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

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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.

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):

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

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:

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

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:

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

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:

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

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 'guestimate' the 14 sectoral π's needed. In (7) f follows the usual specification of *iceberg* transport cost (see e.g. Bröcker, 1998):

$$f(d) = 1 + \vartheta \cdot d^{\omega} \tag{5}$$

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