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Predicting market allocations, user benefits and wider economic impacts of large infrastructure investments for freight transportation

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Abstract

Conventional cost-benefit analyses of infrastructure projects are often partial analyses in which only the transport market is assessed while adjacent markets are neglected. For large infrastructure investments, however, this is more often than not an unrealistic assumption, especially in the case of investments affecting urban areas where markets adjacent to the transport markets are believed to exhibit a large number of externalities. This paper suggests an alternative approach to tackling the problem; namely, modeling the entire Norwegian economy in a general equilibrium setting. We have developed a Spatial Computable General Equilibrium (SCGE) model for Norway that takes into account urban dynamics through New Economic Geography features. This means modeling centripetal and centrifugal economic forces that produce changes in urban clusters. We use it to calculate direct benefits and the wider economic impacts of infrastructure investments for freight transport in selected case studies. For one particular case study, we find wider economic impacts of 17.0% of the direct benefits for passenger transport and 3.7% for freight transport. This suggests, first, that appraisal of infrastructure projects is to underestimate the real benefits and, second, decisions based on conventional wider economic impact analyses that only take into account passenger transport will tend to overemphasize passenger transport relative to freight transport. We argue that goods and labor demand effects, i.e. effects in markets adjacent to the transport market, are important if we are fully to realize the effects of infrastructure investments.

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Keywords: Spatial computable general equilibrium modeling; SCGE; general equilibrium; wider economic impacts; transport appraisal.

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1. Introduction

In most countries, disaggregated four-step passenger transport models with a detailed road network are used when infrastructure investments are being appraised, and Norway is no exception in this regard (i.e. partial market analyses in which only the transport market is taken into account). Norway also utilizes a transport model for freight, one in which goods demand is held constant and the logistics chain is adapted to minimize logistics costs given the new infrastructure (de Jong and Ben-Akiva, 2007). These models calculate (direct monetary) the benefits of larger infrastructure projects, their main strength being the extremely disaggregated representation of the transport market and infrastructure networks. However, this approach has two shortcomings: First, since demand is held constant for freight transport, it is impossible to predict how the demand for goods adapts to the lower transport costs. Second, it is generally believed that larger infrastructure projects will have repercussions throughout the economy. Hence, without taking the rest of the economy into account, it is not possible to assess how these repercussions will manifest, nor the effect they may have on the benefits of the infrastructure investment.

This paper suggests an alternative approach in a general equilibrium setting where all transactions in the Norwegian economy are taken into account. We have developed a Spatial Computable General Equilibrium (SCGE) model for Norway of the New Economic Geography (NEG) class (Krugman, 1991). This class of models effectively takes into account urban dynamics through centripetal and centrifugal economic forces that produce changes in urban clusters. The model is inspired by, among others, RAEM (Ivanova, Heyndrickx et al., 2007) and RHOMOLO (Brandsma, Ivanova et al. 2011), and is directly based on an updated version of the original PINGO model (Hansen and Ivanova, 2012). The main reason this particular model stands out is the quality of input data; data regarding national accounts from the central statistics bureau and of passenger and freight transport from the national transport models are of high quality.

This approach not only makes it possible to calculate the direct welfare benefits in standard project appraisal, but also the wider economic impacts. Moreover, it makes it possible to forecast the general effect of an infrastructure project on supply, demand, prices and allocations through the repercussions it has on the economy. Our SCGE model is effectively linked to the Norwegian national transport models for both passenger transport and freight transport. Runs with these transport models produce LoS data and trip matrices that are used as input data for the SCGE model. Thus, the SCGE model combines the best of two worlds: the detailed transport network from the network models at the lower level and macroeconomic effects in a general equilibrium setting at the upper level.

In this paper we discuss urban dynamics in light of direct welfare effects and wider economic impacts; we present the main features of the model and, through a case study, show how these can be calculated for freight transport. First, we present the background to cost–benefit analyses and the wider economic impacts, and, second, the prototype of the model. Third, we conduct the case study for freight transport appraisal.

2. Background: Cost–benefit analyses and wider economic impacts

Conventional cost–benefit analyses (CBA) consider the priced consequences of projects, typically the direct user benefits of a project in addition to direct external effects on emissions or accident rates. CBAs are usually conducted as partial market analyses in which the effect in the primary market (the transport market) is assessed partially, while all prices in secondary (adjacent) markets are assumed to remain constant. In reality, the effect of a large infrastructure project will have repercussions throughout an entire economy.

