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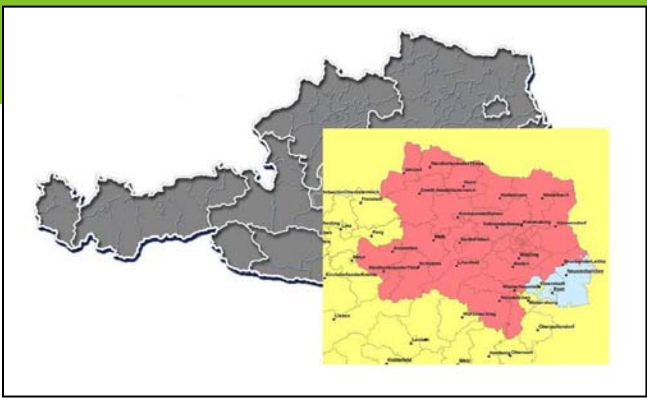

Spatial Dynamic Development and Environmental Sustainability

Olivia Koland and Karl Steininger
(Editors)

December 2006

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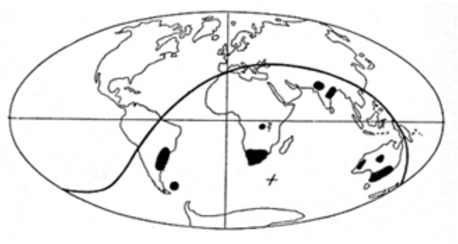

Alfred Wegener (1880-1930), after whom the Wegener Center is named, was founding holder of the University of Graz Geophysics Chair (1924-1930) and was in his work in the fields of geophysics, meteorology, and climatology a brilliant, interdisciplinary thinking and acting scientist and scholar, far ahead of his time with this style. The way of his ground-breaking research on continental drift is a shining role model — his sketch on the relationship of the continents based on traces of an ice age about 300 million years ago (left) as basis for the Wegener Center Logo is thus a continuous encouragement to explore equally innovative scientific ways:
ways emerge in that we go them (Motto of the Wegener Center).

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Spatial Dynamic Development and Environmental Sustainability

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Executive summary

Olivia Koland and Karl W. Steininger[1]

SPATIAL DISTRIBUTION OF ECONOMIC ACTIVITIES, TRANSPORT AND THE ENVIRONMENT

Substantial increases in transport infrastructure supply and transport flows in Austria over the last decades, both in freight and passenger transport, have enabled crucial growth in consumer benefits. But, as a recent OECD (2000, 13-15) report put it, “there have been costs – mostly environmental costs – that are eroding the benefits. […] The challenge for the 21st century is to maintain and even enhance transport's benefits while reducing its impacts to sustainable levels.” For example, mobility activities currently trigger the fastest increasing segment in greenhouse gas emissions. While total Austrian (Kyoto-relevant) greenhouse gas emissions increased by 15.7% between 1990 and 2004, emissions from road transport increased by 87.1% over this period (UBA, 2006). If Austria is to comply with its commitments within the European Union with respect to the Kyoto agreement, effective measures need to be prepared and implemented in due time. Similar demands for transport reorganisation arise from current noise and health impacts (e.g. respiratory illnesses triggered by particulate matter emitted or recirculated by transport).

In the present project we develop a method for improved evaluation of long-term policy measures relevant for the development of the transport sector: instruments that address the interaction of transport volume and mode on one hand and spatial distribution of economic activities on the other hand.

In long-term transport forecasting and planning we still depend upon the so-called 4-step approach (trip generation, trip distribution, transport mode choice and, finally, traffic assignment). It is two features of this 4-step-approach that imply crucial shortcomings, especially in long-term forecasting, and which we thus seek to overcome in the current project. First, the concept is based on bilateral interactions, not multilateral ones, which significantly reduces the degree of future changes beyond initial distributions of transport flows. Second, new infrastructure can be reflected by reduced travel/transport time, changing traffic flows, but each of the simultaneous forward and backward links (more closeness increases economic activity, increasing transport flows in turn, etc.) can be modeled only by a significant degree of exogenous parameter setting. This significantly limits the dynamics of processes that can be depicted.

[1] This research is financed by the Science Fund of the Austrian National Bank (project no. 11502). The authors express their thank for these funds enabling the present work.

We avoid the first shortcoming by a simultaneous general modelling approach: the spatial general equilibrium model. The second shortcoming is eliminated by inherently (and endogenously) allowing for forward and backward linkages, as is made available by economic geography model elements. For both aspects economic considerations play a crucial role.

SPATIAL COMPUTABLE GENERAL EQULIBRIUM MODELLING BUILDING UPON NEW ECONOMIC GEOGRAPHY

Transport flows (from both perspectives of trip generation and trip distribution, and simultaneously relevant across modes) are crucially interlinked with economic activity levels in the production and household sectors. For instance, environmental pressures (pollution) or high housing prices in urban areas can trigger increased transport demand in certain peri-urban areas. On the other hand, availability of transport infrastructure can attract production activities or housing. This mutual interlinkage of transport and eonomic activity is a clear conclusion from the now advanced new economic geography literature, mainly drawing on theoretical and stylised models so far (for the most comprehensive survey to date still see Fujita et al., 1999). With the spatially disaggregated transport and economic data for Austria we are now in a position to test these economic geography models with empirical data and explore their potential role in forecast improvements. In terms of model closure and consistency we use the advancements in spatial computable general equilibrium modelling.

Implementing the monopolistic competition models of the Dixit-Stiglitz (1977) type into multi-region CGE-models, the few empirical examples of spatial computable general equilibrium (SCGE) models available so far start from one of two ends: (i) broad regional coverage with few economic sectors (Bröcker, 1998), or (ii) from a fully fledged sectoral structure, with regional diversity restricted to within a single country (Tavasszy et al., 2003; Thissen, 2004). In both cases the transport cost component is exogenously given by (separate) companion-models. Therefore, the issue here is to transfer transport cost to an inherently endogenous variable.

For that end, we develop models for Austrian subregions in two veins. First, for the analysis of urban sprawl and policy instruments to address its welfare deceasing implications. This is in the tradition of Krugman´s core-periphery model (1991). It extends these models to integrate labour and interregional housing market interactions, thereby opening up for a fully-fledged analysis of the choice of location of living and commuting. Second, we analyse the implementation of new primary transport infrastructure in terms of its implications on the spatial distribution of economic development. In doing so, we develop a three-region CGE model for the eastern Austrian border region in order to analyse the opening of the

A4 motorway in the early 1990s, inducing developments such as the vast shopping area in Parndorf.

URBAN SPRAWL IN SPATIAL COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

We experience a clear trend towards dispersed settlement structures in Austria. The urban sprawl is a result of changes in lifestyles and a rising per capita income, together with a high degree of motorisation and accessibility by road in the hinterland. What we observe is a rising demand for housing space, preferably near green belts with a high recreation value (OECD, 2005). In doing so, transportation interacts with urban development via real income effects, housing demand and mode choice. The issue we therefore address is that of suburbanisation of central areas in connection with commuting behaviour and environmental concerns. We investigate how the residents' locational decisions "aggregate up" over time and space and thereby steer the spatial extension of the city region. The point in this respect is that transport demand depends on the spatial organisation of an economy via distances and modal split which differs across locations. This in turn explains how emission impacts may be either re-enforced or abated by current mobility patterns.

We develop a two-region computable general equilibrium model of the core-periphery type, in which residents are mobile between an urban core and its hinterland. Migration is linked to shifts in pollution levels, caused by residents' mobility patterns, and shifts in congestion levels as well as regional differences in real wages, housing prices and in the number of varieties of consumption goods. Building on New Economic Geography forces, changed environmental preferences induce urban sprawl and affect settlement structures via a circular linkage of spatial environmental quality and mobility patterns. Thus, differences in both real income and environmental quality constitute the welfare differential for utility maximising households choosing their location of residence. The model is expanded to the empirical domain for the NUTS III region Graz (Austria). Simulation results explain the need for a spatial restructuring of urban areas in order to change transport related pollution.

The political instruments suggested by our analysis fall into two groups. First, spatial planning instruments in the hinterland need to be chosen such that public transport is economically feasible also in the hinterland, the use of which results in significantly lower pollution feedback impact on ever rising migration rates. Second, economic instruments such as cordon pricing could be used to internalize the otherwise present externality. While the first class of instruments is more long-term oriented, the second is also available for short-term effects.

Concluding on these policy instruments to reduce the level of urban sprawl we find the following. Cordon pricing, or as for that matter other instruments that increase interregional consumer transport costs, acts as strengthening the weight of the pre-policy more strongly populated region. In the European context it is usually the centre, that is the more populated area; congestion pricing or similar instruments thus generally reduce urban sprawl. We also find a circular causality in initial levels of urban sprawl increasing the environmental impact per capita in the hinterland, thus acting as a negative feedback loop in decreasing the incentive for further urban sprawl. Furthermore, spatial planning in the hinterland directed at more dense development acts in two ways to reduce urban sprawl, both enforcing each other. First, hinterland *intra*regional consumption transport costs are reduced. Second, housing prices in the hinterland increase and supply a further, even stronger, disincentive to resettle to the peripheral region.

In terms of environmental feedback of the spatial policy, we find that cordon pricing hardly improves environmental quality. Further, while intraregional transport cost reduction in the hinterland (e.g. via improved public transport) does have a positive impact on environmental quality, we see that this is strongly dominated by the negative environmental impact due to the simultaneously induced rise in urban sprawl (the hinterland has become more attractive). Finally, the policy instrument of spatial planning towards more concentrated development in the hinterland clearly dominates the other two instruments. This instrument is the only one among the three that can significantly improve overall environmental quality. It does so by inducing incentives for both higher use of environmentally friendly transport modes and reduction on urban sprawl.

NEW INFRASTRUCTURE AND THE SPATIAL DISTRIBUTION OF ECONOMIC DEVELOPMENT

In mature economies new transport infrastructure (beyond bottle-neck elimination) is considered to hardly influence overall economic growth, but well so its spatial distribution. In a sectorally diversified spatial computable general equilibrium (SCGE) model of the Lower Austrian–Burgenland new motorway A4 (opened in 1991) to the now new EU-member state Hungary, we analyse regional sectoral economic development.

We expand the domain of the available literature in two directions. First, we acknowledge actual freight transport cost reduction by sector and interregional link. We derive these costs from a GIS-based approach accounting for the bilateral – political district by political district – sectoral trade flows. This enables a sectorally accurate analysis for economic structures of particular subregions and the impact transport infrastructures can exert on these.

Second, we empirically acknowledge the impact of accessibility change. Contemporary *Computable General Equilibrium* (CGE) models are well capable to simulate the economic development of a region, but face difficulties to integrate effects that derive from outside the region. In our attempt to account for this shortcoming, we thus develop approaches to introduce accessibility potentials into CGE-models. We calculate time-varying accessibility potentials of population, workplaces and regional income for the Austrian municipality of Parndorf. Highly dynamic developments are identified that are explained by (i) political changes that have happened since the end of the 1980s and (ii) the construction of new infrastructure – especially new motorways in Eastern Austria. On the basis of these results, we suggest productivity, income levels and price mark-ups as potential linkages between CGE models and accessibility potentials.

For the incorporation of these two new developments, a three-region monopolistic competition CGE model is implemented, focusing on the region of core analysis: (i) Parndorf (comprising the two political districts of Neusiedl and Eisenstadt surrounding), (ii) a surrounding region (the remaining of the province of Burgenland and Lower Austria) and (iii) ROW (rest of world, i.e. rest of Austria and abroad).

We find that freight transport cost reduction even for the small region that we analyse does have only negligible overall economic impacts. However, it is a few transport intensive sectors that show substantial impact in interregional trading prices and regional output. These include agriculture but also sufficiently regionally footloose activities (such as distribution centres), which react to the change in cross-region transport costs by regional restructuring or relocation respectively.

For the implications of accessibility increase (due to new transport infrastructure, but also border opening, the impacts of which are separable by our analysis), the regional economic impacts are quite larger. For the A4 motorway opening in 1991, for example, we find a medium term welfare increase for the core region at the order of magnitude of 4%. The causation here runs via both lower efficiency wages and increased consumer demand due to lower prices.

Overall, we do find a confirmation of the dominating view in the literature that new transport infrastructure in mature economies hardly increases overall economic output, but may have a significant impact on its regional distribution. In particular our findings point out, that locally specific sectoral shares in production, freight transport cost shares, and – most of all – accessibility determine the order of magnitude of regional economic impact.

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PART I:

Urban Sprawl and Spatial Policy

1. Urban Sprawl and Policy Instruments

Olivia Koland and Brigitte Gebetsroither

1 CURRENT TRENDS OF URBAN SPRAWL

The development of transport structures is highly dynamic, on a European and likewise on an international level. While transport services are crucial to economic activities, the transport sector in its current shape is also connected to a range of substantial detrimental impacts. While total Austrian CO_2 emissions increased by 24.4% between 1990 and 2003, emissions from transport – stemming to a large extent from road passenger transport – increased by 69% over this period. (Berdnik et al., 2006). Regarding passenger transport related emissions; the largest share of car mileage accrues to agglomerations (64% for Austria). (Steininger et al., 2005). Similar demands for transport reorganisation arise from current health and noise impacts which are mainly felt within urban areas. Most notably among these, particulate matter (PM_{10}) is a currently serious problem in Austria. Studies identify up to 60% of particulate matter concentration levels as triggered by transport activities. Thereby, transport turns out most important when also acknowledging the importance of raising particulate matter and vehicle-related dust (Provincial Government of Styria/Austria, 2003).

Though public transport infrastructure is available to address these problems, often settlement structures are too dispersed. While the ultimate objective of mobility is granting access to goods and people, it is equally land use devoted to residence, work, shopping, leisure and production that affects the level of fossil fuel emissions. The point in this respect is that transport demand depends on the spatial organisation of an economy via distances and modal split which differs across locations. This in turn explains how emission impacts may be either re-enforced or abated by current mobility patterns. In Austria, for instance, we experience a clear trend towards dispersed settlement structures. The urban sprawl is a result of changes in lifestyles and a rising per capita income, together with a high degree of motorisation and accessibility by road in the hinterland. What we observe is a rising demand for housing space, preferably near green belts with a high recreation value (OECD, 2005). In doing so, transportation interacts with urban development via real income effects, housing demand and mode choice. The issue we therefore want to address is that of suburbanisation of central areas in connection with commuting behaviour and environmental concerns. We investigate how the residents' locational decisions "aggregate up" over time and space and thereby steer the spatial extension of the city region. Broadly speaking, sprawl is associated with any expansion of the developed land of an urban area. Burchell et al. (1998) suggest that sprawl can take several characteristics including low density, leapfrog development, and widespread commercial strip development. Galster et al. (2001)

propose that sprawl can be defined as a pattern of land use that exhibits some combination of dimensions including low density, discontinuity of development, and little open space within the urban area.

2 A SELECTION OF POLICIES TO REDUCE TRANSPORT EMISSIONS

Current transport-related environmental (as well as health and noise) challenges with a focus on greenhouse gas emissions reduction clearly call for a reorganisation of transport systems. The aim is to achieve environmentally friendly mobility and access options, directing long-term impacts on transport structures.

Central to the idea of policy selection is the spatial restructuring of concerned areas – at either scale – in order to steer motorised transport patterns. However, though the spatial structure of an economy depends on transport organisation, spatial planning policy may be more effective in steering (long-term) mobility patterns than transport policy. An increase in operating costs of car transport, for example, will change transport behaviour, but it is expected to have major effects on individual location decisions only in the long run. Thus, choices in transport and long-term choices in land use and settlement structure are mutually dependent. As for spatial planning measures and related instruments such as e.g. the restructuring of housing subsidies, it is central to steer the location choice of residence and work such as to enable preferably short ways. The main argument for introducing spatial planning policies is that they contribute considerably to transport prevention, even though in a long-term perspective.

As for urban areas, dense living with high living quality must be supported. The current design of most urban cores and misleading transport policies, causing a degradation of environmental quality, support urban sprawl, however. Thus, the aim is, firstly, to make urban centres more attractive and, secondly yet equally important, to regulate land use in the overall region in order to create mixed-used areas with high density (OECD, 2005). This supports public transport infrastructure and results in a lower car dependency in the overall region.

The following list comprises a selection of policy measures we consider suitable for directing reasonable impacts on (urban) transport structures to address motorised transport-related pollution. In this respect, we focus on spatial planning measures as well as pricing policies to internalise external costs of transport (environment, health, noise, accident); the list comprises both long-term instruments and instruments available for short-term effects. The list collects suitable instruments from a recent OECD study (OECD, 2005)[1] and two national case studies for Austria (Schleicher et al., 2006; Friedl et al., 2000).

[1] For a condensed introduction see Koland et al. (2006).

2.1 SPATIAL PLANNING MEASURES

Adaptation of provincial land use regulation

The adaptation of zoning regulations should focus on newly dedicated building land, especially land used for residential areas. In particular, new dedications have to be intermitted until the already existing building land is exhausted (Prettenthaler et al., 2002). The importance of this issue is illustrated by the current use of land in Austria, where actually one third of the building land is not used; for the NUTS III region of Graz in particular this ratio amounts to 60%.[2]

In Austria, land use regulation is set at the provincial level of government. Thus, political pressure and competing municipalities predominantly contribute to the paradox status of building land. Possible approaches towards a limitation of further dedications include initiating cooperation between municipalities and creating a suitable framework for them to realise effective spatial planning policies. In this context, Finland, which is 2.5 times the size of Austria, serves as an inspiring example: 400 municipalities were reduced to 25 in order to save money and to clear up any fiscal reasons for ill-advised land use.[2] By contrast, Austria is highly small-sized structured, with the province of Styria on its own comprising 542 municipalities.

Other deficiencies in Austrian spatial planning comprise an excess of complementary dedications (*Gefälligkeitswidmungen*) and privileges as well as a lack of instructions for implementation (*Realisierungsanweisungen*). The latter is inter alia addressed by the next instrument.

Charges for the provision of public infrastructure (aimed at idle building land in central locations)

In Austria, a lot of centrally located building land is held back idle by their owners for investment reasons. This behaviour hinders dense living and good access to public infrastructure. It is therefore suggested for lots of land within zones that are devoted to construction activities, yet currently not used, to be included in the tax scheme on land value. This regulation thus prohibits zoning of further areas of free land before the currently zoned land is used for construction. It comprises charges for the development and provision of the local public infrastructure aimed at central locations, i.e. if the site is within a certain distance of a public transport connection. Hereby, these charges foster the creation of mixed-use areas with high density.

Importantly, the spatial structure of production and consumption should be characterised by a spatial mixture of uses and polycentrism, consisting of various

[2] O. Univ.-Prof. Dr. Gerlinde Weber, Universität für Bodenkultur, and Dipl.-Ing. Harald Griesser, Raumplanung Steiermark, „Zersiedeln wir die Steiermark“ – a discourse on urban sprawl in the county of Styria/Austria, 17 May, 2006

subcentres of different size with different functional mixes, for two reasons: Firstly, mixed-use areas allow for a minimisation of transport distance and promote public transport infrastructure, thereby enabling an improved possibility to switch to more favourable transport modes (in terms of environmental and health impacts). A second important point is that the functional mix of these centres (and that of the overall agglomeration) should not only consist of mixed use for living and working but of a mix of all major requirements of everyday life including leisure, shopping and health care facilities. This would thus also decrease the requirement for interurban transport (OECD, 2005).

The province of Salzburg/Austria (partially) solved the problem of idle building land by introducing limited dedications for construction activities with the possibility of re-dedication. In particular, re-dedication takes place if the proprietors do not implement the previously declared local plan and use of land within 10 years. However, this limitation does not touch existing dedications.

