and (b) local supply does not affect the world price of exported goods, i.e. demand for exports is infinitely elastic. However, if the region produces a relatively large proportion of the world output for a particular good, then assumption (b) may not be appropriate (at least for that good).

The strong assumption also implies that the region cannot have a trade deficit or surplus, because of the GDP identity. In the standard AGE model, hoarding of money or spending on credit is not permissible. This also generally applies to labour, i.e. excess demand for labour is zero.

This implies that constructing an AGE model for a small region, while not invalid, may to some extent not be a very efficient use of resources. Given the considerable difficulties associated with parameterising a large number of coefficients and parameters when there is virtually no local data available, the increased 'fuzziness' may more than offset the increase in model sophistication. In such cases, the old maxim of 'simple models for simple economies' may be worth keeping in mind.

Data implications: Irrespective of the model category, the primary data base is a regional input-output table. Australia is fortunate in that are a number or organisations, both private and government, producing high quality regional IO tables based on extensive region-specific data.

Apart from the IO table, the IOEC data requirements are mainly time-series. Here again, Australia is fortunate having full sets of annual state accounts on which to base its equations. Virtually all econometric equations in the QUIP model, for example, are estimated using region-specific data. However, small regions would impose substantial hurdles in this regard.

The standard AGE model does not use time series data, but in many ways its data requirements are even more stupendous. Of particular concern is the prespecification of numerous elasticities of substitution, between local and imported inputs, labour and capital, local and imported capital, and different skill categories of labour to name but a few. These are in addition to various capital and other adjustment coefficient matrices. With an almost complete void of regional empirical data to base these estimates on, 'best guess' values must be used.

It is clear that small regions pose significant data implications on both models. Generally speaking, the smaller the region, the less available and less reliable are the data. Both the AGE and IOEC models suffer in this respect, and there is no doubt that a rich region-specific data set clearly opens the door to a wider range of modelling possibilities. But here again, econometrics appears to provide the more reliable guide as demonstrated by Conway's (1979) Washington model which has not required major respecification over two decades of use and ex-post validation.

Desirable modelling framework

This section tentatively recommends features that an integrated framework for modelling the impacts of road investment should exhibit. It is clear that that both model types discussed in the previous section exhibit desirable properties, yet experience indicates that, in spite of strong competition between the two modelling camps, little attempt has been made to reconcile or integrate the two approaches As both approaches have obvious strong points, this would appear to be the next logical step in model development.

The unique characteristics of road investment and its impact on gross regional product and employment necessitate careful attention to the model development for road planning Road investment has a much longer tail with respect to both construction expenditures and flow-on impacts to the surrounding area For example, a new arterial link to a port facility will impact on the global and local economies for many years as local development takes advantage of the new facilities. General equilibrium models, lacking real-time dynamics, are not well suited to analysing these problems.

It is tentatively suggested that an 'ideal' model should possess the following properties:

- It should be a bottom-up model, not just a scaled down version of the national economy. For example, the west Queensland town of Longreach and the metropolitan region of Logan south of Brisbane have completely different characteristics, both in terms of labour composition and economic structure. These characteristics cannot be identified using national averages, but require detailed region specific information.

- Possess both impact and forecasting capability, to take into account future trends and machinations of national and international markets.

- To adequately explain real world phenomena, particularly short-term adjustment processes which are an important characteristic of road investment, dynamics has to rely heavily on econometric analysis, but supplemented by general equilibrium constructs.

- Comprehensive supply-side specification, if possible supplemented by real word data on capacity limits. Prices should be endogenised to adequately explain resource reallocations in impact scenarios.

- Structural change needs to be clearly identified by separate component, i.e. relative prices, technological change and import substitution, to allow for analysis of differential effects on the local economy of road investment.

- Full integration with the national economy with feed-back interactions to measure both region-specific and national policy impacts at the region level. Ideally this would encompass an interregional model to measure interregional flow-on effects to surrounding regions. Gains in one region can be offset by losses in another region.
- A fully comprehensive labour market sub-model, taking into account differential skills, labour turnover and mobility.

These properties strongly indicate that the model should be based on an IOEC framework. In particular, the short-run dynamics of road investment programs can only be adequately represented through this type of structure. However, it is also possible to utilise general equilibrium constructs, particularly in the long-run specification of the model.

It is also clear that such a modelling system would need to be tailor made for the problem at hand. Given the unique characteristics of road investment and its effect on local and state economies, no current general purpose IOEC or AGE model would fit the bill. Thus modelling road investment to determine its impact on GSP and employment requires an investment in its own right.

There is one other point which so far has not been mentioned. Input-output based models are, by their nature, deterministic, although there have been several attempts to develop the stochastic properties of the model. This remains an important research issue for the future. The integration of econometric methods which are stochastic lends support for this line of research.

Road investment expenditure requirements

One further point needs to be briefly addressed. Presupposing the model described in the previous section can be constructed, to effectively answer the question of what would be the impact on GSP and employment arising from alternative funding strategies on a state run roads network over, say, a 10 year period within the suggested modelling framework, the following minimum data are required.

For each funding level, and for each year of the study period, expenditures by major category by region for each combination of road set (e.g. national highway, state highway, rural road) are required in the form of Table 1.

In addition, if the expenditure items are sourced in a region different to that in which they are used, this will need to be identified. For example, the amount (or proportion) of bitumen products used on road construction/maintenance in the South East Queensland Region which are sourced from the South East Queensland Region, other regions within Queensland, or even from outside Queensland, will need to be clearly defined.

Table 1. Expenditure in Year X on Road Set Y at Funding Level Z

Expenditure Item	Region 1		Region 2		Region 3		Region 3	
	U	R	U	R	U	R	U	R
Raw Materials Bitumen Rock fill Oil products								
Services Water Gas/Electricity Transport Communication Maintenance								
Labour Costs Plant operators Professional								
Total Expenditure								
Labour Plant operators Professional								

Conclusion

This paper has outlined the essential features, advantages and disadvantages, and data requirements of two main macroeconomic modelling approaches which are relevant to the interests of road planners and government policy makers in assessing the impacts of road investment on regional development, employment and State gross product. It is our view that adoption of the IOEC approach is probably the best option for State Treasuries and road agencies. We also emphasise that such modelling procedures are not a substitute for proper application of SBCA in the evaluation process. The two approaches are complementary. Development and application of macroeconomic modelling procedures are, in this context, intended to provide additional information concerning impacts of road investment on such matters as employment and regional development. Adoption of the two methodologies should enable trade-offs between policy objectives to be more accurately determined, and result in more informed decision-making.

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