A SYSTEMS APPROACH TO MODELLING THE REGIONAL ECONOMIC EFFECTS OF ROAD PRICING

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Abstract

The costs of congestion, environmental costs arising from transport-related emissions, and the cost of transport infrastructure provision are major problems in many European countries. These issues are linked, as taxation of transport can both reduce some of the negative externalities, creating a welfare improvement, and it can also provide revenue for construction of more transport infrastructure or subsidy of public transport. Further, revenues from taxation on transport can be used to reduce taxation on earned income, giving rise to a possible double dividend effect. There is growing interest in road pricing as a policy instrument directed at the solution of congestion problems. Road pricing raises a range of questions, both theoretical and practical. The welfare implications of road pricing and the potential distortionary effects of taxation are the subject of discussion. The present paper is a contribution to the study of the regional economic effects of the introduction of road pricing, using Denmark as an empirical example.

Keywords: Road pricing; Congestion cost; Environmental externalities; Denmark
Topic Area: B7 Input-Output System and Transportation

1. Introduction

As road traffic grows rapidly in Europe, the problems which it creates become increasingly serious. Congestion is a major problem in many European countries, largely, though certainly not exclusively, an urban phenomenon. The costs of congestion are considerable, perhaps of the magnitude of 2% of GDP (Gomez-Ibañez 1997, Mayeres & Van Dender 2001). Environmental damage, both local and global, arising from transport-related emissions also represents a substantial and increasing cost, with potentially extremely costly though uncertain consequences. Both problems involve externalities and raise issues concerning the extent to which external costs can and should be internalised (Rothengatter 2000). A further problem is the cost of transport infrastructure provision, which is considerable, whilst its net benefits are difficult to calculate in the presence of externalities (Jansson 2000a). These issues are of course linked, as taxation of transport can both reduce some of the negative externalities, creating a welfare improvement, and it can also provide revenue for construction of more transport infrastructure or subsidy of public transport. Further, revenues from taxation on transport can be used to reduce taxation on earned income, giving rise to a possible double dividend effect (Pearce 1991). Parry & Bento (2001) have recently claimed that recycling tax revenues into transport sector subsidy is markedly less efficient than using the tax revenues to reduce income tax.

There is growing interest in road pricing as a policy instrument directed at the solution of congestion problems, seen as one of a set of alternative measures (Button 1998, De Borger et al. 2001a) as well as being a measure which simultaneously addresses other problems. Road pricing can also be used to internalise environmental damage costs (Johansson-Stenman & Sterner 1998) and there are a number of important issues linking congestion pricing to road and transport infrastructure investment (McDonald 1995, Hau 1998).

Road pricing raises a range of questions, both theoretical and practical. The welfare implications of road pricing and the potential distortionary effects of taxation are the subject of discussion (see for example Arnott et al. 1994, Jansson 2000b, Hau 1998). There are four components of welfare in the transport market: consumer and producer surplus, tax revenues and external costs. Unlike many other markets, time costs must be taken into account when dealing with consumer and producer surpluses. In addition, different surpluses and costs fall typically on different groups. Further, different transport sub-markets are interdependent. For example, reduced congestion through road pricing will increase consumer surplus for users of road-based public transport. Alternatively, improvement of rapid transit and metro systems will confer benefits on car users, through reduced congestion. The welfare gains of road pricing (Proost & Van Dender 1998) seem to be superior to most other forms of regulation of congestion. However, efficiency issues are inextricably linked to the difficult problem of evaluation of social marginal costs. Practical problems are related to the technology to be employed in managing the system, particularly at the user interface, and to the problem of traffic diversion (McDonald 1995). These problems are, in turn, closely related to the recurrent theme of political and social acceptability (Jones 1998, Rietveld & Verhoef 1998, Larsen & Ostmoe 2001).

The European Union and many individual countries are moving towards road pricing as a key element in future transport policy (De Borger et al. 2001b). In Germany road pricing for lorries on motorways, using a GPS-based system was planned to be implemented in 2003 but has been delayed due to up-start problems of technical nature It is to be expected that a number of European countries will follow and that it will be expanded to cover all types of road and possibly in the longer term, all types of vehicle. The European PROGRESS project has established experiments and demonstrations in road pricing systems in 8 different European cities, including Copenhagen (Nielsen 2003, Herslund 2003 on the Danish AKTA sub-project). This increased political interest in road pricing is fuelling research interest in the field. A number of studies have attempted to assess the effects of road pricing on congestion, the environment, tax revenues and welfare in concrete geographical contexts (see De Borger & Proost 2001 for a number of case studies). The studies are usually *ex ante*, as only a few projects have actually been implemented and these are limited in extent and impact. Amongst others, Proost & Van Dender (2001b) have developed an urban model based upon a transport market equilibrium derived from maximisation of a social welfare function which includes the four components named above, and which permits assessment of the effects of different policies on transport supply and demand.

Most of these studies treat transport as an independent commodity, whilst in reality it is derived demand. The spatial configuration of the economy and the development of spatial patterns of economic activity play a substantial role in the pattern and growth of transport activity. This means that road pricing will have effects both on the level and distribution of economic activity and in turn, patterns of regional economic development will affect both the need for, and revenues from, road pricing. There are both efficiency and distributional issues when examining the relationship between road pricing and regional economic growth.

The relationship between transport infrastructure and regional economic development has been examined in a number of studies (see for example, Rietveld & Nijkamp 2000, Jensen-Butler & Madsen 1999). Equity issues, directly related to the distribution of economic activity and population in space, have been the subject of some studies (for example Richardson & Bae 1998). However, there have been few attempts (Madsen & Jensen-Butler 2001 2002c) to include road pricing within a regional or interregional economic model and even fewer in the context of local economic modelling. Eliasson & Mattsson (2001) present one of the few attempts to relate road pricing to location and transport flows, using a simulation model for a city. They conclude that impacts on location seem to be modest, compared with impacts on traffic. In an empirical analysis, using an interregional economic model and Danish data, Jensen-Butler & Madsen (1996) find evidence to suggest that environmental gains from distance related taxation of transport far outweigh income loss.

The present paper is a contribution to the study of the regional economic effects of the introduction of road pricing, using Denmark as an empirical example. The two-stage approach adopted is to model the effects of road pricing on regional economies. The paper covers only the first stage, where a local economic model is used to forecast changes in commodity prices and household income, together with the effects on demand, as a consequence of the introduction of road pricing. At this stage of the modelling process, it is assumed that the underlying behavioural relationships are constant. The second stage, which is not dealt with in the present paper, is to incorporate changes in behavioural relations, transforming the modelling approach in the first stage to a Computable Interregional General Equilibrium model, permitting a more complete analysis of changes in prices on economic activity in a regional system.

2. A systems approach to regional and sub-regional economic modelling

At different levels, international, national and regional, complex problems of analysis and planning of the relationships between specific sectors and the broader economy are emerging. One example of this complexity is the relationship between the transport sector, the broader economy and the environment. Another example is the relationship between agriculture, the economy and the environment. There are two fundamental issues to be examined when considering the nature of the relationship between a specific sector and the broader economy: i) data and accounting principles and ii) modelling approaches.

2.1 Data and accounting principles

Statistics and accounting aim to provide a picture of the complex system. At this level, either the complex system can be represented through a system of national/regional accounts together with satellite accounts for specific sectors, or it can be represented by sector specific statistics which have been extended to include the broader economy. Principles for setting up national/regional accounts together with satellite accounts for specific sectors are provided by United Nations (1993) and the European Union (Eurostat 1996). Similar activities are to be found at sectoral level. The main advantage of the economic system approach is uniformity in statistical framework and therefore, they are comparable and consistent with constraints. However, the basic units of accounting are value, rather than physical units, such as transport volumes and quantities of emissions. Description of physical units, where this appears, is highly aggregated. The main advantage of sector-specific approach is the level of detail with respect to physical components, whereas the value based information in these accounts is more ad hoc, less consistent and highly aggregated.

At the regional and sub-regional levels, the statistical material available is much less developed than is the case for the national level. The statistics relating to the broader economy are based upon local social accounting matrices (SAMs) or local national accounts. Sattelite accounts do not exist at this spatial level, except for tourism, where they are at present being developed. Sector based statistics exist in the form of detailed accounts for agriculture and in the form of ad hoc data bases on transport flows in the case of the transport sector.