Restructuring of funding schemes for housing construction and development

Although zoning regulation is the more direct instrument and mainly to blame for urban sprawl and induced traffic, the reorientation of funding schemes for housing construction can well contribute to reduce transport emissions in this respect. Importantly, such institutional regulations do support a transport system, which produces negative environmental effects yet scarcely positive economic effects. In this context, the restructuring of residential funding schemes is able to steer long-term transport demand via its influence on spatial structures.

Funding schemes for housing currently exist largely without any reference to public transport accessibility. The essential point is to raise subsidy rates for buildings close to areas well-served by public transport. It is suggested that funding of residential property be reduced if the construction site is not within a certain distance of a public transport connection. In urban areas, additionally, subsidies for new constructed homes should be redirected to the remodelling of old houses. New homes – predominantly single-family houses, primarily constructed on the outskirts – induce transport and additional environmental effects unless the provided public transport infrastructure offers proper accessibility. Thus, beside the consumed space, new homes require additional transport infrastructure (Prettenthaler et al., 2002). In Austria, subsidies for new constructions are trice the rate for the restoration of old houses (Cerveny and Tretter, 2003).

As a result, the mentioned measures promote dense living in two different aspects: On the one hand, they reduce urban sprawl and foster dense living in central regions. On the other hand, they promote dense living in peripheral areas and therefore support public transport. An accessory effect in urban areas is reduced energy consumption, since new houses may be better isolated due to stronger legal requirements.

2.3 OTHER INSTRUMENTS

Fixed tax allowances for commuters

The Austrian Law determines that expenditures for trips to and from the working place are tax-deductible. For trips which are longer than 20km and for which the use of public transport is possible and reasonable there is the deductibility of a lump-sum per year. It is also called small fixed tax allowance for commuters.

distance	deductible lump-sum (2006)
> 20km	€ 495
> 40km	€ 981
> 60km	€ 1,467

For trips smaller than 20km and longer than 2 km where the use of public transport is neither possible nor reasonable[3] the big fixed tax allowance for commuters is deductible.

distance	deductible lump-sum (2006)
> 2km	€ 243
> 20km	€ 1,071
> 40km	€ 1,863
> 60km	€ 2,664

The current supporting scheme for commuters in Austria clearly tends to work in favour of longer commuting distances and also fosters private car use. Fixed tax allowances for commuters currently increase with distance from work and decrease when the use of public transport can be expected of the commuter.

The total amount of tax deduction is valued at about 356.1 Mio. Euro for the year 1999 (Federal Ministry of Finance, 2005), where differences between provinces according to the degree of accessibility of public transport and rusticity can be observed. In 2001 in the county Burgenland the lump sum per inhabitant and year amounts to € 115.90 whereas in Vienna commuters got a tax deducted of about € 10.6 per inhabitant on average.

A possible reform of the current refunding scheme for commuters would suggest (i) to reduce the number of different schemes to one in order to equally treat all modes of transport and (ii) to couple the deductibility for commuters with the ownership of a season ticket.

How can these reform options be achieved and what would be the advantages?

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[3] A trip is not reasonable if: (i) the use of public transport is not possible because there is no service is the time schedule is not in line with the needs; (ii) commuter is physically handicapped; (iii) trip times are longer than 1,5 hrs for distances < 20km, 2 hrs for distances > 20km and 4hrs for distances > 40km.

The reduction of different schemes would not only simplify administration but would furthermore have the effect that the same lump-sum deductible would hold for any mode of transport and the incentive to buy and use a private car would be abolished. However, should an individual incur actual costs from commuting that are higher than prescribed by this scheme, for legal reasons the person must still be allowed to claim a deductible equal to the actual cost.
Furthermore an increase of about 10% of the tax-deductible lump sum for commuters who are owner of a season ticket could give an additional incentive to favour public transport and therefore avoid all the negative effects (accidents, congestion, emissions etc.) accompanying the use of car.

Parking management for central regions: Strict parking restrictions and/or provision of park & ride facilities

The aim of parking management measures is to alter transport demand especially for cities. While there will be fewer total trips due to increased parking fees or strict parking restrictions, people will have an incentive to switch to public transport due to attractive park&ride facilities. Thus, parking options may be managed in various ways, on their own or as combined measures, such as (i) the reduction in the number of parking lots in central regions (regulatory instrument), (ii) the increase of parking fees (fiscal), and (iii) the provision of park&ride facilities on the outskirts (investment), offering connections at frequent intervals and at moderate prices.
However, parking fees represent a second-best solution, compared to other fiscal instruments (e.g. road pricing), in view of the fact that primarily the number of trips are reduced yet hardly the total of vehicle miles travelled (trip length) (Verhoef, 1996).

2.4 FISCAL INSTRUMENTS / PRICING POLICIES

General road pricing

Road pricing schemes, meaning that motorists pay directly for using a specific section of the road network, intend to steer transport demand via prices. They aim at covering infrastructure maintenance costs and at internalising environmental and health costs of passenger transport. Moreover, if pricing measures are accompanied by the promotion of public transport, a more desirable spatial structure of consumption can be supported via the spatial allocation of investments.
Increased operating costs of passenger road transport will make motorised individual transport more expensive and thus less attractive. As a consequence, broadly speaking, there are fewer total vehicle miles travelled, which directly eliminates emissions of harmful pollutants. What happens in detail is that, firstly, high road transport costs make alternative modes of transport more attractive; yet

modal shift is only possible where alternatives do exist. Secondly and more specifically, urban areas, since they are characterised by a low car-dependency and short distances, may gain in attractiveness relative to rural regions. Thus, the trend of urban sprawl could be weakened, because people have an incentive to move closer to their workplace (OECD, 2005). As for freight transport, road pricing systems are expected to have an impact on transport intensive industries, especially on the primary industry (Puwein, 2000). As a result, firms will change location in order to be close to upstream/downstream producers.

Cordon pricing

Cordon pricing is a particular form of congestion pricing, a transportation control measure often referred to as “value pricing”. In general, congestion pricing provides a disincentive to driving on highly used roadways by imposing fees. These fees are intended to reduce congestion and improve air quality by encouraging people to change their travel patterns, i.e. shifting to off-peak periods, to less congested roads or to public transport.

The cordon pricing mechanism in particular charges cars that enter a high-activity area such as a central business district. The concerned area is encircled with a cordon such that fees are collected via toll booths or parking permits from people driving into the respective region. Moreover, prices may vary by time of day in order to address peak congestion periods. Emissions of harmful pollutants will be mitigated because vehicle miles travelled will decrease. In particular, the imposed fees will result in people switching to higher occupancy vehicles or mass transport. In addition, idling, which is known to contribute significantly to carbon dioxide emissions and global warming, will decline. Other environmental benefits may result from lower oil and fuel consumption.

Cordon pricing systems are most effective in concentrated areas, thereby relieving inner-city congestion. However, this pricing policy may not reduce traffic on the region’s freeway system leading into the city. Furthermore, cordon pricing policies may result in an inequitable situation for downtown business if people decide to shop in the suburbs. As for equity concerns, however, cordon pricing may benefit high income groups, which tend to value time savings more than travel cost savings. Yet, moderate income groups may benefit only if the revenue generated from the congestion pricing measure is used to construct or improve already existing mass transport systems. Thus, if congestion pricing policies successfully encourage people to switch to mass transport, the generated revenue may be used for transportation improvements and thus make these programs highly cost-effective (EPA, 1998).

Tradable permit systems for CO_2 emissions of transport

In January 2005 the European Union implemented the European Emission Trading Scheme (EU-ETS) as a 3rd flexible mechanism of the Kyoto protocol and therefore important instrument to reach its commitments on Climate Change. Some 12,000 large industrial plants covering about 46 % of the EU‘s total CO_2 Emission currently participate in the first 3 years phase of this trading system. The scheme allows companies to buy and sell permits to release carbon dioxide into the atmosphere, so called allowances. Following so called national NAPs (National Allocation plan), the number of allowances allocated to companies (caps) and the method to allocate them is set on EU member state level. Companies exceeding their individual CO_2 emissions targets can purchase allowances from others who fall below them. The philosophy behind this system is that emission reductions are carried out, where they are cheapest and that measures to reduce CO_2 emission, such as switching to a low emission fuel mix and investments in new climate friendly technologies are encouraged.
Cars and airplanes are major sources of the carbon dioxide emissions linked to climate change. Neither is currently covered by the scheme that gives industry incentives to cut CO_2. The European Commission is currently reviewing the scheme and may recommend expanding it to other sectors, such as transport. While the Commission will soon put forward plans to include airlines, the inclusion of the transport sector seems unlikely before 2010, however.

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2. Driving Forces in Urban Sprawl and Policy Options: A Spatial Computable General Equilibrium Analysis

Birgit Friedl, Olivia Koland and Karl W. Steininger[1]

1 INTRODUCTION

The mutual linkage of transport and economic activity is a conclusion from the now advanced New Economic Geography (NEG) literature, mainly drawing on stylised models so far (see e.g. Fujita et al., 1999). Building on the theoretical NEG modelling advances, we develop a two-region framework of a city centre and its hinterland, based on several modifications of the canonical core-periphery (CP) model (Krugman, 1991; Fujita et al., 1999; Baldwin et al., 2003). The modeling approach of Krugman has been modified along several lines (Ottaviano and Puga, 1998; Eckey and Kosfeld, 2004; Fujita and Mori, 2005). With respect to the present approach, however, two extensions of Krugman's CP model are particularly important: (i) the incorporation of urban features (housing market, commuting, transportation networks) into the NEG framework (Helpman, 1998; Tabuchi, 1998; Murata and Thisse, 2005), and (ii) the consideration of environmental aspects within a NEG framework (Yoshino, 2004; Lange and Quaas, 2006). It is useful at this point to give a short overview of similar work in that field, in particular of comparable modifications of Krugman's standard CP model.

1.1 KRUGMAN'S CORE-PERIPHERY MODEL: SHORTCOMINGS, MODIFICATIONS AND EXTENSIONS

The CP model, which is conveniently laid out in Fujita et al. (1999), contains the analytical essence of the NEG. It shows how the interactions between transport costs, increasing returns at firm level and factor mobility endogenously determine the extent of regional specialisation through simultaneous location choices of firms and labour. Thus, the model depicts how a region can become differentiated into an industrialised core and an agricultural hinterland. Hereby, in order to explore agglomeration patterns, Krugman focuses on the firm's location decision. A second important point is that, even when two regions have absolutely identical location conditions, agglomeration and dispersion processes can occur. Clearly, the CP model focuses on the alteration of transport costs to explain agglomeration patterns. But in order to understand regional differences in population density and to depict human behaviour appropriately, additional forces such as housing scarcity and urban pollution problems are to be included.

[1] The authors thank Laurent Franckx for inspiring discussions and helpful comments.

Consideration of non-tradable services in the NEG goes back to Helpman (1998), who, however, remains in the two sector model. In doing so, he replaces the standard agricultural sector with housing services. Each region is assumed to have a fixed stock of housing, yet housing stocks are equally owned by all individuals. In addition, residents are mobile, but they live and work in the same place. In other words, he abstracts from commuting. While in the standard NEG model dispersion is driven by region-specific demands by farmers, who own the homogenous product, in this model it is region-specific supplies (of homogenous housing) that act as a dispersions force. Helpman finds that agglomeration is more likely to occur when (interregional) transport costs are higher, which contradicts Krugman's result that falling transport costs lead to regional divergence.

All three sectors (agriculture, manufacturing, housing) are taken into consideration by Suedekum (2006) and Pflueger and Suedekum (2006). Suedekum's (2006) model implies that the true costs of living may be higher in the centre region, contradicting standard CP model predicitions. He builds on the integration of housing scarcity as a main determinant of regional price differentials. By contrast, Pflueger and Suedekum (2006) investigate the welfare effects of agglomeration and the efficiency arguments for policy invention in an analytically tractable model. Their main contribution is in finding an analytically precise way to disentangle the net pecuniary externality with mobile firms in the monopolistically competitive sector. These two papers basically differ in that Pflueger and Suedekum (2006) draw on the quasi-linear "footloose entrepreneur model" of Pflueger (2004), which is a tractable variant of the standard Krugman (1991) model. What they share, however, is the assumption of housing as a non-traded and non-produced consumption good (as in Helpman (1998)). As a result, there is no differentiation between the place of work and residence.

A number of papers (e.g. Tabuchi, 1998; Murata and Thisse, 2005) add urban structures to the NEG such that households face a trade-off between transport costs for space and amenity. Thereby, Murata and Thisse (2005) aim to unify the work of Helpman (1998) and Tabuchi (1998). However, the regional specification of these models is based on the monocentric residential model (Alonso, 1964), where workers live around a (spaceless) CBD (central business district) and commute to it. With two regions of this type, these models do allow for the interplay between interregional commodities' transport costs and workers' intraregional commuting (and housing) costs in a spatial economy. By this means, however, they abstract from interregional commuting, i.e. the possibility of different regional locations for residence and work for some fraction of workers. Furthermore, existing spatial models of pollution often presume a predetermined separation between polluters and pollutees, equally into a CBD and a residential ring (e.g. Verhoef and Nijkamp, 2002).

Lange and Quaas (2006) extend the canonical CP model to include local environmental pollution, which is linked to production and thus to a concentration of skilled labour. Urban environmental problems act as a spreading force, because they make agglomerations less favourable (producer-consumer externalities). In comparison to Krugman's results, their model can explain a third and more realistic type of equilibrium, i.e. a stable asymmetric and incomplete agglomeration of skilled workers in one of the two regions.

The aim of this chapter is to propose a simple model of economic geography to analyse the main determinants of urban sprawl and to address efficiency arguments for policy intervention. While in the CP model agglomeration is slowed down only by transport costs – which have to take implausible dimensions to explain dispersion processes, we integrate other forces such as rising property prices with concentration size, and negative environmental impact due to dense living, on the one hand, and commuting behavior, on the other. This implies a more realistic assumption of re-dispersion of economic acitivity. Hence, following Helpman (1998) and Suedekum (2006) we introduce a housing market into the NEG, and following Lang and Quaas (2006) we add local environmental quality to the framework, yet both extensions with specific modifications. In addition, the production of manufacturers involves labor and capital and does not occur exclusively by the use of the factor labor.

Analogously to Helpman (1998), yet different to the remaining modifcations of the CP model, we chose to abstract from the agricultural sector, which allows for a realistic investigation of urban and peri-urban settlement structures. Unlike Helpman, however, we let housing to be traded at a cost in our empirical implementation of the theoretical model. In doing so, we are in a position to model interregional commuting. Moreover, we make a different assumption on the factors which determine the local level of environmental quality. Hereby, it is firstly the regional population density, and secondly the intensity of mobility trends, e.g. urban sprawl, that affect the local level of environmental quality. The important point is that pollution is caused by commuting residents only, i.e. the occurring externalities are not of the producer-consumer type typically found in environmentally oriented models (e.g. Verhoef and Nijkamp, 2002; Arnott et al., 2004; Marrewijk, 2005; Yoshino, 2004; Lange and Quaas, 2006). An urban general equilibrium model with pollution from commuting was developed by Verhoef and Nijkamp (2003), but, unlike the present approach, in a monocentric city setup.

In order to unify elements of urban economics and NEG to study both the development of cities, having spatial extent, and agglomeration in the same space, we address the economics of residential choice by agglomeration and dispersion forces at two levels. First, at the interregional level, households face a trade-off between transport costs for space and amenity (jobs, proximity to infrastructure, shops). Second, at the intraregional level, households search for amenities that are provided by the neighbourhood of a given location. These include the openness of the landscape and the quality of living.

Regarding the spatial extension of urban regions, we consider (interregional and intraregional) commuting costs. We assume that commuting and shopping costs that occur in the centre are compensated by the convenience of public goods and local (urban) amenities prevailing in agglomerations. An important point is that commodities' transport costs as argued in the CP model are interpreted as the consumers' way to a shopping facility. Hence, while the NEG has dealt mainly with firms' location of production, the present chapter focuses on consumers' decisions. I.e. residents choose where to live and work depending on the differences in commuting (and shopping) costs, in agglomeration economies and land rents as well as environmental quality. Thus, the levels of real income and environmental quality are crucial endogenous variables, which determine the long run allocation of economic activities across the two regions.

Space matters not only by inducing transport costs but also by reducing pollution via spatial planning. To address that issue, we investigate how pollution interacts with the other forces which have been identified in the literature as affecting the pattern of land use such as returns to scale in production. This, together with the circular linkage of car-related pollution and housing structures, is therefore the innovative aspect of the present chapter.

1.2 POLICY ISSUES IN A NEW ECONOMIC GEOGRAPHY FRAMEWORK

Regarding policy intervention, the overall aim is to evaluate various instruments we find suitable to counteract current environmentally unfavourable mobility trends, which prevail within most urban areas. We do so by expanding the NEG framework for a selected test area (Graz basin) to the empirical domain. Needless to say most evaluations of policy proposals have to be concerned about the magnitude of impacts of the proposed measures. In this respect, the analysis of structural adaptation processes, as conducted within CGE, is found capable to help gaining insights for policy formulation.

First, we analyse the dominant explanatory forces in urban settlement structures. As a second step, we seek to quantify policy impacts on spatial production and consumption patterns. This is carried out for a selected Austrian area, which is characterised by a very dynamic development with substantial detrimental effects in the transport sector. These include high amounts of local pollutants like particulate matter (PM_{10}) and regular collapses of traffic flows in rush hours. However, the addressed area is illustrative for many other Austrian and European cities facing similar challenges. Since long-term choices in land-use and choices in transport are mutually dependent, we will investigate more general land use instruments such as housing zoning restricitions as well.

Regarding environmental effects, the focus of the present analysis is not solely on greenhouse gas emissions. On the contrary, it is on overall mobility related health effects in urban areas. Furthermore, it deals with congestion both between regions due to commuting and within a single region because of dense living. By this means, the chapter on hand investigates the potential of combining spatial planning and transport policy for more environmentally sustainable settlement structures.

2 MODEL OUTLINE

We model a two-sector economy consisting of two regions, an urban core and its hinterland. An asterisk (*) marks variables/equations relating to the hinterland. The regions differ in terms of (i) agglomeration advantage, (ii) the price of housing as well as (iii) environmental quality. Consumers derive benefit from the consumption of housing and a variety of other goods as well as the local level of environmental quality. Households purchase differentiated products in both regions, whereby "imported" brands are costly to transport in the sense of additional passenger transport costs for shopping.

The economy modelled comprises two sectors of production; input factors are assumed to be factor-specific. First, a variety of consumption goods is produced under increasing returns to scale (at firm level) in a monopolistically competitive market. Manufacturing production requires labour and capital. Second, the housing sector operates under perfect competition and constant returns to scale by use of labour only, i.e. $p_H = w_H$, $p_H^* = w_H^*$. Capital is equally owned by all individuals working in manufacturing.

Thus, there are three production factors: Capital K_M, manufacturing labour L_M and labour available for housing production L_H. The last factor mentioned is immobile and equally distributed between the regions. By contrast, manufacturing workers are mobile between the regions, thereby determining a specific settlement structure. We choose units for the supply of manufacturing workers $\overline{L}_M = L_M + L_M^* = \alpha$ and for housing producers $L_H = L_H^* = (1-\alpha)/2$, i.e. $\overline{L}_H = 1-\alpha$. Moreover, $L = L_M + L_H$ and $\overline{L} = \overline{L}_M + \overline{L}_H = 1$. In addition, capital is freely mobile across regions, and total capital supply is $\overline{K}_M = K_M + K_M^* = 1$.

2.1 *CONSUMPTION*

All workers are final consumers and share the same preferences on the composite consumption good *M*, the housing good *H* and environmental quality *Q*, which enters the utility function in an additive-separable form (see Lang and Quaas, 2006)

$$U(M,H,Q) = M^{\alpha} H^{1-\alpha} + Q \qquad 0 \le \alpha \le 1 \qquad (1)$$

The composite *M* is a subutility CES function defined over a continuum of varieties of consumption goods with a constant intensity of preference for variety ρ

$$M = \left[\int_0^n m(i)^{\rho}\, di \right]^{1/\rho} \qquad 0 < \rho < 1 \qquad (2)$$

with the consumption of each variety denoted by $m(i)$ and a range of varieties described by n. When different varieties are imperfect substitutes in consumption ("love for variety"), as expressed by (2), doubling industry output means more than doubling (aggregate) utility gained from *M*.