Economic theory states that if markets adjacent to the transport market are complete, the benefits arising from price and allocation changes in secondary markets will only be a redistribution of the user benefit calculated in a partial CBA (Jara-Diaz, 1986). Hence, considering effects in adjacent markets in such a perfect competitive environment will lead to double counting of welfare effects (Mohring, 1993).

A central assumption behind the economics of conventional CBAs is that of complete markets. If it is no longer realistic to assume that the secondary markets are complete, there may be additional benefits to those calculated in the CBA, benefits known as wider economic impacts (WEI). The two most important imperfections in secondary markets effectively leading to WEIs are “market power” and “agglomeration effects”. Market power characterizes a situation in which a producer can earn positive revenues by setting the price higher than it would have been in a perfect competition scenario. This leads to a lower number of traded commodities in equilibrium and thus to inefficient resource allocation. Agglomeration effects mainly denote the fact that larger or denser labor markets increase the amount of potential interaction between agents. This tends to reduce frictions in the labor market, thus reducing transaction costs of participating in the labor marketplace. For instance, larger labor markets tend to map specialized human capital to the right specialized job more quickly. Other agglomeration includes knowledge spillovers and sharing effects. When agents interact in a market, they do not take into account the externalities they inflict upon others when increasing the density of the market. This leads to less efficient labor allocation than under the assumption of perfect competition.

3. Data and metadata

The model is calibrated for the base year 2012 and includes 25 sectors (three agricultural, two related to oil, gas and mining, thirteen commodity producing industry sectors and seven service sectors). Production takes place by means of the two production factors ‘capital’ and ‘labor’ and intermediate inputs from other sectors. The spatial dimension of the model is implemented as consisting of 90 zones, as can be seen from the illustration below. Furthermore, seven foreign sectors are included for imports, exports and net transfers abroad. The main data sources used for calibration are listed below the figure.

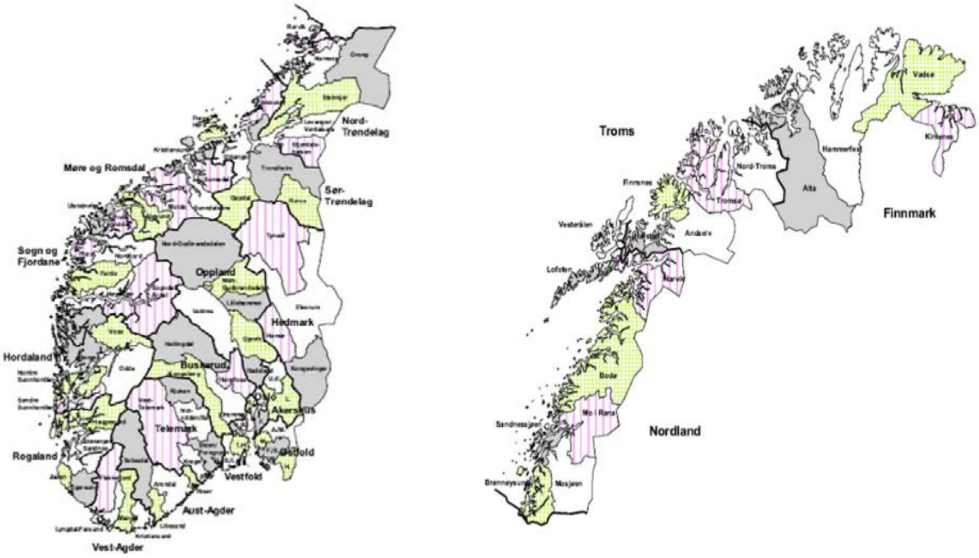

Fig. 1. The spatial dimension of the model: The set of 90 zones.

- *The social accounting matrix (SAM):* This is the main data source for the SCGE model. A SAM is a complete list of all transactions in the economy for a given year (the base year of the model) at the national level. Rows represent use, while columns represent supply, and there is one row/column pair for each sector, each commodity, and for other transactions such as capital supply/use, government consumption/production, household consumption/production (labor), imports/exports, transfers, etc. The most fundamental underlying assumption in SCGE modeling is that the economy is in a state of equilibrium represented by transactions in the SAM. This is formalized through row sums being equal to column sums, i.e. there is neither excess demand nor supply in the economy. The SAM is compiled of data from the national statistics bureau for the base year 2012 and balanced through a least squares minimization procedure.
- *Sectoral growth rates:* In order to run the model starting in other years (than 2012), sectoral growth rates are applied to each element of the SAM, and then the balancing procedure is repeated. It is therefore possible to forecast changes resulting from infrastructure projects implemented in the future as well. The growth rates are collected from MSG, the equilibrium model owned by the Ministry of Finance and administered by the National Statistics Bureau.