2.2 Modelling principles

In terms of modelling, both in relation to the broader economy and individual sectors, several trends seem to be emerging. First, there is a growing interest in the interaction between the broader economy and specific sectors seen from the perspective of the broader economy. Second, modelling the interactions between specific sectors, such as agriculture and transport, and the broader economy, seen from the sectoral perspective, is developing. Broadly speaking, therefore, there are two alternative modelling approaches. Economic system modelling involves modelling the economy as the core question, whilst sectors are treated as additions, usually as a front end or back end sub model, and sometimes as an integrated element in the core model. In Denmark, examples are provided by models such as ADAM (Dam 1995) and AAGE (Frandsen et al. 1995) and in relation to transport see Fosgerau & Kveiborg (2003). Sector-specific modelling on the other hand has as a point of departure, a partial or free-standing model for the sector in question. This model is then usually extended to capture interactions with the broader economy. In Denmark, examples are provided by (Stryg 1992, Hansen 2001, and Madsen 1999).

At regional and sub regional levels the same two issues arise, but in even more complex form.

Stand alone approaches

In relation to modelling activity, a number of analyses of the broader economy have been undertaken. Starting with straightforward single region Keynesian input-output models (Groes 1982, Madsen 1992a), interregional input-output models were developed (Holm 1984, Madsen 1992b), followed by interregional General Equilibrium models (Madsen et al. 2001). Regional sector-specific models have been mainly concentrated in the agricultural and transport sectors. For agriculture, the approaches adopted have included input-output models (Pedersen 1986), linear programming models (Stryg et al. 1991) and econometric models (Jensen et al. 2001, Hansen 2001).

For the transport sector, a number of models have been developed (For an overview see: Madsen 1999). There is a national transport model as well as transport models developed to analyse specific infrastructure investment projects, for example the Femer Belt Link (Trafikministeriet 1999, Jensen-Butler & Madsen 1999) and the Øresund link (Øresundskonsortiet 1997) and upgrading or extending existing rail networks, for example the Ringsted model (Nielsen 1998).

A traditional approach and fundamentally stand-alone approach involves identification of changes in transport flows and changes in direct and indirect (time) costs for travellers. This information is then used to undertake a cost-benefit analysis of the changes in the regulation of the transport system, involving an evaluation of changes in direct costs, time savings and changes in other costs, such as accidents and environmental costs. Normally, the diffusion of changes in the costs of the transport sector to commodity prices and incomes in other sectors is not dealt with. This means that the traditional cost-benefit approach cannot be used for analysis of distributional questions in relation to regions, factors, sectors and household types. In addition, as behavioural reactions from producers and consumers are not included explicitly in the cost-benefit approach, determination of the value of time for different categories of traveller is made exogenously rather than endogenously.

Different approaches to model integration

Treating the general economy and the specific sector as two independent components is theoretically less than satisfactory, as development of the individual sector is partially dependent upon the general economic development and vice-versa. Therefore, there is a need to develop a more integrated approach to the problem.

Four avenues in the development of integrated models at the regional and sub-regional levels are identifiable.

- Extension of sector specific models
- Extension of regional and sub-regional models
- Loosely coupled models (framework approach)
- Fully integrated models

The first can be illustrated by the extension of models specific to the transport sector with regional and macroeconomic elements. An important representative of this approach is use of the established growth factor model in forecasting total traffic flows. For passenger transport, attempts have been made to develop strategic models which include more developed modelling of interaction between the transport system and the broader regional economy including migration and commuting flows (Husted & Christensen 2001).

The second avenue is represented by the extension of regional and sub-regional models of economic activity to include specific sectors, again typically transport. In the case of the Great Belt Link (Jensen-Butler & Madsen 1996), the analysis included not only the effects of the establishment of the Great Belt link on regional economic activity (employment and GDP by region), but also an analysis of the consequences for structural change in interregional trade patterns. In the case of the Femer Belt link (Jensen-Butler & Madsen 1999) a simple transport model was incorporated into the analysis to estimate the shifts in traffic flows by transport corridor in order to estimate the redistribution of regional economic activity.

The third avenue is based upon a different modelling strategy, where economic models and sector models are linked together in a loosely coupled framework, consisting of separate and independent models linked together inside a general framework. Loose coupling implies that the models are independent but that output from one model constitutes a data input to another. This strategy has developed most strongly in the agricultural sector. In an initial attempt to evaluate the regional economic consequences of restructuring of the European Union's agricultural policy in 1991 (the McSharry proposal) the results emerging from an agricultural sector model (Stryg et al. 1992), consisting of changes in gross value added (GVA), other taxes linked to production, employment together with estimates of impacts on the food industry, all by region, were taken as inputs to the single region model EMIL (Madsen 1991a).

This contrasts with an integrated model, where the different sub-models are solved simultaneously, constituting a fourth avenue. Here, one single model user has an overview of the entire system.

2.3 Optimal model structure

The optimal model structure depends on both the nature of the object of analysis and the analytical capacity of the model users. If the focus is on a specific sector, then the choice of a specific sector model (a partial model) should be made. Here, it is assumed that the key parameters required for the operation of the model are supplied unambiguously (for example the inputs of a growth factor model to a transport model). Alternatively, if it is assumed that there are strong interactions between the specific sector and the general economy, then it is necessary to integrate the models. The two basic forms of integration can, as mentioned above, be described as loosely coupled models or fully integrated models. In the case of transport and agriculture, loose coupling is here more appropriate, whilst in the case of the public sector and of tourism an integrated approach is more relevant. This is because the transport and agriculture sectors are complex, requiring a special modelling approach, which makes it necessary to build up specific models for each of the two sectors reflecting the complexity of the technical relations involved. Analysis of tourism and the public sector involves lower levels of technical specification, being more directly based on the conventional theory and models of consumption and production.

An important requirement for loose coupling of models is that they rest on the same or a very similar theoretical foundation. In addition, there has to be consistency in exogenously given assumptions and parameters. Also, practical considerations related to the fact that single research groups only cover specific areas and model sets promotes the use of loose coupling.

2.4 A loosely coupled model for transport and agriculture

On the basis of the above discussion, a combination of a fully integrated and a loosely coupled modelling system has been developed and used in a number of studies of the interaction between developments in specific sectors and regional economies in Denmark, also including interactions between international, national and local levels. The model system is presented in figure 1. The horizontal dimension shows in the centre general (equilibrium) models for the entire economy whilst to the right and left at this level are shown the specific sectoral models (for agriculture and transport), which are loosely coupled together with the general models. Tourism and the public sector are, however, fully integrated models, to be found in the centre of the figure.

The vertical dimension shows the different levels of spatial resolution from the international level to the sub-municipality level. Each box represents an independent model and the arrows between the boxes represent flows of data (results) between the models.

As can be seen from the figure, the total model system has been developed on a top-down principle, starting with a model of the international economy, GTAP, (Bach et al. 2000) to estimate the equilibrium values of central variables in the international economy, for example gross output, disposable income, aggregate demand, imports and exports. On this basis, the model for the national economy, AAGE, (Frandsen et al. 1995) determines equilibrium values for the Danish economy, including national values for the agricultural sector. The links between the economic model and the agricultural model and between the international, national and local level models are documented in Hasler et al. (2002). The link between the economic model and the transport model is documented in Kronbak & Leleur (2003) and in this paper.

The economic model, LINE, is linked to the models for the transport sector by an interaction model, MERGE (Kronbak J 2002). MERGE not only links the models in the general economic sector with the models in the transport sector, but also links the models within the transport sector together. The models used in the transport sector are the environmental impact model TicMap (Wass-Nielsen & Hviid Steen 2001), the transport model TSM and the assessment model COSIMA (Leleur 2002).

3. The link procedures

The linking procedures are described in a bottom-up way where first the linking of models within the transport sector is dealt with and second the linking of the transport and the regional economic models. By giving some detail information about the individual model elements, the potential of the comprehensive modelling on the basis of the suggested systems approach – also for other types of examination than road pricing - is more easily apprehended.

3.1 Linking the models within the transport sector

The models within the transport sector are connected using a geographical information system as linkage. This GIS based linkage has been named MERGE (Model for Exchanging Regionalised Geographic Entities).