The representative household[2] maximizes (1) subject to (2) and the budget constraint (3), where *Y* represents total regional income, $p_m(i)$ the consumer price of variety *i* and p_H the price of one unit of housing:

$$Y \geq p_H H + \int_0^n p_m(i) m(i) di \quad ^3 \tag{3}$$

This maximisation problem can be solved in two steps. First, the representative household splits per capita income *y* between *M* and *H*. Second, each $m(i)$ is chosen such that the costs of attaining the level of *M*, as determined in the first step, are minimized. The latter step means solving the expenditure minimization problem

$$\text{min. } \int_o^n p_m(i) m(i) d_i \tag{4}$$

$$\text{s.t. } M = \left[\int_0^n m(i)^\rho di \right]^{1/\rho}$$

The FOC for this minimisation problem establish the equality of marginal rates of substitution to price ratios for any pair of varieties $\{m_i, m_j\}$, which, substituted into constraint (2), yield the Hicksian demand for variety $m(j)$ as in (5),

$$m(j) = \left(\frac{p_m(j)}{G} \right)^{-\sigma} \cdot M \qquad \sigma \equiv 1/(1-\rho) \tag{5}$$

$$\text{where } G = \left[\int_0^n p_m(i)^{1-\sigma} di \right]^{1/(1-\sigma)} \tag{6}$$

with σ indicating the elasticity of substitution in preferences between any pair of varieties and *G* the price index of composite *M*. When σ is low, products are strongly differentiated or, expressed differently, there is a strong preference for diversity. More specifically, the index *G* decreases with *n*, whereby σ determines

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[2] Since consumers are identical in preferences, final demand will be the same for them differing only in terms of sources of income. We assume that there is a representative consumer in each region, i.e. the relevant income comprises all different sources.

[3] Equations (2) and (3) are also representable as summation without alteration of the fundamental results. Thus, for the discrete case, (2) and (3) can be written as

$M = \left[n(m(i))^\rho + n^* (m(j)^*)^\rho \right]^{1/\rho}$ (2) and $Y \geq p_H H + \left(n \cdot p_M \cdot m(i) + n^* \cdot p_M^* \cdot m(j)^* \right)$ (3)

the scale of reduction in *G*. This can easily be shown, since $0 < \rho < 1$ and $\sigma = 1/(1-\rho)$, by assuming the same price p_M for all available varieties[4], i.e. $p_m(i) = p_M$ for all varieties *i*, such that the price index (6) becomes $G = p_M \cdot n^{1/(1-\sigma)}$. The lower *σ*, the greater the reduction in *G*. In this vein, consumers' utility level increases with *n*, while the quantity of consumed goods and the income level remain unchanged.

Equation (5) is the solution to the lower-level step of the consumer's maximisation problem, showing how total demand of *M* is divided between varieties. In the upper-level step, total income is divided between *M* and *H* so as to

$$\begin{aligned} &\max. \ U(M,H,Q) = M^{\alpha} H^{1-\alpha} + Q \\ &\text{s.t.} \quad Y \geq p_H H + G \cdot M \end{aligned}$$

which yields the demand functions for housing and the consumption composite

$$H = \frac{(1-\alpha)Y}{p_H} \quad \text{and} \quad M = \frac{\alpha Y}{G} \qquad \text{(7a) and (7b)}$$

Combining the upper and lower step, the (total) Marshallian demand functions for the housing good and a single variety are given by

$$H = \frac{(1-\alpha)Y}{p_H} \quad \text{and} \quad m(i) = \alpha \cdot Y \frac{p_m(j)^{-\sigma}}{G^{1-\sigma}} \qquad \text{(7a) and (8)}$$

2.2 *ENVIRONMENTAL QUALITY*

Besides manufactured goods and housing, it is environmental quality that contributes to consumers' welfare. However, with respect to monetary terms, environmental quality *Q* enters the utility function (1) directly as a public good. The local level of *Q* is given by the function

$$Q = e^{-\mu \cdot L} \quad \text{and} \quad Q^* = e^{-\mu \cdot^* L^*} \qquad (9)$$

thereby depending on the number of manufacturing workers $L = L_M + L_H$ per region. Parameter *μ* thus scales the population congestion impact on the level of environmental quality.

[4] For this assumption, see the section on production.

2.3 PRODUCTION IN MANUFACTURING

The analysis of production is presented for the centre region, yet it is identical for the hinterland. Moreover, all firms both in the centre and the hinterland are assumed to use the same technology.

Production of all varieties requires labour and capital. The labour l_M required to produce quantity q_M of any variety i involves fixed labour input F and marginal labour input a_M

$$l_M = F + a_M \cdot q_M \tag{10}$$

Thus, there are increasing returns to scale in the production of each variety. This and the fact that there is an unlimited number of varieties that could be produced, together with consumers' love for variety, imply that each firm produces just one variety and that no variety is produced by more than one firm.

A firm's demand for capital k_M is determined by a constant capital-to-labour ratio $c_M = k_M / l_M$ (see Eppink and Withagen, 2006), which is identical for all firms. In the monopolistically competitive market firms behave non-strategically taking price index G as given. Let w_M be the wage rate, p_M the f.o.b. price and p_K the price of capital. Then, given demand for variety i (8), each firm producing a specific variety behaves so as to

$$\text{max.} \quad \pi = p_M \cdot q_M - (w_M + p_K \cdot c_M) \cdot (F + a_M \cdot q_M) \tag{11}$$

$$\text{s.t.} \quad m(j) = \alpha \cdot Y \frac{p_m(j)^{-\sigma}}{G^{1-\sigma}} \tag{8}$$

The FOC, together with a constant price elasticity of demand, $\varepsilon = \sigma = 1/(1-\rho)$, thus give the profit-maximising price for each variety as a fixed mark-up over marginal cost, $a_M(w_M + p_K \cdot c_M)$, with ρ as defined before in equation (2)

$$p_M = \frac{a_M(w_M + p_K \cdot c_M)}{\rho} \tag{12}$$

By use of the same technology, the producer price p_M is identical for all firms. Firms earn economic rents by applying mark-up pricing, yet costless entry and exit drives profits to zero.

Equations (11) and (12), together with the zero-profit-condition, give the equilibrium output, or alternatively equilibrium size, of a single firm

$$q_M = \frac{\rho \cdot F}{a_M \cdot (1-\rho)} = \frac{F \cdot (\sigma - 1)}{a_M} \tag{13}$$

and, from (10) and (13), equilibrium labour demand

$$l_M = F + a_M \cdot \frac{F \cdot (\sigma - 1)}{a_M} = F \cdot \sigma \tag{14}$$

and accordingly the equilibrium demand for capital in the sector for consumption goods

$$k_M = c_M \cdot F \cdot \sigma \tag{15}$$

The equilibrium number of firms, which equals the number of varieties produced, is, with total labour supply in manufacturing denoted by L_M,

$$n = \frac{L_M}{l_M} = \frac{L_M}{F \cdot \sigma} \tag{16}$$

Therefore, total labour demand is $L_M = n \cdot F \cdot \sigma$. On the other hand, total capital use in the sector for consumption goods is $K_M = n \cdot k_M = n \cdot c_M \cdot F \cdot \sigma$.
From equations (12) and (13) we get the crucial result that the size of the market affects neither the mark-up over marginal costs nor the scale at which consumption goods are produced. Instead, in the Dixit-Stiglitz model all market size effects, or scale effects, work through changes in the number of varieties available. This results from the CES demand function (2) and the assumption of firms' non-strategic behaviour taking price index *G* to be constant.[5]
Since each firm in either region produces by using the same technology, together with identical consumer preferences across all consumer types, equations (10) to (15) turn out identical for both core and hinterland. Solely, yet most importantly, equation (16) determining the equilibrium number of firms, differs across regions.

2.4 TRANSPORT COSTS

Transport costs are assumed to be of the iceberg form, i.e. only a fraction $1/T$, $T \geq 1$, of the good arrives in the other region. In other words, for each unit delivered *T* units have to be shipped. Then, $T-1$ represent transport costs, which in the present approach are considered as passenger transport costs. I.e. they are incurred whenever residents living in a region decide to shop in the other region. Consequently, the price index (6) rises to

[5] This effect can also be explained by the micro-founded mechanism of sharing the gains, on the supply side, from a wider variety of intermediate inputs (Duranton and Puga, 2004, 2069-2071). This mechanisms works like a supply-side version of the Dixit-Stiglitz approach. In this context, final producers become more productive when they have access to a larger variety of intermediate inputs. Thereby, a larger workforce causes more varieties of intermediates to be produced. Yet, this increase in the workforce rises final output more than proportionally due to the CES aggregation of intermediate inputs (which works in a parallel fashion to equation (2)).

$G = [n\,(p_M)^{1-\sigma} + n^*(p_M^* T)^{1-\sigma}]^{1/(1-\sigma)}$ for the core, and (17)

$G^* = [n\,(p_M T)^{1-\sigma} + n^*(p_M^*)^{1-\sigma}]^{1/(1-\sigma)}$ for the hinterland (17*)

Consumption demand for variety *i* in the centre region follows from (8) as

$$m(i) = \alpha \cdot \left[Y(p_M)^{-\sigma} G^{\sigma-1} + Y^*(p_M T)^{-\sigma}(G^*)^{\sigma-1} \right] \quad (18)$$

yet to supply this level of consumption, *T* times this amount has to be shipped, such that demand for differentiated products produced in both regions amounts to

$$m(i) = \alpha \cdot \left[Y(p_M)^{-\sigma} G^{\sigma-1} + Y^*(p_M^*)^{-\sigma} T^{1-\sigma}(G^*)^{\sigma-1} \right] \quad (19)$$

By this means, the demand for consumption goods in the centre region is made up of its own demand and the demand of the peripheral region. The same holds true for the hinterland, where total demand for variety *j* adds up to

$$m(j)^* = \alpha \cdot \left[Y^*(p_M^*)^{-\sigma}(G^*)^{\sigma-1} + Y(p_M)^{-\sigma} T^{1-\sigma} G^{\sigma-1} \right] \quad (19*)$$

2.5 HOUSING SUPPLY

The supply of housing goods in each region is fixed at $H = H^* = (1-\alpha)/2$. Following Helpman (1998), who replaces the agricultural sector of the standard NEG model with an immobile housing stock, and Suedekum (2006), who, by contrast, adds non-tradable home goods as a third sector to it, the availability of housing represents an essential driving force behind dispersion of economic activity. However, an increase in hinterland residents works as a centripetal force, i.e. with a rise in urban sprawl activity, hinterland residents are confronted with a loss in real wage due to rising housing costs. While the price index of the consumption aggregate is lower in the core region, aggregate costs of living may therefore actually be higher in the more densely populated centre due to regional differences in housing costs

As manufacturing workers can migrate to the other region, but housing production is fixed in quantitative terms (not in terms of prices) in each region, oversupply in one region and undersupply in the other will occur. The arising changes in housing prices induce a fraction of the population in the more densely populated region to commute and look for housing in the other region; a fraction that is growing as long as the other region has cheaper housing prices.

3 INSTANTANEOUS EQUILIBRIUM

3.1 NORMALISATIONS

To simplify the set of equilibrium equations, we choose the following units of measurement, most of which resemble the normalisations of the standard NEG model (see for example Fujita et al., 2001). Equations denoted by an apostrophe (‘) include normalisations.

Setting $a_M \equiv \rho = (\sigma - 1)/\sigma$ (20)

implies, for equations (12), (13) and (14),

$p_M = w_M + p_K \cdot c_M$ (12’)
$q_M = F \cdot \sigma$ (13’)
$l_M = q_M$ (14’)

Normalisation of fixed costs at $F \equiv \alpha / \sigma$ gives (21)

$l_M = q_M = \alpha$, $n = L_M / \alpha$ and $n = K_M /(c_M \cdot \alpha)$, and (14’), (16’) and (15’)

for the equilibrium number of firms, since labour supply is set at $L_M + L_M^* = \alpha$,

$n + n^* = 1$ (22)

Using (16’), the relationship between the equilibrium number of varieties per region *n* and the respective labour force in manufacturing, the number of residents per region, including manufacturing and housing workers, can be expressed by

$L = n \cdot \alpha + (1 - \alpha)/2$ and $L^* = n^* \cdot \alpha + (1 - \alpha)/2$ (23)

3.2 EQUILIBRIUM CONDITIONS

The migration decision of mobile workers L_M depends on both differences in real income and the level of environmental quality. Equilibrium occurs when no resident has any incentive to relocate, i.e. $u_M = u_M^*$. Expressing the consumers’ maximised utility as a function of income and prices yields the indirect utility function, i.e. from (7) and (1) we get the per capita utility of (mobile) manufacturing workers

$u_M = \alpha^\alpha (1 - \alpha)^{1-\alpha} y_M G^{-\alpha} (p_H)^{-(1-\alpha)} + Q$ (24)

which, in this approach, is the base for the spatial equilibrium analysis. Furthermore, total income Y per region is denoted by

$$Y = w_M L_M + w_H L_H + p_K K_M = w_M \cdot \alpha \cdot n + w_H (1-\alpha)/2 + p_K \cdot n \cdot c_M \cdot \alpha \qquad (25)$$
$$Y^* = w_M^* L_M^* + w_H^* L_H^* + p_K^* K_M^* = w_M^* \cdot \alpha \cdot n^* + w_H^* (1-\alpha)/2 + p_K^* \cdot n^* \cdot c_M^* \cdot \alpha \qquad (25^*)$$

such that per capita income y_M of manufacturing workers can be expressed as

$$y_M = w_M + \frac{p_K K_M}{L_M + L_H} = w_M + \frac{p_K \cdot n \cdot c_M \cdot \alpha}{\alpha \cdot n + (1-\alpha)/2} \qquad (26)$$
$$y_M^* = w_M^* + \frac{p_K^* K_M^*}{L_M^* + L_H^*} = w_M^* + \frac{p_K^* \cdot n^* \cdot c_M^* \cdot \alpha}{\alpha \cdot n^* + (1-\alpha)/2} \qquad (26^*)$$

Equilibrium hinterland housing prices are determined by the equality of (fixed) housing supply and demand (7a):

$$p_H = w_H = 2Y \text{ and } p_H^* = w_H^* = 2Y^* \quad \Leftrightarrow$$
$$p_H = 2n(w_M + p_K \cdot c_M) \text{ and } p_H^* = 2n^*(w_M^* + p_K^* \cdot c_M^*) \qquad (27) \text{ and } (27^*)$$

As for the equilibrium wage rate, by using demand function (19), centre firms attain q_M (13), the equilibrium output satisfying the zero-profit condition, if

$$q_M = \alpha \cdot \left[Y (p_M)^{-\sigma} G^{\sigma-1} + Y^* (p_M^*)^{-\sigma} T^{1-\sigma} (G^*)^{\sigma-1} \right]$$
$$\Leftrightarrow (p_M)^{\sigma} = \frac{\alpha}{q_M^*} \left[Y \cdot G^{\sigma-1} + Y^* \cdot T^{1-\sigma} (G^*)^{\sigma-1} \right] \qquad (28)$$

Taking the profit-maximising price (12), (28) can be expressed as

$$w_M = \left[Y \cdot G^{\sigma-1} + Y^* \cdot T^{1-\sigma} (G^*)^{\sigma-1} \right]^{\frac{1}{\sigma}} - p_K \cdot c_M \qquad (29)$$

which is the centre wage at which firms break even. For the hinterland region, from (19*), (13*) and (12*) we find the wage equation

$$w_M^* = \left[Y^* (G^*)^{\sigma-1} + Y \cdot T^{1-\sigma} G^{\sigma-1} \right]^{\frac{1}{\sigma}} - p_K^* \cdot c_M \qquad (29^*)$$

In addition, real income is given by

$$\omega = y_M / [G^{\alpha} \cdot (p_H)^{1-\alpha}] \text{ and } \omega^* = y_M^* / [(G^*)^{\alpha} \cdot (p_H^*)^{1-\alpha}] \qquad (30) \text{ and } (30^*)$$

Instantaneous equilibrium is characterised by equations (17), (17*), (25), (25*), (29) and (29*). Thus, the consumers' location decision is determined by the respective per capita utility

$$u_M = \Phi \cdot y_M \cdot G^{-\alpha}(p_H)^{-(1-\alpha)} + Q(L_M) = \Phi \cdot \omega + Q \quad (31)$$

$$u_M^* = \Phi \cdot y_M^* \cdot \left(G^*\right)^{-\alpha}(p_H^*)^{-(1-\alpha)} + Q^*(L_M^*) = \Phi \cdot \omega^* + Q^* \quad (31^*)$$

where $\Phi = \alpha^{\alpha}(1-\alpha)^{1-\alpha}$

The adjustment dynamics are assumed to have the ad hoc form

$$\dot{\lambda} = \left[(Q - Q^*) + (\omega - \omega^*)\right] \cdot \lambda \cdot (1-\lambda) \quad (32)$$

The number of active firms is then equal to the share $0 < \lambda < 1$ of manufacturing labour in the respective region, so that $n = \lambda$ and $n^* = 1 - \lambda$. Equation (32) indicates that, in the long run, manufacturing workers migrate to the region that offers the higher level of welfare, determined by different levels of real income ω and environmental quality Q. In the base case, $Q < Q^*$, $p_H > p_H^*$, $w_M > w_M^*$ and $G < G^*$; the relationship of regional real income levels ω is therefore ambiguous. Thus, a spatial equilibrium arises at λ when

$$\Delta u_M \equiv u_M(\lambda) - u_M^*(\lambda) = 0 \Leftrightarrow \dot{\lambda} = 0 \quad (33)$$

3.3 THE PRICE INDEX EFFECT AND THE HOME MARKET EFFECT

The price indices and wage equations imply important relationships with respect to the spatial equilibrium. In particular, the regional equilibrium structure of real wage differences depends on the balance of three effects, namely (i) the *price index effect* (or cost of living effect) (ii) the *home market effect* (or market size effect) and (iii) the *competition effect*. The first and the second effect are agglomeration forces, while the third acts as a dispersion force.

