TOWARDS AN INTERREGIONAL FRAMEWORK FOR JOINT ASSESSMENT OF TOURISM AND THE ENVIRONMENT

Guy R. West
Regional and Urban Economics Research Unit, Department of Economics, University of Queensland, Brisbane, Qld. 4072, Australia.

John R. Roy
ETUDES (Environmental, Transport and Urban Development Studies), Mallacoota, Vic. 3892, Australia.

ABSTRACT The CSIRO, in co-operation with major stakeholders in the tourism industry and related academics, recently initiated a project to investigate the long term viability of tourism and assess its impact on the economy and environment. This project is called Tourism 2020. Within the Tourism Futures sub-project, a decision was made to develop a decision support framework to specifically handle the nexus between tourism and the environment in an economy-wide interregional context. This paper describes the proposed model which is based on the existing interregional input-output and econometric model for Queensland and enhanced with a price-sensitive supply model which can evaluate the effects of both supply and price shocks, such as restrictions on the usage of certain facilities due to potential environmental degradation and related transport and facility pricing. The modelling framework is an attempt to extend the CGE model structure to encompass various forms of disequilibrium, especially those caused by effects such as sunk investments in infrastructure and lags in the provision of facilities to meet changing demands. It is believed that such a product fills a niche between the important CGE studies of national tourism or tourism for a single State, and more local studies of a single region. Whereas infrastructure development policies and environmental capacity restrictions are often specific to single regions, they can generate significant spill-over effects on tourism in adjacent regions.

1. INTRODUCTION

It is now generally accepted that tourism is an integral part of the Australian economy, with all state governments competing aggressively for the tourist dollar. For example, in Victoria alone, expenditure by domestic and international tourists in 1992 amounted to $5.2 billion and $785 million respectively, which accounted for approximately 5 per cent of gross state product and provided jobs for over 100,000 people (Tourism Victoria, 1994). A similar story applies to Queensland where international and interstate tourist expenditure accounted for approximately 4.7 per cent of gross state product in 1994 (Queensland Treasury, 1996). In the same year, international tourism contributed over 1.6 per cent to gross national product.

At the same time, tourism activities have come under closer scrutiny with respect to their long term sustainability and environmentally interactive and sensitive nature.

Eco-tourism is just one form of (supposedly) sustainable, ecologically friendly tourism to arise from comprehensive analysis of the tourism industry, both in Australia as a whole and by regional tourist organisations, which attempts to match tourism demands with limited resources. This has resulted in improved data bases and understanding of tourist requirements and behaviour, as well as how tourism-related activities are integrated within the wider economic system. It has enabled tourist organisations to improve marketing services and to identify and respond to tourist needs, as well as the needs of the environment.

At the same time, it is important to understand how tourism activities interact with the wider economic framework, as support industries, such as trade, transport and manufacturing, can benefit from and in turn improve the economic viability not only of tourism, but of local communities in general. For example, decision makers at the state and national levels tend to overestimate the benefits accruing to an area from international tourists compared with those from domestic or local sources. Furthermore, the benefits arising to a region from day trippers are often underestimated or ignored completely because of "expenditure switching" arguments, although there is little evidence to suggest the extent of this expenditure switching. It is unlikely that the impacts would be neutral because different expenditure *patterns*, as distinct from aggregate expenditure, will result in different multiplier effects. In any case, irrespective of such speculation, it is important to get a handle on actual tourism activity in the regions, irrespective of its source, as a guide for decision makers who want to know the size of the tourist industry associated with different tourist types and what sectors are the main sectors affected by these activities. The supply of adequate infrastructure to accommodate local day-tripping recreational fishermen is just as important to the sustainability of a small coastal resort as supplying high quality resort accommodation and facilities to attract international tourists to say Cairns or the Gold Coast.

Late last year, the CSIRO in co-operation with major stakeholders in the tourism industry and related academics initiated a project to investigate the long term viability of tourism and assess its impact on the economy and environment. This project is called Tourism 2020. In the Tourism Futures sub-project, a resolution was made to develop a decision support framework termed CREATE (Capability for Regional Economic Assessment of Tourism and the Environment) to specifically handle the nexus between tourism and the environment in an economy-wide interregional context.

Desirable properties for this decision support system were deemed to be:

- It should be bottom-up, which allows for region-specific impacts to be measured at the sectoral regional, state wide or national levels, and national or state policies to be measured at the sectoral regional level.
- It needs to be price-sensitive to enable modelling of environmental shocks and constraints.
- It should be dynamic to enable lagged responses to changes in local and national factors.
- It should have the ability to model short-run partial or non-equilibrium adjustments reflecting firms and operators having incomplete information on

optimal strategies.

- It should be non-deterministic in nature to allow for endogenous estimation of parameters on real-world observations.

It follows from the above that the model must have a spatial, i.e. interregional, dimension with regions of interest aggregating to the state and ultimately to the nation. It should also have a fair degree of sectoral or interindustry disaggregation to enable reasonable identification of impacts.

