Social Cost-Benefit Analysis and Spatial-Economic Models in the Netherlands

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1. Introduction

After the appearance of the so-called OEI-guide on social cost-benefit analysis (Eijgenraam et al. 2000), performing a cost-benefit analysis (CBA) has become an obligatory step in the decision-making process on all national transport infrastructure investments in the Netherlands. Like the comparable UK report (SACTRA, 1999), the OEI-guide advocates to seriously consider the question whether or not the indirect economic effects of improving transport infrastructure represent additional welfare effects on top of the direct transport effects (time and cost savings) and the direct external effects (emissions, noise, etc.). Of course, social cost-benefit analysis is not only relevant for infrastructure policy. It is also a useful evaluation tool for all other types of spatial policy, such as physical planning, housing policy, environmental policy and spatial economic policy.

The core complication in all cases is that the direct cost and benefits of any policy are passed on through markets to parties that are not directly affected by the policy measures at hand. This generates two major analytical complications. First, during this process cost and benefits may increase or decrease in size, due to economies of scale and all kind of market imperfections. Second, during that process cost and benefits may be passed on or flown in across regional or national borders. Thus, the net total regional or net total national welfare effect may well be smaller or larger than the direct net effect for the region or nation at hand. Obviously, the only way to handle these complications in a systematic manner, without running the risk of double counting or undercounting additional welfare effects, is by means of spatial economic modelling.

In this contribution we discuss this issue at two levels. First, we discuss the essence of social CBA as a policy evaluation tool, and indicate the nature of the complication on different markets. In doing so, we use transport infrastructure as an example and discuss the land market in somewhat more detail. Second, we give an overview of whether and how well

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a series of Dutch spatial models are dealing with these complications, per type of market. There again, transport infrastructure is used as an example of a spatial policy intervention, but the emphasis in the discussion of the models will be on their treatment of product and labour market imperfections, as the land market is absent in most of the models. Further details on both issues can be found in the update on the indirect effects' chapter of the OEI-guide (Elhorst, et al. 2004).[2] In the concluding section, some thought is given to problems that arise when different models are combined to capture the full array of effects.

2. Complications of social cost-benefit analysis per market

Advantages, disadvantages, and partial versus integral CBA

The most important general feature of social CBA is its chosen policy goal: the aggregate welfare of a group of citizens, usually the inhabitants of a certain region or country. This means that all kind of intermediate policy goals, such as fighting regional unemployment or improving the quality of the built environment, are only treated implicitly in as far as they improve the welfare of the designated group of citizens. The most important technical feature of social CBA is the way in which the change in welfare is measured, namely as the aggregate willingness to pay (WTP) for the effects of a certain policy intervention. Measuring the WTP is relatively simple when changes in the provision of market goods to consumers are analysed. Then the so-called rule of half can be used: the change in the market price is multiplied by the average of the old and the new quantity consumed: $\frac{1}{2}(P_{new} - P_{old})(Q_{old} + Q_{new})$. However, when it is the provision of public goods that changes or when the external effects of the production and consumption of both private and public goods change, measuring the WTP may be quite complicated.

The advantage of social CBA is its use of one single criterion (the aggregate welfare change) that summarises the relative attractiveness of different policy options, as opposed to the multitude of criteria that have to be weighted somehow in the case of multi-criteria analysis.[3] Besides, the aggregate welfare of citizens, according to many, ought to be the single leading criterion for public policy, instead of the often-conflicting lower level policy goals of separate government departments. The disadvantage of social CBA relates to the fact that

[2] This report is in Dutch. The authors like to thank their co-authors of this update, J. Paul Elhorst and Carl C. Koopmans, and discussants from several government department and the CPB for their comments on the so-called OEI-update.

[3] In fact, there are two criteria, the *net present value* that gives an absolute measure for comparing competing solutions for the same problem, and the *rate of return* that give a relative measure for comparing non-competing policy measures (cf. Elhorst and Oosterhaven, 2004).

measuring the welfare effect of changes in non-market goods by means of the monetary WTP is something that is quite difficult to comprehend by non-specialists. Besides, using one single aggregate criterion implies that changes in the distribution of the aggregate welfare over the designated citizens are disregarded. To neutralise the first disadvantage, the OEI-update on the presentation of CBA results (Koopmans, 2004) advocates presenting the welfare effects for non-market goods also in non-monetary physical terms, such as in tons of CO_2, number of jobs and acres of land lost. To neutralise the second disadvantage, the OEI-update on distribution effects (AVV, 2004) advocates to also present the distribution of the welfare effects over different groups of citizens, if that is considered important.

Technically more complicated is the way in which all the welfare effects of even a seemingly simple policy measure, like a new road, may be measured in the first place. Individual citizens are often affected in many different ways along many different causal chains. CBA evaluation would be far simpler if this measurement could be restricted to the first order direct effects of a policy measure. Luckily this is possible when two conditions are met. When all markets are working perfectly and when there are no border-crossing effects, the passing on of the direct welfare effects to non-involved other actors will only change the distribution but not the size of the aggregate welfare effect. Thus, when these two conditions are met, a social CBA may be restricted to measuring the welfare effects only with the directly affected actors. Such a cost-benefit analysis is called a *partial CBA*, as opposed to an *integral CBA* that takes all ramifications through all different kinds of markets into account.