In order to investigate agglomeration forces (i) and (ii), the price indices (17) and (17*) and wage equations (29) and (29*) can be rewritten as

$$G^{1-\sigma} = \frac{1}{\alpha}\left[L_M\,(w_M + p_K c_M)^{1-\sigma} + L_M^*[(w_M^* + p_K^* c_M)T]^{1-\sigma}\right] \quad (17)$$

$$(G^*)^{1-\sigma} = \frac{1}{\alpha}\left[L_M[(w_M + p_K c_M)T]^{1-\sigma} + L_M^*\,(w_M^* + p_K^* c_M)^{1-\sigma}\right] \quad (17^*)$$

$$\left(w_M + p_K \cdot c_M\right)^{\sigma} = Y \cdot G^{\sigma-1} + Y^* \cdot T^{1-\sigma}(G^*)^{\sigma-1} \quad (29)$$

$$\left(w_M^* + p_K^* \cdot c_M\right)^{\sigma} = Y^*(G^*)^{\sigma-1} + Y \cdot T^{1-\sigma} G^{\sigma-1} \quad (29^*)$$

Since these pairs of equations are symmetric, they have a symmetric solution, i.e. if $L_M = L_M^*$ and $Y = Y^*$, then the equilibrium values are equally symmetric: $G = G^*$

and $w_M + p_K c_M = w_M^* + p_K^* c_M$, more specifically $w_M = w_M^*$ and $p_K = p_K^*$. The relationship between these equilibrium values can be expressed by

$$1+T^{1-\sigma} = \frac{\alpha}{L_M} \cdot \left(\frac{G}{w_M + p_K c_M} \right)^{\sigma} = \frac{w_M + p_K c_M}{Y} \cdot \left(\frac{G}{w_M + p_K c_M} \right)^{\sigma} \tag{34}$$

By totally differentiating the price indices around the symmetric equilibrium and letting $dG = -dG^*$, $dL_M = -dL_M^*$, $d(w_M + p_K c_M) = d(w_M^* + p_K^* c_M)$ and $dY = -dY^*$, we get

$$(1-\sigma)\frac{dG}{G} = \frac{L_M}{\alpha}\left(\frac{G}{w_M + p_K c_M} \right)^{\sigma-1} \cdot \left(1-T^{1-\sigma}\right) \cdot \left[\frac{dL_M}{L_M} + (1-\sigma)\frac{d(w_M + p_K c_M)}{w_M + p_K c_M} \right] \tag{35}$$

Applying the same for the wage equations yields

$$\sigma \frac{d(w_M + p_K c_M)}{w_M + p_K c_M} = \frac{Y}{w_M + p_K c_M} \cdot \left(\frac{G}{w_M + p_K c_M} \right)^{\sigma-1} \cdot \left(1-T^{1-\sigma}\right) \cdot \left[\frac{dY}{Y} + (\sigma-1)\frac{dG}{G} \right] \tag{36}$$

In both (35) and (36), the term $1-T^{1-\sigma}$ captures the effects of an increase in a variable in one region and the corresponding decrease in the other.
To explore the *price index effect*, let us consider equation (35), thereby assuming $dw = 0$, i.e. a perfectly elastic supply of manufacturing labour, for a moment. We find that an increase in manufacturing labour dL_M / L_M lowers the price index:

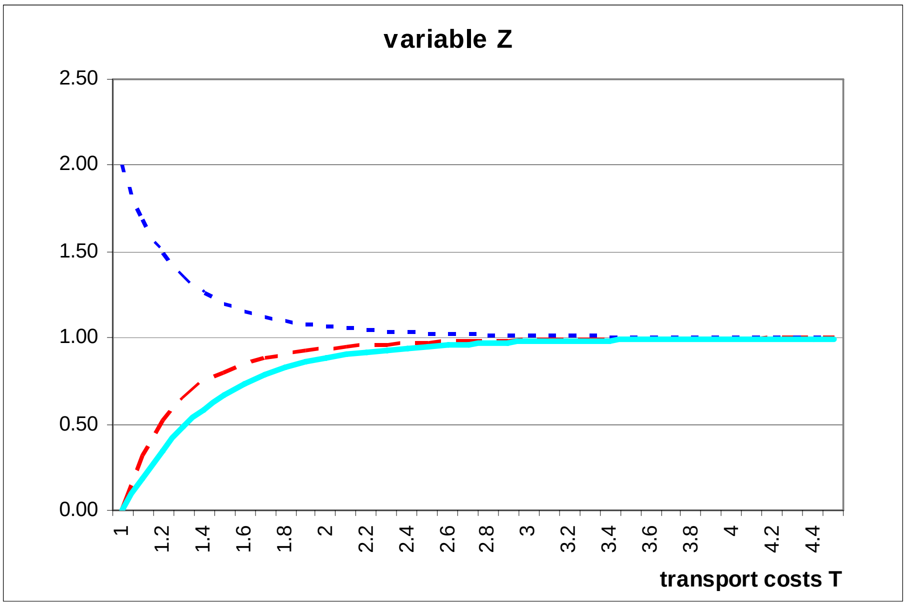
$$\frac{dG/G}{dL_M / L_M} < 0 \tag{37}$$

In order to investigate the home market effect, let us define a new variable *Z*, which is an index of transport costs.

$$Z \equiv \frac{1-T^{1-\sigma}}{1+T^{1-\sigma}} \qquad 0 \le Z \le 1 \tag{38}$$

When there are no transport costs, i.e. $T = 1$ (free trade), $Z = 0$. When, on the other hand, transport costs are prohibitively high, i.e. $T \to \infty$ (trade is impossible), $Z = 1$. Figure 1 shows how the numerator (dashed line) and the denominator (dotted line) of equation (38) determine *Z* (solid line).

Figure 1: The transport cost factor Z as a function of transport cost parameter T



Eliminating dG/G from (35) and (36) yields

$$\left[\frac{\sigma}{Z} + Z(1-\sigma)\right]\frac{d(w_M + p_K c_M)}{w_M + p_K c_M} + Z\frac{dL_M}{L_M} = \frac{dY}{Y} \tag{39}$$

This equation implicates the *home market effect*, i.e. assuming $dw = 0$, an increase in demand for the manufacturing good dY/Y causes a more than proportional rise in the employment and production of manufactures dL_M / L_M:

$$\frac{dL_M / L_M}{dY/Y} = \frac{1}{Z} > 1 \tag{40}$$

What follows is that the location with the larger home market also exports manufactured goods. Otherwise, with an upward sloping labour supply curve, the positive effect $1/Z$ is smaller for the sake of higher nominal wages and less exports. Then, the important point is that locations with a higher demand for manufactures offer higher *real* wages both because (i) the nominal wage is high due to the market size effect and (ii) the price index is low due to the cost of living effect.

Summing up, the home market effect and the price index effect are key elements of cumulative causation that lead to agglomeration. Generally speaking, because of increasing returns, it is advantageous to concentrate production at a few locations. The best locations are those with good access to markets and suppliers and where mobile factors of production have been attracted to. More specifically, backward linkages – the use by one firm of produced inputs from another firm, create an incentive for producers to concentrate where the market is large. This is equally true for forward linkages – the provision by one firm of produced inputs to another firm. As for workers, backward and forward linkages create an incentive for them to be close to the production of consumer goods: The larger is the manufacturing sector, the lower is the price index for manufactured goods, because a larger variety of goods is produced locally (price index effect). Going further, the higher is the demand for manufactures, i.e. the larger the manufacturing sector, the higher is the real wage paid to workers (home market effect).

4 SIMULATIONS

Equations (17), (17*), (25), (25*), (29) and (29*) constitute the equilibrium conditions for a 2-region general equilibrium model, which we use for the analysis of core forces in urban sprawl. Being interested in the equilibria that this system tends to, we need to explore system behaviour under the specification of particular functional forms and parameters. We thus numerically solve this system, i.e. we apply spatial computable general equilibrium analysis.

We take one region to be the centre, the second region its hinterland. Basically, we are interested in the relative per capita utility u_M / u_M^* as a function of λ. Population distribution across regions will be in equilibrium, when per capita utility is equal across regions, and thus no incentive for cross-region migration is present. The share λ, which characterizes this equilibrium, specifies the share of manufacturing labour in the centre and thus the degree of urban sprawl.

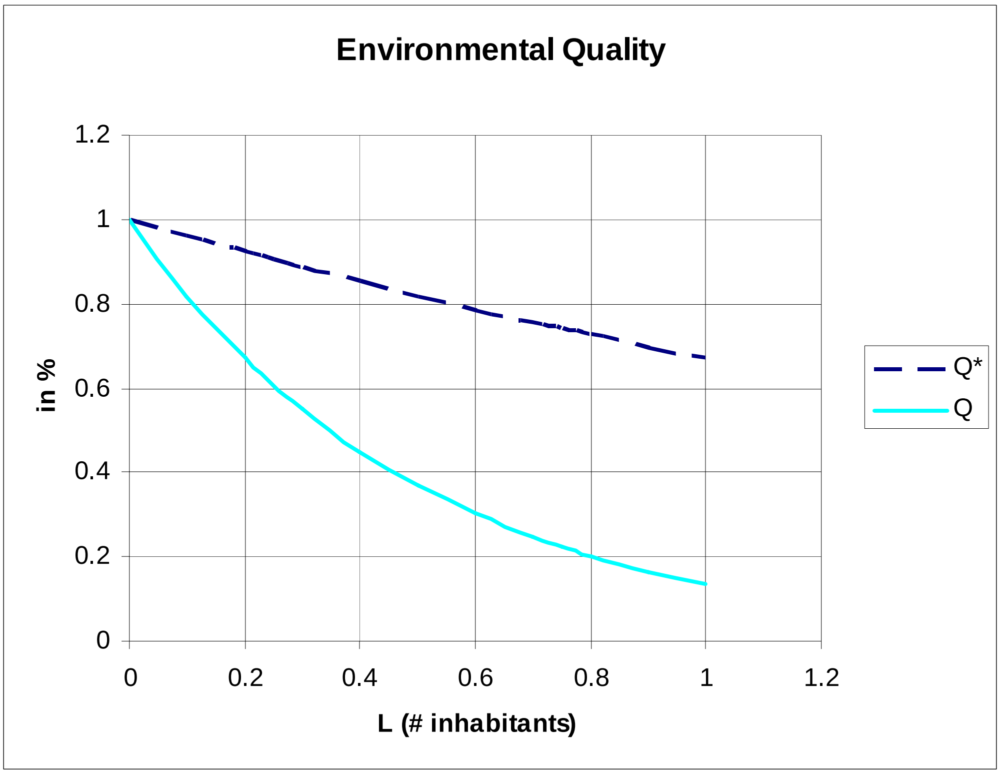
4.1 REFERENCE SPECIFICATION

We define three input factors: capital, labour in the manufacturing sector (mobile between regions) and labour in the housing sector (immobile). Factors are employed in a Cobb-Douglas production technology in manufacturing. For varieties of the manufactured good traded across regions each unit arriving requires a shipment of T units, with T>1 (iceberg transport costs). Furthermore, and in addition to the explicit theoretical model specification above, interregional trade in the housing sector is implemented in order to allow for commuting, with the costs of commuting modelled as simple mark-up pricing. The housing market is cleared by the Armington assumption. On the demand side, households are assumed to have Cobb-Douglas utility, with the elasticity of substitution between manufactured goods and housing set low (at 0.1), reflecting the basic need characteristic of housing demand.

Before discussing the impact of some policy scenarios, we describe the baseline solution. As argued above, the long-run equilibrium for two regions, i.e. $u = u^*$, is characterized by equal per capita utility levels in both regions.

Regarding the share of population in the two regions, for $\mu = \mu^*$ (equal environmental impact factors) we assume equal shares, i.e. λ=0.5, in order to ease interpretation and to stick to the theoretical analysis as closely as possible. For this case we can explore the incentive structure for urban population to migrate.

Figure 2: Environmental Quality as a function of *L* and *L respectively (*Q* for $\mu = 2$ and *Q** for $\mu^* = 0.4$)**



Regarding environmental quality, we assume that the center population exerts stronger environmental pressure due to density, and we thus set the environmental impact factor for the center region larger than that of the hinterland: $\mu > \mu^*$. It is reasonable to assume environmental absorption capacity per capita to differ between the centre and the hinterland region, simply considering the different spatial extension of the two regions. Figure 2 illustrates the impact of the scaling parameter on environmental quality *Q* and *Q**, for different population numbers.
Let us next specify exogenous parameters as introduced in the theoretical model in order to calibrate the baseline solution. For the description and normalizations of the variables, we refer to Appendix 1, the values are given in Tables 1 and 2.

Table 1: The parameters values for the SCGE model

Parameter	Value	Description
$0 \le \alpha \le 1$	0.75	expenditure share consumption good (*own calculation for Graz area*)
$1-\alpha$	0.25	expenditure share housing
$0 < \rho < 1$	0.8	intensity of preference for variety (*Eppink and Witthagen, 2006*)
$\sigma = 1/(1-\rho)$	5	elasticity of substitution between varieties (*Eppink and Witthagen, 2006*)
$\mu \ge 0$	2	population congestion impact on environmental quality in center (*assumption*)
$\mu^* \ge 0$	1	population congestion impact on hinterland environmental quality (*assumption*)
T	1.3	iceberg transport cost factor (initial value; implies zero transport cost)
comm	1.5	commuting transport cost factor (in housing market)
σ_{IM-M}	0.6	elasticity of substitution between home production of manufactures and imports
σ_{IM-H}	1	elasticity of substitution between home production of housing and imports
σ_{MH}	0.1	elasticity of substitution between consumption of manufactures and housing

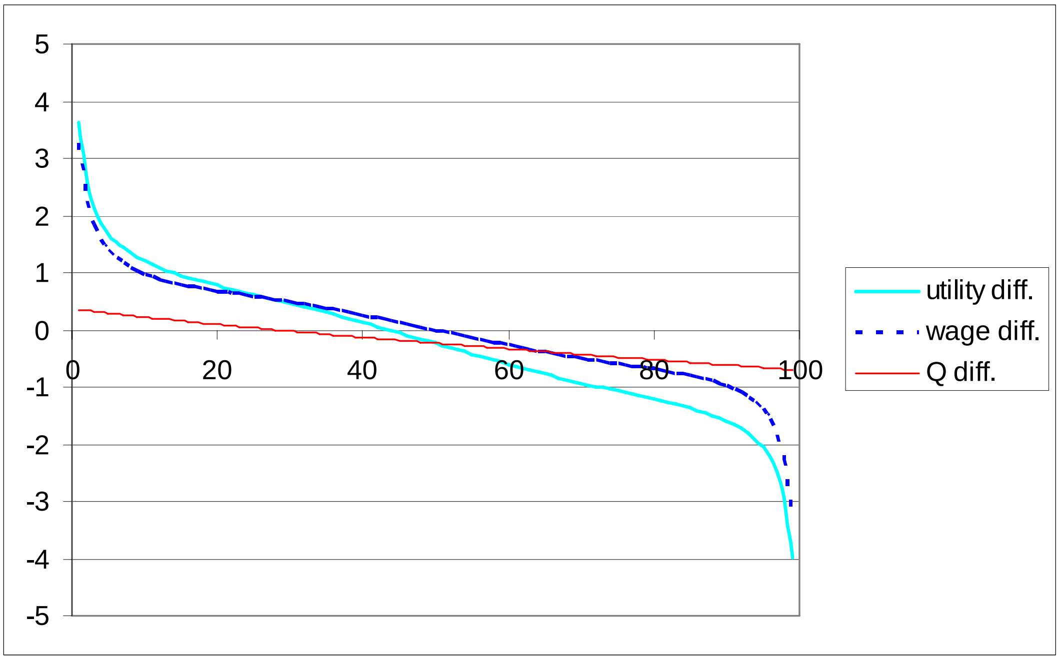
For the wedge in environmental impact given in Table 1 ($\mu = 2$, $\mu^* = 1$), we find in equilibrium λ = 0.43. Thus, 43% of manufactured workers are working in the center and 55% in the hinterland. Note that $u = u^*$ at λ = 0.43 implies that the positive real wage differential ($w - w^* > 0$) just compensates the negative environmental quality differential ($Q - Q^* < 0$). Thus, the higher real wages in the center just suffices to compensate for the lower environmental quality in the center and there exists no pressure to move from the center to the hinterland or vice versa.

Table 2: The exogenous and initial variables for the SCGE model

variables	Value	Description
$\overline{L}_M = L_M + L_M^* = \alpha$	0.75	manufacturing labour (both regions)
$L_H = (1-\alpha)/2$	0.125	housing producers (per region)
$\overline{L} = \overline{L}_M + \overline{L}_H = 1$	1	total labour (both regions)
$\overline{K}_M = K_M + K_M^* = 1$	1	total capital use in manufacturing (both regions)
λ	0.5	share of manufacturing labour in center (initial value)

For λ = 0.27, the environmental quality is equal in both regions due to the different values of μ and μ^*. If the environmental damage factors were equal across regions, the thin solid line in Figure 3 would cut the horizontal axis at λ = 0.5. The thick solid line in Figure 3 depicts the (off-equilibrium) utility differentials for different values of λ, where λ=1 is 100%. If the utility difference is positive (for values of λ below 0.43), the share of manufacturing workers in the center will increase and vice versa for values of λ between 0.43 and 1.

Figure 3: Utility difference $u - u^*$, real wage difference $w - w^*$and difference in environmental quality $Q - Q^*$ for different initial values of λ (with T=1.3, μ=2, μ^*=1)



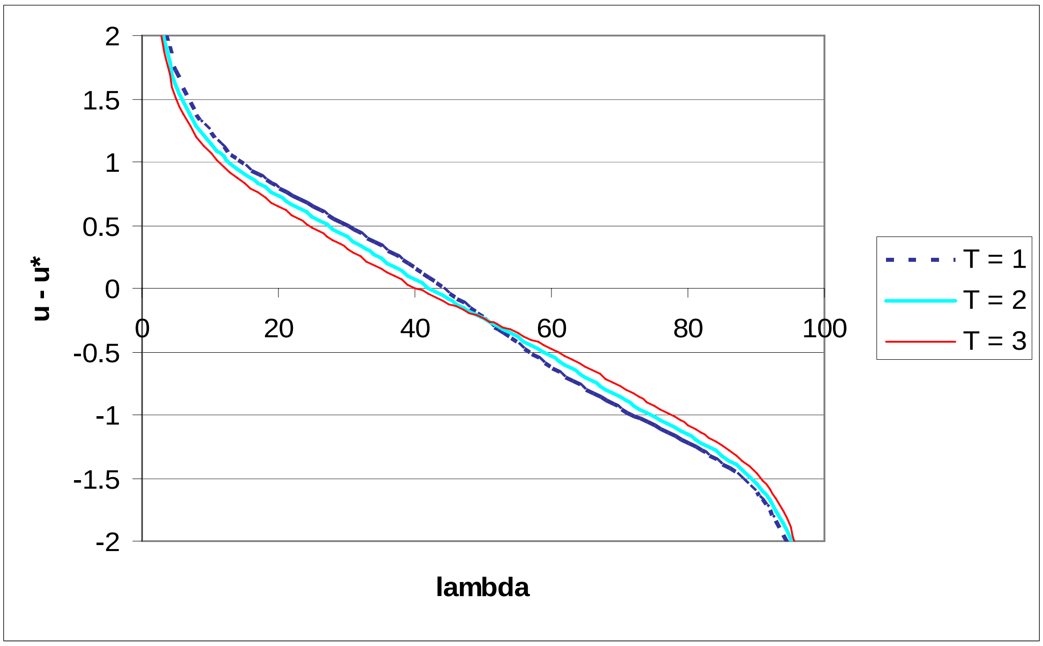
4.2 *POLICY RESULTS*

In our policy analysis, we change four parameters:

- The iceberg transport cost factor T to represent a change in transport costs in cross-regional consumption (e.g. cordon pricing)
- The environmental impact factor μ to model changes in environmental awareness (e.g. an increased acknowledgement of particulate matter health impacts in the hinterland)
- The hinterland-intraregional transport costs in consumption to reflect a change in spatial planning in the hinterland (e.g. more dense spatial planning reducing these costs)
- The supply level of housing space in the hinterland, more specifically the reduction of production inputs in hinterland housing, to reflect spatial planning instruments addressing the prevention of excessive urban sprawl.

We find increasing cross-region transport costs in consumption to be a force enhancing unequal regional population distributions (centrifugal forces). In our case, with the higher centre environmental impact factor, and the arising urban sprawl, we find a further incentive to move to the hinterland, which initally is the more populated region. The reason for this is that the increase in T translates into higher manufacturing prices in both regions, but to a larger extent in the center region because the labor force and thus also the manufacturing supply is larger in the hinterland. Consequently, fewer goods have to be imported. As depicted in Figure 4, the center per capita utility drops by more than the hinterland per capita utility, and the equilibrium level of λ decreases to λ=0.42 for T=2, and to λ=0.40 for T=3. Figure 4 shows that the utility per capita in the centre is higher than that in the hinterland only over a smaller range of λ.