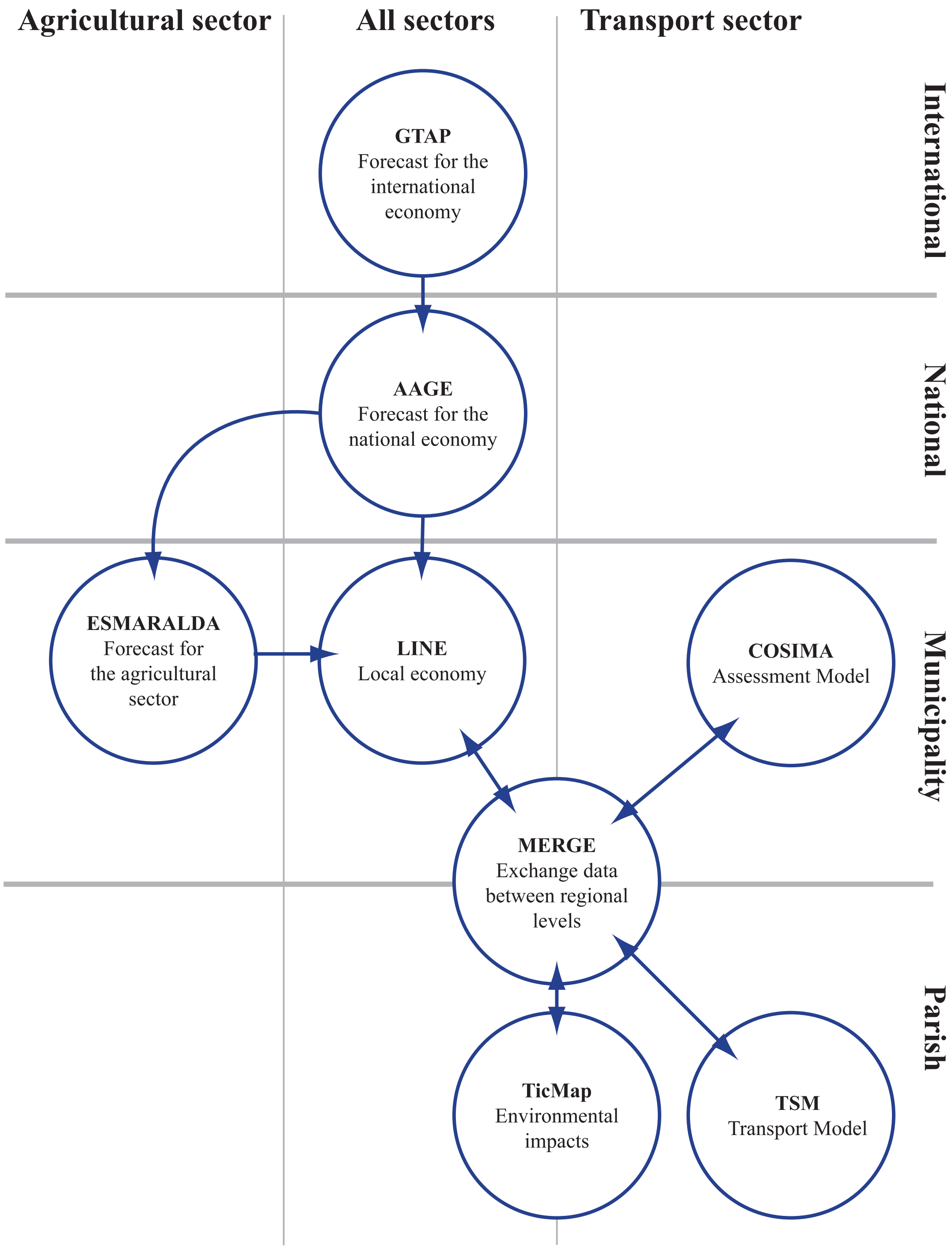

Figure 1. Linking Danish models of different types and levels

MERGE

The keyword in MERGE is model integration. Within the transport sector MERGE has to link the transport, environmental impact and assessment models together into a decision-making tool by making procedures for transferring in- and output data between the models. Besides that MERGE also has to make the linkage between the models in the transport sector and the interregional economic model (LINE).

For each type of models within the transport sector an existing model has been chosen for the decision-making tool:

- The Transport Sketch Model, TSM, developed at the Centre for Traffic and Transport, Technical University of Denmark.
- The environmental and economic impact assessment tool TicMap, developed at Centre for Traffic and Transport, Technical University of Denmark.
- The Composite Model for Assessment (COSIMA) developed at Centre for Traffic and Transport, Technical University of Denmark.

The integration of these models has addressed some questions that are not only relevant for the specific models in question but has also a more general application. This means that some of the procedures developed in MERGE are quite universal for loosely coupled model integration. As for most loosely coupled models, the starting point for MERGE has been a more general approach to model integration (incl. data transfer) and from there on to focus on the specific models.

This approach has had the advantage that if/when other (or better) models become available they can be utilised with less effort than if MERGE was specifically designed for the mentioned models in a fully integrated model. This can be referred to as model modularity and the principle is that other models can be ”snapped” on to MERGE and used in coherence with the total modelling framework.

Besides the modularity of MERGE another important factor in the loosely coupled model integration has been consistency. One of the objectives of MERGE has been to provide data exchange between the transport, impact and assessment models (and also to the regional economic model). All these types of models rely to a certain extent on spatially distributed data but not necessarily on data with the same spatial distribution or level of aggregation. When integrating the models into a decision support system, it is important to ensure a common consistent basis so that results and conditions to some extent are identical or at least consistent. It is especially important to be able to reproduce results and datasets.

An example is e.g. that if a model requires 50 zones MERGE has to be able to generate this number of zones, preferably from any base dataset, under a number of different conditions e.g. equal number of inhabitants within the zone; equal area of the zones etc. At the same time it has to be possible to keep track of where data originated from and to give some estimates of the accuracy of not only the original data, but also of the generated data. This is commonly known as metadata (or data on data).

Generation of new datasets from an existing dataset is where GIS have been proven as a very powerful tool. Results and input data all have some kind of spatial attributes e.g. population data can be on a municipal or a parish level. It is not necessary that all the integrated models actually use the spatial reference but the spatial reference can be used in MERGE to generate and exchange datasets.

Transport Sketch Model (TSM)

The TSM is a more or less a traditional 4-step traffic model. Some of the advantages of this model are that it is already fully integrated in a GIS (ArcInfo) and since it is conceptually simple it runs fast – even on large networks. Although national and regional individual road transport is in focus of the model it also provides an assessment of transport by rail, bus and ferry in Denmark.

Traffic Impact and Cost Mapping (TicMap)

The TicMap model (Wass-Nielsen & Hviid Steen 2001) is a tool for traffic impact calculation. The basis of TicMap is four GIS-based impact models for:

1. Accidents
2. Noise
3. Emission
4. Severance and perceived risk

Each of these impact models are based on Danish impact assessment models and the can be run individually from within the geographical information system (MapInfo).

The results from the impact models are used to make an assessment of the impacts on each road segment in the network. For a closer description of the impact models see e.g. Wass-Nielsen & Hviid Steen (2001), Clausen et al. (1991) or Leleur (2000).

Composite Model for Assessment (COSIMA)

The COSIMA model has been worked out to provide a more comprehensive assessment of transport initiatives than made possible by applying a conventional cost-benefit analysis (CBA). Thereby COSIMA deals with a mix of CBA effects and non-CBA effects. Typically the non-CBA effects – when seen from a modelling viewpoint – are more difficult to handle as compared to the CBA effects where handbook approaches (pricing and procedures) are available for many transport planning problems. In brief one can refer to the CBA effects as effects where pricing manuals and procedures exist and to the non-CBA effects as multi-criteria analysis (MCA) effects as this type of analysis, stemming from operations research, becomes relevant for the extension of the conventional CBA. The idea of COSIMA can briefly be described by the following seven steps as formulated for the assessment of a number of alternative by-pass projects for a Danish town currently in need of relieving of the through traffic (Leleur 2001).

1. The first task is to determine the CBA effects being relevant for the concrete appraisal study. In the by-pass example, following the Danish Road Directorate's standard model, the effects are: travelling time, vehicle operating costs, accidents, maintenance costs, noise, air pollution and severance & perceived risk. The investment enters the analysis denominated as the construction costs.

2. The next task is to determine the MCA effects of relevance. These may be measured either in some type of quantitative unit, an example could be changes in strategic mobility see Kronbak (1998), or by judgement using a +5, .., 0, .., -5 scale. Three possible MCA effects of relevance for many Danish road projects are: network accessibility, urban planning and landscape.

3. With CBA and MCA effects laid down the so-called "anchoring" part of the model formulation can take place. Hereby is meant determining the importance of the MCA effects against the CBA effects and in-between each other. Several MCA techniques are relevant here: direct weights, pairwise comparison, swing weights, etc. see Leleur (2000). Criteria importance is denominated by weights on the individual criteria adding up to 100%.