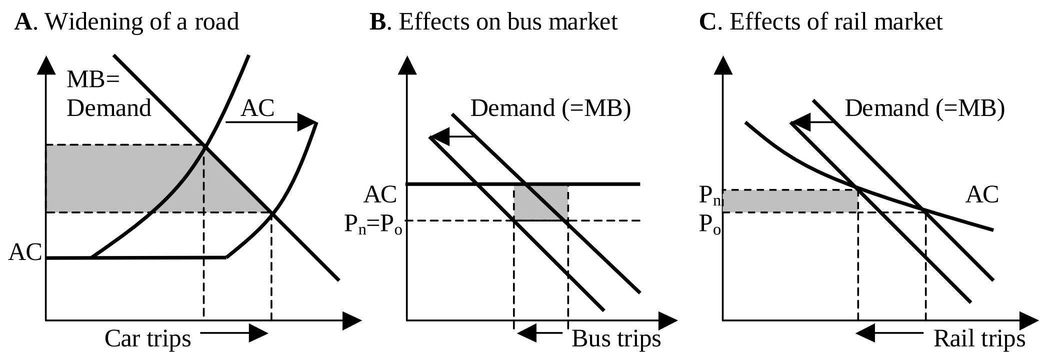
Unfortunately, most markets do not work perfectly. Moreover, especially when sizeable infrastructure projects are considered, border-crossing effects are unavoidable. In fact, such effects may even be aimed at, as border-crossing effects do not need to be negative. They may also be positive due to an increased competitive position of domestic firms or an increased locational attractiveness of domestic regions. Below we will briefly discuss the nature of the most important market imperfections, in general and specific per market.

Market imperfections in general

Markets may be imperfect for different reasons. First and foremost, actors on all markets usually take their own private cost and benefits into account but disregard the *external cost and benefits* caused with other actors. The consequence is a gap between private and social cost and benefits. Naturally, these external effects have to be taken into account when a social CBA is done, and have to be added in full to the direct effects. Second, the *market price* may be *unequal* to the *private cost* on the supply side, or unequal to the *private benefits* on the demand side. Such a difference may have several causes. Subsidies and taxes may cause a gap between the market price and private cost or benefits. Market power also may cause this gap.

Figure 1 shows how the direct transport benefits, generated by the widening of a certain road, may cause additional welfare effects on competing transport markets because of market imperfections. In panel A, the road capacity enlargement leads to a reduction in congestion and thus to a reduction in the average social cost (AC) that equals the marginal private cost of using the road. Car users will compare this with their marginal private benefits (MB), which equal the demand for road usage. The large grey trapezium shows the *total direct benefits*. The little grey triangle indicates the part of this increase that accrues to new car trips. Naturally this modal shift results in a reduction of demand for other types of transport. If the other transport markets work perfectly, the grey triangle measures the full welfare change of these modal shifters, and the total welfare change could simply be measured by using the rule of half on the directly affected road market.[4]

Figure 1. Example of direct benefits on one market and additional benefits on other markets.



But transport markets do not work perfectly. Panel B shows how the presence of a subsidy (on bus services) may lead to additional welfare effects on top of the direct effect in panel A. If the price and average cost of bus services do not change, a reduction in demand will lead to a reduction of the subsidies needed to fill the gap between price and AC. This reduction of subsidies, equal to the grey rectangle in panel B, represents an *indirect additional benefit* of the road widening. Panel C shows how the presence of economies of scale (in rail services) may lead to another additional welfare effect. There it is assumed that the rail operator is required to set its price equal to its average cost, which secures a zero monopoly profit. In that case, a reduction in demand will lead to fewer economies of scale (i.e. higher AC) and consequently higher prices ($P_o \rightarrow P_n$). These higher average costs for the remaining rail services, indicated by the grey rectangle, represent an *indirect additional cost* of the road widening.

[4] Note that the disappearance of the consumer surplus of former public transport users in panels B and C (not shown) is accounted for in the grey triangle in panel A (VU, 2001, appendix 3).

Product market imperfections, agglomeration economies and knowledge spillovers

On product markets, product-specific taxes and subsidies also *distort prices*, as in figure 1B. Moreover, on many product markets, economies of scale lead to market power that mostly is not regulated, like in Figure 1C. In unregulated monopolies or oligopolies, changes in *monopoly profits* again represent additional welfare effects, next to changes in *economies of scale* (see Rouwendal, 2001). Finally, monopolistic competition potentially induces yet another kind of additional welfare effect. In the standard Dixit-Stiglitz (1977) model of monopolistic competition, competition drives down the price to the average cost and monopoly profits to zero, but *product differentiation* (e.g. different brands) still allows producers the market power needed to set their prices above marginal cost. New transport infrastructure and consequently lower transport cost, in that model, allows firms to spatially extend their markets by exploiting their economies of scale. For consumers this leads to a larger variety of supply that represents an additional welfare effect (Rouwendal, 2001). The Dixit-Stiglitz model of monopolistic competition provides the theoretical core of the so-called 'new economic geography' models (see Krugman, 1991; Fujita, Krugman & Venables, 1999).