- *Region-specific sectoral production statistics:* Since the SAM is at a national level, region-specific sectoral production statistics for production, gross value added, capital investments, wages and employees are used to distribute transactions, capital, labor, production, consumption, etc., from the SAM to the zones of the model. The model is calibrated to 90 zones corresponding to Norwegian regions. The region-specific sectoral production statistics are collected from the National Statistics Bureau.
- *Runs with the national transport models:* Results from the national freight model are used to calibrate inter-zonal trade of commodities, while results from national passenger models calibrate the travelling and commuting pattern within and between zones. Furthermore, scenario runs with the freight and passenger models are used as input for scenario runs for the SCGE model by shocking the economy with new LoS data and predicting the macroeconomic repercussions.
- *Elasticities and econometric estimates:* It is not possible to calibrate all model elasticities based on the available data, so some are collected from the literature. This includes income elasticity, a firm's substitution elasticities between capital and labor, the Frisch elasticity, the Armington elasticities with respect to national production and import, elasticities for export and the agglomeration elasticity. These are within reasonable bounds. Furthermore, the migration part of the model is implemented based on econometric estimates conducted on a panel of migration between counties, with wages and unemployment as explanatory variables. Sensitivity tests with respect to these parameters and estimates can be found in Hansen and Johansen (2016). Information regarding choice of specific model elasticities may be obtained from the authors on request.

4. The model

The model is based on the notion of representative agents, e.g. households, firms and the government. It is assumed that these agents act by predefined optimization criteria; firms maximize profits according to the production function, while households and the government maximize a utility function. According to economic theory, the competitive equilibrium is defined as the price vector that maximizes the optimization criteria for each agent, such that budget constraints hold and markets clear, i.e. the prices that impose equality between supply and demand (Arrow and Debreu, 1954). The structure of the model is shown in the figure below:

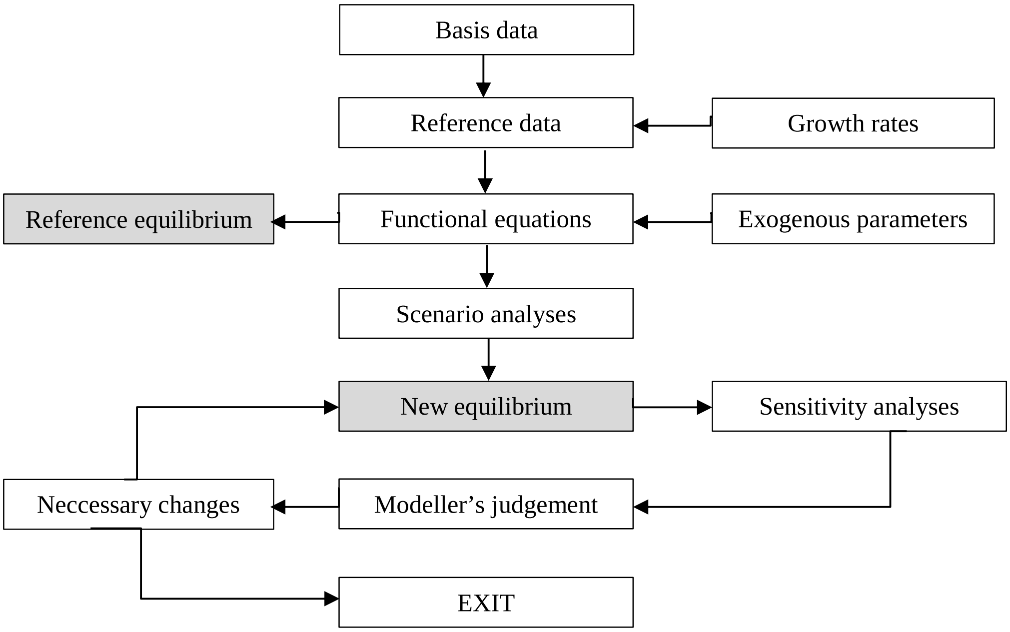

Fig. 2. Running the SCGE model for scenario analyses (adapted from Hansen, 2015).

The above figure illustrates the process of running the model. First, a reference dataset is produced based on the SAM, the regional-specific sectoral production statistics and the MSG growth rates, as explained in the previous section. This reference dataset, along with numerous exogenous parameters and elasticities, is then used to calibrate the analytical equations of the model. The SCGE model is calibrated correctly when the agents of the model maximize their optimization criteria in such a way that the reference data are replicated in a reference equilibrium. This means the agents of the model act in a way that is consistent with the input data, i.e. that they produce a reference equilibrium equivalent to the national accounts in the base year as reported by the national statistics bureau and all the transactions as reported in the SAM take place.

