



Challenges in the application of spatial computable general equilibrium models for transport appraisal

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ARTICLE INFO

Article history:

Available online 24 December 2010

Keywords:

Cost-benefit analysis

Indirect effects

SCGE models

Transport modelling

ABSTRACT

The use of spatial computable general equilibrium (SCGE) models for assessing the economic impacts of transport projects is one of the key items on the research agenda for project appraisal in the Netherlands. These models are particularly suitable for analysing indirect effects of transport projects through linkages between the transport sector and the wider economy. Potentially, according to the literature, indirect effects that are additional to first-order direct cost reductions can turn out to be up to almost 80% in magnitude of the direct impacts. Given the relevance of these models for policy appraisal, experiences with this new modelling approach are important to report. After two years of development and application of SCGE models for transport appraisal, we found that the translation of theory behind the spatial equilibrium models into practical model specifications and empirical applications is a challenging task, and may lead to problems in project appraisal in terms of inaccuracies in the assessment of impacts. This paper discusses some key challenges we encountered with the specification of the Dutch SCGE model RAEM. This chapter is especially useful for researchers developing SCGE applications for use in transport appraisal and those who want to get a better understanding of differences between theoretical and computable SCGE modelling.

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1. Background and objective of the paper

The use of spatial computable general equilibrium (SCGE) models for assessing the economic impacts of transport projects is one of the key items on the research agenda for project appraisal in the Netherlands. These models are particularly suitable for the analysis of indirect effects of transport projects through linkages between the transport sector and the wider economy. Potentially, according to the literature, indirect effects that are additional to first-order direct cost reductions can turn out to be up to almost 80% in magnitude of the direct impacts (see e.g. Bröcker et al., 2004). We note that this number can vary widely, however, and can also be negative, depending on the specific policy or project at hand, its geographical location, and the exact form of measurement.

Given the relevance of these models for policy appraisal, experiences with this new modelling approach are important to report. After two years of development and application of SCGE models for transport appraisal, we found that the translation of theory behind the spatial equilibrium models into practical model specifications

and empirical applications is a challenging task, and may lead to problems in project appraisal in terms of inaccuracies in the assessment of impacts. This paper discusses some key challenges we encountered with the specification of the Dutch SCGE model RAEM. The ideas should be especially useful for researchers developing SCGE applications for use in transport appraisal and those who want to get a better understanding of differences between theoretical and computable SCGE modelling.

After a short introduction to SCGE modelling and its use for transport policy analysis (Section 2) we introduce the problems identified and, where appropriate, propose alternative specifications (Section 3–6). We summarise our findings and recommendations in Section 7.

2. SCGE modelling for transport appraisal

2.1. Introduction

There is a large amount of literature on the economic impacts of infrastructure (see Blonk, 1979; Rietveld & Bruinsma, 1998, for overviews) as well as a large variety of methods to estimate these impacts (see Oosterhaven, Sturm, & Zwaneveld, 1998; Rietveld &

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Nijkamp, 2000, for overviews). The methods most used are the following (Oosterhaven, Knaap, Ruijgrok, & Tavasszy, 2001):

- micro surveys with firms,
- estimations of quasi production functions,
- partial equilibrium potential models
- macro and regional economic models,
- land use/transportation interaction (LUTI) models, and
- spatial computable general equilibrium (SCGE) models.

SCGE models typically are comparative static equilibrium models of interregional trade and location based in microeconomics (though generally applied at the more aggregate, sectoral level), using utility and production functions with substitution between inputs. Firms often operate under economies of scale in markets with monopolistic competition of the Dixit and Stiglitz (1977) type. The few empirical applications of this approach are Bröcker (1998) and Venables and Gasiorek (1996). Interesting theoretical simulations with a SCGE model with a land market are found in Fan, Treyz, and Treyz (1998). These models are part of the new economic geography school (Fujita, Krugman, & Venables, 1999; Krugman, 1991) and have been around for less than a decade.