4. At this stage a base case scenario is modelled and presented to the decision-makers together with the assumed interesting assessment questions; these concern issues that may have a principal influence on the decisions to be made from the study. The decision-maker involvement may lead to revision of both the kind of MCA impacts included and their weights in the base case scenario. Part of this exchange with decision-makers is also to formulate suitable additional scenarios.

5. Afterwards COSIMA is run for all the scenarios and the assessment questions are scrutinised and related to possible sources of uncertainty. This “deterministic run” of the model and the identification of “varying levels” of information give intermediate results that in the following model step are examined as concerns their “feasibility risks” which indicate that a result in the deterministic run may be associated with such uncertainty that precaution is needed.

6. Next the so-called “stochastic run” of COSIMA is undertaken. This in fact is a Monte Carlo simulation where parameters and data have been replaced with suitable probability distributions that can represent the actual information level. In the by-pass example used as background for this overview of steps in COSIMA both distributions arrived at empirically by data fitting and distributions set on the basis of reasoning are made use of. One could refer to those as “objective” and “subjective” probability assessments.

7. At this stage the assessment questions are addressed on the basis of the model results and the assumptions behind and a second exchange with the decision-makers is carried out. With the layout of the COSIMA model as a transparent tool box two principal possibilities are available now. The study may simply end here if the decision-makers are confident about the model outcome, or the decision-makers may want to feed back in the process and re-address some of the previous model settings to shed light on some issues.

It should be noted that COSIMA is more or less tailored dependent on the concrete application. As should appear from the overview of methodological steps above, features for applying both scenarios and risk examinations are available. When incorporating COSIMA in the MERGE model software, the way the other three model categories are set for the actual planning problem will influence the possibilities for the assessment analyses to be carried out in the COSIMA module.

3.2 Linking the transport and regional economic models

The role of transport costs and the transport system are integrated into LINE, though the integration is as yet incomplete. In LINE supply and demand for transport are modelled in a full and consistent manner, what is not yet modelled is transport in physical terms. Transport costs and transport system changes feed into the present version of LINE in an ad hoc way and the effects of changes in the local and regional economy on traffic flows are not yet modelled explicitly. In order to illustrate the division of labour between transport models and regional economic models in a fully developed modelling framework, an idealised set of relationships between LINE and a standard sequential transport model can be seen in figure 2.

The linked model is simultaneous as there are linkages in both directions. Spatial interaction forms the link from the transport model (transport costs) to the regional economic model (to the cost-price circle) and from the regional economic model (interregional interaction, such as trade or shopping) to the transport model (to the real circle).

Compared with a traditional free standing regional economic model, determination of transport costs takes place in the transport model, which replaces exogenous estimates of transport costs. In relation to a traditional free-standing sequential transport model (see for example Wilson et al. 1969) the economic model has replaced the trip generation, attraction and distribution steps by an economic model for interaction (trade, commuting etc) and a model for trip frequency.

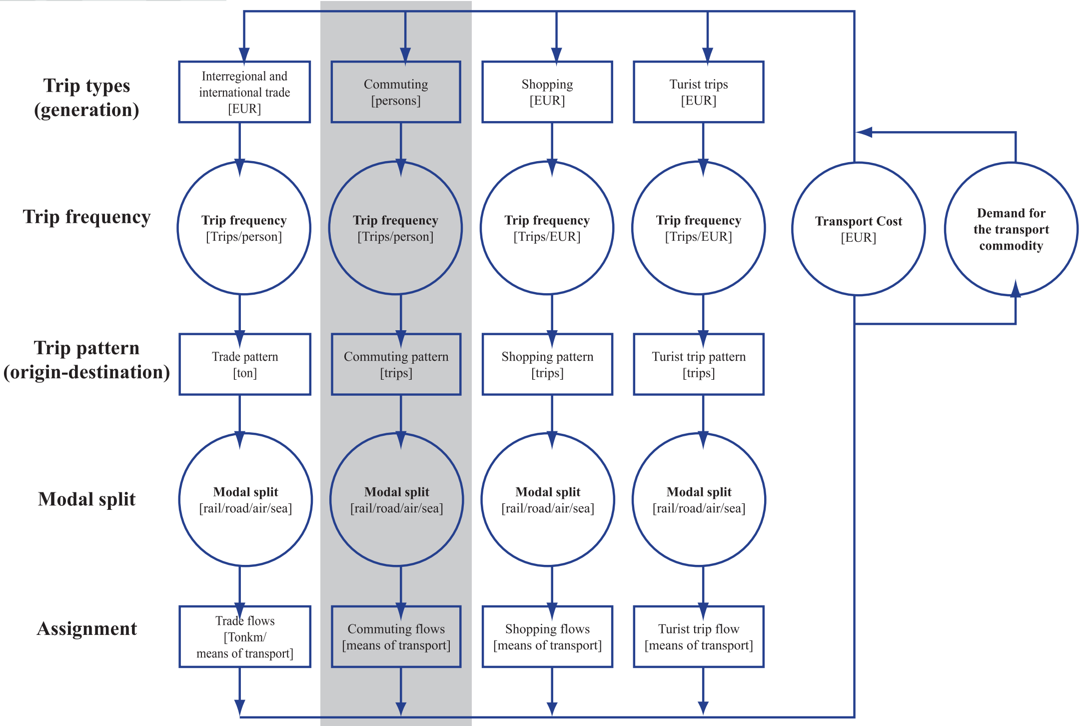

Figure 2. An idealised integrated model of transport and regional economic change

Transport inside LINE

A number of features of the treatment of transport inside LINE are important. First, the model distinguishes between mobile and immobile commodities. Mobile commodities are transportable commodities whilst for immobile commodities place of demand is by definition the same as place of production, including various forms of private and public service, for example hairdressing and hospitals. For immobile commodities the relation between demand and supply of commodities is direct as there is no interregional trade and, therefore, there are no transport costs. In the case of hairdressing the problem of transport costs is related to shopping trips. This is also the case for a number of components of consumption, for example services related to real estate.

Second, different price concepts are used. Commercial margins and net commodity taxes enter into the full model and in relation to the transport commodity, which means that price depends on the level of net commodity taxes (for example fuel taxation and road pricing).

Third, in a detailed version of LINE the transport sector can be subdivided into different transport subsectors, each having different productivity and employment levels.

4. LINE: the full model, a graphical presentation

Here a brief graphical presentation of LINE is made. The full model and its equations are described in detail in Madsen et al. (2001a). The data used in the model, together with the interregional SAM, are described in Madsen & Jensen-Butler (2002b) and Madsen et al. (2001b).

LINE is based upon two interrelated circles: a real Keynesian circuit and a dual cost-price circuit. Figure 3 shows the general model structure, based upon the real circuit employed in LINE. The horizontal dimension is spatial: place of work (denoted R), place of residence (T) and place of demand (S). Production activity is related to place of work. Factor rewards and income to institutions are related to place of residence and demand for commodities is assigned to place of demand. The vertical dimension is more detailed and follows with its five-fold division the general structure of a SAM model. Production is related to activities; factor incomes are related to i) activities by sector ii) factors of production with labour by sex, age and education and iii) institutions: households; iv) demand for commodities is related to wants (aggregates of commodities or components of final demand and intermediate consumption); v) commodities, irrespective of use.

The real circuit corresponds to a straightforward Keynesian model and moves clockwise in figure 3. Starting in cell RE in the upper left corner, production generates factor incomes in basic prices, including the part of income used to pay commuting costs. This factor income is transformed from sectors (RE) to sex, age and educational groups (RG). Factor income is then transformed from place of production (RG) to place of residence (TG) through a commuting model. Employment follows the same path from sectors (RE) to sex, age and educational groups (RG) and further from place of production (RG) to place of residence (TG). Employment and unemployment is determined at place of residence (TG).

Disposable income is calculated in a sub-model where taxes are deducted and transfer and other incomes are added. Disposable income is distributed from factors (TG) to households (TH). This is the basis for determination of private consumption in market prices, by place of residence (TW). Private consumption is assigned to place of demand (SW) using a shopping model. Private consumption, together with intermediate consumption, public consumption and investments constitute the total local demand for commodities (SV) in basic prices through a use matrix. In this transformation from market prices to basic prices (from SW to SV) commodity taxes and trade margins are subtracted. Local demand is met by imports from other regions and abroad in addition to local production. Through a trade model exports to other regions and production for the region itself is determined (from SV to RV). Adding export abroad, gross output by commodity is determined. Through a reverse make matrix the cycle returns to production by sector (from RV to RE).