When spatial economic models cover all of the above imperfections, the question may arise whether or not the spatial agglomeration of economic activity represents a separate additional welfare effect. The literature distinguishes localisation economies that relate to separate industries, from urbanisation economies that relate to all economic activity. Furthermore, it distinguishes Marschall-Arrow-Romer cluster economies that are stimulated by local monopolies, from Porter cluster economies that are stimulated by local industrial competition, from Jacobs urbanisation economies that are stimulated by knowledge spillovers between different industries (see van Oort, 2004, for an overview). If any kind of policy intervention stimulates spatial agglomeration, the core question is whether or not the economies or diseconomies of agglomeration are passed on through markets or outside of them.

If the (dis)economies are passed on through (higher)lower prices, the agglomeration effects will only produce additional welfare if the markets at hand work imperfectly, as indicated above. When all markets work perfectly, adding passed on external cluster and agglomeration economies to internal economies of scale at the firm level would imply double counting the same effects. Most *knowledge spillovers*, for example, are either passed on as part of regular customer/supplier relations or by people moving from one firm to another. In such cases, the market price or the wage paid accounts for the knowledge passed on. Only when knowledge is passed on *outside market transactions* for free, for example during parties and receptions, a truly external effect occurs that has to be added in full to the direct effect of the policy intervention at hand. In all other cases, adding them as a separate effect would simply imply double counting them.

Labour market imperfections in prices and quantities

Of all markets, the labour market is probably, and in the Netherlands definitely, the most imperfect one: first at the national level and even more so at the regional level. At the national level there is a large gap between the gross wage cost for the employer and the net wage for the employee, which reduces both the demand and the supply of labour. Besides, social security and all kind of other benefits, raise the minimum wage against which people are willing to supply labour (the reservation wage). The consequence is a considerable amount of inactivity, both registered as official unemployment and hidden in low participation rates. Finally, most wages are nationally set in bilateral negotiations between labour and employer unions and declared binding. Consequently, wages only react to national unemployment changes, only with delay, and hardly in a downward direction. At the regional level, the immobility of lower educated labour in particular, and inflexibility of wages with regard to regional unemployment and inactivity, aggravates these national imperfections.

As spatial policy per definition affects some regions more than others, spatial models first need to specify the first order impacts on regional labour supply and demand, and second to specify the reactions of regional supply, demand and wages (if any) to these changes. The result needs to be a prediction of the change in *regional matching of supply and demand* in terms of unemployment, vacancies, commuting and migration. Summed over regions, either a national increase or a national decrease in employment, unemployment, productivity and related taxes and benefits will result. These net national changes then have to be valued in the usual way of willingness to pay while avoiding double counting the direct effects (see Eijgenraam et al. 2000; Elhorst et al. 2004).

One type of impact is especially important in the case of transport infrastructure investments, namely the reduction of commuting cost. A reduction in these costs will increase the *spatial range* of all affected labour markets. This may have two types of effects. First, supply and demand may find a better *qualitative match* in terms of education, profession, experience etc. These benefits will be especially relevant for more differentiated, scarce types of labour. Second, the *quantitative match* may also improve when inactive people would be willing to commute and search for jobs over longer distances. These benefits are more likely to be important for lower educated labour. However, only that part of the matching benefits that is not already reckoned with in the employee’s commuting and employer’s hiring decision has to be added to the direct commuter benefits measured on the transport market. The extra benefit is estimated at about 25% of the direct commuting benefits (see Elhorst et al. 2004).

Land market: zoning restrictions and subsidies

Like the labour market, at least in the Netherlands, the land market is also heavily regulated, but in a quite different manner. Prices, especially in the owner-occupied housing market and in the real estate office market, are rather flexible and may well be modelled such that they clear these markets, whereas wages in general do not clear the labour market.

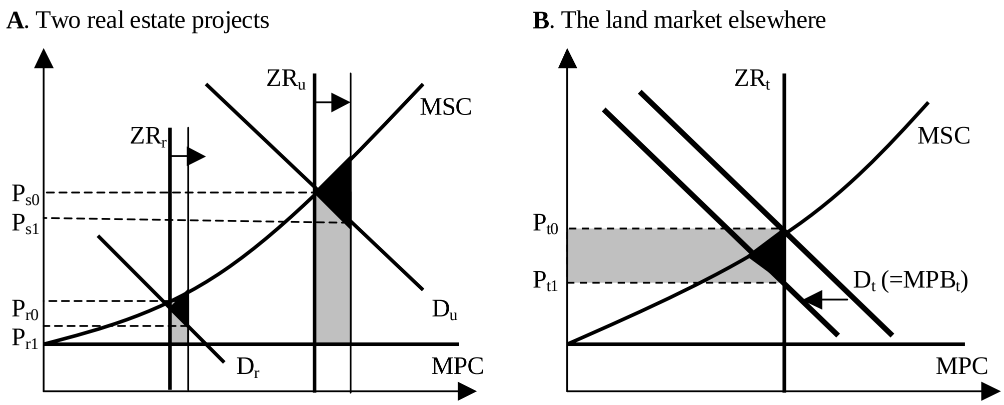
Notwithstanding their flexibility, land prices are distorted by all kind of subsidies, which may well lead to additional welfare effects. Location specific subsidies are directly relevant in the market of industrial real estate and in the rental housing market. Besides, several general subsidies influence prices in rental housing markets both directly, and indirectly in the case of individual rent subsidies. In the owner-occupied housing market, prices are mainly influenced indirectly because of the tax deductibility of mortgage interest payments. Including all these *price distortions* in a spatial model of the land market is not an easy task, which is probably why it is hardly done in practice.