The present, still young SCGE models lack detail and a sound empirical foundation, but should benefit from their sophisticated theoretical foundation and non-linear mathematics. The latter is precisely the reason why SCGE models are able to model (dis)economies of scale, external economies of spatial clusters of activity, continuous substitution between capital, labour, energy and material inputs in the case of firms, and between different consumption goods in the case of households. Moreover, monopolistic competition of the Dixit–Stiglitz type allows for heterogeneous products implying variety, and therefore allows for cross hauling of close substitutes (i.e. trading apparently similar products back and forth) between regions.

Due to the fact that SCGE models are comparative static models, their main strengths in transport appraisal lie in the comparison of outcomes of different equilibrium states, such as:

- Benefits of generalised transport cost reductions due to changing prices, production, consumption and trade, while holding the number of workers per region constant; showing what could be labelled as the short-run effects, or the ‘planned’ effects considering the governments housing policy.
- Benefits when the number of workers is allowed to change too, showing the long run effects of new transport infrastructure.

Below we discuss the basic characteristics of a typical SCGE model developed in the Netherlands (see Oosterhaven et al., 2001).

2.2. The RAEM model

Following recommendations from the Dutch OEEI study (Eijgenraam et al., 2000) concerning guidelines for Cost Benefit Analysis of transport projects, we have recently developed a new spatial CGE model (RAEM) for the Netherlands, tailored towards applications in transport project appraisal. Below we give the basic specification of the model based on (Oosterhaven et al., 2001). Comparisons with other spatial economic models can be found in (Oort, Van, Thissen, & Wissen, 2005). Further down in the paper, we return to specific parts of this model, which deserve additional comment. We show how the specification should be interpreted and how it can be improved.

In the RAEM model we assume that all markets are of the monopolistic competition type and each firm in each industry produces one and only one variety of the product of that industry. In all production and utility functions the inputs with volume X and

with n varieties i produced by n firms in regions j are added to aggregate intermediate deliveries Q_j with the following CES-function (see Dixit & Stiglitz, 1977):

$$Q_j = \left(\sum_{i=1}^n x_{ij}^{1-1/\sigma} \right)^{1/(1-1/\sigma)} \quad (1)$$

In (1) σ represents the elasticity of substitution among the n different varieties of industry j . All utility and production functions have a Cobb–Douglas specification. The production function only uses intermediate inputs and labour:

$$Y_j = L_j^\alpha \left(\prod_{i=1}^m Q_i^{\gamma_i} \right)^{1-\alpha} \quad (2)$$

In (2) parameter α controls the division between labour and the total of the intermediate inputs and γ_i gives the relative weight among the intermediate inputs from different sectors.

In the equilibrium all prices are a function of all other prices. In this solution the complement of the quantity aggregate (4) is the following price index function:

$$G_j(p_{1j}, \dots, p_{nj}) = \left[\sum_{i=1}^n p_{ij}^{1-\sigma} \right]^{1/(1-\sigma)} \quad (3)$$

In (3) p_{ij} is the price of variety i in sector j . This price index varies across different regions, as these purchasing prices are inclusive of the transport and communication cost of delivering the product.

In the monopolistic competition equilibrium, prices are a mark-up over marginal costs, including the transport costs. Thus, the way in which transport costs are included in the prices is decisive for the functioning of our model. We have followed standard practice and introduce transport costs as a mark-up over the regular f.o.b. (free on board, i.e. including loading costs but excluding trunk haul and delivery costs) price. Specifically, in view of the problem at hand, RAEM uses a new bi-modal (people/freight) transport cost mark-up:

$$p^* = [f_g(d_g)]^\pi \cdot [f_p(d_p)]^{1-\pi} \cdot p \quad (4)$$

In (4) π gives the importance of freight transport for the transportation costs of the sector at hand. Information on this parameter proved to be scarce. Hence, expert judgement was used to ‘guessimate’ the 14 sectoral π ’s needed. In (7) f follows the usual specification of iceberg transport cost (see e.g. Bröcker, 1998):

$$f(d) = 1 + \vartheta \cdot d^\omega \quad (5)$$

In (5) θ and ω are parameters to be estimated and d is the distance between the producer and the customer. For freight, simple road kilometres used as distances do not change in the application. A new railway link for passenger transport is modeled as a decrease in ‘people-distance’ d_p .