The stylised version of the model with the real circle illustrated, as well as the price concepts used, is shown in figure 3, where the price level of real circle variables (constant/current) is shown.

Using again the stylised version of the model shown in figure 3, the anticlockwise cost/price circuit shown in figure 4 corresponds to the dual problem. In cell RE sector basic prices (current prices) are determined by costs (intermediate consumption, value added and indirect taxes, net in relation to production). Through a make matrix, sector prices by sector are transformed into sector prices by commodity (from RE to RV). These are then transformed from place of production to place of demand (RV to SV) and further into market prices through inclusion of retailing and wholesaling costs and indirect taxes (from SV to SW). This transformation takes place using a reverse use matrix. Finally, private consumption is transformed from place of demand to place of residence in market prices (from SW to TW). Figure 3 shows the structure of LINE in more detail.

Figure 3. Simplified version of LINE: the real circle

	Place of production (R)	**Place of residence (T)**	**Place of demand (S)**
Activities (Sectors) (E)	Gross Output Interm. consumption GVA GDP at factor prices Earned income(RE)		Intermediate consumption (SE)
Factors of Production (education, gender, age) (G)	Earned income Employment (RG)	Earned income Employment Unemployment Taxes and transfers Disposable income (TG)	
Institutions (households, firms, public sector) (H)		Earned income Taxes and transfers Disposable income (TH)	
Demand components (W)		Local private consumption Residential consumption Tourist expenditure (TW)	Intermediate consumption Local private consumption Tourist expenditure Public consumption Investments (SW)
Commodities (V)	Local production Exports to other municipalities Exports abroad (RV)		Local demand Imports from other municipalities Imports from abroad (SV)

_____________ Constant prices

_ _ _ _ _ _ _ _ _ Current prices

Figure 4. Simplified version of LINE: the cost-price circle

	Place of production (R)	**Place of residence (T)**	**Place of demand (S)**
Activities (Sectors) (E)	Gross Output Interm. consumption GVA GDP at factor prices Earned income(RE)		Intermediate consumption (SE)
Factors of Production (education, gender, age) (G)	Earned income Employment (RG)	Earned income Employment Unemployment Taxes and transfers Disposable income (TG)	
Institutions (households, firms, public sector) (H)		Earned income Taxes and transfers Disposable income (TH)	
Demand components (W)		Local private consumption Residential consumption Tourist expenditure (TW)	Intermediate consumption Local private consumption Tourist expenditure Public consumption Investments (SW)
Commodities (V)	Local production Exports to other municipalities Exports abroad (RV)		Local demand Imports from other municipalities Imports from abroad (SV)

____________ Basic prices (exclusive transport costs

_ _ _ _ _ _ _ _ Market prices

▬▬▬▬ Basic prices (inclusive transport costs)

4.1 The dimensions of LINE

In the standard version of LINE the dimensions of the axes are normally the following:

Sectors: 12 sectors aggregated from the 133 sectors of the national accounts.

Factors: 7 age, 2 sex and 5 education groups.

Households: 4 types, based upon household composition

Needs: For private consumption and governmental individual consumption 13 components, aggregated from the 72 components in the detailed national accounts. For governmental consumption, 8 groups. For gross fixed capital formation, 10 components.

Commodities: 20 commodities, aggregated from 131 commodities in the national accounts.

Regions: 277 municipalities (the lowest level of spatial disaggregation). Regions are defined either as place of production, place of residence or as place of demand. It is possible to aggregate the (277) municipalities into any regional unit. Standard regions are the (16) counties and (45) labour-market districts.

In the version of the model used here, 23 sectors are used, 27 commodities and an aggregation of factors and households has been made, so that they do not enter the model. It uses 16 counties (regions).

5. Road pricing and modelling its impacts

The design of road pricing systems relates to general issues concerning transport policy and technical constraints and possibilities, in concrete social and cultural contexts.

5.1 Road pricing

Five basic dimensions underlie all road pricing systems.

1) Whether the tariff is kilometre-dependent, time dependent or flat rate

2) Whether the tariff depends on the type of road to be used (motorway, main road, secondary road etc)

3) Whether the tariff depends upon type of area in which the road is used (for example, urban, rural or simply the national territory)

4) Whether the tariff depends on time of day (rush hour, daytime, evening, night)

5) Whether the tariff depends upon behaviour (changes in speed for example)

For example, an urban cordon is a flat-rate charge for entering a specific type of area (as in the case of London). A motorway toll is typically kilometre and road type dependent (as in the case of the proposed German motorway lorry charges). Choice of system depends partly upon the dimensions chosen and partly upon technological, administrative and political alternatives available.

Figure 5. Danish regions (counties and two municipalities with county status, Copenhagen M and Frederiksberg M). Three fixed links: A: Oresund, to Malmo, Sweden, B: Great Belt, C: Femer Belt to Germany. Four ferry routes: D : Spodsbjerg-Taars, E: Odden-Aarhus (Mols Line), F: Odden-Ebeltoft (Mols Line), G: Frederikshavn-Gothenburg (Sweden). Other very local and international ferry routes are not shown.

In Denmark a pilot project (AKTA, see Nielsen 2000, 2003, 2004, Herslund 2003, Herslund et al. 2001) is at present being developed involving both kilometre and area dependent tariffs. In the future, more complex systems, which also take account of the road hierarchy and time of day, may be developed. Technically, it is based on GPS technology, permitting precise identification of the location of the vehicle and thereby its road use related in turn to toll level for the road. This level depends on road status in a road hierarchy, time of day and level of urbanization. Cars are fitted with receivers which function as meters, registering both current expenditure as the road is used, and cumulated expenditure for a given period. The meter is read at periodic intervals and the user is charged.

6. Results from the Danish road pricing toll study

Application of LINE permits analysis of the consequences for the regional economy of any change in the transport system which affects the costs of transport. The change in transport costs examined in this case, the introduction of road pricing, has been described above.

The analysis begins in the interaction components of the cost-price circle shown in figure 4. Starting with trade in commodities, (RV to SV), the prices of commodities decline. Given the point at which the analysis commences, the presentation follows the two circles, where first the effects on commodity prices are derived, followed by the real effects on demand, production, employment and income. For other cases the starting point depends on the nature of the initial shock.

6.1 Changes in transport costs

Changes in transport costs are calculated using a) an interregional satellite account for transport used to determine *levels* of transport costs and b) exogenously given interregional transport costs, based on a digital road map**, Vejnet DK**, used to calculate *changes* in transport costs.

The data in the interregional satellite accounts are estimated in four steps:

a1) Taking the national make and use tables, national transport activity is determined by i) transport mode ii) subdivided by transport costs related to intermediate consumption (by sector) and to private consumption (by component) and iii) by external (transport firm based) and internal (own transport, within a non-transport producing firm or a household) costs. Six different modes of transport activity are used in the interregional satellite accounts, four for passenger transport and two for goods. Passenger transport is divided into car, rail, aeroplane and other and freight is divided into lorry and rail.

a2) In the second step national transport activity related to passenger transport is subdivided (using data from the National Travel Survey) by trip purpose: i) commuting ii) shopping, iii) tourism iv) business travel and v) recreation.

a3) National transport activity is then divided by origin and destination using data on intra and inter-regional trade (freight and business trip transport activity) and interregional shopping, tourism and commuting (personal trip transport activity)

a4) Regional transport activity is then corrected (using regionalised National Travel Survey data) to ensure that the data reflect regional transport activity by mode.

Changes in interregional transport activity for car transportation are estimated using the digital road map **Vejnet DK.** Transport costs in Vejnet DK are based upon both time and distance where the generalised cost has been calculated as Time costs + Distance costs. Also included are costs (tickets, tolls) of travelling by ferry and using fixed links. In addition, costs are calculated both with and without road pricing. The calculations are based on assumptions shown in Table 1.

Table 1. Maximum speeds, distance and time costs, road pricing tariffs (DKK) (DKK 7.50=ca 1 Euro=ca 1$US)

	Car	**Lorry**
Motorway	110 km/t	80 km/h
Non-urban highway	80 km/t	70 km/h
Urban	50 km/t or local restrictions taken from VejnetDK	Max 50 km/h or local restric-tions if under 50 km/hour
Distance cost per kilometre	1,82 DKK	2,60 DKK
Time cost pr. hour	0,75	2,78 DKK.
Road pricing – Urban	0,60	-
Road pricing – Rural	0,30	-

The estimation of level of transport activity by region, mode, purpose and by type of consumption described above reflects a basic assumption that data on transport activity obtained from National (transport satellite) Accounts used in a top down procedure, are superior to data on transport activity obtained from different statistical sources, used in a bottom-up approach.