In the following sections, existing regional models are briefly reviewed before deciding on an appropriate modelling strategy for the Tourism Futures sub-project. The framework is at a relatively early stage of development, and suggestions from participants are welcome.

2. ALTERNATIVE MODELLING STRATEGIES

There have been numerous studies of the economic impact of tourism in Australia. The models used range from naive economic-base type models through to highly complex computable general equilibrium (CGE) models like ORANI (or its later derivative, MONASH). However most studies of the economic impact of tourism at the regional level have been based on partial equilibrium conventional IO analysis (see, e.g. West and Bayne, 1990), probably because of the ready availability of regional IO data and the relative ease of manipulation of the IO model by regional practitioners. Unfortunately, conventional IO analysis has several limitations. In addition to its linear static nature, it is both deterministic and not directly price-responsive. This implies not only that it is incapable of handling price shocks (which may be an element of future environmental policy), but also that it cannot apply environmental capacity constraints which may be needed if certain fragile areas start to become degraded due to a heavy concentration of visitors. Similarly, there are no provisions to handle lags in the supply of relevant infrastructure.

At the national or state levels, some of these problems are potentially surmountable by running a CGE model. The CGE model, whilst incorporating supply constraints into the model, does so through the use of neo-classical assumptions; namely perfect competition, full market clearing of all goods and services, perfect knowledge in the market place, and full mobility of resources (labour and capital). The equilibrating mechanism between supply and demand is prices, including wage rates. It is better suited to a national-type closed economy (at least is the sense of discernible external trade barriers, notwithstanding the restrictive neo-classical assumptions) operating at full capacity.

At the regional level, CGE modelling exposes its own unique set of problems, mainly attributable to the relative openness of the regional economy, in addition to a lack of adequate regional accounts upon which to base the model. Generally, the smaller the region relative to the nation, the more open will be the economy, and the smaller will regional demands be relative to available supplies elsewhere in the nation. Unless the region dominates the production of certain products, local prices will gravitate to the external price levels (taking into account transport margins). Consequently, it is less likely that the conditions of (local) general equilibrium will hold. At best, we will observe a partial equilibrium situation[1], at worst the economy will lurch from one disequilibrium to the next in response to factors outside the region over which it has no control.

It is obvious that in order to capture the regional characteristics which the CGE model is intended to replicate, it is important to incorporate interregional feed-back effects. This in turn requires some obscure information, such as interregional substitution elasticities. Given the difficulties experienced with estimating elasticities at the national level, this would appear to be a major problem with the reliability of the CGE model at the regional level. Thus interregional CGE models are rarely seen in Australia, although they are somewhat more common overseas[2].

Finally, the CGE model is comparative static and deterministic, and thus suffers from the same criticism as the IO model. The deterministic profit-maximizing framework of all these classes of model does not allow for endogenous estimation of parameters on real-world observations, reflecting firms and operators having incomplete information on optimal strategies. Local versions generally impose a market-clearing equilibrium, rather than allowing certain levels of disequilibrium to exist, including lags between changes in demand and the associated supply response. In addition, there is no in-built mechanism for handling environmental capacity constraints. If the economy is allowed to respond to non-equilibrium conditions, then a more sophisticated model of the linkages is required that would, among other things, introduce a dynamic structure to capture the response through time as the economy is subjected to external shocks.

A relatively new extension to the field of regional modelling is the input-output / econometric (IOE) or 'integrated' model, although the notion of integrating the two techniques has been around for some time[3]. The aim is to retain the detailed sectoral disaggregation of the IO system and close it using a system of endogenous non-linear econometric relationships. This closure forms the basis of the feedback mechanism between primary factors and final demand. An application of this methodology to tourism analysis is given in West (1993).

Compared to the conventional IO and CGE models, the integrated modelling approach appears to have an advantage in several respects. It is not restricted by the linearity requirements of the basic IO model, nor its static limitations. The integrated model attempts to track the time path of the economy, including business cycle fluctuations, rather than just giving an optimising comparative-static picture. More often than not, this class of model uses variable-coefficient IO tables, which are better able to capture the marginal changes over time resulting from price changes, technological change and changing returns to scale.

The integrated model is not cocooned within the neo-classical framework. It

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[1] In such situations, the IO model has been demonstrated to converge to the far more complex CGE model (see, e.g. McGregor and Swales, 1994).

[2] Kraybill (1992), e.g. reviews ten bottom-up multi-regional CGE models in the U.S.

[3] National IOE models have been around for about three decades (e.g. the INFORUM project was initiated in 1967; see Almon, 1991). Well known regional models include the Washington model (Conway, 1990), the REAL family of models (e.g. Israilevich *et al.*, 1994) and the San Diego model (Rey and Dev, 1996).

does not assume perfect knowledge of the marketplace, nor require full market clearing. However, prices are still determined endogenously. Like the CGE model, but unlike the IO model, the integrated model is extended into a social accounting matrix (SAM) framework in order to capture transfer payments other than just wages and salaries. In other words, the model captures all income transfers, including social security and unemployment benefits, aged and invalid pensions, income taxes and other taxes and deductions (which influence domestic tourism). Other variables such as government revenue and expenditure, and capital expenditure are also endogenised. It therefore presents a more complete picture of the economy than the conventional IO model, without the limiting assumptions of the CGE model.