To run a scenario analysis, the economy is shocked with changes in some of the baseline values. For an infrastructure investment, this means that new LoS data for passenger and/or freight data from the transport model are read in. Agents then have to re-optimize their criteria functions subject to the changes, and this produces the new equilibrium. Note that the model does not explain the transitory changes between the equilibria; the only output is the new equilibrium, which may be interpreted as the long-term state after the economy has settled down. The equilibrium is thus the set of prices and allocations that satisfies all agents with their own choices given the choice of everyone else in the economy. To assess the effects of the infrastructure investment, the reference equilibrium and the new equilibrium are compared. In this way, the relative changes in prices, allocations and agents' welfare may be calculated.

When the new equilibrium has been produced, sensitivity analyses will be conducted and the modeler will make a subjective judgement regarding the realism of the results. If the modeler is not satisfied, the necessary changes must be conducted. This procedure will be repeated until the modeler is satisfied.

The model is a set of 251,920 endogenous variables and 251,920 analytical equations. In the following subsections, certain central equation sets are listed explicitly, although most are omitted. A full list of model equations can be seen in Hansen and Johansen (2016). In the following, subscripts q, r, s denote zones, while subscripts i, j denote sectors. The superscript 0 will denote baseline values, i.e. values from the initial equilibrium.

4.1. Households

The economy is modeled so that each zone entails one representative household, which chooses consumption of goods and services in a way that the consumption bundle maximizes a utility function subject to a budget constraint. The income of each household is the sum of wages, capital rents and transfers from the government. Labor income includes the income from working in the home zone, as well as from commuting to and working in other zones. The commuting pattern between zones is discussed in subsection 4.6. Capital income is calculated as the sum of capital inputs over all regional sectors multiplied by the sector-specific rate of return on capital. The consumption budget of a household is calculated as after-tax income minus savings and transport costs plus social transfers. Since the model does not include a banking agent (i.e. households are not allowed to borrow money), the savings cannot exceed the total income and the consumption budget is strictly positive. The utility functions are of the Stone-Geary form (Stone, 1954):

$$U_r = A_r \prod_i \left(C_{ri} - \mu H_{ri} \right)^{\alpha H_{ri}}$$

where U_r is utility, C_{ri} is consumption, A_r is a scaling constant, μH_{ri} is the household's subsistence consumption level and αH_{ri} is the budget share of commodity i for the household in zone r. Stone–Geary utility functions ensure that the expenditure system is linear, and may be interpreted as a Cobb–Douglas function with $\tilde{C}_{ri} = C_{ri} - \mu H_{ri}$ as inputs (utility derives from consumption level above subsistence level).

We make a sharp distinction between "utility" and "welfare". Utilities are abstract measures used only as optimization criteria for households. Welfare is used to measure the monetary benefits of an infrastructure investment, and is calculated based on the notion of compensating variation (CV). CV is the amount households would need to pay to be indifferent between the investment and the baseline scenario, i.e. the transfer that would be necessary to make aggregate utility the same as in the baseline scenario given the new price vector.

4.2. Market power

We assume that firms in industry and the service sectors have market power of the Dixit–Stiglitz type (Dixit and Stiglitz, 1975). These firms face fixed and variable costs of production, implying increasing returns. All firms in each sector and zone are identical in size and production technology, but they produce different varieties that act as imperfect substitutes. Consumers prefer to have a bundle of varieties and will therefore demand a positive amount of each variety even if prices are different. Firms are therefore able to set prices higher than variable costs to cover the losses of the fixed costs and still be able to sell their commodities. Since we assume free market entrance, the number of firms is determined endogenously, such that profits are equal to zero (when firms start making profits new firms enter the market and drive prices down again, such that the revenue is always equal to the firms' fixed costs). The mark-up on the price due to market power is determined according to the equation:

$$PDC_{ri} = \frac{(PD_{ri} \cdot NF_{ri})^{\frac{1}{1-\xi_i}}}{(PD_{ri}^{0} \cdot NF_{ri}^{o})^{\frac{1}{1-\xi_i}}} \cdot d_i + PD_{ri} \cdot (1 - d_i)$$

where superscript 0 denotes values from the baseline equilibrium, PDC_{ri} is the final price for the commodity, PD_{ri} is the price under the assumption of perfect competition, NF_{ri} is the number of firms, ξ_i is the elasticity of substitution between varieties and d_i is a dummy equal to 1 if the sector exhibits market power and 0 otherwise. Thus, the mark-up on the perfect competition price is high when the number of firms and the elasticity of substitution are low (i.e. when consumers are not able to substitute between varieties).