Beside price distortions, *spatial planning restrictions* (zoning) are often thought to distort the land market as well, but this does not need to be the case. Zoning basically should be viewed as an attempt, be it an imperfect one (see CPB, 1999), to correct for the external effects of specific types of land-use for non-users. Unregulated land-use would lead to too much land getting occupied by urban functions and too little by agriculture and nature, as urban landowners and users do not take the welfare loss of the former non-paying users of agricultural land and nature into account. If zoning would perfectly reflect the external costs of urban land-use, it would in fact internalise these external costs, and the land market would work perfectly (except for all subsidies). Additional welfare effects would only occur in as far as zoning is not perfect, which is likely given its slow reaction time.

Figure 2 illustrates the above argument with more precision, in more detail. It assumes *optimal* zoning restrictions in the base situation (the bold ZR lines), with optimal land prices in a rural region (P_{r0}), an urban region (P_{u0}), and a third region (P_{t0}). The land price in the urban region is significantly higher than that in the rural region. The reason is that the external effects drive the marginal social cost of urban land-use (MSC) much more above the marginal private development cost (MPC) in urban areas where green is scarcer, than in rural areas where green is more abundant.

Next, in panel A, urban development is allowed by extending the zoning restriction in both regions (ZR $\rightarrow$). As a consequence, urban land prices will decline a little to P_{r1} and P_{u1}, and landowners will reap a profit equal to the two light grey trapeziums. Panel A clearly shows that project development in urban areas is much more attractive, but the profits only represent a transfer of welfare from the former non-paying users of that land to the (speculative) land-owners. Therefore, these profits do not represent an increase in aggregate welfare. In fact, aggregate welfare reduces with the size of the two black triangles, as the amount of urban land, is assumingly increased to a sub-optimally large size.

Figure 2. Zoning restrictions and profit versus welfare effects on land markets



Panel B, shows the indirect effects of these two projects in a third region. Demand there will decrease and land prices will also decrease. Existing landowners will experience a financial loss equal to the grey rectangle (inclusive of the black triangle), but again this only represents a transfer, now from the present owners to (future) private users. It represents no change in aggregate welfare. Aggregate welfare changes for a different reason, as too much land remains zoned for urban use compared to the now lower marginal private benefits (MPB). As urban land-use can only be returned to non-urban land-use at considerable cost, simply limiting the amount of land zoned for urban land-use to the new optimum cannot take this negative welfare effect away.

Of course, the case described in Figure 2 is very specific, but it illustrates the complex task of modelling the impact of zoning in such a way that the model outcomes can be used in a social CBA. Moreover, it shows that private profits of landowners and developers need to be corrected for the increase in the external cost of urban land-use. When zoning restrictions are considered more or less optimal, it also shows that actual land prices may be used as a proxy for the external cost of less green (e.g. Elhorst et al. 1999). Besides, as mentioned earlier, the direct and indirect effects on (land and housing) subsidies should be taken into account.

International effects and macro-economic feedbacks

Especially when large *line* transport infrastructure is considered, both directly and indirectly, time and cost benefits may accrue to foreign firms and citizens. This will result in a downward correction of the direct transport benefits. And, especially when large *point* infrastructure is considered, there may also be flow-on effects of increased foreign investment. This will require an upward correction of the direct transport benefits. Spatial economic models preferably should be able to capture both types of effects to be useful for social CBA.

When all indirect regional effects are summed, the net national indirect effect either may or may not be estimated correctly. This mainly depends on the question whether macro-economic feedbacks that only work at the national level are incorporated. Two sequential effects that mainly operate at the national level are of prime importance. When spatial policy interventions lead to a net national increase in the demand for labour, national bilateral wage negotiations will produce higher wages in all regions, which will result in cost and price increases for products from all regions. This will result in a decrease of exports, an increase of competing imports, and a subsequent decrease in labour demand in all regions, which will reduce the pressure on wages. When these feedbacks are absent, spatial economic models will produce an overestimation of the (international) benefits (Eijgenraam, 1995).

3. Spatial models

Next, we will discuss whether and how well existing Dutch spatial models incorporate the complications discussed above. If a model of the affected markets and regions contains a measure of consumer welfare, and explicitly accounts for the relevant market imperfections and cross-border effects, a correct estimate of the total of the welfare effects of a spatial policy intervention may be derived. Still we can pose the question why we need models to attain this. Why not use a qualitative assessment of the way in which the direct policy effects are passed on and then estimate the most important additional effects in an ad hoc fashion?

The answer is that models, as opposed to non-structural approaches, clarify the way in which effects are passed on, accounting for interactions and feedbacks between the affected markets and regions. Thus, both double counting and undercounting indirect effects can be avoided much easier. In addition, estimating the distribution of the welfare effects across different groups of citizens, and estimating the indirect external effects of production and consumption in different regions, also requires a systematic and consistent estimation of indirect effects. A disadvantage of models compared to non-structural approaches is that the extent to which different markets can be included, along with their imperfections and cross-border effects, is necessarily limited due to restrictions with regard to computational and data requirements.