It would appear from general observation that the integrated modelling approach, supplemented with a capability for incorporating environmental capacity constraints at the interregional level, satisfies the Tourism 2020 requirements. In Roy (1997), a price-sensitive supply model was formulated which, whilst only needing regional input-output and transport data, is calibrated to actual observations. The coupling of the above supply model with the interregional version of the input-output/econometric model of West (1994) has been chosen as the preferred type of framework for the Tourism Futures sub-project of Tourism 2020.

In the next section, a more detailed outline of the West model is described. This is followed by a discussion of Roy's new supply model, not only as an important component within an interregional economic analysis, but more particularly as a way of incorporating the regional and sectoral interactions between tourism, the environment and the economy.

3. THE INTERREGIONAL INPUT-OUTPUT / ECONOMETRIC MODEL

The model on which this study is based is a derivative of QUIP. The Queensland Impact and Projection Model (QUIP) is a 5-region, 15-sector interregional model of the Queensland economy. It represents the latest in a series of developmental models for Queensland which started with exploratory work in 1988 for the Queensland Treasury (see, e.g. West and Jensen (1989), Dewhurst and West (1989), and West (1991, 1994)). QUIP specifically addresses the demo-economic integration of regional input-output and econometric methods as applied to the Queensland economy.

In addition to the usual employment-related production, the Queensland model explicitly incorporates the contribution to local economic activity from unemployed and economically inactive household consumption of local goods and services. Households should have the ability to move from one category to another in response to an economic stimulus, growth or decline in the economy. Other non-wage income, such as distributed profits, social security payments, etc., also become important, as well as population growth over time, both via natural fertility and through migration. The Queensland model is an attempt to meet these requirements.

In simple terms, the demo-economic structure of the QUIP model can be represented as in Figure 1. The regions are shown in Figure 2. The 15 industrial sectors are: 1) Primary, 2) Mining, 3) Food manufacturing, 4) Wood and paper