In this paper, only results based upon road pricing for private cars is presented.

Table 2 shows the consequences of introducing road pricing. It is assumed that all ferry routes and fixed links will continue with unchanged ticket prices. The table shows that transport costs in general increase from 2% to 13%, outside the main cities of Copenhagen and Arhus least in the interregional links where use of rural roads is important and/or where a significant part of the journey uses ferries. In Copenhagen and Aarhus transport costs decline as road pricing results in a reduction of congestion, and thus, transport costs.

6.2 Changes in commodity prices and disposable incomes

In table 3, column 1, shows that prices for commodities produced domestically at national level increase by 0.10%. However, prices fall in Greater Copenhagen, whilst they increase with increasing distance from Copenhagen, except for Bornholm, which benefits from transport via Copenhagen. Likewise, price increases in Aarhus, the other main urban centre, are lower than elsewhere in the periphery.

Import prices (column 2) are not really affected by road pricing, for imports on their way to the Danish market. This means that prices for the total demand (column 3) rise by a similar, though slightly smaller percentage and the regional distribution of price rises has the same pattern as for demand for domestic products.

Column 4 shows that prices for intermediate consumption are similarly affected by the reduction in transport costs, related to the fact that only service commodities enter into the calculations. These changes affect prices of gross output (column 5) though their effect is smaller as intermediate consumption is a part of gross output.

Column 6 shows that export prices relative to foreign prices increase by 0.12%, again least in Greater Copenhagen and most in the industrial and peripheral regions of Jutland. The regional pattern is similar to that in column 1 and for the same reasons.

Column 7 shows private consumption by place of demand, and exhibits a similar structure to the previous columns in the table. However, when private consumption by place of residence is examined (column 8), significant changes appear, because road pricing affects the cost of trips for shopping, trips to visit family and friends, cultural and recreational visits, as well as tourist trips. There are now substantial price increases in the outer areas of Greater Copenhagen and Aarhus. This is because of longer trips and higher road price tariffs.

Table 2. Changes in total transport costs (%) for transport between Danish regions after road pricing for cars

(%)	Cp & FrbM	CpC	FrC	RoC	VsC	SsC	BhC	FyC	SjC	RbC	VjC	RkC	ÅrC	ViC	NjC
Copenhagen & Frederiksberg M	0,91	0,96	1,02	1,01	1,06	1,07	1,00	1,05	1,07	1,07	1,07	1,05	1,01	1,04	1,04
Copenhagen C	0,96	1,13	1,13	1,13	1,13	1,12	1,00	1,08	1,09	1,09	1,09	1,05	1,02	1,05	1,05
Frederiksborg C	1,02	1,13	1,10	1,12	1,11	1,12	1,00	1,08	1,09	1,09	1,08	1,04	1,02	1,05	1,05
Roskilde C	1,01	1,13	1,12	1,08	1,13	1,11	1,00	1,07	1,09	1,09	1,08	1,09	1,02	1,05	1,05
Vestsjællands C	1,06	1,13	1,11	1,13	1,12	1,11	1,01	1,05	1,08	1,08	1,07	1,08	1,00	1,04	1,04
Storstrøms C	1,07	1,12	1,12	1,11	1,11	1,13	1,02	1,07	1,09	1,09	1,08	1,09	1,03	1,06	1,05
Bornholms C	1,00	1,00	1,00	1,00	1,01	1,02	1,09	1,02	1,03	1,03	1,03	1,03	1,01	1,02	1,02
Fyns C	1,05	1,08	1,08	1,07	1,05	1,07	1,02	1,12	1,12	1,12	1,12	1,12	1,10	1,11	1,12
SønderjyllandsC	1,07	1,09	1,09	1,09	1,08	1,09	1,03	1,12	1,15	1,12	1,12	1,11	1,10	1,11	1,12
Ribe C	1,07	1,09	1,09	1,09	1,08	1,09	1,03	1,12	1,12	1,12	1,12	1,11	1,10	1,11	1,11
Vejle C	1,07	1,09	1,08	1,08	1,07	1,08	1,03	1,12	1,12	1,12	1,12	1,11	1,07	1,11	1,11
Ringkøbing C	1,05	1,05	1,04	1,09	1,08	1,09	1,03	1,12	1,11	1,11	1,11	1,11	1,11	1,11	1,11
Århus C	1,01	1,02	1,02	1,02	1,00	1,03	1,01	1,10	1,10	1,10	1,07	1,11	0,97	1,10	1,09
Viborg C	1,04	1,05	1,05	1,05	1,04	1,06	1,02	1,11	1,11	1,11	1,11	1,11	1,10	1,11	1,09
Nordjyllands C	1,04	1,05	1,05	1,05	1,04	1,05	1,02	1,12	1,12	1,11	1,11	1,11	1,09	1,09	1,12

Table 3. Price changes for demand and supply by type, by geographical origin. Percentage changes

	(1) Demand: Domestic production (SV)	(2) Foreign Import (RV)	(3) Demand (SV)	(4) Intermediate consumption (RE)	(5) Gross output (RE)	(6) Foreign export (RV)	(7) Privat consumption Place of market place (SW)	(8) Private consumption Place of residence (TH)
Copenhagen og Frederiksberg Municipalities	-0,10	0,00	-0,08	-0,04	-0,07	0,13	-0,04	-0,17
Copenhagen County	-0,04	-0,01	-0,04	-0,02	0,00	0,39	-0,01	0,46
Frederiksborg County	0,12	-0,03	0,09	0,09	0,14	0,10	0,07	0,55
Roskilde County	0,09	-0,02	0,07	0,08	0,12	0,14	0,06	0,48
Vestsjællands County	0,18	-0,02	0,15	0,14	0,26	-0,01	0,11	0,64
Storstrøms County	0,21	-0,02	0,18	0,16	0,24	0,05	0,12	0,69
Bornholms County	0,04	-0,01	0,03	0,04	0,07	0,16	0,03	0,38
Fyns County	0,19	-0,02	0,16	0,15	0,23	0,08	0,12	0,65
Sønderjyllands County	0,24	-0,01	0,20	0,19	0,29	0,10	0,15	0,83
Ribe County	0,26	-0,02	0,21	0,20	0,34	-0,04	0,16	0,74
Vejle County	0,25	-0,02	0,20	0,19	0,32	0,03	0,14	0,74
Ringkøbing County	0,20	-0,02	0,16	0,15	0,29	-0,01	0,11	0,63
Aarhus County	0,08	0,00	0,07	0,08	0,12	0,16	0,05	-0,03
Viborg County	0,17	-0,01	0,14	0,13	0,23	0,11	0,10	0,59
Nordjyllands County	0,17	-0,01	0,14	0,13	0,22	0,11	0,11	0,62
Outside the regions	0,06	-0,01	0,04	0,05	0,07	0,01	-	-
Whole country	0,10	0,00	0,08	0,09	0,14	0,12	0,07	0,44

6.3 Changes in demand, production and income

In general, road pricing means that real private consumption declines markedly, as consumer prices increase. On the other hand, export declines less because road pricing for cars only affects export prices marginally. Total demand and total production are therefore affected to a lesser degree than is the case for private consumption.

Table 4, column 1 shows the consequences for disposable income (in current prices) of increases in transport costs which affect commuting. As most commuting is towards Copenhagen, then the principal increases are to be found outside Copenhagen and Aarhus.The decrease in disposable income registered for Aarhus arises because transport costs in Aarhus decrease , because of reductions in congestion and the shorter commuting distances in Aarhus, as compared to Copenhagen.

Column 2 shows how real disposable income changes if price reductions on commodities are also included. The overall reduction in real disposable income is almost 1%. The effect is almost identical to that for private consumption by place of residence (column 3). Here again. Copenhagen and Frederiksberg Municipalities and Aarhus have small absolute gains, whilst all other regions have losses, which increase with increasing distance from Copenhagen. Column 4 shows the increase in private consumption by place of demand, reflecting the more even spread of the effects noted in column 3 through shopping trips. Column 5 shows the real effect on total demand, which is more than for private consumption. The impacts are for all regions negative, though these negative effects are lowest in the cities.

This pattern is the same for changes in real production, intermediate consumption and Gross Value Added (see columns 9 and 10).