2.3. Typical problems in the application of RAEM

After two applications of the multi-sector RAEM model to major Dutch transport infrastructure schemes, a number of lessons have emerged with respect to the applicability of such models to transport appraisal. These lessons concern, in broad terms, the specification of the relations between the transport system and the spatial economic system of production, consumption and trade. More specifically, they have to do with:

- Interfacing problems between SCGE and transport models
- The modelling of the influence of transport costs on sectoral production

- The interpretation of the conventional, micro-level specification of product variety in aggregate applications
- The problem of irrational agglomeration effects in economic activities

We treat these issues in more detail within Sections 3–6 of the paper.

3. On the interface between SCGE and transport models

3.1. Introduction

The transport system enters the spatial economy through the costs of transport services. Typically, in transport evaluation practice transport models are applied to feed SCGE models with cost changes in the transport sector as a result of policy measures. This section treats practical difficulties that can arise when linking SCGE models with transport models. Our assumption is that SCGE models treat spatial interactions between regions, based on a description of their production and consumption, and do not describe the choices made with respect to alternative services offered within the transport system. This is the main reason for complementarity between transport and SCGE models.

We also describe some problems that haven't yet been solved – and cannot be on the short term – due to limitations in data availability. Our aim here is to gain clarity in conceptual terms how these modelling difficulties arise and to raise a discussion about how these could be solved (Fig. 1).

Linking these models can reveal problems that are not visible when one only considers one type of model. They are however in part well known to the Land Use-Transport Interaction or LUTI type models (see e.g. Wilson, 1998). In part, as these models do not share the rigorous economic framework of CGE models (see Oosterhaven et al., 2001 for a discussion). We treat the following common problems:

- differences in linkages required between freight and passenger transport
- the choice of a correct specification of the costs of transport

- possible inconsistencies between SCGE and transport models in the description of trade patterns

3.2. Transport costs by sector

Passenger and freight transport are linked to transport using sectors by different mechanisms. Freight transport is needed to acquire goods and is thus directly linked to sectoral inputs. Passenger transport is a complex of different motives: business traffic for the delivery of services (we distinguish 2 types of services: those sourced directly by the firm – e.g. the cleaning company – and those related to goods delivered to the firm, e.g. the traveling salesman) and commuting traffic of employees. Other purposes of transportation are not included explicitly in the production functions. Apart from the general question about the degree to which efficiency gains in transport are made productive in the transport using industry, there is a much more commonplace problem that deserves attention: the contribution of transport costs to product value. For freight transport these costs are well identifiable and existing statistics indicate that depending on the sector these lie between 5% and 25% of the value of the product. As a significant share of firms uses transport on an own account basis (in NL this share is estimated at 30% for low valued goods and 60% for high valued goods), we cannot in general rely on aggregate industry statistics – as own account transport is not registered in I/O tables as a separate flow, the input to industry from the transport sectors which appears in these statistics simply does not give the full picture.

For commuting, these relationships between transport spending and sectoral turnover can be identified using labour costs statistics per sector. Business traffic is the most difficult category. For services sourced directly by firms, a similar problem as with freight transport arises in terms of own account transport, which is usually the case with services. Additional services that go with the acquisition of goods (advisory services, sales) are considered as an overhead to the costs of production and delivery of goods. No (official) statistics exist, however, on the proportion of the costs of business trips in the product costs.

As the spendings on transport services concern a key assumption in the application of SCGE models for transport appraisal, we recommend that additional research is undertaken in this area to produce relevant and representative indicators.

3.3. Which transport costs?

The meaning of “transport costs” varies across disciplines. In transport appraisal, where the transport engineering and regional economics disciplines collide, the definition of transport costs for SCGE modelling can in many cases be too wide or too narrow:

- Firstly, the costs that the transport using sectors incur have nothing to do with generalised costs (as e.g. a weighted sum of costs and times) of transport. The market price that firms pay for transport – a structural relationship between the transport sector T and the transport using sectors TU – is something different than the shadow price of services assumed in transport choice models – a behavioural relationship between T and TU. It should be clear what is included in the value of time used in transport models (drivers' wages? capital loss in transport? costs of fulfillment downstream?) in order to avoid double counting.
- Secondly, on the other hand, we must take care not to limit ourselves to transport costs only. In broad terms, it is the cost of interaction between regions that interests us, i.e. the costs to get goods in the right shape, in the right quantities and on the right time between A and B (see Ruijgrok, Tavasszy, & Thissen, 2002).