Figure 4: Utility difference *u* – *u for *T* = 1, 2, 3 and for different initial values of λ**

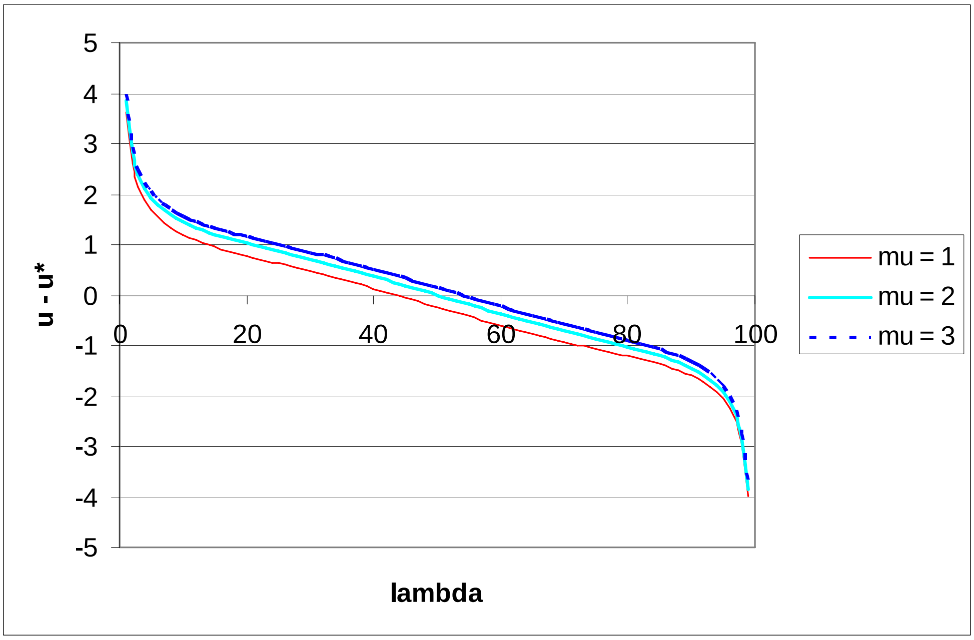


Thus, urban sprawl can be enhanced by an increase in transport costs. If the majority lives in the hinterland and also works there, the center tends to be further depopulated by increasing transport prices. In other words, for regions with different environmental absorption quality but otherwise equal, we find a policy instrument such as cordon pricing to increase urban sprawl in the long-term equilibrium.

Second, let us introduce the currently observed development of higher environmental awareness into our model. Lowering emission targets, such as recently done for PM_{10} within the European Union, raises awareness of health impacts of environmental quality. In order to implement this increase in awareness, we assume that the hinterland population in the basic simulation has a too low value of the environmental absorption capacity, $\mu^* = 1$. Assume also that the “right” level of μ^* were the same as in the center, i.e. $\mu^* = \mu = 2$. Then, we investigate the effects of an increase in μ^*, as illustrated by Figure 5.

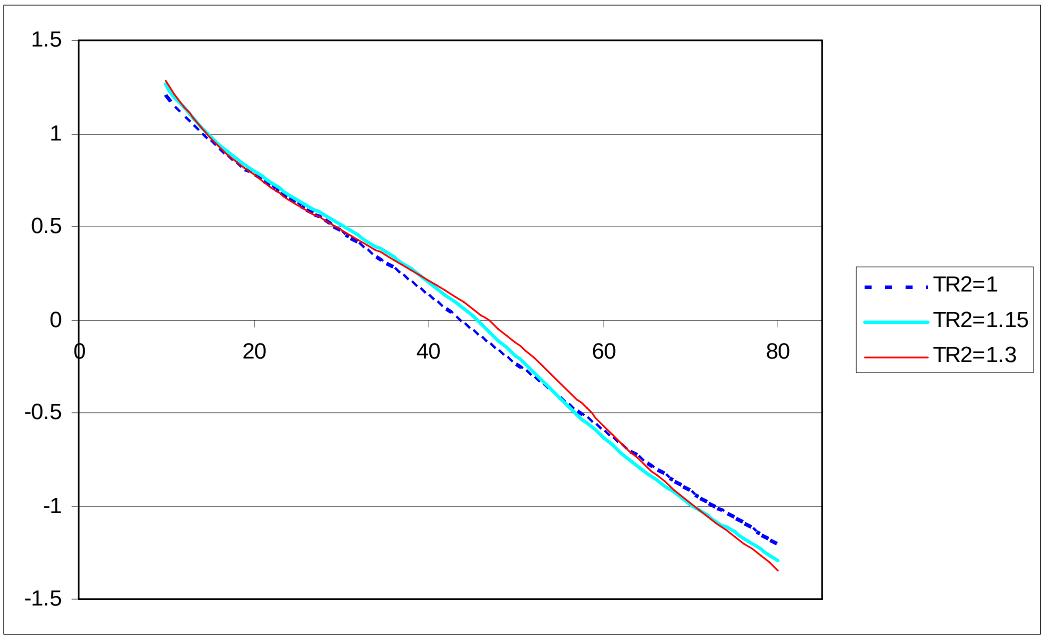
We find the reference equilibrium population distribution of $\lambda = 0.43$ to increase such that less population in the hinterland emerges (centripetal force). For $\mu^* = 2$, the initial gap between Q and Q^*, with the environmental absorption capacity in the hinterland being acknowledged to be better, falls to zero. We conclude that, with rising marginal environmental damage in the hinterland we find urban sprawl to decrease, with 7% of the mobile population migrating inward.

Figure 5: Utility difference $u - u^*$ for μ^* = 1, 2, 3 and for different initial values of λ (and μ = 2)



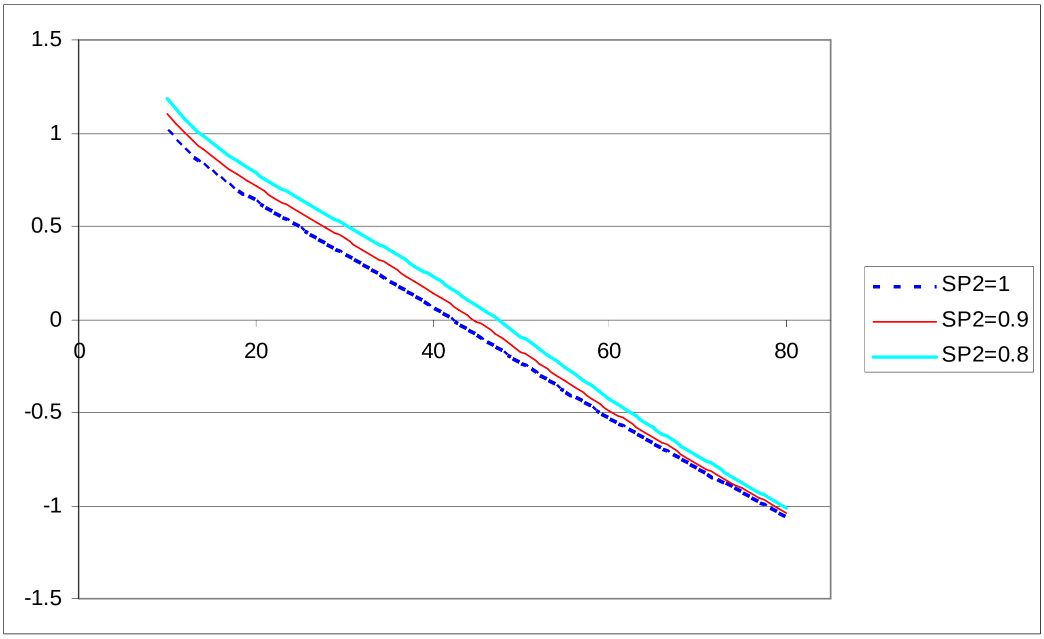
Third, we model intraregional transport cost reduction in the hinterland (e.g. via improved public transport). As reference level we choose a hinterland intraregional transport cost level TR_2=1.3, i.e. at the same level as *inter*regional transport costs. We explore the decrease of these costs in two steps, down to their full elimination (i.e. to arrive at a level equal to that in the centre region). Figure 6 indicates that these transport level reductions imply only a slight change in the level of urban sprawl. Acknowledging the fact that higher hinterland intratransport costs reduce urban sprawl, the equilibrium level of λ increases to λ=0.45 for TR_2=1.15, and to λ=0.46 for TR_2=1.3. However, just improving public transport in the hinterland has a net negative environmental impact, because the increase in the environmentally benign mode choice is dominated by the increased attractiveness of the peripheral region. We will compare the overall environmental impacts across policy simulations in section 5 below.

Figure 6: Utility difference *u* – *u for TR_2 = 1, 1.15, 1.3 and for different initial values of λ**



Finally, we model spatial planning in the hinterland seeking for denser housing development, i.e. we restrict supply of housing inputs (such as development space) in the hinterland. Figure 7 indicates that such policy does have a substantial impact on the level of urban sprawl. For a restriction of housing space in the hinterland by 10% (SP_2=0.9) the equilibrium level of λ increases to λ=0.44. For a restriction by 20% (SP_2=0.8) the equilibrium λ increases even to λ=0.47. The environmental impact per capita (μ^*) in the hinterland is reduced with denser housing enabling public transport service and shorter distances to be traveled. We will compare the overall environmental impacts across policy simulations in section 5 below.

Figure 7: Utility difference *u* – *u for SP_2 = 1, 0.9, 0.8 and for different initial values of λ**



5 CONCLUSIONS

We extended a standard CP model to analyse housing location decisions by consumers, both in the theoretical and empirical domain. Reflecting the conclusions on spatial policy instruments to reduce the level of urban sprawl we find the following.

Cordon pricing, or as for that matter other instruments that increase interregional consumer transport costs, acts as strengthening the weight of the pre-policy more strongly populated region. In the European context it is usually the centre, which is the more populated area (conversely in the US often city belts dominate population statistics), congestion pricing or similar instruments in the European context generally reduce urban sprawl.

We also find a circular causality in initial levels of urban sprawl increasing the environmental impact per capita in the hinterland, thus acting as a negative feedback loop in decreasing the incentive for further urban sprawl.

Spatial planning in the hinterland acts in two ways, contradicting in their impact on urban sprawl. On the one hand, denser development enables a higher level of public transport supply (and thus an improved environment); equally, the concurrent reduction in hinterland *intra*regional consumption transport costs makes the hinterland more attractive. On the other hand, housing prices in the hinterland increase and supply a – in net terms dominating – *dis*incentive to resettle to the peripheral region.

It is inspiring to also consider the environmental impact of each of these policies. Table 3 reports for each of the respective equilibrium population distributions the overall environmental quality as esteemed by the population.

Table 3: Aggregate environmental quality index across both regions for different policy stringency levels

cordon pricing		hinterland transport cost reduction		housing development restrictions	
T=1	0.982	TR2=1.3	1.129	SP2=1	0.986
T=2	0.986	TR2=1.15	1.051	SP2=0.9	1.049
T=3	0.986	TR2=1	0.986	SP2=0.8	1.124

In terms of environmental feedback of the spatial policy, we find that cordon pricing hardly improves environmental quality. Second, while intraregional transport cost reduction in the hinterland (improved public transport) does have a positive impact on environmental quality, we see that this is strongly dominated by the negative environmental impact due to the simultaneously induced rise in urban sprawl. Finally, the policy instrument of spatial planning towards more concentrated development in the hinterland clearly dominates the other two instruments. This instrument is the only one among the three that can significantly improve overall environmental quality. It does so by inducing incentives for both higher use of environmentally friendly transport modes and reduction on urban sprawl.

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APPENDIX 1: LIST OF VARIABLES

			Eppink and Withagen (2006)	Suedekum (2006)	Fujita et al. (1999)
composite consumption/ manufacturing good	M	*	same	same	same
consumption of variety *i*	$m(i)$	*	same	same	same
housing	H	*	A	same	A
number of varieties/firms	$i=1,\dots,n$ normalized: $n^*=1-n$	*	same	same	same
share of manufacturing labour in centre region	$0 \le \lambda \le 1$ $(= n)$		same	same	same
manufacturing wage	w_M	*	same	w	same
housing wage (equals price of one unit of housing)	$w_H = p_H$ $w_H \neq w_H^*$	*	$w_A = p_A = w_A^* = p_A^* = 1$ agr. good = numeraire	$w_H = p_H$ and $w_A = w_A^* = 1$	$w_A = p_A = w_A^* = p_A^* = 1$
price index consumption good (for one unit of *M*)	G	*	same	same	same
consumer price of variety *i*	$p_m(i)$	*	same	p	p
producer (f.o.b.) price of variety *i*	$p_M = p_m(i) \quad \forall i$	*	same	p	same
total (regional) income	Y	*	same	same	same
per capita income of manufacturing workers	y_M	*	same	-	-
real income in manufacturing	ω	*	-	same	same
per capita utility for manufacturing workers	u_M	*	same	-	-
environmental quality	Q	*	B biodiversity	-	-

			Eppink and Withagen (2006)	Suedekum (2006)	Fujita et al. (1999)
share of manufacturing labour in hinterland	$\lambda^* = 1 - \lambda$ (= n^* =1- n)		same	same	same
manufacturing labor per region	$L_M = \lambda \cdot \alpha$ $L_M^* = (1-\lambda) \cdot \alpha$	*	$L_M = n \cdot \mu$ $L_M^* = n^* \cdot \mu$	$L_M = \lambda \cdot \mu$ $L_M^* = (1-\lambda) \cdot \mu$	$L_M = \lambda \cdot \mu$ $L_M^* = (1-\lambda) \cdot \mu$
total labour (per region)	$L = L_M + L_H$	*	$L = L_M + L_A$	$L = L_M + L_H + L_A$	$L = L_M + L_A$
capital (per region)	$K_M = L_M \cdot c_M$ $K_M^* = L_M^* \cdot c_M$	*	$S_M = L_M \cdot b_M$ $K_M^* = L_M^* \cdot b_M$	-	-
fixed labour input in manufacturing	$F \equiv \alpha / \sigma$		same	same	same
variable labour input in manufacturing	$a_M \equiv \rho$		c_M	β	c_M
manufacturing output of a single firm	$q_M = F \cdot \sigma$	*	same	q	same
labor demand of a single firm (man.)	$l_M = q_M = F \cdot \sigma = \alpha$	*	same	l	same
capital demand of a single firm (man.)	$k_M = c_M \cdot l_M$	*	b_M (labour-to-land ratio)	-	-
capital-to-labor ratio	$c_M = 1/(F \cdot \sigma) = 1/\alpha$		$b_M = s_M / l_M$	-	-

* different values for the two regions

3. Circular Causality in Spatial Environmental Quality and Commuting

Birgit Friedl, Christoph Schmid and Karl W. Steininger[1]

1 INTRODUCTION

The explanatory focus of this chapter is spatial land use development, arising from the interaction of consumption and production activities at various locations with the respective transport system characteristics. The mutual interlinkage of transport and economic activity is a conclusion from the New Economic Geography (NEG) literature (see for example Fujita et al., 1999), predominantly drawing on theoretical and stylised models so far. In addition, NEG has focused mainly on issues of interaction of location of production and transport costs, i.e. on firms' location decision.

The present model is an empirical effort to unify urban economics and NEG. By doing so, we extend the analysis to focus on consumers' location decision in a two-region spatial computable general equilibrium (SCGE). To that end, we refine, first of all, the insights from the core-periphery model (Krugman, 1991) by incorporating urban features (commuting, transportation networks, land and housing market). In other words, starting with concepts from (traditional) location theory, we proceed with the incorporation of NEG key elements to put them into a computable general equilibrium model. Secondly, the model is calibrated for one Austrian test region, comprising a two-region structure of political districts.

Mobility activities currently trigger the fastest increasing segment in fossil fuel emissions. We will thus show how the spatial structure of job location and housing is linked to mobility demand (with current transport technologies related to fossil fuel emissions), and reversely, how a reorganisation of the transport system via changes in the spatial structure can reduce transport demand. Due to the economy-wide feedback effects of transport policy and spatial planning, respectively, the empirical policy analysis is carried out within a general equilibrium model. In particular, for modelling the interlinkage of land use and (passenger) transport related to environmental consequences, the spatially explicit extension of CGE serves as a basic starting point (SCGE).

In a first approach, we highlight consumers' decision of location of residence. As a consequence of that, the occurring externalities are not of the producer-producer or

[1] An earlier version of this chapter is also published in Ecomod Network (2006), *Proceedings of EcoMod International Conference on Regional and Urban Modeling,* Free University of Brussels, Brussels. The authors want to thank the participants of the EcoMod Conference 2006 for helpful comments on an earlier version of this paper.

producer-consumer type, typically found in environmentally oriented CGE models, yet we model consumer-consumer (pollution, health) externalities.
This chapter starts with an introduction on the interlinkage of transport and economic activity, as addressed in New Economic Geography. Section 3 presents the two-region general equilibrium model. Section 4 describes the numerical implementation of the SCGE model and reports simulation results and insights. The chapter closes with a summary of major conclusions.

2 LESSONS FROM NEW ECONOMIC GEOGRAPHY

New Economic Geography represents a new branch of spatial economics, initiated by Paul Krugman in the early 1990s, which aims to explain the agglomeration or the clustering of economic activity that occurs at many geographical levels. In the analytical general equilibrium framework of NEG the location of agglomeration is determined explicitly through a micro-founded mechanism. In NEG models results are primarily driven by the tension between *centripetal* forces that pull economic activity into agglomerations and *centrifugal* forces that cause dispersion of activities and limit the size of agglomerations, relying on the trade-off between increasing returns and different types of mobility costs. Thus, endogenous mechanisms of agglomeration such as cumulative processes via backward and forward linkages and the importance of history lie at the heart of NEG. These mechanisms are the driving forces for the concentration of economic activities.
The fact that the pioneering ideas which motivated economic geography did not become part of mainstream economic thinking is mainly due to technical problems in spatial modelling. Increasing returns and imperfect competition – crucial elements in any sensible analysis about regional developments – have always posed difficulties for economic theorists (Krugman, 1995).
The new insights from NEG concern rather the integration of new modelling techniques in general equilibrium analysis than revolutionary ideas. To formalise monopolistic competition, the approach of Dixit and Stiglitz (1977) is the most powerful "modelling trick" (Fujita et al., 1999, 6). The Dixit-Stiglitz model thus offers a way to handle the problem of market structure posed by the assumption that there are increasing returns to scale at the level of the individual firm.
NEG models are characterised by four key elements: *general equilibrium modelling* (in contrast to traditional location theory), *increasing returns* or indivisibilities at the level of the individual firm (to realise a market structure of imperfect competition), *transport costs* (to make location matter) and finally *locational movement* of factors of production and consumers (as a prerequisite for agglomeration) (Fujita and Mori, 2005, 3).
To study both the development of cities, having spatial extent, and agglomeration in the same space, the model presented below unifies elements of urban economics and NEG. Although traditional urban models and NEG models deal with the same

spatial phenomena, they differ in two major respects – the source of dispersion force and the range for political action (Fujita and Mori, 2005, 17):

> "On the one hand urban economics models consider land rents for urban housing […] as a dispersion force. [I]n these models […] the intra-city and inter-city spaces are not integrated in the same location space. […] On the other hand, the models in the early stage of the NEG framework […] considered the immobile resources (such as land) as the source of dispersion force, and by doing so focused on the *spatial distribution of cities*, while abstracting from the intra-city structure [i.e., a city consists of a (spaceless) point in the location space]."
>
> "[U]rban economic models assign big roles to developers and city governments, while the NEG has been concerned with self-organization in space."

3 MODEL STRUCTURE

We model a single-sector economy consisting of two regions, an urban core and its hinterland. In particular, we address the political districts of Graz (core) and Graz-Umgebung (hinterland). The focus is on urban sprawl, originating foremost from the circular causality in spatial quality of housing and commuting, which reflects the interaction of consumers' decision of location of residence and the costs of passenger transport. The regions are closed in the sense that we have a constant population. Moreover, there is no interregional trade in the first and simplest version of the model.