Here we will look at the extent and quality of the way in which existing Dutch spatial models incorporate and forecast indirect effects and additional welfare effects. First, we look at differences in spatial model approaches. Next, we assess how market imperfections are incorporated in these models. Then, we assess the quality of the models in terms of economic theory, plausibility of the assumptions, empirical validation and scope of application. Finally, we identify which model extensions and improvements are desirable.

Transport models

To measure direct effects of new transport infrastructure, spatial transport models are available that mainly focus on the distribution of transport demand over the available transport network. Changes in the available transport infrastructure may lead to changes in transport cost, which are the first order direct effects. Changes in transport cost then affect production, labour supply and labour demand, and the demand for land and real estate, which in turn lead to changes in transport demand. The effect on transport cost of this change in transport demand is a second order feedback effect that can also be assessed by spatial transport models. Since most spatial transport models are not integrated into spatial economic models, the first and second order effects can only be calculated in separate model runs. Full feedback effects are therefore not taken into account.

The main Dutch regional transport models are the National Model System (LMS) for passenger transport (see www.rand.org/randeurope/) and the Strategic Model for Integral Logistics and Evaluation (SMILE) for freight transport (see www.inro.tno.nl).

Spatial models that focus on product markets

Quasi production function models estimate regional production as a function of traditional production factors, like capital, labour, land and intermediate inputs, and a number of additional factors, like infrastructure, transport cost and accessibility. The direct effects of new transport infrastructure in terms of increased accessibility or a decrease in transport cost are then translated into changes in regional production. The problematic assumption for these types of models is that regions with comparable amounts of traditional production factors, but with better accessibility, show higher production levels. Since the relation between accessibility and economic activity runs both ways, the econometric estimation of the quasi production function can be problematic (see Sturm, 1998). Assuming fixed macro-economic growth solves this problem, but implies that the model can no longer estimate the generative effects of transport infrastructure, i.e. an increase in production, but can only estimate the distributional effects. This makes this type of model less suited for estimating additional welfare effects, but very suitable for estimating the distribution of the indirect effects over different regions. The best example of a Dutch quasi production function model is REGINA, which stands for Spatial Economic Growth Indication model (see www.inro.tno.nl).

Simple regional input-output models explain regional production levels per sector by endogenous intermediate output and exogenous final demand of consumers, the public sector, private investments and regional exports (Leontief, 1966). In more advanced interregional input-output models, consumer demand from other regions as well as intermediate exports to other regions are treated as endogenous (Oosterhaven, 1981). This way, interactions between regions and sectors that depend on accessibility and transport cost are modelled more explicitly than in quasi production function models, leading to more realistic distributional effects of transport infrastructure investments. However, traditional input-output models only account for backward effects on suppliers and service providers. Hence, these models are not suited for assessing the forward effects of changes in transport prices on prices in other markets and are therefore unable to estimate generative effects. Adding forward effects exogenously without fundamentally modifying the standard model, leads to double counting of effects.

In the Netherlands, two models are available that do this, though in quite different ways. The REMI-NEI model extends the interregional input-output model in a quantitative manner, inter alia by making interregional trade coefficients dependent on transport cost (see Van Bork and Treyz, 2004; Ecorys-NEI, 2004), while the Economic Impact Study (EIS®) extends the input-output model in a qualitative manner by adding project-specific survey information (see www.policyresearch.nl). The REMI-NEI model has a recursive structure, which leads to moving averages, resulting in a dynamic instead of a comparative static process. As a result, it does not show equilibrium situations and in addition hardly account for market imperfections. Therefore, additional welfare effects do not follow directly from these interregional input-output models, and must be estimated separately.

General equilibrium models

Spatial general equilibrium models are comparative static models of interregional trade and location choices, based on the micro-economic theory of utility and profit maximising agents in the economy. Therefore, additional welfare effects follow directly from these models. In addition, the equilibrium framework enables the easy inclusion of market imperfections and feedback mechanisms between markets that can be compared to a base situation in equilibrium. The disadvantage is that time-paths are absent in the model and that markets which do not clear need additional assumptions. Another disadvantage is that additional welfare effects cannot easily be separated from the total welfare effects in the model's output (see Oosterhaven and Knaap, 2003).

For the Netherlands, the Spatial General Equilibrium Model (RAEM) is the only model of this kind (see Thissen, 2004). Like the quasi production function model and interregional input-output models treated above, RAEM is mainly directed towards indirect effects in terms of production and to a lesser extend towards labour markets, although this has been adjusted in the latest version of the model (RAEM-2). Still the model hardly treats effects that are passed on through the housing market or through real estate markets.

Land-use/transport interaction models

Land-use/transport interaction (LUTI) models try to solve the land market deficiency in most spatial models by linking transport models to land-use or location choice models. These models generally use system dynamics to analyse the interaction between transport and the location of production and households (labour supply). They have become very detailed in terms of regions, types of households, sectors, transport modes and transport motives, and are therefore well suited for the estimation of distributional effects (see Oosterhaven and Knaap, 2003, for further discussion and comparison with spatial equilibrium models).