Since market power of the Dixit–Stiglitz type implies that various varieties are produced in each firm in each zone, cross-hauling of close substitutes is allowed between regions. This means that the model can be calibrated such that it reproduces the interregional trade flows we observe in the data.

4.3. Firms

Firms minimize production costs for each output level given production technology, output prices, wages, capital rent and the prices of intermediate consumption goods. This gives the cost-minimizing levels of labor, capital and intermediate consumption units that is required to produce one unit of the composite sectoral output. Output is then determined according to the no-profit condition. The production function is a nested function where the trade-off between labor and capital is determined by a constant elasticity of substitution (CES) production technology at the lower level. The proportion of intermediate input factors from other sectors and the composite capital–labor input is assumed to be fixed, determined through input–output tables and operationalized through Leontief production technologies at the upper level. The composite capital–labor bundle KL_{rj} and the intermediate inputs II_{rij} from sector i to sector j are thus determined by:

$$II_{rij} = io_{rij} XD_{rj} \qquad KL_{rj} = ioKL_{rj} XD_{rj}$$

where io_{rij} and $ioKL_{rj}$ are fixed input-output shares and XD_{rj} are production levels. The prices of the capital–labor bundles are determined as weighted after-tax averages of wages and capital rents. Thus, demand for capital and labor can be calculated from cost-minimization of variable costs from the CES function plus fixed costs. Fixed costs of labor and capital are calculated as fixed costs per firm multiplied by the number of firms in each zone and each sector. The production level is determined so that the no-profit condition holds for each firm. The resulting capital demand given the price vector will be:

$$K_{ri} = KL_{ri}\left(\frac{\gamma K_{ri}}{(1+tk_r)\cdot RK_{ri} + \delta_{ri}\cdot PI}\right)^{\sigma KL_i} \cdot PKL^{\sigma KL_i} \cdot aKL_{ri}^{(\sigma KL_i - 1)} + NF_{ri} \cdot fcK_{ri}$$

where γK_{ri} and aKL_{ri} are parameters of the CES function, σKL_i is the elasticity of substitution between capital and labor, tk_r is the tax rate on capital, RK_{ri} is the capital rent, δ_{ri} is the depreciation rate, PI is the price of the investment good, PKL is the price of the labor–capital bundle, NF_{ri} is the number of firms and fcK_{ri} is the average fixed cost of capital. The demand function for labor is defined similarly (using the after-tax wage rate as the price of labor), but not listed here owing to space restrictions.

4.4. Government

The federal government is included in the model as a single agent who collects taxes, consumes commodities according to a utility function and distributes social benefits. These elements add up to the governmental budget constraint from which the government chooses a consumption bundle to maximize its utility. The utility function is in the Cobb–Douglas form:

$$UG = \prod_{r,i} \left(CG_{ri} \right)^{\alpha G_{ri}}$$

UG is the maximization criterion of the government, αG_{ri} are sector and zone specific consumption shares and CG_{ri} is the government's consumption of commodity i in zone r. Hence, the consumption bundle resulting from this optimization procedure distributes governmental consumption between various regional commodities.

4.5. Freight transport and interregional trade

According to the Armington specification, goods imported and goods produced in domestic zones have slightly different specifications, such that households will prefer to consume goods from more than one location (Armington, 1969). This ensures that we are able to replicate the trade pattern between countries and regions that we observe in the data. Consumers will substitute between the various specifications based on changes in relative specification price according to a CES function, where the level of substitution is defined by Armington elasticities:

$$XDDE_{sri} = XDD_{ri} \cdot \left(\frac{\gamma A_{sri}}{PDC_{ri} + PTM \cdot trmV_{sri}} \right)^{\sigma A1_{ri}} PDDT_{ri}{}^{\sigma A1_{ri}} aA_{ri}{}^{(\sigma A_{ri} - 1)}$$

where $XDDE_{sri}$ are the sector i freight flows from zone s to zone r, XDD_{ri} is the composite domestic commodity of type i consumed by zone r, $\sigma A1_{ri}$ are Armington elasticities and γA_{sri} and aA_{ri} are share parameters of the CES function calibrated from freight flow data. PTM is the national price of transport margins and $trmV_{sri}$ the transport margin for moving goods of type i from zone s to zone r. The price of the composite domestic commodity consumed $PDDT_{ri}$ is calculated as the weighted average price of commodities consumed from all zones according to the equations:

$$PDDT_{ri} \cdot XDD_{ri} = \sum_{s} \left(XDDE_{sri} \cdot \left[PDC_{ri} + PTM \cdot trmV_{sri} \right] \right)$$