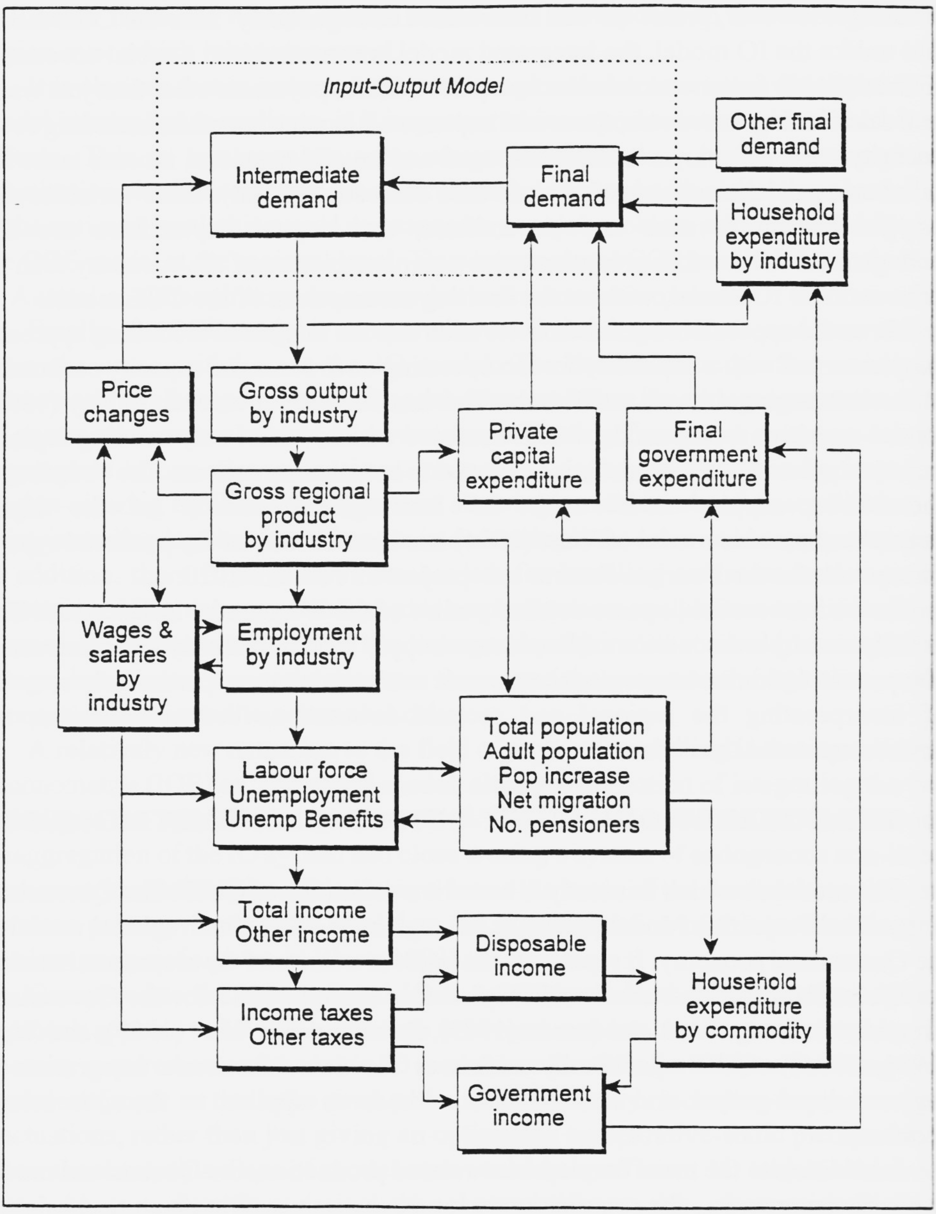

Figure 1. Schematic Representation of QUIP

manufacturing, 5) Machinery, appliances and equipment, 6) Metal products, 7) Non-metallic mineral products, 8) Other manufacturing, 9) Electricity, gas and water, 10) Building and construction, 11) Wholesale and retail trade, 12) Transport and communication, 13) Finance and business services, 14) Public administration, defence and community services, and 15) Recreation and personal services.

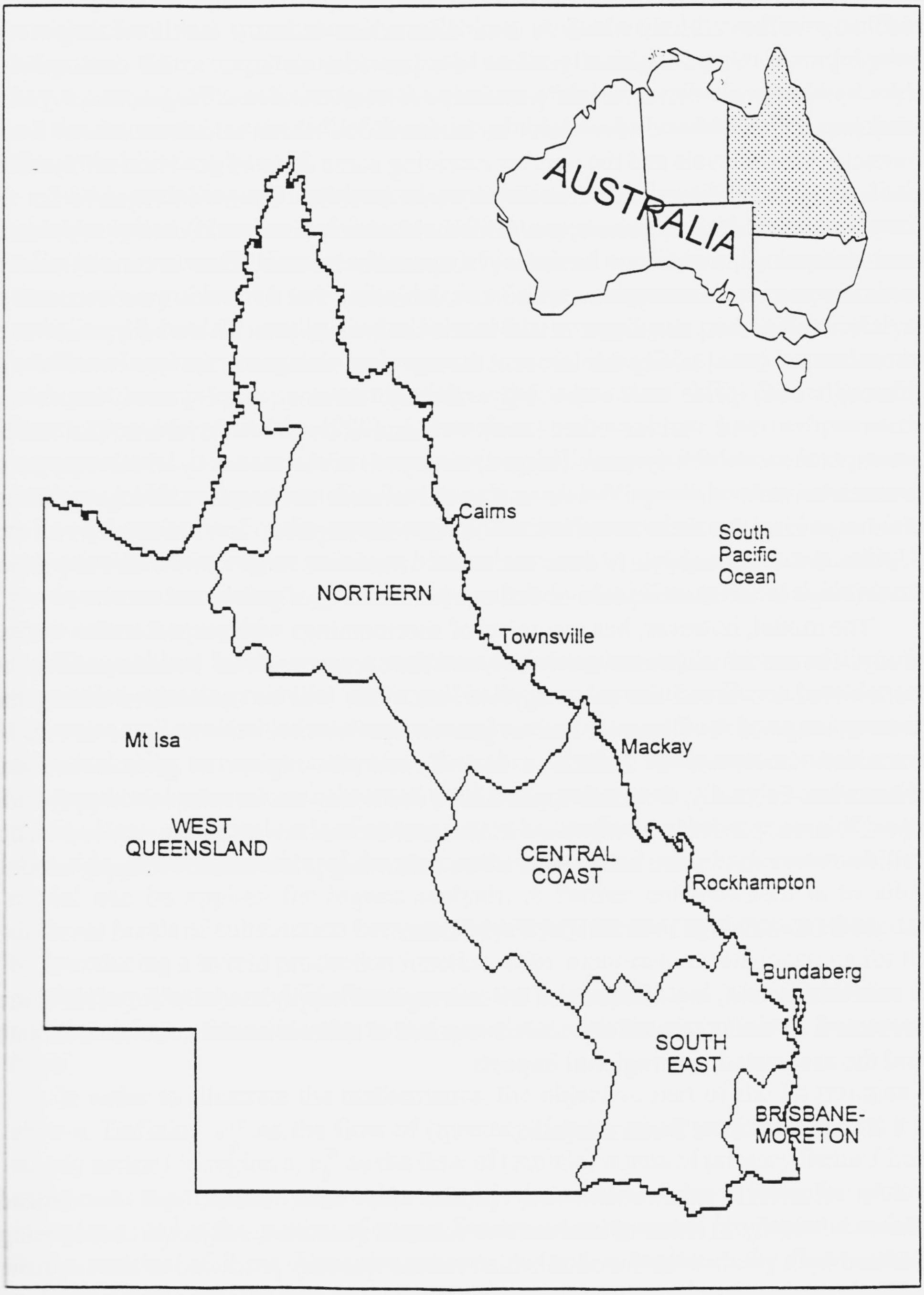

Figure 2. The Regions of Queensland

The closure mechanism is a set of endogenous econometric relationships using both cross-sectional and annual data. Industry output levels provide estimates of industry value- added, which in turn determines industry levels of wages and employment. Gross regional product also provides an input to the demographic block, which calculates various population related variables. Wages, employment and population statistics feed into the labour block which calculates labour force, unemployment levels and the number receiving some form of government benefits, including social security and unemployment benefits. These are required for the income block which calculates total household income, income taxes and other taxes and deductions, and hence household disposable income. This in turn is used to estimate private consumption expenditure, including that for tourism and recreation.