Column 8 shows the effects on exports of both the price increases for export noted in table 4 and the regional commodity export composition, as different commodities have different price elasticities. Correspondingly, import from abroad is calculated as a function of changes in domestic prices, which rise, and import prices from abroad, which in general are unchanged (see column 6 in table 4). LINE uses the national import and export price elasticities used in Statistics Denmark’s national macro-economic model, ADAM (Dam 1995).

6.4 Changes in employment and income

In table 5 column 1 shows that employment declines by 9,764, (by place of production).

The distribution of these employment decreases follows closely the distribution of increases in Gross Output from table 4. Fyn and North Jutland have the biggest declines in absolute terms whilst Greater Copenhagen and Aarhus have, in relative terms, the smallest declines. By place of residence, differences are somewhat reduced. Column 3 shows the consequences for earned income (wages and salaries plus surplus on self employment) that decreases markedly in the areas which suffer from higher commuting costs. These losses are modified by decreases in tax payments, (column 5) because of the income effect. Changes in transfer incomes (column 4) further modify the pattern of income change. Increases in transfer incomes are, other things being equal, greatest in the regions where employment declines faster.

Column 6 shows the net result of these changes on disposable income. Greater Copenhagen and Aarhus are almost neutral and declines are related to increasing distance from Copenhagen.

Table 4. Consequences for demand, production and income. Percentage changes

	Disposable income (current prices) (TH)	Real disposable income (TH)	Private consumption Place of residence (TW)	Private consumption Place of demand (SW)	Demand (SV)	Foreign imports (SV)	Demand Domestic production (SV)	Foreign export (RV)	Gross output (RE)	GDP at factor prices (RG)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Copenhagen & Frederiksberg Municipalities	-0,05	0,17	0,17	-0,06	-0,05	-0,03	-0,05	-0,01	-0,08	-0,07
Copenenhagen County	-0,21	-0,71	-0,71	-0,68	-0,23	-0,17	-0,25	-0,15	-0,23	-0,25
Frederiksborg County	-0,28	-1,24	-1,24	-1,20	-0,54	-0,56	-0,52	-0,34	-0,48	-0,49
Roskilde County	-0,27	-1,03	-1,03	-0,99	-0,50	-0,50	-0,49	-0,35	-0,46	-0,47
Vestsjællands County	-0,26	-1,40	-1,40	-1,37	-0,64	-0,60	-0,65	-0,57	-0,66	-0,64
Storstrøms County	-0,27	-1,50	-1,51	-1,47	-0,70	-0,65	-0,70	-0,48	-0,66	-0,69
Bornholms County	-0,20	-0,95	-0,96	-0,97	-0,41	-0,36	-0,41	-0,18	-0,37	-0,41
Fyns County	-0,25	-1,41	-1,41	-1,40	-0,62	-0,55	-0,63	-0,43	-0,59	-0,61
Sønderjyllands County	-0,34	-2,02	-2,03	-1,98	-0,77	-0,61	-0,77	-0,45	-0,72	-0,75
Ribe County	-0,26	-1,56	-1,57	-1,56	-0,67	-0,54	-0,69	-0,60	-0,71	-0,67
Vejle County	-0,28	-1,43	-1,43	-1,41	-0,61	-0,50	-0,63	-0,59	-0,66	-0,61
Ringkøbing County	-0,25	-1,48	-1,49	-1,48	-0,59	-0,46	-0,62	-0,50	-0,63	-0,59
Aarhus County	0,01	0,05	0,05	-0,01	-0,08	-0,03	-0,10	-0,26	-0,17	-0,11
Viborg County	-0,27	-1,50	-1,51	-1,49	-0,59	-0,46	-0,61	-0,42	-0,58	-0,58
Nordjyllands County	-0,26	-1,41	-1,42	-1,39	-0,57	-0,46	-0,58	-0,39	-0,56	-0,56
Outside the regions	-	-	-	-	-0,04	-0,01	-0,05	0,00	-0,16	-0,13
Whole country	-0,20	-0,98	-0,98	-0,98	-0,41	-0,33	-0,42	-0,33	-0,41	-0,40

Table 5. Impacts on employment and disposable income

	(1) Employment at place of production (RG)		(2) Employment at place of residence (TG)		(3) Earned Income (TG)	(4) Income transfers (TG)	(5) Taxes (TG)	(6) Disposable income (TG)
	Pct	Number	Pct	Number				
Copenhagen og Frederiksberg Municipalities	-0,08	-291	-0,14	-434	-0,13	0,13	-0,09	-0,05
Copenhagen County	-0,21	-787	-0,19	-604	-0,39	0,18	-0,36	-0,21
Frederiksborg County	-0,41	-648	-0,32	-638	-0,52	0,39	-0,48	-0,28
Roskilde County	-0,39	-376	-0,30	-389	-0,48	0,43	-0,48	-0,27
Vestsjællands County	-0,52	-675	-0,46	-686	-0,57	0,39	-0,52	-0,26
Storstrøms County	-0,55	-598	-0,50	-623	-0,61	0,33	-0,54	-0,27
Bornholms County	-0,32	-64	-0,31	-63	-0,44	0,17	-0,41	-0,20
Fyns County	-0,50	-1125	-0,49	-1146	-0,56	0,33	-0,50	-0,25
Sønderjyllands County	-0,60	-755	-0,59	-753	-0,71	0,49	-0,65	-0,34
Ribe County	-0,56	-674	-0,55	-646	-0,58	0,55	-0,50	-0,26
Vejle County	-0,52	-954	-0,50	-916	-0,59	0,52	-0,53	-0,28
Ringkøbing County	-0,51	-757	-0,50	-735	-0,56	0,70	-0,48	-0,25
Aarhus County	-0,11	-347	-0,14	-449	-0,03	0,13	0,00	0,01
Viborg County	-0,47	-579	-0,46	-562	-0,57	0,46	-0,52	-0,27
Nordjyllands County	-0,46	-1134	-0,45	-1120	-0,56	0,39	-0,50	-0,26
Outside the regions	0,00	0	-	-	-			-
Whole country	-0,35	-9764	-0,35	-9764	-0,43	0,33	-0,38	-0,20

6.5 Recycling the revenue from road pricing: a balanced budget

The revenue arising from road pricing can be used for different purposes. The allocation of these revenues by activity will have different economic effects as well as different effects in terms of regional distribution.

The following alternatives are examined:

1. Reduction of income tax: high rate taxation
2. Reduction of income tax: low rate taxation
3. Reduction of commodity taxes: VAT
4. Reduction of commodity taxes on fuel

Table 6a shows the consequences of reducing tax income by the state, whilst table 6b shows the combined effects of road pricing and reductions in taxation.

Table 6a shows that disposable income for households increases most if income taxes are reduced and least if commodity taxes are reduced. This can be explained by the fact that reductions in commodity taxes in part are transferred to abroad via exports and to other components of final demand.

There are regional differences in the different tax reduction strategies. Reduction of income taxes benefits Greater Copenhagen marginally more than the rest of the country. This is because the marginal tax rate in Greater Copenhagen lies above the national average because of the progression in the tax system. Alternatively, reduction of commodity taxes benefits the peripheral areas in Jutland because the marginal propensity to consume is higher in these areas. Regionally, reduction of income taxes at the lower bound provides the Greater Copenhagen area (except for the municipalities of Copenhagen and Frederiksberg) with a slightly greater increase in disposable income than reduction of upper bound taxes. This is probably related to higher levels of housing consumption, which in turn explains higher relative deductions from gross income, for tax purposes, as interest can only be deducted at the rate corresponding to the lower bound.

Table 6b shows the net effect of road pricing and tax recycling. The principal result is that combined rod pricing and tax reduction gives a small increase in disposable income. This can be explained by the fact that even though there is a balanced budget, the expenditure on road pricing by the individual household is tax deductible. The other result is that recycling via commodity taxes results in a decrease in disposable income. This can again be explained by the fact that reductions in commodity taxes do not benefit domestic private consumption to the full extent of the reduction, as discussed above. Regionally, the net effects are similar to the gross effects because the regional differences in tax reductions are very limited.