4.6. Commuting and migration

Individuals living in zone s will distribute themselves between working in zone s and commuting to zone r. Commuters will earn their wages in zone r based on this zone's specific salary, and spend the wages on consumption in zone s. Thus, commuting is an effective way of transferring values between zones. To benefit from the predicted commuting pattern from the transport models, commuting preferences are calibrated such that the commuting pattern in the SCGE model replicates the commuting pattern from the transport model. The labor supply is defined as:

$$LS_r = \sum_{s} LCOMM_{sr}$$

Where LS_r is the labor supply (to be split between sectors) in zone r and $LCOMM_{sr}$ is the sum of commuters from zone s to zone r, the commuting preferences are implemented as:

$$LCOMM_{sr} = comm\_pref_{sr} \frac{\sum_i L_{ri} \cdot \exp(\alpha_{sr}^{time} \cdot TCOMM_{sr})}{\sum_q \sum_i L_{qi} \cdot \exp(\alpha_{sq}^{time} \cdot TCOMM_{sq})}$$

where $comm\_pref_{sr}$ are commuting preferences calibrated according to the transport model, L_{ri} is sectoral labor supply, α_{sr}^{time} is the cost coefficient for generalized travel cost and $TCOMM_{sr}$ is the generalized travel cost for commuting between zones s and r. In other words, commuting trips are distributed according to a gravity model in which a correction term is included to fit commuting to the data from the transport model. When scenario analyses are conducted, the generalized travel cost between zone pairs can be changed and will produce a new commuting pattern. Note that s and r can be the same zone, i.e. the commuting preference model also calculates intra-zonal commuting.

We do not go into detail on the migration part of the model here due to space limitations. However, a short, description follows. We allow migration to change between model runs. Historic migration data from the National Statistics Bureau are read in for the baseline equilibrium. In the scenario equilibrium, the baseline migration is changed by a percentage determined based on the relative wage changes between zones, i.e. migration will increase in zones where the wage increases. The parameters that drive this effect were estimated in a panel data regression on historic data of migration and wage levels between counties.

4.7. Agglomeration effects

Agglomeration effects are widely recognized in the WEI literature and are modeled taking into account that large labor markets produce positive externalities. This includes both productivity gains due to urban clusters, and reduced frictions in the labor market due to better matches between employers and employees in industries where specialized human capital is required. Agglomeration effects are assumed to directly influence the total factor productivity (TFP) of the production function of the firms, thus making both labor and capital more productive. Agglomeration effects are implemented through the factor ψ_{ri}, such that an increase in this factor of Δ increases TFP by Δ percent. The factor is modeled as:

$$\psi_{ri} = \left(\frac{\sum_s LCOMM_{sr}}{\sum_s LCOMM_{sr}^0} \right)^{\sigma_{ext}}$$

where superscript 0 denotes values from the baseline equilibrium and σ_{ext} is the agglomeration elasticity. We follow the WEI literature and have adapted the value $\sigma_{ext} = 0.03$. This expression connects the productivity of each worker in zone r to the total size of the zone's labor market, and allows for productivity gains across sectors.

4.8. Market clearing

The market clearing condition ensures that demand is equal to supply in all markets. Since the model only predicts relative price changes, one price must be chosen as the numeraire – in our case the exchange rate. In line with Walras's law, given equilibria in all other markets, the exchange rate must also be the equilibrium exchange rate.

The model assumes trade balance, so the values of exports and net transfers abroad are restricted to being equal to the value of imports. Furthermore, prices clear both capital and labor markets in all zones, which means that firms' capital stock must be equal to households' total savings, and that number of workers must be equal to the workforce. To ensure that zonal supply of a commodity is equal to zonal demand of a commodity, the following equation must hold:

$$X_{ri} = C_{ri} + CG_{ri} + I_{ri} + SV_{ri} + TMX_{ri} + \sum_j io_{rij} \cdot XD_{rj}$$

where X_{ri} is sectoral and regional supply, C_{ri} is households' consumption, CG_{ri} is governmental consumption, I_{ri} is investments, SV_{ri} is changes in stocks, TMX_{ri} are the commodities consumed for trade and transport margins; the last term is the consumption of i as an intermediate good for production of the other j goods.