It is a dynamic, non-linear model in which the base year IO model is rolled over on an annual basis, taking into account the marginal changes in the input coefficients (through both price and technology effects), income, employment, household consumption and various other (such as demo-economic) variables. The model attempts to model the dynamic (lagged) time path of the economy which may be in a continual state of disequilibrium as it tracks towards continually shifting *equilibria, thus capturing the short term fluctuations* in consumption, investment, labour, etc. Unlike the CGE model, it does not make restrictive assumptions about perfect knowledge in the marketplace or full market clearing of goods and services.

The model, however, has a number of shortcomings with respect to the current study. The model is Queensland-based, and the current regional boundaries may be considered too broad for some applications. This will be maintained during the current stage of development and progressively extended in later stages. It will be extended, however, to include a rest-of-Australia region to give a national dimension. Secondly, for some applications, there may not be adequate supply-side specification, particularly when environmental factors are taken into account. This will be overcome by the integration of the following price-sensitive supply model.

4. PRICE-SENSITIVE SUPPLY MODEL

In this section, key elements of the interregional supply model of Roy (1997) are presented, as well as the enhancements required to address tourism, the environment and the associated interregional impacts.

4.1 Probabilistic vs Deterministic

In classical microeconomics, profits for each sector are maximized deterministically in terms of intermediate demand quantities, subject to output being defined by a production function which relates quantity produced to the requisite (efficient) quantities of inputs (Binger and Hoffman,1988). However, even if firms were perfectly competitive and possessed perfect information, the necessary aggregation of (non-identical) firms into sectors and regions for practical analysis would in itself yield departures from the deterministic solution, which is based on identical representative firms. Furthermore, such an optimization approach does not permit estimation of any parameters in relation to 'observed' revenue and costs, reducing its relevance for empirical analysis. Finally, at the regional level, individual establishment data is not usually available to evaluate the IO coefficients. Thus, rather than their computation being based on the classical IO production function, they are usually obtained simply as the quotient of the respective intermediate input and the associated output. All of the above problems can be addressed by adoption of a probabilistic approach.

In the modelling of final demand, probabilistic random utility theory has been widely applied (Hensher and Johnson, 1981), supported by preference surveys of individual consumers. However, because of perceived confidentiality requirements, firms are very reluctant to release details of their competitive performance. As a result, supply models usually need to be based on an aggregate probabilistic analysis in terms of appropriate sectors and regions. A useful interdisciplinary procedure for such problems is entropy maximization or the 'equivalent' MPS (Most Probable State) approach of Smith (1990). Although such an analysis is carried out at the aggregate level, it is based on an enumeration of all the possible micro level events associated with an aggregate distribution, with each such micro level event assumed to be equi-probable. For the supply model, the fundamental micro level event is an individual firm in a region making a bilateral contract to supply a certain quantity of goods or services (within a given sector) to an individual firm (or household) in the same or another region.

The problem is set up as a mathematical program, with the constraints for estimation denoting relevant 'observed' base period quantities for each sector and region, as well as observed total revenue and costs computed from price and quantity data, including transport costs. Note that, the inclusion of separate constraints on observed total revenue and observed total costs, rather than a single constraint on profit, allows different levels of uncertainty to be handled on the revenue side vs the cost side. After estimation of the parameters associated with each constraint, the model can be applied for impact analysis. A further enhancement is to allow different levels of substitution between the primary factors (eg. labour and capital) by introducing a hybrid production function, with input-output relationships for the production sectors and CES functions for the primary factors. This introduces an additional form of non-linearity to that associated with the probabilistic framework itself.

In order to illustrate the mathematics, the objective part of the Lagrangian is shown. Defining x_{ij}^{rs} as the flow of (quantity) inputs of sector *i* from region *r* to supply sector *j* in region *s*, z_{lj}^{rs} as the flow of (mobile) inputs of primary factor *l* from region *r* to supply sector *j* in region *s*, N_i^r is the number of input firms for sector *i* in region *r*, N_j^s is the number of output firms producing sector *j* in region *s* and E_l^r is the number of input firms for primary factor *l* in region *r*, the flow entropy problem (Roy, 1997) for the case of inequality supply constraints (see later) is given as

$$\text{Max}\, Z_a = \max\{x_{ij}^{rs}, z_{lj}^{rs}\} - \sum_{ijrs} x_{ij}^{rs}\left[\log\left(\frac{x_{ij}^{rs}}{N_i^r N_j^s}\right) - 1\right] - \sum_{ljrs} z_{lj}^{rs}\left[\log\left(\frac{z_{lj}^{rs}}{E_i^r N_j^s}\right) - 1\right] \quad (1)$$

which is a strictly concave function.