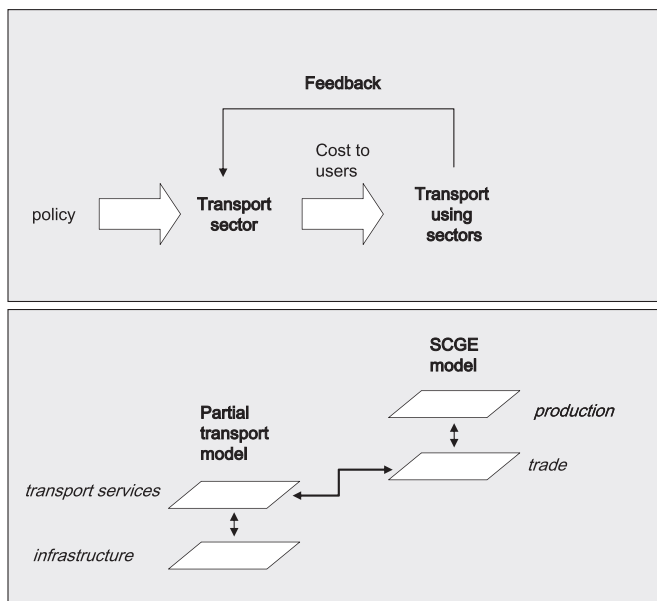


Fig. 1. Linking scheme for the transport and SCGE models.

This includes easily discarded, but highly relevant categories like “physical distribution costs” or “border crossing costs”.

3.4. Consistency with 4 step transport models

Most transport models are not limited to the markets of transport services but also describe the patterns of trade between regions. This introduces a source of inconsistencies between SCGE and transport models. The fact that, conceptually at least, the most common model form for describing these patterns, is implicitly also part of the SCGE mechanism (the gravity model), is of little comfort. SCGE models are fundamentally different in the sense that – in transport modelling terms – the production and attraction rates are elastic. The total flows leaving or entering a region will thus differ between the two types of models.

These elasticities are endogenous in SCGE models which places limits on the transferability to transport models. This problem can in principle be solved by attempting to let the two models reach convergence in these spatial patterns, by feeding back spatial patterns of transport flows from the SCGE model to the transport model.

4. Modelling the influence of transport costs on sectoral production

4.1. Introduction

Samuelson's (1952) iceberg approach is commonly used in regional general equilibrium models. The approach, in which it is assumed that transport costs can be modeled as produce ‘melting’ while being transported, is theoretically elegant for one-sector models but inappropriate in case of multi-sector models. The iceberg approach will cause a severe mis-specification of the production costs in the transport sector. Moreover, as argued in Oosterhaven and Knaap (2003), the iceberg approach mixes up volume and price effects and may even lead to incorrect and perverse model results.

4.2. Transport production

The first mis-specification of modelling the transport sector using the iceberg approach in a multi-sector framework is due to the implicit production function that is used in producing transport. The iceberg approach implicitly assumes that the transport of goods is produced in the same way as the product transported. For, transport is expressed in units of the product transported. One only has to think of the mining sector to understand that this is a fundamental mis-specification, which may have severe consequences for factor use in the economy. In a one-sector economy it is assumed that all products have the same production function. Obviously, the iceberg approach will not lead to any (additional) mis-specification in a one-sector model.

4.3. Price and volume effects

Reducing iceberg transport costs implies that the suppliers need to produce less to satisfy the same level of demand on the part of the customers. Hence, consumption is able to increase more than production. This may even lead to perverse effects where a reduction in the transport costs leads to increased consumption of a good, while production actually declines. This is caused by the basic assumption of the iceberg approach that a reduction in transport costs may be modeled as an increase in the amount of produce that arrives in a certain region.