4.9. Centripetal and centrifugal forces

The SCGE model contains both centripetal and centrifugal forces. Centrifugal forces weaken spatial concentration and urbanization, while centripetal forces work towards further agglomeration and urban clusters. It is the balance between the two that defines the urban dynamics at work between the baseline and scenario equilibria. Centrifugal forces include:

- *Congestion:* Congestion is measured through the generalized transportation costs for passenger and freight transport. These costs are used as input directly from the transport models and therefore are not the outcome of the equilibrium model, but taken as given. Urban clusters increase congestion, thus increasing the cost of transport. Therefore, firms and individuals may derive benefits from localizing in and commuting to zones with less congestion.
- *Market power:* Firms with market power will find it beneficial to localize in areas where the markets are relatively small. This leads to fewer varieties for consumers to substitute between, thus increasing the market power of each firm and allowing firms to set a higher mark-up on their products.

Centripetal forces include:

- *Shorter transport distances for households:* Households locating in urban areas will have more work opportunities close to where they live. This can reduce transport costs for both commuting and leisure trips. In the model, this is implemented by increasing their consumption budget accordingly. Agents are therefore effectively able to substitute between transportation and consumption.
- *Increased variety:* Households will prefer to live in areas where markets are as large as possible. This leads to increased variety in their consumption bundles through both the Dixit–Stiglitz market power and Armington assumptions.
- *Reduced costs of consumption:* When households buy consumption goods they are faced with a price that is influenced by the transport costs from the firm to the retailer. Being located close to the producing firms reduces this cost, which again reduces the price of the consumption goods.
- *Shorter transport distances for firms:* Firms located close to other firms will pay a lower price for intermediate consumption goods through lower transportation costs. Furthermore, firms located close to the workforce may be able to reduce salaries, since lower commuting costs for the workers increase their consumption budget.
- *Increased market potential for firms:* Firms will prefer to be located as close to as many markets as possible, thus increasing their market potential. The fact that firms produce varieties that are imperfect substitutes ensures that they are able to sell their products in nearby zones. Moreover, firms less distant to the retailer will be able to sell their products at a more competitive price since freight costs are lower.
- *Agglomeration effects:* As discussed earlier, large labor markets in urban agglomerations impose positive externalities on TFP. This makes production more efficient; firms can pay higher wages, and product prices decrease. Consumption is cheaper. The increase in TFP also allows for more firms given the zero-profit condition. This produces more varieties, which increases utility of the consumption bundle.

5. Model application

In this section we conduct a case study of an infrastructure improvement project between two Norwegian cities – Ålesund and Molde. It is part of the National Transport Plan for Norway and means the main road (E39) between these two cities becoming ferry-free after construction of one tunnel and one bridge, their total length being 22 km. In addition, the general quality of the remaining road network will be improved and the entire investment is forecast to be completed by 2022.

While the urban areas of Molde and Ålesund have 23,710 and 38,855 inhabitants respectively, the corresponding zones of the model – consisting of some of the nearby municipalities – have 60,781 and 82,933 inhabitants. The figure below shows the model zones Molde and Ålesund, as well as the new road between the urban areas. The road will be approximately 85 km in length.

Fig. 3. Model zones for Møre og Romsdal county.

Runs with the National Transport Models indicate that general transport costs between these two cities will be reduced by approximately 8.8%. The changes in transport costs for both passenger and freight transport between all the zones of the model are used as input data in the SCGE model, and the equilibria before and after the infrastructure change are compared. Results of the analysis are presented in the table below. The first column displays the direct benefits, i.e. social welfare under the competitive market assumption, without market power and agglomeration effects; the second, the social welfare of the full model, i.e. direct benefits plus wider economic impacts; the third, the wider economic impacts as a percentage of the direct benefits.

Table 1. The discounted net present value of social welfare over 40 years. Social welfare is calculated as the sum of CV over all zones. Monetary values are displayed in 2016 currency (mill. NOK).

Molde–Ålesund	Social welfare	Social welfare	WEI
	Direct benefits	Direct benefits + WEI	(%)
Passenger transport	11,770 mill. NOK	13,770 mill. NOK	17.0
Freight transport	4,359 mill. NOK	4,520 mill. NOK	3.7
Total	16,129 mill. NOK	18,290 mill. NOK	13.4

Even though the WEIs are noticeably higher for passenger transport (17.0%), the SCGE model produces significant WEIs for freight transport as well (3.7%). The total WEIs (13.4%) signifies that there are in fact large external effects in secondary markets that alter the allocations of workers and commodities, leading CBA to significantly under-estimating the real benefits of the infrastructure investments.

The main mechanisms governing magnitude of the WEIs are the interplay between centripetal and centrifugal forces and the changes in agglomeration effects and market power these produce. Changes for passenger transport lead to higher WEIs since passenger costs affect the labor market to a greater extent through direct effects on the commuting pattern.