4.2 Special Properties of Input-Output Relationships

It turns out that the classical input-output production function is discontinuous, with the classical result for input demands identified as a 'corner' solution. Under these special circumstances, prices disappear from the deterministic input demand functions. In addition, in contrast to the case for other production functions, where input demands are obtained absolutely and re-substituted into the production function to yield the corresponding output, the input demands for input-output are just known relatively, as proportions of an (as yet) unknown output. The implication is that input-output does not generate the price-sensitive supply functions associated with the other production functions and is thus not directly adaptable to situations such as assessing the impacts of price shocks.

Whereas the above limitations apply to the conventional input-output model, the probabilistic approach described above retains all prices explicitly. In addition, all input demands are obtained absolutely, as well as the corresponding output. This enables the supply remaining for final demand to be obtained endogenously, by merely subtracting the supply to satisfy the intermediate demands from the total output. In the conventional approach, the supply to final demand is forced to conform with that given exogenously from a demand model or demand scenario. As this latter property requires the inversion of the (I - A) matrix, this task is not required for the probabilistic approach. Instead, in conjunction with the associated interregional demand model (West, 1994), a price adjustment or 'tatonnement' process ensures short run market clearing, similarly to the process adopted for CGE models, albeit at the interregional level and adapted to assessing the interactions between tourism and the environment. In addition, the supply response to changed demand can be 'lagged', introducing the flavour of disequilibrium into the model framework. Whereas the main objective for introduction of the probabilistic model was the potential for improved empirical performance, the simultaneous neutralization of many of the 'pathological' properties of the deterministic model represents an 'unintended' bonus.

As touched on earlier, regional base period IO coefficients a_{ij}^{s} are computed simply as the ratio x_{ij}^{s0}/x_j^{s0} of the observed total inputs x_{ij}^{s0} of sector *i* allocated in region *s* to supply sector *j* divided by the observed output x_j^{s0} of sector *j* in region *s*. Analogous relations enable computation of the primary factor coefficients b_{lj}^{rs} from the observed primary factor inputs *z*. If p_i^{r} denotes the unit price for inputs of sector *i* from region *r*, p_l^{r} the unit price for inputs of primary factor *l* from region *r*, p_j^{s} the unit price of sector *j* outputs in region *s*, with *m* the number of production sectors and *n* the number of primary factors, it is possible to write an expression for the 'observed' total revenue R^0 as follows

$$\sum_{ijrs} \frac{x_{ij}^{rs}\, p_j^{s}}{(m+n)\, a_{ij}^{s}} + \sum_{ljrs} \frac{z_{lj}^{rs}\, p_j^{s}}{(m+n)\, b_{lj}^{s}} = R^0 \qquad (2)$$

and for observed total costs C^0 as

$$\sum_{ijrs} x_{ij}^{rs}(p_i^r + c_i^{rs}) + \sum_{ljrs} z_{lj}^{rs} p_l^r = C^0 \tag{3}$$

where c_i^{rs} is the transport cost per unit of production input i between regions r and s.Note that, (2) and (3) are precisely satisfied when the observed interregional flows x_{ij}^{rs0} and z_{lj}^{rs0} are substituted for x_{ij}^{rs} and z_{lj}^{rs} respectively into their left-hand sides. The modelled results then satisfy (2) and (3) as a whole, without having to reproduce in detail the deterministic result that $(\sum x_{ij}^{rs})/a_{ij}^{s}$ equals a constant (the relevant output) over i - rather, this relation is met *on the average* by division of the sum over i by the length (m+n) of vector i. Similar reasoning applies for the factor inputs z_{lj}^{rs} and the associated regional coefficients b_{lj}^{s}. Of course, if required, the constraints (2) and (3) could be expanded to constraints on the revenue and costs respectively in producing goods of each output sector j in each producing region s.

4.3 Input Supply Capacity Constraints in Impact Analysis

The new price-sensitive input-output model is 'short run', based on the assumption that input supply capacity (including labour) is temporarily fixed. This implies that the actually computed supply must never be greater than this limit capacity. The model handles these short run constraints in two different ways, depending on whether or not the supply for a sector within a region is primarily homogeneous or rather heterogeneous.