Since the Graz – Graz hinterland relationship cannot be only viewed as two distinct regions, some modelling tools from urban economics will be integrated. To that end, we assume not only interregional but also (positive) intraregional passenger transport costs, following Tabuchi (1998) based on theories by Alonso (1964), Henderson (1974) and Krugman (1991).[2]

Two types of externalities occur. On the one hand, agglomeration effects explain why most production is concentrated in core region c. On the other, pollution externalities lead to spatial differentiation in environmental quality. Emissions are solely caused by passenger transport, and differences between the two regions in terms of pollution are mainly driven by commuting to work. *Commuting* also includes intraregional ways to work, not only interregional.

[2] In a "Synthesis of Alonso and Krugman", Tabuchi (1998) presents a two-city system framework with two regions, each containing a central business district. He concludes that while Alonso and Henderson assume zero *interregional* (interurban) transportation costs and positive *intraurban* commuting costs, Krugman assumes positive *interregional* transportation costs and ignores *intraurban* commuting costs.

3.1 CONSUMPTION

We assume three groups of consumers each living in one of two regions. The representative consumer of group 1 both lives and works in region c, the consumer of group 2 lives in region c (core) and works in region h (hinterland), and the consumer of group 3 both lives and works in region h. The group of consumers who live in region c but work in region h is assumed to be negligibly small. Moreover, we assume that only consumers of group 2 can choose to shop in either of the regions whereas groups 1 and 3 shop in the region they live and work in. Furthermore, consumers across all groups are identical. They have a preference for variety of the single (non-transport) consumption good, i.e. utility levels depend inter alia on the availability of different varieties which better fit their preferences.
We assume utility maximising behaviour. Then, consumers' location decision (whether to stay or move to the other region) is based on the level of utility gained for the region they live in, i.e. region c for group 1 and region h for groups 2 and 3.
The representative household's utility maximisation problem is defined as

$$\max\ U_r = \left(X_r, H_r, T_r\right) \tag{1}$$

subject to

$$Y_r = \sum_i p_r X_{r,i} + HC_r + TC_r \qquad i = 1,\ldots,n_r \tag{2}$$

The level of utility of a representative household is a function of (non-transport) consumption goods *X*, the quality of housing *H* and transport *T*. Subscript *r* refers to the respective region, with $r = c, h$. *Y* is the level of income, *HC* denote housing costs and *TC* denote transport costs. Let *p* be the price of the consumption good and let $i = 1,\ldots,n_r$ be the number of varieties of the consumption good produced in either region.
For the base year, the hinterland, region *h*, is assumed to offer a higher quality of housing than the centre *c*. This is because it offers a "green" environment and a low level of emissions relative to the core region *c*. On the other hand, distances are shorter in the core region *c*, but this time advantage is partially offset by congestion.
Housing costs *HC* depend on *H*, the quality of housing. They involve health costs caused by a polluted environment and congestion costs such as increased gasoline consumption. Housing quality, however, does enter the utility function also directly, now linked to monetary expenses and the budget constraint. Residence location is connected to a specified environmental quality level, supplied as public good at one level for the hinterland, and one for the centre. Thus, only part of utility is restricted by the budget equation (2), H_r also depends on environmental quality level, entering the utility function directly.

Transport costs *TC* depend on the demand for transport required for commuting to work, for the main part, or for shopping. *TC* hinge on the number and distances[3] of transport ways demanded and on mode choice. In particular, consumers' ways can be taken by car or by public transport. A lower car dependency due to better public transport infrastructure and smaller distances imply lower *TC*.
Then, utility levels for each region U_r can be modelled by a nested constant elasticity of substitution (CES) function. Utility maximising consumers demand non-transport goods, a certain quality of housing and transport for commuting (work – home). The expenditure shares are given by α, β and ($1-\alpha-\beta$); σ^C is the elasticity of substitution in preferences between any pair of goods.

$$U_r = \left(\alpha^{1/\sigma^c} X_r^{(\sigma^c-1)/\sigma^c} + \beta^{1/\sigma^c} H_r^{(\sigma^c-1)/\sigma^c} + \left(1-\alpha^{1/\sigma^c}-\beta^{1/\sigma^c}\right)^{1/\sigma^c} T_r^{(\sigma^c-1)/\sigma^c} \right)^{\sigma^c/(\sigma^c-1)} \quad (3)$$

By assuming consumers' preference for product variety, utility maximisation yields the following demand for the consumption good

$$X_r = \left(\sum_i \rho_i^{1/\sigma^X} \left(X_{r,i} \right)^{(\sigma^X-1)/\sigma^X} \right)^{\sigma^X/(\sigma^X-1)} \qquad i = 1,\dots,n_r \quad (4)$$

with $\sum_i \rho_i^{1/\sigma^X} = 1$

This functional form is suitable to model the advantage of proximity. Parameter ρ is the respective expenditure share of variety *i*, and σ^X denotes the elasticity of substitution.

3.2 PRODUCTION

We assume only one sector producing non-transport (consumption) goods. Its production involves *internal* economies of scale at the level of the individual firm. Then, agglomerations emerge from the interaction of increasing returns, transportation costs (for goods) and factor mobility. Contrary to traditional urban models that assume increasing returns (and agglomeration benefits) as *external* to firms, in our approach externalities emerge due to market interactions involving *internal* economies of scale. As pointed out by Krugman (1995, 93), while the direct assumption of external economies allows perfect competition, with internal economies we need to model an imperfectly competitive market structure.
Then, following the approach of Dixit and Stiglitz (1977), the sector for consumption goods is characterised by monopolistic competition: an endogenous

[3] Distances determine the type of way, i.e. if it is interregional or intraregional.

variety of *n* goods is produced in either region *r*. Different varieties of goods are imperfect substitutes in consumption. Each firm acts as a monopolist on its output market, taking the actions of the other firms as given. Again, imperfect competition arises due to the assumption of internal economies of scale at the level of the individual firm and the consideration of transport costs.

Based on empirical data for the city of Graz and Graz hinterland, production in either region involves different marginal input requirements of labour (*m*) and capital and different fixed factor requirements (*F*), independently of the quantity manufactured and assumed to comprise labour only: $l = F + m \cdot x$, where l is the labour required to produce any output *x*. Then, the production of a quantity *x* of any variety *i* in region *r*, with production coefficients *γ* and *δ*, involves

$$x_{r,i} = l^{\gamma_r} \cdot k^{\delta_r} \qquad \text{with } \gamma_r + \delta_r > 1 \tag{5}$$

inducing each firm to produce exactly one variety. Internal scale economies at the level of the individual firm and agglomeration externalities, accordingly, explain why most production is located in the centre region *c*. This implies a corresponding distribution of jobs. More specifically, forward and backward linkages create an incentive for workers to be close to the production of consumer goods.

3.3 ENVIRONMENTAL QUALITY AND POLLUTION

In each region a pure public good of environmental quality is supplied (and demanded) at a level specific to the respective region. In the hinterland, a larger share of utility is due to environmental quality than in the centre. In the initial equilibrium of settlement distribution the marginal household in each region is indifferent with respect to resettlement in the other region, per person utility level are equalized.

We will then exogenously shock the equilibrium, assuming rising environmental awareness in the centre, reflected by a decline in environmental quality supply in the centre. City inhabitants experience a net incentive to resettle to the hinterland, at least for some with their job remaining in the centre. Commuting activity level thus rises, contributing to further pollution, foremost in the centre, and enhancing urban sprawl.

3.4 DISPERSION AND URBAN AGGLOMERATION

In the present context "dispersion" is understood as urban sprawl and "agglomeration" as the development of dense housing structures in the centre. Accordingly, agglomeration and dispersion forces shape the spatial distribution of *consumers*, not firms. Dispersion and agglomeration processes are strongly interlinked with transport possibilities and costs and, equally important, with the spatial differentiation in environmental quality. As stated above, environmental quality is modelled as public good, supplied at two different quality levels, entering the respective utility function at household residence location, higher in the hinterland and lower in the centre. Environmental quality thus acts as a dispersion force. Moreover, increasing returns of scale imply different varieties of products in the centre and the hinterland. Thereby, consumers in the centre have access to a larger range of varieties than in the hinterland. Thus, agglomeration forces originate from increasing returns to scale and the implied spatial distribution of jobs with consumers minimising commuting effort.

4 NUMERICAL IMPLEMENTATION AND SIMULATION INSIGHTS

The NUTS III region Graz within Austria consists of the two political districts Graz city and Graz hinterland. Past decades have shown a strong movement of its population towards Graz hinterland (see Table 1), with currently 22.5% of the labour force working in the city of Graz commuting from outside.

Table 1: Development of population split up in NUTS III region Graz

	City of Graz [inhabitants]	share [%]	Graz hinterland [inhabitants]	share [%]
1971	249,089	71.4	99,806	28.6
1981	243,166	69.6	106,343	30.4
1991	237,810	66.8	118,048	33.2
2001	226,244	63.3	131,304	36.7

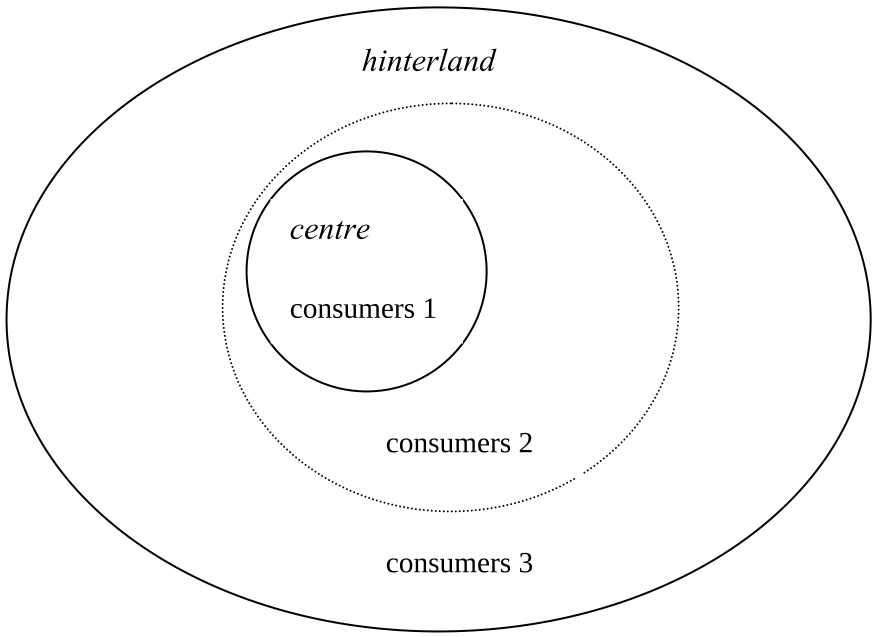
The strong shift in residence choice towards the hinterland is due to a range of factors, including real estate price differences, for example. Increasingly, also environmental considerations (particulate matter concentration in city centre regions, noise, etc.) contribute to relocation decisions as well. It is these environmental considerations that we take as a starting point in our analysis, and look at their interaction with other forces involved, such as housing prices or arising transport costs.

The model presented in section 3 has been implemented within GAMS (Brooke et al., 1998) using the modelling framework MPSGE (Rutherford, 1998) and the solution algorithm PATH (Dirkse and Ferris, 1995) in its – with Todd Munson – expanded version 5.6.04. The empirical model does help us to identify the relevance of centrifugal and centripetal forces at work in this interaction.

Using a two-regional split up of economic data of the NUTS III region, derived by using the provincial input output structure of Styria, the model of section 3 also requires further assumptions. Most importantly among these, we use an initial share of environmental quality contributing to welfare by 25% with inhabitants of the City of Graz and by 33% with inhabitants of the hinterland.

We calibrate the model to the 2001 data set, including the 2001 reference split up of residence location in the centre and in the hinterland. As Figure 1 indicates, households are of consumer type 1 to 3, as specified in section 3 above. Consumers of type 1 live, work and shop in the centre. Consumers of type 2 work and shop in the centre, but live in the hinterland. Consumers of type 3 have located all their activities within the hinterland, they work, shop and live there. Thus, we can identify an "economic sphere centre", including the geographical centre, but also each of the households living in the hinterland, but being bound to the economic interactions of job and shopping location in the centre. This economic sphere centre is indicated with a dashed line in Figure 1.

Figure 1: Residence Location of Consumer Types



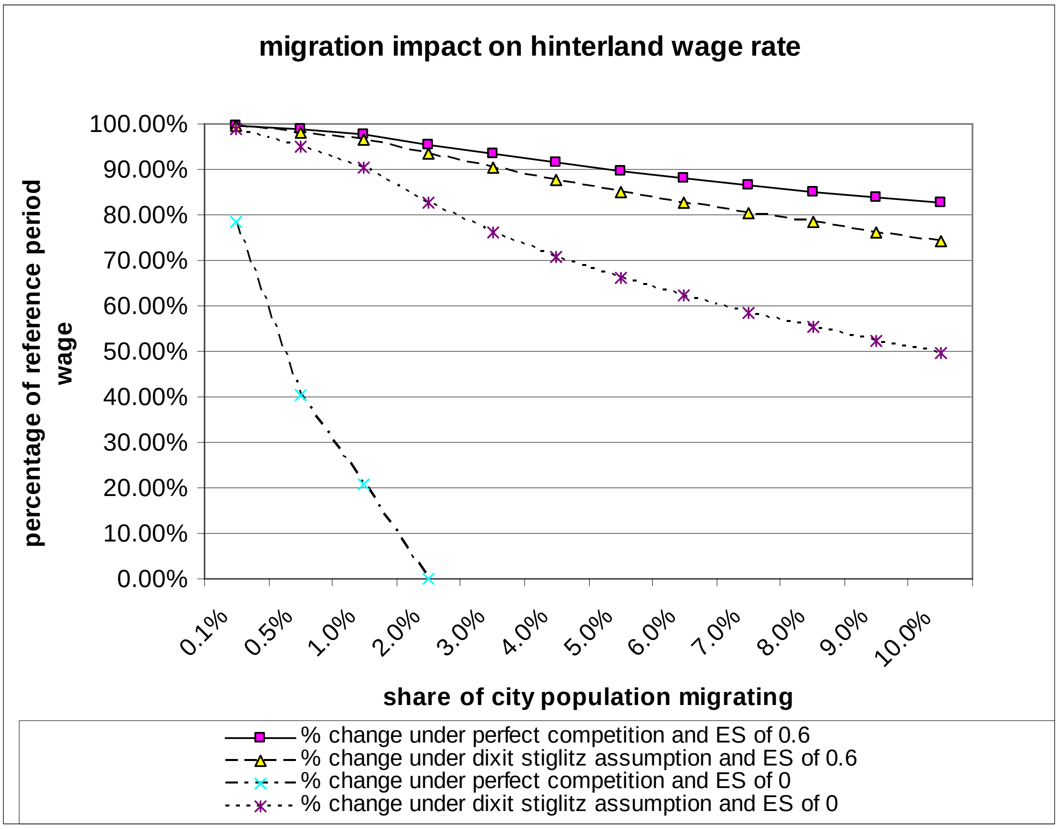
Ultimately we are interested in the forces triggered by an environmentally motivated change of residence location. We will, therefore, introduce an exogenous change in environmental awareness, more specifically in the recognition of new environmental dangers in the city (the supply level of the public good environmental quality is exogenously reduced for the region *c*). This depicts the fact, that environmental awareness for Graz city inhabitants is rising. We could think of them becoming aware of health impacts of particulate matter concentration, for example – an empirically relevant development currently observable.

City households (consumers 1) are then confronted with the choice whether to relocate their residence to the hinterland, and if so, whether to also look for a job there (thus transferring to the group of consumers 3) in order to avoid commuting, or to keep their job in the city (thus transferring to the group of consumers 2). While the environmental quality is a centrifugal force (in our case exogenously set) at a single strength for the hinterland as such, and thus driving towards migration to become a consumer of type 2 and 3 equally strong, there are centripetal forces, driving towards remaining in the centre, but of different magnitude across consumers of group 2 and 3. We will first analyse the migration decision between consumers 1 and 3 in more detail in section 4.1, before we look at the one between consumers 1 and 2.

4.1 THE INCENTIVES FOR AND AGAINST FULL MIGRATION TO THE HINTERLAND

Households can benefit from the hinterlands environmental quality while avoiding commuting expenses by shifting all their activities to the hinterland, i.e. look for a job in the hinterland and shop there, once they move their home to the hinterland (i.e. they switch from consumer of type 1 to type 3).

Figure 2: Migration of City Inhabitants to the Economic Sphere Hinterland – Impact on Hinterland Wage Rate

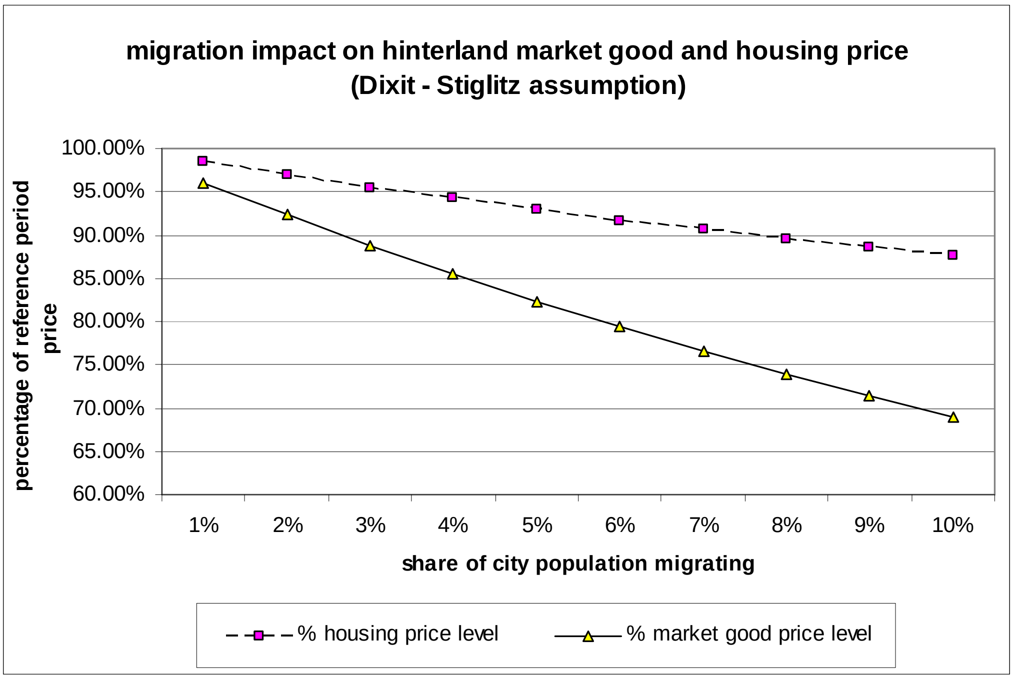


The empirical analysis identifies the major economic forces that counterbalance a situation where all households move to the hinterland and become consumers of type 3. Figures 2 and 3 summarise model results with respect to the most significant of these forces.

Figure 2 indicates hinterland wage impact due to a city population share of up to 10% migrating to the economic sphere hinterland, also including sensitivity analysis for this impact. We do find a significant decline in hinterland wages. This is due to (a) the divergence in the capital/labour ratio across the two economic spheres (K/L_c=0.78, K/L_h=0.81) and (b) the different group sizes, population of consumer type 1 being 3.4 times as large as that of consumer type 3.