It is not possible to generalize based on the numbers from this analysis. WEIs will always be dependent on the specific markets that are influenced, the firm structure in the relevant zones, the nearby commuting opportunities and the wage differences compared to adjacent labor markets. Nevertheless, the analysis shows that for this specific infrastructure investment, WEIs are significant. Furthermore, analyses of 14 other cases with the same model give WEIs in the range 10–30% for passenger transport and 2–6% for freight transport (Hansen and Johansen, 2016). The conventional WEI literature only considers passenger transport effects, often through partial analysis of the labor market only.

These results have two major implications. First, conventional CBA will underestimate the total effect of infrastructure investments. Second, decisions based on conventional WEI analyses that only take into account passenger transport will tend to overemphasize the impact of passenger transport relative to freight transport.

6. Concluding remarks

We have formulated and implemented an SCGE model based on the New Economic Geography literature, one that calculates the long-term general equilibrium in the Norwegian economy resulting from changes in infrastructure. By taking into account urban dynamics through centripetal and centrifugal forces and imperfections in markets adjacent to the transport market, we are able to calculate the direct user benefits as well as the wider economic impacts of infrastructure changes.

We have implemented the model for a specific case study; namely, an improvement of the European highway between Molde and Ålesund in the Møre og Romsdal region. We present the results for freight transport as well as passenger transport. The model indicates that there are significant wider economic impacts for passenger as well as freight transport and this has two major implications. First, conventional CBA will underestimate the total effect of infrastructure investments. Second, decisions based on conventional WEI analyses that only take into account the wider economic impacts of passenger transport will tend to overemphasize passenger transport relative to freight transport.

However, we emphasize that it is not possible to generalize based on the numbers from this analysis. WEIs will always depend on the specific markets that are influenced, the firm structure and sector composition in the relevant zones, the nearby commuting opportunities and the wage differences compared to adjacent labor markets. The results from an SCGE model should therefore be used as supplementary to those from conventional CBAs if decision-makers are to be well informed of the total effects of various investments. Moreover, this framework enables predictions of how infrastructure investments will change relative prices and market allocations through repercussions in the economy.

Meticulous sensitivity analyses and more elaborate numerical results can be found in Hansen and Johansen (2016).

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The model is an extension of PINGO, described in Hansen and Ivanova (2012). We again make reference to the SCGE models RHOMOLO and RAEM (Brandsma et al., 2011; Ivanova et al., 2007), on which much of this model is based. RHOMOLO and RAEM contain many of the same mechanisms described here.

References

Armington, P. (1969). "A Theory of Demand for Products Distinguished by Place of Production " Staff Papers-International Monetary Fund: 159-178.

Arrow, K. J. and G. Debreu (1954). "Existence of an equilibrium for a competitive economy." Econometrica: Journal of the Econometric Society: 265-290.

Brandsma, A., O. Ivanova, et al. (2011). RHOMOLO, a dynamic spatial general equilibrium model. 19th international input-output conference. Alexandria, Virginia, USA.

de Jong, G. and M. Ben-Akiva (2007). "A micro-simulation model of shipment size and transport chain choice." Transportation Research Part B: Methodological 41(9): 950-965.

Dixit, A. K. and J. E. Stiglitz (1975). “Monopolistic competition and optimum product diversity”. Economic research paper no. 64, University of Warwick, England.

Graham, D. J. (2007). "Agglomeration, productivity and transport investment." Journal of Transport Economics and Policy (JTEP) 41(3): 317-343.

Hansen, W. and B. G. Johansen (2016). "Beregning av netto ringvirkninger på utvalgte prosjekter, NTP 2018-2029." TØI report 1471/2016.

Hansen, W. and O. Ivanova (2012). "Wider Economic Benefits in Transport Appraisal, a SCGE-model approach with application to a proposed Norwegian road infrastructure project." European Transport Conference 2012, Glasgow Scotland.

Ivanova, O., C. Heyndrickx, et al. (2007). "RAEM: version 3.0 Final report", Transport and mobility Leuven.

Jara-Diaz, S. (1986). "On the relation between users' benefits and the economic effects of transportation activities." Journal of Regional Science 26: 379-391.

Krugman, P. (1991). "Geography and trade", the MIT Press.

Mohring, H. (1993). "Maximizing, measuring, and not double counting transportation-improvement benefits: A primer on closed- and open-economy cost-benefit analysis." Transportation Research Part B: Methodological 27(6): 413-424.

Stone, R. (1954). "Linear expenditure systems and demand analysis: an application to the pattern of British demand." The Economic Journal 64(255): 511-527.