For sectors such as mining, where merely one or two major plants may exist in a region, it is reasonable to regard the capacity as homogeneous. In such cases, when demand increases, more and more capacity is uniformly brought into operation until suddenly the total capacity is reached, with no more production then being allowable. This case is handled by introduction of a (less than or equal to) constraint for supplied input with respect to capacity. However, for other sectors such as consumer services, the performance is distinctly heterogeneous, with demand increases being more likely to be absorbed by diverse large shopping and recreational centres than by less efficient groups of 'corner shops' (except for cases of certain niche products). In this case, an increase of demand in a region where efficient capacity is already highly utilized may cause 'spillovers' into the adjacent regions if good quality facilities there are still relatively uncongested. This may well occur in preference to using the lesser quality facilities in the region where the demand increase arose. Also, for the primary factors, such as labour, a strict inequality supply constraint may be unrealistic, with large extra demands for labour not just accessing the pool of the short-term unemployed, but potentially making inroads into the pool of the longer-term unemployed. In such cases, the model applies a 'soft' logistic constraint, yielding a lower propensity to supply more as capacity is approached. In fact, such a constraint acts rather like a compressing spring as more and more of the lesser quality supply is activated, forcing the demand into adjacent regions. Such sectors are typical for the many goods and services providing inputs to the tourism industry. If X_i^r is the short run limit capacity of input sector i in region r and Z_l^r is the short run limit capacity of factor l in region r, the removal of N_i^r and E_l^r from the log denominators of (1) and addition of the expression Y_a to (1) given as

$$Y_a = -\sum_{ir}(X_i^r - \sum_{js} x_{ij}^{rs})[\log(X_i^r - \sum_{js} x_{ij}^{rs}) - 1] - \sum_{lr}(Z_l^r - \sum_{js} z_{lj}^{rs})[\log(Z_l^r - \sum_{js} z_{lj}^{rs}) - 1] \quad (4)$$

yields the total entropy objective for the logistic capacity case. This formulation ensures, that so long as total demand does not exceed the total limit supply over all regions, capacity will never be exceeded in any one such 'logistic' region. In application of this logistic approach, some effort will need to be spent in obtaining data on the limit input supply capacities of each sector/factor in each region.

4.4 Other Required Calibration Information and Corresponding Models

In order to reliably calibrate the model, certain base period row sum and column sum information should be provided in addition to the observed revenue and costs in (2) and (3). For instance, the model should reproduce the observed inputs X_j^{r0} of each sector *i* produced in each input region *r*, as well as the observed inputs X_j^{s0} of each sector *i* available for production in each producing region *s* via the constraints

$$\sum_{js} x_{ij}^{rs} = X_i^{r0} \qquad \sum_{jr} x_{ij}^{rs} = X_i^{s0} \quad (5)$$

Similar constraints exist with respect to the factors *l*. For the logistic constraint case, the model is also constrained to reproduce the observed intersectoral flows X_{ij}^0 over all regions in the form

$$\sum_{rs} x_{ij}^{rs} = X_i^0 \quad (6)$$

with an analogous constraint for the primary factors *l*. If (1) is maximized under the nominated constraints, the following result emerges for the non-logistic case

$$x_{ij}^{rs} = N_i^r A_i^r B_i^s N_j^s \exp[\alpha\{\frac{p_j^s}{(m+n)a_{ij}^s}\} - \beta\{p_i^r + c_i^{rs}\}] \quad (7)$$

where the 'bias' terms A_i^r and B_i^s reflect the Lagrange multipliers on (5) and α and β those on the revenue constraint (2) and cost constraint (3) respectively. For the primary factors, the corresponding result is

$$z_{lj}^{rs} = E_l^r D_l^r F_l^s N_j^s \exp[\alpha\{\frac{p_j^s}{(m+n)b_{lj}^s}\} - \beta p_l^r] \quad (8)$$

These *input demand functions* are seen to be separable, in line with the separable results $x_{ij}^{rs} = a_{ij}^{rs} x_j^s$ of the conventional deterministic interregional model, where x_j^s is the output of sector *j* in region *s*. Whereas inversion of the ***(I-A)*** matrix provides the interdependencies in the conventional model, the interdepedencies here are given by insertion of the supply functions of our model, obtained by substituting the input demand functions into our production function expressed as

$$x_j^s = \frac{(\sum_{ir} x_{ij}^{rs} / a_{ij}^s) + (\sum_{lr} z_{lj}^{rs} / b_{lj}^s)}{(m+n)} \tag{9}$$

into the final demand equations

$$y_j^s = x_j^s - \sum_{ir} x_{ji}^{sr} \tag{10}$$

where y_j^s is the supply of sector j available to final demand in region s. In conjunction with an appropriate model for final demand (see QUIP), the price adjustment (tatonnement) process provides further interdependencies. On the other hand, for the logistic capacity case, the input demand functions, obtained in the form

$$x_{ij}^{rs} = X_i^r A_{ij} B_i^s N_j^s \frac{\exp(\alpha r_{ij}^s - \beta c_i^{rs})}{1 + \sum_{kv} A_{ik} B_i^v N_k^v \exp(\alpha r_{ik}^v - \beta c_i^{rv})} \tag{11}$$

where A_{ij} is the Lagrange multiplier associated with (6), r_{ik}^v the unit revenue and c_i^{rv} the unit costs, are already **non-separable**. Similar results occur in the logistic capacity model for the primary factors. Note that, for the case of inequality supply constraints, relations (5) [and corresponding relations for the primary factors] are now applied as ≤ inequalities with respect to the currently available capacities.

If good data is available for the primary factors, it is possible to establish a hybrid production function, with linear relations between the production sectors supplemented by non-linear relations (eg CES - Constant Elasticity of Substitution) between the primary factors (Roy,1997). The parameters of the CES functions need to be calibrated before such hybrid production functions are inserted into the revenue and cost relations (2) and (3). The resulting non-linearities in the constraints (2) and (3) will merely cause extra computation, not influencing the uniqueness properties of the solution.