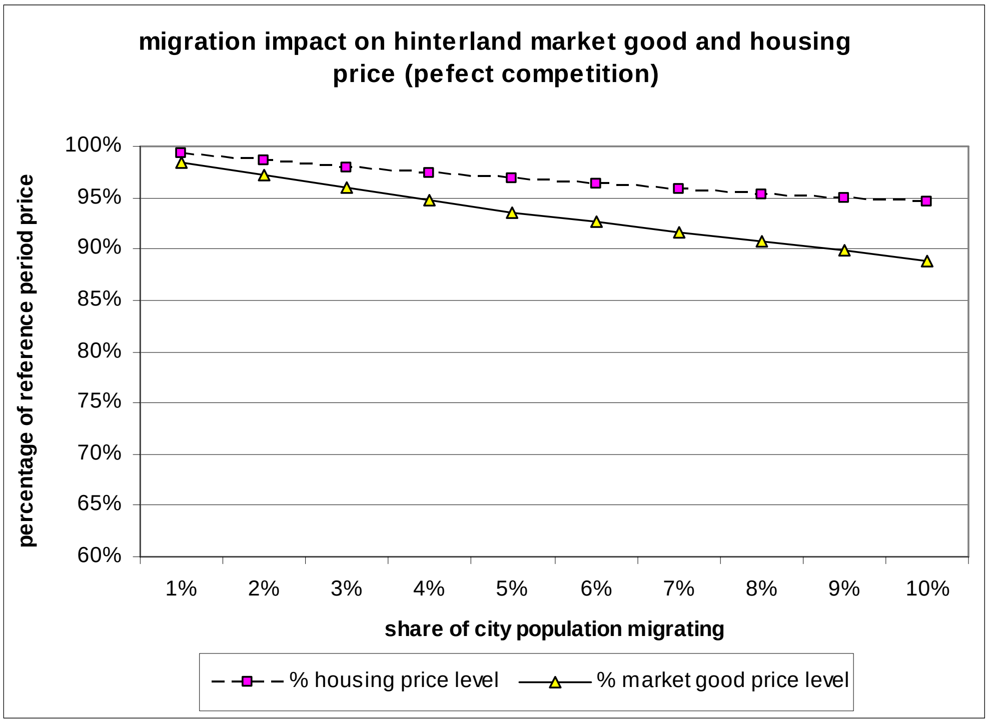
Results are thus obviously strongly dependent on the elasticity of substitution between capital and labour. Using a usual intermediate and long term value from the literature of 0.6, hinterland wages end up at around 80% of their reference level when 10% of the city population migrate, using the centre region product price as numeraire throughout this chapter. When we use a Leontieff production function instead, the impact on wage loss is much stronger, as indicated in Figure 2. In Figure 2 we also test for the relevance of the Dixit-Stiglitz production assumption, as we present results under a market structure of perfect competition for comparison. We find that the preference for variety (Dixit-Stiglitz) does "smooth" the wage impact, as migration of labour to the hinterland does increase the number of varieties there, and thus feed back on the demand for labour. In the following we only use the elasticity of substitution between capital and labour of 0.6 throughout the chapter.

Figure 3: Migration of City Inhabitants to the Economic Sphere Hinterland – Impact on Hinterland Market Good and Housing Price under Dixit-Stiglitz-Production Assumption



Figures 3 and 4 report the levels of product price and housing price in the hinterland at different levels of migration and under different degrees of market competition (Figure 3: Dixit-Stiglitz monopolistic competition; Figure 4: perfect competition).

Figure 4: Migration of City Inhabitants to the Economic Sphere Hinterland – Impact on Hinterland Market Good and Housing Price under Perfect Competition Assumption



We find that the commodity price – relative to the commodity produced in the centre (the price of which serves as numeraire) – does decline, which is mainly due to the reduction in wage costs (and income), an effect stronger under Dixit-Stiglitz than under perfect competition. We also see a housing price rising relative to the other marketed goods price level.
We thus conclude that there are significant centripetal forces:

- labour market impact of migration reducing hinterland wage rate
- hinterland housing prices rising relative to other hinterland production

as well as centrifugal forces:

- increase of variety in the hinterland, decrease of centre product variety and
- the triggering environmental quality higher in the hinterland

Most importantly, we see why especially the labour market feedback implies a very low “absorption capacity” of the hinterland economic sphere. In other words, migration flows that want to benefit from the hinterlands better environment will be deterred by labour market impacts from fully moving all their activities to the hinterland, but rather remain dependent for work (and thus also shopping) on the city. In our model language: the more relevant move to the hinterland is a switch of consumer type 1 to type 2. We turn to an analysis of this shift next.

4.2 THE INCENTIVES FOR AND AGAINST MIGRATION TO THE HINTERLAND WHILE REMAINING WITHIN THE CENTRE ECONOMIC SPHERE

By definition, a household only moving its residence to the hinterland but remaining in the centre economic sphere for work is not confronted with the wage loss it would observe when also shifting the location of its job to the other region. Thus, a larger share of city migrants will choose this option. The environmental feedback effect implied by this choice is commuting and related pollution, however. We can use model simulation to indicate the relevance.

For a migration equilibrium condition of equal per person utility across consumer types, we find the following impacts once we reduce the observed environmental quality in the centre by 10% (exogenous change), but do not account for commuter pollution. So to speak we first look at an equilibrium under "individual optimization". The new endogenous equilibrium is characterized by an increase in the number of commuters by 12.3% and a rise in housing prices in the hinterland (for both commuters and non-commuters) by 18.9% (see Table 2).

Table 2: Individual optimisation in migration after a 10% decline in environmental quality in the centre – results for three consumer groups

	Centre	*Hinterland*	
	Consumers 1	Consumers 2	Consumers 3
		change [%]	
Group size	-3.4	12.3	1.2
Housing price	0	18.9	
Housing demanded	-3.4	-8.1	
Varieties	-0.2	0.7	
Capital price	-0.6		
Wage	0.6		-5.5
Commodity price (centre region: numeraire)	0		-2.9

However, such rising commuter activity levels do have a pollution feedback, which generally will be more relevant in the centre. This is especially true when we acknowledge that current residence structures in the hinterland foster the use of cars for commuting. Assuming an increase of centre pollution by 2.5% due to the 12% increase in commuting (i.e. reducing the public good environmental quality in the centre by this amount reflecting the dominant use of the car for commuting) we find an increase in the share of people migrating from the centre to the hinterland.

Including the pollution of commuting impact and solving for the endogenous equilibrium, we find the share of commuters to rise by another 3.1% points to the level of 15.4% (with arising pollution feedbacks of this further increase already acknowledged).

5 CONCLUSIONS

Using a two-region spatial computable general equilibrium analysis we supply an empirical implementation in the new economic geography sphere. In particular we analyse household residence location decision in balancing benefits and costs of residence in the centre versus in the hinterland.
Usually the literature distinguishes the following elements in the two classes of forces effective in opposite directions, the first leading to urban sprawl (centrifugal) and the second causing dense housing (centripetal):

centrifugal forces:

- *lifestyle effect*: people want to enjoy much living space, high recreation and better environmental quality
- *cost of housing effect*: real estate prices are lower in the peripheral region.

centripetal forces:

- *cost-of-transport effect*: people tent to migrate to the region where distances are shorter and the possibility for modal choice is higher, i.e. provision of public transport is better.
- *proximity effect*: people want to enjoy spatial proximity (thereby saving transport time and costs) and access to a variety of differentiated products as well as to local public goods

In our analysis we find a major further centripetal force with respect to the economic sphere hinterland: wage decline. The migration induced relative over-supply of labour in a hinterland region producing relatively capital intensive causes wage decline, and implies for those consumers shifting their residence to the hinterland rather to keep their job in the centre.
The resulting increase in commuting activities triggers a pollution feedback-effect. Pollution in the centre declines even further, increasing in turn the share of people relocating their residence to the hinterland. A vicious circle has started, resulting in both too high hinterland population and too high commuting levels.
The political instruments suggested by our analysis fall into two groups. First, spatial planning instruments in the hinterland need to be chosen such that public transport is economically feasible also in the hinterland, the use of which results in significantly lower pollution feedback impact on ever rising migration rates. Second, economic instruments such as cordon pricing could be used to internalize the otherwise present externality. While the first class of instruments is more long-term oriented, the second is also available for short-term effects. The side-effects of the latter are less evident, however. Overall, the relevance of the analysis of spatial planning aspects in environmental policy, especially in long-term environmental policy, has been explored in this chapter.

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PART II:

New Infrastructure and Spatial Economic Development

4. Infrastructure Provision, Accessibility and Economic Development Dynamics – the Planners' Perspective

Stefan Schönfelder, Alfried Braumann and Romain Molitor

1 INTRODUCTION

The interaction of transport, land use and economy has been for long the fundamental area of interest of geography and regional science and still initiates the development of countless theoretical constructs as well as empirical studies. The sphere offers exciting research opportunities into space and society and has important implications for public policy and planning. The threats of the limitation of economic growth due to negative environmental effects and the paradigm of sustainable development has emphasised the importance of a deeper knowledge of that relationship. In an era of a complex system of partly opposing requirements such as residential pressure, the need for fast and reliable transport connections or environmental protection imperatives, transport and land-use policy faces enormous challenges. These challenges are unquestionably easier to accept if the fundamental mechanisms are better explored.

The present research effort with its results summarized in this WegCenter Report provides a further methodological contribution to the analysis of transport infrastructure and its economic impact. As a contribution of economic geography to the project, Braumann (2006) provides the fundamental theories and a variety of findings of the infrastructure investment – economic development interaction. Furthermore, his paper assesses the suitability of selected Austrian case study regions to investigate the potential impact of transport on land-use and the economy. The main study with the development of several modelling approaches mainly highlights the macro-economic level of that relationship (see Friedl and Koland, 2006; Friedl et al., chapter 3, this volume; Gebetsroither et al., chapter 7, this volume; Braumann and Schönfelder, chapter 6, this volume).

This chapter finally makes some notes on the definition and measurement of the multifaceted relationship from the perspective of urban and transport planning. It defines data requirements to reveal "micro" effects and goes into the area of institutional and individual decision making as an outcome of infrastructure improvements.

A range of questions are addressed which are often neglected within the discussion of a transport-economy feedback. These cover aspects such as the common generalisation of impacts by research and practice as well as the undesirable side-effects of infrastructure expansion. In general, this chapter wants to be understood as a "selective but important list of planners' comments" on that subject.

2 THE CONCEPT OF ACCESSIBILITY

2.1 THE PARADIGM OF ACCESSIBILITY AND CONCEPTS OF INTERACTIONS BETWEEN INFRASTRUCTURE PROVISION AND ECONOMIC DEVELOPMENT

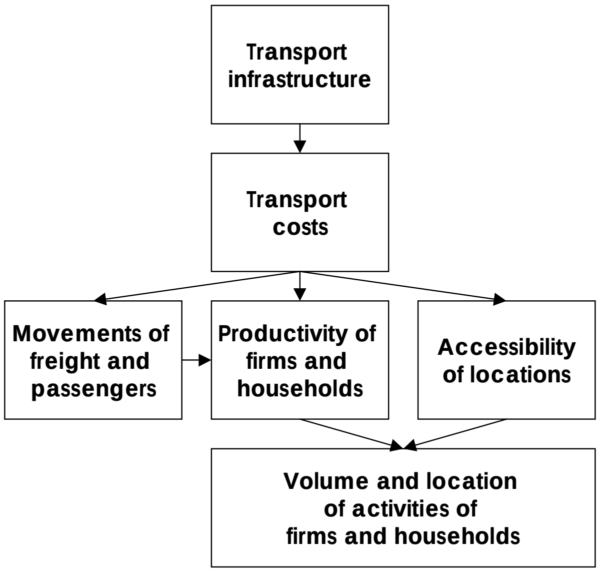
Accessibility is one of the key concepts in transportation planning. Its measurement, calculation and the assessment of its economic effects has attracted enormous interest in transportation science as well as in the policy and planning community. Transport policy consistently employs accessibility improvement as rational for investment into road, rail and airport infrastructure (Rietveld, 1994). Comprehensive "access to opportunities" is taken as a proxy for welfare. Transport as well as land use planning define their major goal as the provision of infrastructure and services in order to guarantee and improve accessibility (Rodrique et al., 2006).

From an approach which allows for individual and firm behaviour as well as decision making, *accessibility* may not only be characterised from the perspective of transport supply (infrastructure and services), but also from a perspective of travel demand. In principle, all locations are accessible from a chosen reference point – and infrastructure expansion obviously decreases travel times and increases accessibility (see below). However, due to the limitation of the traveller's time budget, the availability of private vehicles or public transport services, the general physical capability of the traveller or the willingness of local firms to exploit non-local markets, accessibility is always relative to an individual's situation. This involves the decision makers' time budget restrictions, his/her choice preferences and finally the household/firm location itself. This needs to be taken into account carefully when using the term accessibility and evaluating the following discussion.

Generally, transport infrastructure is planned and constructed to extend the reach of travellers and the economy. Planning measures such as the enlargement of road capacities and the improvement of public transport timetables usually decrease travel times and therefore generalised costs of travel. A wide range of studies supports the interrelation (see Fürst and Wegener, 1999 for a good overview). Travel time gains usually lead to an enlargement of market areas, not only for companies but also for individuals which for example are searching for a new job matching their professional profile.

Figure 1 presents the major mechanisms of transport infrastructure (investment) and regional economic activities. The effects in detail are manifold and are summarised only unsatisfactorily in the simple statement that "improved transport infrastructure increases productivity and generates higher welfare for the affected region".

Figure 1: Infrastructure, transport costs and the allocation of firms and households



Source: Rietveld (1994)

The availability of adequate transport infrastructure is generally accepted as a prerequisite for economic exchange. However, there is an ongoing debate about how investments into transport infrastructure systematically affects regional, national or even international economic utility (see e.g. Offner, 1992 as an example for an older source and Ecoplan and Büro Widmer, 2004 for a more recent reference).

2.2 A "MICRO" PERSPECTIVE OF ACCESSIBILITY IMPACTS

Generally, the measurement of the interaction of investment into transport infrastructure and economic development may be conceptualised as a micro or a macro economic approach. As mentioned, the latter aspect has been touched empirically elsewhere in this project focusing on a General Equilibrium Model approach (see especially chapter 7, this volume). Such analyses and models often try to analyse the *direct* impact of accessibility gains on the economy, i.e. without setting off costs against benefits. Examples of classical analysis types are production functions, the location approach and interregional trade models (for a short overview see Bruinsma, 1995).
Planners usually take the micro perspective which assigns utility gains caused by accessibility improvements to single travellers, firms and households – most often within the framework of a cost-benefit analysis. Micro approaches are able to capture individual impacts on travellers – such as the dominating travel time and cost savings but also more general effects such as accident reduction rates, congestion risk or environmental improvements due to more modern infrastructure.

Planning and spatial development often consider transport investment impacts as change in land-use, population and the number of firms, i.e. as the allocation or relocation of individual decision makers. Hence, locational quality (*Standortgunst*) is believed to contribute to the region's economic activity and growth (potential) and – as a consequence – as a prerequisite for the provision of labour.

There exists a range of theories of the allocation of firms which may be summarised briefly by the categories *classical* (e.g. Thünen, Weber, the Central Place Theory and the Spatial Competition and Spatial Differentiation) and *neo-classical* approaches (e.g. General Equilibrium, Spatial Pricing, Retail and Location Problem, Spatial Margin of Profitability etc.). Recently, the direction of *New Economic Geography* added the interesting aspect of spatial interactions between economic agents and the reasons for and implications of the clustering of regional economic activity.

In summary, the expected "micro" effects of transport infrastructure and therefore accessibility improvements may be categorised into impacts on

- *residential location*:
  Locations with better accessibility to work places, shops, leisure and other facilities will get more attractive for residential location. Land prices usually increase, land will be developed faster. Residential development tend to become more disperse.
- *industrial location*:
  Locations with better accessibility – especially to motorways and rail freight terminals – will be more attractive for industrial development.
- *office location*:
  Especially those locations will get more attractive which offer high accessibility to airports, public transport stations and motorways. As for the other location categories, land prices are higher for those locations which promise lower travel times to important transport hubs and important points of interest.
- *retail location*:
  Locations with better accessibility to customers and co-competitors will be more attractive for retail firms. The gradation of land prices and rents depends on this accessibility.

(Fürst and Wegener, 1999).

Turning in more detail to the allocation and relocation of firms, it can be summarised that those companies which underlie market-oriented price mechanisms and principles of profitability decide according to the following criteria:

a) the demand side (time budgets and motives of their customers) and
b) the supply side (focus of commerce and price segments).

Company owners and leading managers respectively develop individual/ subjective locational preferences. They are the key actors who assess the potential of locations based on their spatial perception. Their locational preferences usually focus on several factors, such as the quality of the macro location (city/district/region), the meso location (within a certain urban district or town) and the micro location which indicates the actual position of the firm as for example the street/street address.
Of a wide range of main and sub-factors accessibility is only one (Maier and Tödtling, 1995, 73ff.; Heineberg, 2001, 175ff.):

- Consumer based factors (density, nearness, structure, consuming habits)
- *Accessibility*
- Competition and agglomerational effects
- Functional advantages of the city/region (e.g. wage level)
- Intra and inter-firm requirement of interaction (contacts)
- Office / shop / manufacturing space requirements, supply and costs
- Legislative / planning / taxation restrictions, urban design and transport planning factors
- Internal factors such as organisational structures, intra-firm communication and division of labour, personal commitments of the management as well as supply of workforce
- Firm and firm location traditions
- Image factors

In a particular case, those single factors might play a predominant role, however, the prediction and the interpretation of the final decisive set of reasons for the allocation is difficult.

3 DATA REQUIREMENTS FOR THE CALCULATION OF ACCESSIBILITY, TRANSPORT AND LAND USE INTERACTIONS

A micro approach to analyse the interaction between transport infrastructure investment and economic activity development requires a complex set of data in order to cover a) the *effects of improvement* (dependent variables) and b) the *reason for behavioural change* (independent variables). As mentioned above, the focus of analysis would be on the allocation and relocation of firms (and households). The latter set of variables usually comprises those items which would go as explaining factors into an utility function – such as travel time gains and potential transport cost reductions, expected comfort and reliability improvements.
The main independent variable to be measured is certainly travel time between chosen places, zones or regions. Based on travel time calculations, potential accessibility can be calculated – such as done in Braumann and Schönfelder,

chapter 6, this volume. Travel forecast studies such as Käfer et al. (2006) provide exact travel times based on calculations of comprehensive transport models. Usually travel time matrices are developed which give travel times between a large number of zones.

As dependent variables, i.e. as indicators of behavioural change (due to transport infrastructure improvement), a wide-ranging analysis would require variables of the

- socio-economic
- economic
- planning and development
- transport and travel behaviour

sphere. This involves location-related data, such as

- population
- number of work places
- number of out-commuters, in-commuters and commuting origins as well as destinations
- available land resources (according to planning documents and market)
- construction activity
- land prices and rents
- number of dwellings
- size of retail and commercial area
- production and service output of local firms etc.

It should be noted that an analysis which traces behaviour before, during and after an infrastructure improvement would be best made "*dynamically*", i.e. an analysis of a time series of the mentioned data would be desirable. Time series analysis techniques – which allow for temporal autocorrelation – usually provide promising results.

The mentioned data is only partly available on an adequate level, i.e. high level of spatial resolution. Population and workforce data is readily available from national statistical offices (Statistik Austria or Eurostat for Austria). Yet coherent data on land-use, rents or local productivity is more difficult to procure and has normally to be post-processed. Seldom, local or regional authorities – which are the natural holders – do systematically collect and/or provide such information. Tools for permanent observation of activities in space (*Laufende Raumbeobachtung*) have only been recently installed (approximately beginning of the 1990s). Time series of those data (e.g. data reaching back to the 1970s or 1980s) are especially sparse, which makes it problematical to run ex-post analyses.