Two very different types of LUTI models exist for the Netherlands. First, there is the Transport Infrastructure Land-use Interaction Simulation model (TIGRIS XL), which focuses on location choices by companies and households that are based on the relative attractiveness of regions, which is determined by the supply of infrastructure and transport cost (see Rand Europe et al. 2003). The model assumes a certain economic growth and labour demand growth and is more suited for estimating distributional effects than generative effects, although it takes a number of market imperfections into account. The second type of land-use/transport interaction model is MOBILEC, which stands for Mobility and Economy. Based on regional investments, which depend on the attractiveness of regions, the regional production and employment are adjusted the next period (see Van de Vooren, 2004). This model is better suited for estimating generative effects. However, market imperfections that would lead to additional welfare effects are hardly accounted for in the model.

Regional labour market models

The other Dutch spatial economic models that are available for estimating indirect effects all focus on labour markets, which are important as most market imperfections may be expected to occur there. Examples are the Regional Labour Market Model (RAM) and the Commuting Location Model. RAM aims at the estimation of the regional distribution of population and employment, accounting for their mutual influence (see Verkade and Vermeulen, 2004). Labour participation, commuting and unemployment are linked to the regional distribution of economic activity. National economic development, however, is taken as given. Therefore, also the RAM model is mainly suited for the calculation of distributive effects rather than generative effects. The same is true for the Commuter Location Model, which specifically aims at the residential location choice (migration) of the working population (see Elhorst and Oosterhaven, 2004). It is a partial model that can be used in addition to other spatial economic models. This can only be done correctly when special attention is paid to the danger of double counting the welfare effects of spatial policy interventions.

Market imperfections and international effects in spatial models

To assess the extent to which Dutch spatial economic models account for market imperfections and international effects, we give an overview of whether and how these effects are handled in Table 1. The following imperfections and effects are covered:

- Price ≠ marginal cost on product markets, both as a result of taxation and subsidies, and as a result of economic profits and losses in non-competitive markets;
- Economies of scale in production, both internal and passed on from other firms, i.e. cluster economies and agglomeration economies;
- Product differentiation that improves the quality of the match between the demand and supply of goods;
- The qualitative matching of labour, which may improve as a result of changes in the size of the accessible labour market (spatial range of the labour market);
- The quantitative matching of labour, which may improve as a result of changes in the supply of labour (spatial range of labour supply);
- Limited demand-to-supply matching as a result of wage rigidities and immobility of labour demand and supply across regions;
- Knowledge and innovation spillovers between economic agents outside market transactions. Although spillovers are external effects, they primarily take place between companies and are therefore included in this overview;
- International relocation of production and labour (in a direct sense);
- Macro-economic feedbacks from international relocation and domestic generative effects;
- Land market zoning restrictions and industrial site subsidies for companies;
- Land market zoning restrictions and land and housing subsidies for households.

If these market imperfections and international effects are not incorporated, the model outcomes may still enable the calculation of the additional welfare effects that result from them (indicated by +). For example, starting with the changes in employment by region that follow from a certain model, the change in the amount of unemployment benefits that follows may be calculated outside the model, enabling the estimation of related additional welfare effects. If market imperfections and international effects are incorporated in the spatial model, this may either be done in an ad hoc manner (indicated by ++) or in a theoretically ideal manner (indicated by +++). Below we explain the scores in Table 1 for each of the models.

Table 1. Spatial models per type of market imperfection

Model	Product markets			Labour market rigidities			Knowledge /innovation spillovers (external effects)	International effects		Land market: zoning restrictions and subsidies	
	Price ≠ marginal cost	Economies of scale	Product differentiation	Spatial range		Demand-to-supply matching		Direct relocation of production and labour	Macroeconomic feedbacks	Companies	Households
				Qualitative	Quantitative						
Production functions:											
REGINA	+	++	0	0	0	+	0	0	0	+	0
Input-output models:											
EIS®	+	+	0	0	0	0	0	++	0	+	0
REMI	+	++	+++	++	+	++	0	++	++	+	+
Equilibrium models:											
RAEM-2	++	+++	+++	+	+++	+++	0	0	+	+	+
LUTI models:											
TIGRIS XL	0	0	0	0	+	+	0	0	0	++	++
MOBILEC	0	0	0	0	+	+	0	+	0	+	0
Labour markets:											
Commuter location	0	0	0	+	0	0	0	0	0	0	++
RAM	0	0	0	+	+	+	0	0	0	+	+

0 = market imperfection is not taken into account, additional welfare effects can not be derived from the indirect effects as calculated by the model
+ = market imperfection is not taken into account, additional welfare effects can be derived from the calculated indirect effects (danger of double counting!)
++ = market imperfection is taken into account in a simple (ad hoc) manner
+++ = market imperfection is taken into account explicitly and theoretically correct

Product market imperfections, agglomeration economies and knowledge spillovers

Additional welfare effects of market imperfections in product markets can be derived from most of the models that explicitly model product markets, either by a quasi production function, an input-output model or an equilibrium approach. In most cases, the additional welfare effects from non-perfect competition (profits or losses) can be derived outside the spatial models from the production levels per sector. RAEM-2 is the only model that explicitly models monopolistic competition, following the Dixit-Stiglitz (1977) approach. It does so for 14 distinguished product markets. In addition, markets disturbances that result from product-specific taxation or subsidies can be added ex post to all these models.