4.5 Long Run Provision of New Plant and Facilities

In the long run, new capacity may be created, firms may re-locate or unsuccessful firms may finally exit from the market. This case is usually handled by removing the capacity constraints and adopting a zero profit criterion for all sectors and regions. However, in contrast to the conventional approach, where all prices are relative, the probabilistic models deal with absolute market prices (with one price still needing to be provided exogenously to satisfy the Walras law, eg. the price of capital). This means that the long run criterion is for unit profits to equalize across regions to a value regarded as that necessary for 'survival' in each sector. In this case, no firm will have the incentive to either re-locate or to exit from or enter the market. Although it is reasonable to suppose that the system of regions moves *towards* such a long run equilibrium, it is not very realistic to expect that it ever reaches such a state before being deflected by faster adjusting changes, such as price movements and changes in costs. Thus, in order to evaluate long run dynamic behaviour, it is necessary to obtain data on the speeds of adjustment of long run movements to different levels of profit differentials between regions. After all, sunk investments in less efficient plant and equipment provide a great inertia to upgrading, making states of dynamic long run disequilibrium more likely in practice.

A future option for the combined model is to 'nest' our short run lagged supply/demand model in the slow framework of re-location, capacity increase or decrease, entry and exit (Haken,1983), in which after long run re-adjustment at the end of each chosen time period, the prices and quantities of the short run lagged demand/supply model re-equilibrate before the increment of long run change is evaluated for the next time period. This implies that the path towards long run equilibrium is automatically re-directed at the end of each time period. Although such a recognition of long run disequilibrium seems highly desirable, practical implementation will be a major challenge. The inherent non-linearities in both the short run and long run models may also yield possible bifurcations or chaotic behaviour. For instance, regions with a few high concentrations of tourist activity could, under some circumstances, move towards a much more dispersed pattern.

4.6 Capacity Constraints on Tourism Activity Output

With continuing projected increases in overseas tourism into Australia (so long as tourists of all races continue to feel welcome), it is possible that certain fragile areas will be threatened with degradation, especially if eco-tourism increases more rapidly. Of course, a possible response is to close certain areas in sensitive seasons (eg. the wet season) or to limit the times of day when public access is permitted. Such policies could be supported by 'virtual reality' experiences of these environments, as well as greater provision of pleasant ancillary facilities, such as innovative restaurants and local craft outlets. In addition, for rapidly expanding tourist nodes, lags in infrastructure provision may, in the short run, limit the potential expansion of tourist facilities. It appears likely that such factors will cause (i) some reduction in total demand and (ii) some re-direction of existing demand into adjacent areas and facilities. In any case, it is clear that environmental/infrastructure capacity constraints on tourism output can only be introduced meaningfully in a interregional context, rather than in a model at the State level. At the same time, it will be necessary to segment tourist activity at least into that occurring in 'hard-paved' sites and that related to direct appreciation of nature. In contrast to the capacity constraints on short run inputs discussed in an earlier section, capacity constraints on the permissible output T_j^s of say nature tourism (sector j) in region s should be applied, with guidance from (2), in the following form

$$\sum_i \frac{\sum_r x_{ij}^{rs}}{(m+n)a_{ij}^{s}} + \sum_l \frac{\sum_r z_{lj}^{rs}}{(m+n)b_{lj}^{s}} \le T_j^s \qquad (12)$$

For instance, if the Gold Coast and its Hinterland were considered as a region in an interregional analysis for Queensland, it is certainly necessary to distinguish the activity on the coast itself from the more nature-based activity in the hinterland, with the environmental capacity constraints just applying to the latter. From an economic point of view, it will be necessary to identify hinterland activity as to whether it occurs as 1/2 day or day trips from the Gold Coast or whether it originates from the (currently rather limited) accommodation in the hinterland itself. From an ecological point of view, less transport energy would be consumed if tourists take linked journeys of several days through the hinterland rather than radiating out of the Gold Coast each day. Similar reasoning applies with the Atherton Tableland/Port Douglas/Daintree areas out from Cairns or its northern beaches. In any case, the model implementation will require data surveys to segment the tourist activity between 'paved' and 'natural' areas, as well as identifying the typical mix of these activities by visitors of different ages and income categories, both overseas and domestic. Although at the moment, a typical visitor to the Gold Coast may spend most days on the beach or at Dreamworld etc., these tastes may change in the future, particularly for the younger generation. The models are being set up to assess the impacts of environmental and infrastructure capacity constraints if or when they occur.

5. CONCLUSION

The development of this integrated modelling system is an exciting and desirable addition to the tourism research agenda. Although it is an ambitious project, it is eminently 'do-able', as has been demonstrated by existing modelling practices. What is innovative is the merging of the different approaches in a way which effectively removes many major criticisms of existing models, as well as providing for the first time a realistic insight into the sustainable nature of tourism, the economy and the environment.

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