When a macro SCGE is used, this property does not pose a serious problem as the macro economic output is inclusive of

transportation output that does (implicitly) reduce. In a multi-sectoral SCGE, however, this iceberg type transport costs imply a serious mis-specification as they lead to an underestimation of the output effects in the non-transport sectors, especially in those sectors for which transport costs reduce most, whereas the opposite should be the case.

The price and volume effects are however easily corrected by making transport costs per sector explicit and subtracting them from the sectoral production effects. In other words, one should always calculate sectoral production net of transport production. This does however not solve the earlier mentioned problem of using an inappropriate production function.

5. On the interpretation of micro-level variables in a macro setting

5.1. Introduction

In the theoretical specification of SCGE models, the firm and the representative consumer are the basic entities whose behaviour we want to describe. At this level, which we will call the micro-level, the SCGE framework is unambiguous. Despite this clarity, however, the interpretation of central theoretical concepts such as the firm and product varieties becomes problematic, when we apply the SCGE framework at the regional and sectoral level. Our argument is linked to the theoretical model described here and the type of agglomeration effects distinguished in our model. In contrast to other applications, e.g. the case of knowledge spillovers, the discussion below addresses the case of a model with agglomeration effects due to Dixit–Stiglitz varieties in vertical linkages (Venables, 1996) where an increase in varieties of intermediate inputs available to the firm will have positive effects on the firm's productivity.

5.2. The variable n

In the literature there is much discussion about the interpretation of a variable which is central in the Krugman style regional equilibrium model: the region and sector specific number of varieties, usually noted as $n_{i,s}$ (Fujita et al., 1999).¹ Normally the number of varieties is associated with the number of firms in a region. In this chapter we will argue that it should be neither interpreted as an indicator for the absolute number of firms nor of varieties in a region. Moreover, we argue that the interpretation of $n_{i,s}$ becomes unclear in our type of model and is only of little practical importance.

To understand what is the meaning of $n_{i,s}$ we have to look into the way $n_{i,s}$ is determined. In general $n_{i,s}$ is estimated based on the flow of goods d between regions i and j of a sector s good. This flow of goods is a function of the relative price of a good in region j vis-à-vis the price of a good in region i , the substitution elasticity σ_s between varieties of this good in sector s and the absorption (demand) A in receiving region j . This is mathematically described in Eq. (6).

$$d_{i,j,s} = f\left(\frac{p_{j,s}}{p_{i,s}}, \sigma_s, \bar{A}_{j,s}\right) \quad (6)$$

The price in a region is a function of the prices in all regions, the variable $n_{r,s}$ and the substitution elasticity σ_s . The variable $n_{i,s}$ is a function of the fixed costs ψ_s , the substitution elasticity σ_s and the production in a region $\sum_j d_{i,j,s}$:

¹ See among others Bröcker (1999), Elhorst et al. (2000) and Venables and Gasiorek (1996).

$$P_{i,s} = f(n_{i,s}, p_{i,s}, \sigma_s) \quad (7)$$

$$n_{i,s} = f\left(\sigma_s, \psi_s, \sum_j d_{i,j,s}\right) \quad (8)$$

5.3. Calibration and interpretation of n

During calibration we are looking for values of σ_s and ψ_s such that the simulated values for trade flows are as close as possible to observed trade flows. These values determine $n_{i,s}$. The system of Eqs. (6)–(8) is independent with respect to the sectors. In other words, the parameters are calibrated sequentially for all sectors² and the calibrated parameters are sector specific.

This data driven necessary sector aggregation in the calibration process reduces our possibilities to interpret the meaning of the resulting $n_{i,s}$. The theoretical concept of varieties is based on comparable products that only marginally differ. This difference may be the colour of the product. Data on this low aggregation level, which is even below the aggregation level of production lines, is never available. Varieties in computable CGE models are therefore always aggregates of bundles of product varieties. This takes away the possibility to compare values with those found in other studies, or even regional statistics (showing e.g. the number of firms or production lines in a region).