The level of competition in product markets also determines the level of economies of scale in RAEM-2. In most other models, economies of scale are set equal to agglomeration economies, which in general are modelled as an effect of the proximity to other economic activities. Product differentiation is only explicitly modelled in REMI-NEI and RAEM-2 by using a variable number of products in several markets. Additional welfare effects that are the result of an increase in product differentiation cannot be derived in any other way.

Knowledge and innovation spillovers are not treated in any of the Dutch spatial models. The fact that these spillovers occur outside market transactions, and therefore should be considered as external effects, may be a reason for this. Extensions of the models in this direction are desirable to account for these spillovers in social CBA's of spatial policy interventions.

Labour market imperfections in prices and quantities

The extent to which labour market rigidities are modelled varies largely between the models. RAEM-2 shows theoretically the most appropriate way in modelling imperfections on the labour market by linking commuting and migration to transport cost and by explicitly modelling taxes and unemployment benefits. Thus, the regional match between supply and demand is made explicit, as well as the consequences in terms of taxes and unemployment benefits. Since RAEM-2 does not distinguish between educational levels, the welfare effects of the qualitative match of labour are not taken directly into account.

The REMI-NEI model also scores relatively well in enabling the estimation of additional welfare effects, but it does not explicitly model labour market rigidities. However, by accounting for an adaptation process of wages, among other economic variables, and by distinguishing between different educational levels (qualitative match of labour), additional welfare effects from these market imperfections can be derived. The labour market models generally go no further than to estimate levels of regional employment and regional population, on the basis of which additional welfare effects can be calculated under ex post assumptions of wage changes and unemployment changes.

International effects and macro-economic feedbacks

It is remarkable that international effects are hardly given attention in most the Dutch spatial economic models. For a small open economy, international effects may well have a large influence on social CBA when new transport infrastructure links the national transport network to international networks, or when it attracts foreign companies. The reason for the lack of attention for international effects is that most Dutch spatial models focus on a very detailed regional partition for which only national data are available. Collecting of this kind of data for external regions involves relatively much effort (cost) compared to the expected changes in model outcomes (benefits).

Two models pay rather much attention to international effects. EIS® looks at international effects in a qualitative manner, while the REMI-NEI model deals with international effects in a structural way, which also enables the calculation of feedback effects of the international relocation of production and labour on the national economy. Besides, MOBILEC models international effects related to the (relative important) German and Belgium border regions.

Land market: zoning restrictions and subsidies

The only model that explicitly accounts for zoning restrictions and land subsidies for companies is the TIGRIS XL model. This model is specifically aimed at location choices by companies, for which several assumptions can be applied in the model. Developments in land-use are described in detail. For the estimation of additional welfare effects, additional assumptions must be made about land prices, which are not included in the model. For the housing market, the development of housing prices is explained by the development of demand and supply of housing, taking account of zoning restrictions and subsidies. All other models, with the exception of the Commuter Location Model, do not model zoning restrictions and subsidies on the real estate or housing market. However, using model outcomes on regional population and employment, additional welfare effects may be derived from most spatial models by adding additional assumptions outside the models with regard to the demand and supply of housing and real estate, given certain zoning restrictions or subsidies.

Scientific quality of the Dutch spatial models

Although spatial models may claim to be able to estimate several indirect effects on a number of markets, the scientific quality of the way in which these effects are modelled varies. We define scientific quality by the plausibility of the model assumptions, the extent to which the model is theoretically up-to-date, the way in which effects are adjusted over time, and whether the model is empirically validated and can be verified on the basis of available documentation.

All Dutch spatial economic models use a theoretical structure to build empirical relationships. However, not all the model structures are equally advanced. RAEM-2 stands out as a spatial general equilibrium model explicitly derived from profit and utility maximizing behaviour, with a number of central elements from the ‘new economic geography’ (Fujita, Krugman & Venables, 1999). The

REMI-NEI model uses the rather traditional input-output framework, but in a very advanced manner, enabling interactions between several markets. It therefore comes close to a general equilibrium framework, except that model equations are not structurally derived from micro-economic theory. TIGRIS XL uses a theoretically up-to-date land-use/transport interaction approach, but the empirical reduced form equations are kept very simple. RAM and REGINA use theoretically up-to-date structures in which accessibility affects the regional distribution of production, but the models at large are not suitable for estimating generative effects, i.e. production growth. MOBILEC builds an impressive framework of several markets, but the assumptions on the interactions between the markets are rather simple. The EIS® method only uses a traditional input-output model to capture product markets, while indirect effects are further determined in a non-structural manner, using qualitative research techniques.

The development of the effects in time, i.e. the adjustment processes in the economy, are well captured by TIGRIS XL, MOBILEC and RAM, and potentially by EIS® in a qualitative way, but are absent in RAEM-2, REGINA and the Commuter Location Model. In these latter models, the comparative static equilibrium is calculated directly, not showing the adjustment processes that take place. TIGRIS XL uses an iterative process to capture the mechanism in which indirect effects are passed on to different markets. MOBILEC explicitly models time-paths for adjustment processes. RAM allows for a distinction between short-term and long-term adjustments. REMI-NEI claims that adjustment processes can be based on the interactions between market modules in the model, but it is not clear whether and how this has been realised in the current version of the model. Modelling the adjustment process outside the model is possible for all models, including RAEM-2, REGINA and the Commuter Location Model.