Table 6a. Consequences for demand, production and income. Effects arising from reductions in taxation, percentage changes

	Real disposable income at place of residence (TG)				Employment at place of production (RG)			
	State income tax		Commodity taxes		State income tax		Commodity taxes	
	Lower bound	Top bound	General	Transport commodity	Lower bound	Top bound	General	Transport commodity
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copenhagen & Frederiksberg Municipalities	1,19	1,14	0,67	0,67	0,30	0,29	0,17	0,19
Københavns County	1,25	1,17	0,67	0,64	0,34	0,33	0,17	0,23
Frederiksborg County	1,22	1,18	0,72	0,62	0,38	0,37	0,22	0,24
Roskilde County	1,18	1,17	0,72	0,65	0,43	0,43	0,21	0,27
Vestsjællands County	1,08	1,12	0,69	0,71	0,38	0,39	0,11	0,29
Storstrøms County	1,07	1,11	0,74	0,75	0,40	0,41	0,21	0,31
Bornholms County	1,03	1,09	0,74	0,82	0,35	0,36	0,02	0,34
Fyns County	1,09	1,12	0,69	0,72	0,36	0,37	0,14	0,29
Sønderjyllands County	1,06	1,08	0,75	0,79	0,31	0,32	0,16	0,35
Ribe County	1,07	1,09	0,70	0,73	0,33	0,34	0,04	0,32
Vejle County	1,09	1,11	0,72	0,72	0,33	0,34	0,08	0,29
Ringkøbing County	1,05	1,08	0,71	0,75	0,31	0,32	0,05	0,33
Aarhus County	1,13	1,14	0,74	0,68	0,36	0,37	0,17	0,28
Viborg County	1,06	1,10	0,74	0,79	0,32	0,33	0,08	0,32
Nordjyllands County	1,06	1,11	0,74	0,77	0,33	0,35	0,08	0,31
Outside the regions	-	-	-	-	0,00	0,00	0,00	0,00
Whole country	1,13	1,13	0,71	0,70	0,34	0,35	0,14	0,27

Table 6b. Consequences for demand, production and income. Net effects (gross effects minus effects arising from tax reductions), percentage changes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Real disposable income at place of residence (TG)				Employment at place of production (RG)			
	State income tax		Commodity taxes		State income tax		Commodity taxes	
	Lower bound	Top bound	General	transport commodity	Lower bound	Top bound	General	transport commod
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Copenhagen & Frederiksberg Municipalities	1,36	1,31	0,84	0,84	0,22	0,21	0,09	0,11
Copenhagen County	0,54	0,46	-0,05	-0,07	0,13	0,12	-0,04	0,02
Frederiksborg County	-0,02	-0,06	-0,52	-0,62	-0,03	-0,04	-0,19	-0,17
Roskilde County	0,15	0,14	-0,31	-0,38	0,04	0,04	-0,18	-0,11
Vestsjællands County	-0,32	-0,28	-0,71	-0,69	-0,14	-0,13	-0,41	-0,23
Storstrøms County	-0,44	-0,40	-0,76	-0,75	-0,15	-0,14	-0,34	-0,23
Bornholms County	0,08	0,14	-0,21	-0,13	0,03	0,05	-0,30	0,02
Fyns County	-0,33	-0,29	-0,72	-0,69	-0,14	-0,13	-0,36	-0,21
Sønderjyllands County	-0,96	-0,93	-1,26	-1,22	-0,29	-0,28	-0,45	-0,25
Ribe County	-0,49	-0,47	-0,86	-0,83	-0,23	-0,22	-0,52	-0,25
Vejle County	-0,33	-0,31	-0,71	-0,70	-0,18	-0,18	-0,44	-0,23
Ringkøbing County	-0,43	-0,40	-0,78	-0,74	-0,20	-0,19	-0,46	-0,18
Århus County	1,17	1,19	0,78	0,73	0,26	0,27	0,06	0,17
Viborg County	-0,44	-0,41	-0,76	-0,71	-0,15	-0,14	-0,40	-0,16
Nordjyllands County	-0,35	-0,30	-0,67	-0,64	-0,13	-0,11	-0,38	-0,15
Outside the regions	-	-	-	-	0,00	0,00	0,00	0,00
Whole country	0,15	0,15	-0,27	-0,28	-0,01	-0,01	-0,22	-0,08

7. Limitations of the model and future development strategies

A central problem faced by input-output or more general demand-side approaches to regional economic analysis is the influence of supply side conditions on production, this being a primary concern of CGE approaches. Another set of problems relates to some of the central concerns of contemporary urban and regional analysis: the existence of imperfect competition; externalities; product variety and growth in productivity all of which in a modelling context usually involve non-linear functional forms. In its present form, LINE builds on linear relationships. This raises the question of the suitability of LINE to deal with such issues.

In relation to the issue of supply-side conditions, as noted above, development of appropriate links between the real circle and the cost/price circle is the way forward. This road pricing study illustrates the first step, where links has been established between relevant prices and disposable income, foreign exports and imports. In addition, the public sector's budget and finance problems have been considered. A future strategy involves development of similar links for example, in relation to labour participation and productivity, or relating changes in commodity prices to the commodity composition of demand. Adjustments to changes in trade balances can also be included. The basis for this relation is the establishment of equilibrium in both commodity and factor markets and a steady-state equilibrium for institutional balances.

Even though this modelling strategy is similar to mainstream CGE approaches, the development of LINE nevertheless deviates from such CGE approaches to regional and interregional modelling. Both approaches are consistent with established economic theory and ensure equilibria with respect to markets and institutional balances. However, the mathematical complexity involved in the typical CGE approaches, which are often based upon non-linear functional forms, is attained at the expense of detail in the treatment of the regional and local economy. Thus, mainstream approaches, despite theoretical sophistication and complex non-linear mathematics, face severe problems related to lack of detail and a sound empirical foundation. They also frequently involve serious problems of calibration and solution.

One way of dealing with these reservations is to set up a model development strategy which involves the stepwise inclusion of behavioural components requiring non-linear functional forms. As described above, LINE can be developed in different ways. One important direction is a further development of the links between the real circle and the cost-price circle, in order to model productivity, wage determination and labour force participation rates in the labour market and substitution and income effects in relation to commodity markets (private consumption. export etc). Another important direction is to model in greater detail the consequences of a change in the institutional balances, for example, changes in household saving and consumption behaviour. These development strategies will transform LINE into a more advanced CGE model, as these essentially non-linear relationships are included in a step-by-step manner.

It might appear that the two modelling approaches converge towards a similar solution, this being an ideal CGE model. However, in reality the model development strategy employed in LINE, involving basically a linear system, represents a fundamentally different strategy to that utilised by mainstream CGE modelling, where there are often non-linearities in the central model equations which are solved simultaneously. This places substantial constraints on the number of different actors, markets and level of detail which can be incorporated in the models. In LINE, the complexity of the regional and sub-regional economic systems, including the possibility of choosing an appropriate model configuration, is in focus, whereas the mathematical complexity of selected behavioural components will be introduced in a gradual manner.

8. Conclusion

The requirements faced by model-builders today are very diverse, determined by the great variety of problems faced by regions and local authorities and which is reflected in the variety of studies which they generate. The ideal modern modelling tool must be able to respond to this diversity of demands placed upon it. The aim of construction of LINE described above is to ensure a high degree of flexibility, achieved in the basic structure which involves an interregional SAM. On this basis, it is possible to ensure flexibility in the following areas:

1. The model can be structured as either a sub-regional model, a regional model, or a combined model, as it includes both commodity markets and tourism, usually treated as regional phenomena, and labour markets, commuting and shopping which are typical sub-regional phenomena.

2. The overall model includes different types of agent which enter into a SAM, activities. factors, institutions, needs, commodities, which means that there is a degree of flexibility, involving the option of including either all accounts or a choice of accounts, for example, a model covering activities or commodities (a local production environment model) or a model covering institutions and needs (an extended shopping model).

3. Use of three basic types of location. Place of production, place of residence and place of demand enter into the overall model. Choice of combination of type of locality permits specific problems to be addressed, such as a commuting model involving place of production and place of residence and a trade model involving place of production and place of demand.

4. The overall model involves a real circle and a cost-price circle. This permits development of a fixed price model by using the real circle alone or a general equilibrium model based upon links between the real circle and the cost-price circle.

Further, given the above more strategic modelling choices, even more flexibility can be introduced by choice of aggregation of categories of activities, factors, institutions etc.

The paper describes LINE and its use in a number of studies. The configuration of the model and the aggregation of the SAM accounts used in analysis of the regional economic effects of road pricing are presented together with a summary of empirical results from the analysis. The magnitudes and directions of change are all satisfactory and theoretically defensible. The modelling system set up and demonstrated on an application case concerning the introduction of road pricing may also be relevant for other cases. Thus it may be highly relevant to model the consequences of large new transport infrastructure. Here it would be of major interest to address regional economic effects together with other effects relating to changes in transport efficiency and quality. The latter are normally the main focus of such studies but planners and decision-makers could also in this type of examination benefit from the new possibilities in modelling set out with the suggested systems approach.

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