The only meaningful step for empirically interpreting $n_{i,s}$ would be an aggregation over regions, resulting in, say N .³ This N represents the number of varieties in the total economy and would allow a validation of the model with e.g. national production statistics. The only meaningful interpretation of $n_{i,s}$ is therefore the share in the total number of varieties N that is produced in region i .⁴ However, in the model we do not consider the number of varieties on the product level, but at the sectoral level. The practical, empirical interpretation of N is very difficult at the sectoral level as it is still an aggregation of a bundle of product varieties with different weights, substitution elasticities, and fixed costs.

An immediate consequence of the above is that values used for $n_{i,s}$ from theoretical or micro-level modelling studies cannot be taken as a benchmark or a boundary condition during the estimation of the model. The standard theory dictates that $n_{i,s}$ is continuous, above 1 and large. However, considering the implementation of the SCGE model as described above the latter two conditions are no longer obvious. Firstly, the variable $n_{i,s}$ is now only a part of a sectoral demand function and small values could appear as well. Secondly, the actual size of $n_{i,s}$ is subject to the modifiable area unit problem, i.e. it depends on the geographical scale of the analysis. Thirdly, as varieties on the sectoral level (opposite to the product level) are no longer interpretable in this context, imposing the condition of a large $n_{i,s}$ is incorrect and may therefore result in strange model outcomes.

6. Irrational agglomeration effects

6.1. Introduction

Changes in land use are simulated by SCGE models through changes in the volume of regional production and consumption. One can experience problems with the traditional specification of

these functions, however, if constraints upon changes in land use are neglected. More specifically, unrealistic or irrational (i.e. given what we know as rational firm behaviour) agglomeration effects can occur in SCGE models if hysteresis and locational boundedness is not adequately taken into account. This may take several forms:

- Hysteresis: Past decisions affect the future. Setting up a new plant in another location instead of extending an existing plant may for some sectors be very costly. Investments in the past should in this case be seen as ‘sunk costs’ in the production process and should be treated in that way if compared to new investments.
- Locational boundedness due to locational inputs; in other words, production factors may be only locally available. An example is the availability of natural resources. In this case one can think about natural gas, but also about the factor land in the agricultural sector.
- Locational boundedness due to locational outputs: these are mainly government-regulated products. For instance, services supplied by municipalities cannot be substituted. That is, one has to consume municipality services from one’s own municipality. This is exogenous local production.

6.2. Preventing irrational agglomeration effects in RAEM

Locational boundedness can best be modeled by explicitly taking factor markets into account, or by fixing some of the production y .⁵ Hysteresis, (path dependency), however, asks for a more sophisticated approach. Hysteresis affects the productivity of production, because it is inefficient to produce a different amount than the ‘normal’ capacity of the firm $\bar{y}$. In other words: costs have to be made to reduce or increase production in a region. This captures the ‘sunk’ costs idea. It is usually more costly to build a new factory than it is to improve an existing factory. This implies that although it would be more efficient to produce in other regions this will not take place because it is costly to move a plant. It can be argued that in the very long run these effects will be zero. However, over the period of infrastructure policy analysis (a period of approximately 20–30 years) these effects are definitely not equal to zero. Of course these effects are sector specific and depend on the ‘footlooseness’ of a sector $\lambda_{i,s}$ (varies between 0.1 and 1).

Given a ‘normal’ Cobb–Douglas production factor with scaling parameter $\bar{A}_{i,s}$, we propose the following function to capture hysteresis:

$$A_{i,s} = e^{-\lambda_{i,s} \left(\ln \left(\frac{y_{i,s}}{\bar{y}_{i,s}} \right) \right)^2} \bar{A}_{i,s} \quad (9)$$

This idea of productivity effects depending on a ‘normal production level’ draws heavily from the structuralist post-Keynesian tradition. In model simulations we may assume that the normal production is equal to the production in the base-run. The function is plotted for the two extreme cases for $\lambda_{i,s}$ in Fig. 2. This function has the property of being equal to 1 if the production is equal to the normal production. A becomes less than 1 if production deviates from the normal production. The productivity in the sector declines in when A becomes less than 1. This function can also partly be used to capture locational boundedness in case of locally available

² In the model the relative sector prices affect the demand for sector inputs. This is however not the case in the calibration. Moreover, since only relative prices matter, one price can be set as a numeraire for every sector.

³ Thus, $N = \sum n_{i,s}$.