For most models it is not completely clear whether the model equations have been empirically validated. Exceptions are TIGRIS XL, for which the empirical validation is the basis on which the model is developed, and the Commuter Location Model. For MOBILEC and REMI-NEI it is clear that a number of relations are based on Dutch data, but others are based on parameters from other studies, in the case of REMI-NEI mainly on studies from the U.S. The main reason why it is not always clear whether the models are empirically validated, is that the documentation of the models in a number of cases is very limited. This is mainly the case for REGINA, EIS® and RAM, and to a lesser extent for RAEM-2 and REMI-NEI.

Practical usefulness of the Dutch spatial models

Most of the existing Dutch spatial models are only suited to show the distribution of the indirect effects of spatial policy interventions among economic agents. RAEM-2 and REMI-NEI are the only models that explicitly enable the estimation of generative effects. RAEM-2 has the advantage that additional welfare effects are generated by the model, using utility and profit maximisation functions. The disadvantage of this approach is that additional welfare effects cannot be distinguished from the direct welfare effects. All other models can only produce an estimation of additional welfare effects by ex post calculation, based on the estimated indirect effects and additional assumptions on the size of the relevant market imperfections.

If we consider the number of markets and market imperfections that are covered by the models, then REMI-NEI, RAEM-2 and EIS® stand out as most complete. RAEM-2 has the disadvantage that international effects are not included. REGINA is mainly focussed on product markets, TIGRIS on land markets and the Commuter Location Model on commuting and migration.

With regard to the type of transport and transport infrastructure that can be handled by the models, only a few models show limitations, mainly as a result of insufficient regional detail. EIS® requires much additional fieldwork to attain that regional detail, especially in the case of line transport infrastructure. REMI-NEI only has seven main regions for the Netherlands, which will give a rather crude approximation in the case of line transport infrastructure.

Required extensions and improvements

To enable the calculation of additional welfare effects based on a structural analysis of indirect economic effects of spatial policy interventions, a number of extensions and improvements in existing Dutch spatial models are desired. First, there is not one model that explicitly treats knowledge and innovation spillovers. Also, the costs of taxation to finance investments in transport infrastructure are hardly treated by the existing spatial models. A second type of improvement is modelling the link between product markets and labour markets on the one hand, and housing and real estate markets on the other hand. That would ideally imply an endogenous connection between the general equilibrium approach for product markets and labour markets, as shown by RAEM-2 and approximated by REMI-NEI, and a land-use/transport interaction model like TIGRIS XL. Finally, there is a need for a validation of existing model relations. Insufficient validation causes serious doubts about the model results.

4. Conclusion: combining different models

The Dutch spatial models that are treated in this contribution vary greatly in terms of completeness, scientific quality and practical usefulness. None of the models is ideal for estimating the additional welfare effects needed for a social CBA of investments in transport infrastructure or other spatial policy interventions. The REMI-NEI and RAEM-2 model stand out by the number of markets and indirect effects that are modelled, but none of the models account for all relevant effects. The documentation of most models is rather limited, and certainly not complete enough to determine their scientific quality. Finally, the practical usefulness is limited in a number of cases, as not all models are applicable to all types of infrastructure.

Therefore, in practice, a number of these models are used together to estimate the full array of indirect effects. Here the same problem arises as in the case of non-structural approaches: combining the outcomes of several independent models may easily lead to undercounting or double counting effects, as feedback mechanisms and interactions between markets that appear in the different models are not fully captured or are captured in more than one model. The following two conditions are crucial to avoid this:

1. The endogenous output of the first model must be used as the exogenous input for the next model;
2. The estimation of each endogenous variable is done by one spatial model only.

Both conditions are generally met for different modules of the same model, but when separate models, developed for different purposes, are combined, these conditions are only met by coincidence.

A randomly chosen example may illustrate the problem. The use of endogenous transport costs from the spatial transport models, such as LMS (for passengers) or SMILE (for freight), as the exogenous input for the spatial economic models, such as REMI-NEI or RAEM-2, may easily lead to problems. REMI-NEI and RAEM-2 both generate changes in interregional trade that (implicitly) generate changes in freight transport, while RAEM-2 in addition generates changes in interregional commuting that (implicitly) generates changes in passenger transport. However, LMS and SMILE also estimate these changes (differently), and thus the changes in transport cost will no longer be consistent with the changes in transport demand and production.

Only when specifically developed additional modules are used in combination with a single large model, such problems can be avoided. An example of such a combination is the use of the Commuter Location Model in combination with RAEM-1, in which the labour market had been modelled unsatisfactory (see Oosterhaven and Romp, 2003). A method to reduce problems in connecting direct and indirect effects can be the iterative use of spatial transport models and spatial economic models in attaining spatial general equilibrium (see Oosterhaven et al. 1998).

A ready method to avoid double counting of effects or ignoring relevant effects is not available, but awareness of the problem and of its serious consequences for social CBA is a necessary condition to avoid these problems. Finally, it must be emphasised that the effects of spatial policy interventions are generally modelled in different ways in different existing spatial models. Consequently, the empirically outcomes for the relevant effects will be different when using different models. A possible use of these differences in outcomes is to interpret them as a indication of the underlying real uncertainty about the size of these effects.

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