⁴ This should not be mistaken for the agglomeration effects which is an weighted aggregation over several regions.

⁵ Note that in an empirical application of the model fixing production to zero will have large numerical consequences. These sectors should be completely removed from the model for these regions because otherwise prices would reach infinity.

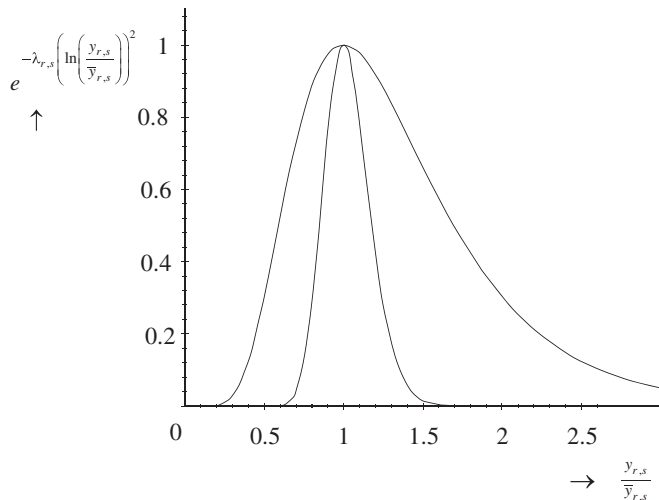


Fig. 2. Scaling of production to capture hysteresis.

production factors.⁶ For example, given the amount of land available the production may be extended at the cost of a loss in productivity (more intensive use of land) or reduced with a loss in productivity (taking valuable land out of production). Especially in the case of land there is a clear limit to the amount available.

7. Conclusions and recommendations

In this paper we discuss a number of complexities in modelling changes in the economy of regions. We focus in particular on

- changes that arise as a result of changes in the efficiency of transport processes
- the modelling approach using transport and SCGE models.

These problems in modelling have not yet received widespread attention, as the application of SCGE models for the appraisal of transport investments and policies is a new phenomenon. We describe 4 types of issues, explain the possible implications of neglecting these issues and, where relevant, propose approaches for their resolution. These issues concern 1) interfacing problems between SCGE and transport models, 2) the modelling of the influence of transport costs on sectoral production, 3) the interpretation of the conventional, micro-level specification of product variety in aggregate applications and 4) the problem of irrational agglomeration effects in economic activities.

Our main conclusion concerning these points are as follows:

1. In order to have a consistent linkage between transport and SCGE models, the main variable that forms this linkage – transport costs– deserves special attention. We firstly observe that there is a severe lack of empirical data on the consumption of transport services by various sectors of industry. Secondly, we identify two cases of a possible mismatch in the definition of transport costs, as they are produced by transport models, and as they should enter SCGE models. Thirdly, we describe how the use of 4 step transport models may introduce inconsistencies in appraisal results.
2. The use of iceberg transport costs is theoretically convenient and empirically acceptable in the case of a one-sector economy.

In a multi-sector economy, it may lead to strange results: an underestimation of the impacts in precisely those sectors that are most sensitive to the reduction of transport costs at hand. Moreover, estimations of factor costs involved in transport are based on the wrong production functions and therefore incorrect.

3. We find that the interpretation of the variable $n_{i,s}$ is less straightforward for our purpose of application than often presented in the literature. This variable seems to be merely a parameter in the regional demand function but of no importance in policy analysis. Moreover it was found that this variable is a theoretical abstract. The implication is that it cannot be used in the calibration, nor is the generally used condition of a large value for n or N still valid.
4. We propose a new method to take hysteresis and locational boundedness of production into account. This is necessary to have a more realistic policy analysis, particularly when it comes to predicting changes in spatial patterns of production and consumption.

As a concluding remark, we feel that such a critical, yet constructive evaluation of the application of SCGE modelling for transport appraisal purposes is a necessary task for the research community. The advent of SCGE modelling, beside improving our insight in how regional economies interact, also includes a promise of improved quality of appraisal results for transport investments and policies. New research into the critical interface with transport modelling is needed, however, for this promise to materialize.

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⁶ Note that the normal production may be to a small figure if the production is zero.

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