4 COMMENTS ON THE ONGOING DISCUSSION OF TRANSPORT – ECONOMY INTERRELATIONS (RESERVATIONS)

4.1 DECREASED TRANSPORT COSTS FOR FIRMS – BAGATELLE OR TRULY DECISIVE?

Changes in transport costs are predominant indicators when analysing the impact of new infrastructure. Transport costs account for up to 25% of total production costs (see Parkinson, 1981; DIW, 1994; Rietveld, 1994; Ernst & Young, 1996). Overall, the share is relatively small in industrialised countries (that's why the New Economic Geography approach discusses to neglect transport costs as a explaining factor for the exchange of goods or passengers). Even if we accept the great variations between sectors, the small reduction in transport costs typically arising from new transport infrastructure does usually not generate lower prices due to decreased total costs of production (Parkinson, 1981; Rietveld, 1994; see also chapter 7, this volume). That's mainly because total time gains of faster transport is small compared with the total time required for loading and unloading. Time gains by faster transport contribute mainly to the reduction of variable transport cost, however, costs for shipment, terminal infrastructure, insurance etc. is not touched at all. Rietveld concludes that the overall supply of transport infrastructure in Western Europe is already so extensive that further improvements have only limited effects on costs. This suggests that most existing firms in regions which benefit from new transport infrastructure investments and accessibility gains take only little advantage of the investment (this might differ for different types of regions (remote versus central)).

The discussion about the impact if infrastructure supply on the transport costs of firms however remains difficult: There also exist opposing studies (see e.g. Diamond and Spence, 1989 or Ernst & Young, 1996) which for example claim that „firms, in a bid to remain competitive, remain keen to control and reduce costs, no matter how small" (SACTRA, 1999). In addition to that, research has put its focus on wider, potentially more indirect micro-level benefits, too. This includes for example the reorganisation and centralisation of distribution operations which might lead to reduced inventory costs (Quarmby, 1989; Mackie and Tweddle, 1993; McKinnon, 1995), the increase of size of catchment areas for the firms' workforce or improved staff punctuality.

The SACTRA (1999) study states that "empirical evidence of the scale and significance of such linkages is (i.e. transport cost elasticity due infrastructure improvement) [...] weak and disputed". We support the hypothesis that a generalisation about the effect is strongly dependent on the specific constellation of analysis, i.e. local circumstances and conditions, company structure, affiliation to certain industries or sector etc.

4.2 TRANSPORT, LAND-USE AND ECONOMY – A ONE-WAY EFFECT?

A linkage between transport, land use and economy is clearly not one-way. Land use itself – as well as the socio-economic situation of places – has a distinct impact on travel behaviour and may therefore influence transport policy and investment measures. There is a range of impacts of which the following might be the most obvious (Fürst and Wegener, 1999):

- Mixed-land use (e.g. mixtures of work places, residential and commercial areas) might reduce trip distances – especially if travel costs do matter.
- High residential density is an important pre-requisite for efficient public transport services and provides opportunities for a "walkable" and "cyclable" environment.
- The concentration of workplaces in few employment centres typically leads to increased trip lengths as commuting distances are long. However, a spatial concentration of jobs might positively affect the possibility to run an efficient public transport which would influence mode choice behaviour.
- An attractive neighbourhood design and streetscape may invite residents to make more local (day-to-day) trips instead of longer ones. There might be also positive effects for a mode choice towards walking and cycling.
- A peripheral location (of for example workplaces) usually leads to longer trips.
- Locations close to public transport stations might attract more trips by tram, bus or train.

From a planning and policy point of view, travel implications like these are important to note. The case of Parndorf for example, where increased road accessibility has lead to the establishing of a huge shopping centre which attracts about 2 Mio. customers per year, shows that only after a short time

- local traffic problems emerge (see http://burgenland.orf.at/stories/53677/)
- car shopping travel dominates (also due to a missing public transport alternative).

Interestingly, economic literature widely omits to analyse these effects of transport infrastructure investment on travel in detail. Often, those effects are wide-ranging and negative. This might involve economic threats such as congestion costs, environmental damage or social costs such traffic accident costs. As planning needs to develop strategies to control and manage individual (travel) behaviour, those negative effects must not be disregarded. Improved accessibility, decreased travel cost and times by and large produce more trips, longer trips and in most cases a car-favoured mode choice – we will not neglect, though, that investment

into public transport infrastructure shows behavioural response, too. This however with a usually lower elasticity for mode choice behaviour (e.g. Gülleret al., 2003).
Hence, transport and land-use interaction should be better analysed as a feedback loop of inter-relations. Where transport infrastructure has been newly built or considerably improved, often additional traffic is induced due to a decrease in travel-time costs (Hills, 1996). Induced travel may emerge where travellers switch from alternative routes to the newly built, trip departure time changes due to the expectation of faster travel, modal shifts (e.g. from public transport to car) or an truly new trip making.
One of the shortcomings of the debate on transport and economy and its analysis is certainly that causality problems are simply neglected: Political decisions on infrastructure investment tend to be taken based on current economic growth rates (see also Rietveld, 1994). Hence, what we often find is the explanation of economic development and growth by transport as an exogenous variable which is in fact endogenous and a response to potential progress.

4.3 UNOBSERVED FACTORS?

The above given list of attributes which are necessary to make a micro analysis of a transport-economy interaction makes clear that the level of data detail clearly depends on the complexity of the analysis or model assumptions which describe the interaction. However, another uncertainty when measuring effects due to infrastructure expansion is the presence of unobserved factors. Unconsidered attributes might influence spatial behaviour of firms. Even if we find a statistically significant correlation between transport systems improvements and local economic activities, there is a certain danger of overlooking explanatory variables. This is especially risky in those cases where only few explanatory factors (such as accessibility gains only) are considered. Unobserved factors might include taste heterogeneity in firm or household allocation/relocation behaviour which should be controlled for in the explanatory models applied. One especially important factor, the political decision making will be analysed further below.

4.4 INFINITE ACCESSIBILITY AND THE DEATH OF THE CITY – THE MYTH OF FOOTLOOSE FIRMS

Furthermore, the question arises if the "myth of footloose firms" (and potentially households) exists in reality: firms which do not anymore need to consider local factors for their decision to settle. Is that really true that companies – due to almost infinite accessibility provided by a fast transport system and ubiquitous IT connections – can neglect any spatial attribute of a potential site? Planning theorists such as Friedman have already proclaimed the death of the city which has submitted itself to irresistible urban sprawl forces (Friedman, 2002). Clearly, those centrifugal forces which support the dissolution of centrality and the sense of place are strong. Apart from high accessibility and mobility (i.e. high speeds), globalisation, digitalisation and the de-limitation of company structures foster urban erosion processes which blur the traditional structural differences between city centre, urban region and periphery (Läpple, 2003).

However, these forces and development trends are by far not single-way. There is some evidence that over the last years the trend of structural and functional deconcentration seems to stagnate. There are even signs that particular firms contribute to a trend reversal. In Germany for example, the number of workplaces in the main urban regions has increased considerably higher/faster than in the national average over the years 1998-2002 (DIW, 2003). Especially the city centres which have experienced a great job and population loss for long show the most positive development compared to all other structural categories.

A driving force of this reurbanisation process is the big economic dynamics of selected service industries, such as finance and consulting industries, media and tourism. The German Institute for Economic Research (DIW) claims that the "metropolitan milieu" with its manifold communication and exchange possibilities provides particularly favourable conditions for companies of those sectors.

Similar trends can be found for the Vienna metropolitan region, too. In the tertiary sector we find a positive (number of) employee development for "knowledge intensive corporate" service industries (Gornik, 2006). In addition to that, software developing firms and so called "niche" companies have increasingly chosen Vienna as the place for business.

Planning needs to have an eye on both, suburbanisation as well as reurbanisation processes. Both trends have strong implications for transport. Whereas suburbansiation tends to increase travel volumes and is widely counterproductive for a sustainable future of our urban regions (see also above), reurbanisation needs to be supported by a strong focus of planning on modes other than car. The latter process of a renaissance of the urban might be a big chance for transport planning to influence modal shift positively.

5 DECISION MAKING AND LAND USE DEVELOPMENT

5.1 THE NEGLECTED PERSPECTIVE

Political decision making exhibits strong influence on spatial processes. Strangely, this decisive factor is widely neglected in the analysis of the complex relationship between infrastructure provision, land use and economic development. Stakeholders in the process of political decision finding include governments of different levels, government agencies, private companies as well as households and other institutions of civil society.

Local reactions towards transport investment – which is mostly made by the superior statutory level such as the regional or national government – may differ considerably between municipalities. This may be quantified easily by the amount of sites made available for construction by local planning following nearby transport improvements, but there are other indicators such as local action to build connections with potential investors or the advertising of local land resources in regional/national newspapers. For example, (mostly larger) municipalities try to attract new firms by offering subsidies, incentive programmes or technical as well as organisational support for their allocation (and expansion). In Austria enterprise companies (*Wirtschaftsförderungs-Agenturen*) such as *ecoplus* in the Bundesland Niederösterreich or the *WWFF* (*Wiener Wirtschaftsförderungsfonds*) in Vienna provide comprehensive service packages for new firms which involve for example the provision of subsidised land and site development, easy access to research institutions, loans and loan guarantees or even tax abatements. These programmes play a vital role in the decision making of firms considering the establishing of a further production, commercial or administrative site.

In other words, local economic development depends only partly as an outcome on external factors such as the improvement of accessibility. As planning in Austria basically remains "intentional" or "purpose-led" rather than "programmed" or "mechanistic", all models of the transport-economy interaction face the challenge of an appropriate integration of institutional decision making.

What is even more difficult is the consideration of private firms' allocation and relocation decisions – as already pointed out above – and household residential choice. As their decision making is not driven by entirely economic motivations, either, we will find that unalloyed , i.e. "unspiritual" behavioural responses do not exist in reality.

5.2 PLANNING PROCESSES AND THE HYSTERESIS OF DEVELOPMENTS IN LAND USE AND THE ALLOCATION OF FIRMS

Another related issue of uncertainty is the time-lag between economic or land use effects and infrastructure expansion. Often, this is due to the long duration of planning processes. Local effects of transport infrastructure development often become observable only a long time after the transport infrastructure was built. Not only the actual decision to provide sites by municipal planning might get unpredictable, but also the duration of the planning procedure itself.

Such delay partly dilutes expected impacts of transport infrastructure investments on local economies. We will eventually find that such an indication of impact can be found three or more years after the completion of the infrastructure. For the case study proposed in Braumann and Schönfelder, chapter 6, this volume, this could mean that the A4 motorway expansion to Parndorf and Neusiedl might show / might have shown effects much later than 1991. In this particular case, it seems even more complicated to reveal local effects as the infrastructure improvement was partly accompanied and superimposed by far-reaching political developments with implications for travel times and behaviour, too.

6 CONCLUSIONS

There is no doubt that investment into transport infrastructure exhibit notable effects on the economy. Accessibility improvements and decreased travel times increase market areas and offer higher spatial degrees of freedom – to work, invest, locate, produce and to consume. Transport policy and planning has decisively supported this trend. However, given the widely equal distribution of good transport connections and generally low transport costs the magnitude of impacts on the allocation decisions of firms is diminishing. Rietveld already 1994 states that "the direct contribution of infrastructure improvement to a reduction in transport costs is in general small in industrialised countries".

Future decisions on new transport infrastructure have to based on a vision of desired spatial development. The societal and political debate about the consequences of our present transport and land-use system is in progress. Accessibility gains by transport system expansion still show an impact on local economies – however, negative external effects tend to outweigh the (expected) benefits. This clearly has implications for transport policy and its future toolbox of strategies: In an era of limited possibilities for infrastructure expansion, the focus must be on the maintenance and improvement of infrastructure quality as a prerequisite for economic wellbeing. Finally, economically successful regions are regions which put a focus on mobility of people and goods, not solely vehicles. Their objectives usually include ensuring that recommendations support sustainable development including environmental quality and ensuring access to jobs, goods and services that people need.

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5. A Method to Calculate Regional Freight Transport Costs with New Infrastructure

Hannes Pichler and Erik Schaffer

1 INTRODUCTION

Standard theory points out the benefit of new infrastructure investment in terms of reduced generalised transport costs, which are complex to determine in empirical terms (see Schönfelder et al., 2006, chapter 4, this volume). This chapter therefore presents a GIS-based method to quantify the change in freight transport costs for a particular infrastructure investement, for both inward and outward bound transport. The particular investment and structure of regional coverage is motivated by the demand of the policy analysis presented in Gebetsroither et al. (2006), chapter 7, this volume. This specific focus can serve as a role model also for the quantification of implications on travel costs of other infrastructure investments.

As specified in Gebetsroither et al. (2006), chapter 7, this volume, in more detail, we analyse the implications of a new motorway in the Southern Austrian border region, the A4 extension in the early 1990s. Further, we distinguish three regions, the region of investment (Parndorf region, i.e. political districts of Neusiedl and Eisenstadt-surrounding; the surrounding region, i.e. rest of Burgenland and Lower Austria; and finally the ROW region, i.e. rest of Austria and abroad).

The costs for a certain route are calculated with ArcGIS that gets input data from a software based on Matlab and Access. The route calculation is based upon minimizing the variable costs, these are composed by the variable costs per kilometers (in the main, the fuel costs and the variable depreciation of the equipment) and per hour. The latter consists only of the wages of the truck driver. The fixed costs are given in €/km and based on the assumption, that the truck is in use 240 day a year and makes 600-700 km[1] per day. The fixed costs are added to the variable costs provided by ArcGIS after the optimization. All the networks were calculated with an unique combination of a semi trailer truck for medium distances and a simple 40" trailer for containers[2].

Results of this calculations enter directly into the model presented in Gebetsroither et al. (2006), chapter 7, this volume.

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[1] We assumed that the trucks are employed mainly in the regional transport for about 16 hours a day. three hours are used for loading and unloading and breaks. Due to the high share of urban areas (Vienna, Wr. Neustadt, St Pölten) and municipal area (tempolimits between 30 and 50 km/h) in the regions under investigation, we set the average speed of the trucks to only 55 km/h.

[2] This may seem inapproporiate for several branches that are known for using special trailers – especially the building industry and the timber industry, but the costs for a trailer for logwood or for building material don't differ essentially from those of a standard trailer for containers. Additionally we'd need the split of designs of the equipment for each branche.

2 THE DATABASE FOR THE CALCULATION OF THE WEIGHTED AVERAGE OF TRANSPORT COSTS BETWEEN THREE REGIONS

The database is programmed with Microsoft Access; all queries are written in the SQL language. Its core is built of the four output tables from ArcGis that consist of 519.881 data records each. These are origin-destination tables (OD tables) which contain the distance between two municipalities in the area under investigation as well as the time and costs necessary to cover the distance between them. Therefore, this database contains more than 2.000.000 data records. Additionally, there is a table with data records for each municipality. It provides the share of employees of this municipality in the political district where it is located. The shares are used to weigh the average cost between two political districts. The calculation related to these values is depicted as follows:

There are two political districts M and N, containing m respectively n municipalities. Each municipality (i) in M has a share in the employment of the district M called μ_i and those in the district N are analogical called ν_j. The costs between all the municipalities in M and N are given by an array K in m×n where each element K_{ij} gives the costs between the i[th] municipality in M and the j[th] municipality in N.

First, we calculate the average cost of the district M to each municipality j in N

$$C_j^{MN} = \sum_{i=1}^{m} K_{ij} \cdot \mu_i \qquad (1)$$

Here each of the m elements to the municipality j in N is weighted by its corresponding share μ_i and the sum of them gives the average cost from the district M to the municipality j.

To obtain the weighed average transport costs between M and N it is necessary to sum up the C_j weighed by the shares ν_j corresponding to the municipalities in N

$$C^{MN} = \sum_{j=1}^{n} C_j^{MN} \cdot \nu_j = \sum_{j=1}^{n} \cdot \sum_{i=1}^{m} K_{ij} \cdot \mu_i \cdot \nu_j \text{ and since } K_{ij} = K_{ji} \Rightarrow C^{MN} = C^{NM} \qquad (2)$$

The database contains a table that provides the number of trips per day between the three political districts building R1 and all the other political districts of Austria. The number of trips is subdivided in 14 branches of trade a,b,c,…,n, so for each branch there exists the number of trips between each of the districts in R1 and the districts in R2 and R3. The number of trips are used to weigh the average of the transport costs A^{XY} between the regions R1, R2 and R3. Here we programmed an SQL-query for each of the 14 branches and each of the four output tables. The regions are combined using a table where the user can assign a number between 1 and 3 (the number of the region) to each political district. Let ${}_uA^{XY}$ depict the weighed average cost between region Rx and region Ry[3] for the branch *u*. Then, the average costs from the region Rx to the region Ry is given by

$${}_uA^{xy} = \sum C^{MN} \cdot \frac{{}_u\lambda^{MN}}{\sum {}_u\lambda^{MN}} \quad \text{such that} \quad M \in Rx \wedge N \in Ry \tag{3}$$

where ${}_u\lambda^{MN}$ depicts the number of trips between the district M and the district N, for the branch u. The query displays five weighed average costs for the branch u.
Analogical to the calculation of the costs, the weighed average distance and the weighed average length of time between the two regions Rx and Ry were calculated by this query. The query displays the following table:

JFahrtenR2R : Auswahlabfrage

R2R	KostBrancheJ	DistBrancheJ	ZeitBrancheJ
1-1	20,67	22	29
1-2	44,45	51	52
1-3	25,65	28	33
2-1	51,52	59	60
3-1	205,61	241	188

Datensatz: 1 von 5

To compare the output of these queries with those for the other OD - tables in the database, we built a query for each branch that gives the differences between the street network of the year 1991 and 2001 as well as between the year 2001 and 2015 in percent:

VergleichJ : Auswahlabfrage

R2R	KostBrancheJva	KostBrancheJarz	DistBrancheJva	DistBrancheJarz	ZeitBrancheJva	ZeitBrancheJarz
1-1	1,148	-1,599	0	0	6,452	3,448
1-2	3,746	-0,188	-4,082	0	20	1,923
1-3	2,471	-3,697	0	-3,571	13,158	9,091
2-1	7,819	-0,398	0	0	25	3,333
3-1	4,999	0,004	2,429	0,415	6,931	1,064

Datensatz: 1 von 5

The name of the column R2R means region to region and gives the number of region x and region y. The difference in average costs between the street network of 1991 and 2001 is given in the column KostBrancheAav, the difference between 2001 and 2015 in KostBrancheAarz. The reader might wonder why the differences do not have the same algebraic sign. What is given here is the benefit of the new built infrastructure. It is a positive one between 1991 and 2001 but a negative one between 2001 and 2015. In the latter case, many new additional highways (Autobahn) are built – this means a saving of time but not of costs. In Austria, trucks are forced by the law to use the Autobahn except for those parts of the trip that are necessary to reach the Autobahn from the origin and to reach the

[3] The intraregional costs are also calculated. This happens when x=y.

destination from the Autobahn. There is road pricing at the highways in Austria and therefore, the costs of trucking can be increased by the extension of the street network[4]. The differences in percent were calculated by subtracting the value from the newer street network from the older. This difference then was divided by the value from the older network. An additional set of 14 queries supplies the absolute costs of the transport between the regions for each branch and also the absolute differences between the two networks.

AbsolutJ : Auswahlabfrage

R2R	KostenBrancheJv	AbsDiffBrancheJva	KostenBrancheJa	AbsDiffBrancheJaar	KostenBrancheJar	AbsDiffBrancheJarz	KostenBrancheJz
1-1	415394	4795	410599	-24287	434886	-7064	441950
1-2	794735	29630	765106	-150818	915924	-1847	917771
1-3	168712	4198	164514	-21120	185634	-6861	192494
2-1	1381153	108035	1273117	-278112	1551230	-6068	1557297
3-1	4527922	226447	4301475	-1256618	5558094	301	5557793

Datensatz: 1 von 5

3 ROAD NETWORK AND THE ROUTE PLANNING PROCESS

The area that is taken into consideration includes the provinces of Lower Austria, Burgenland and Vienna. All the municipalities in this area are used in the calculations whereas Parndorf and the closer area around represent the core region.

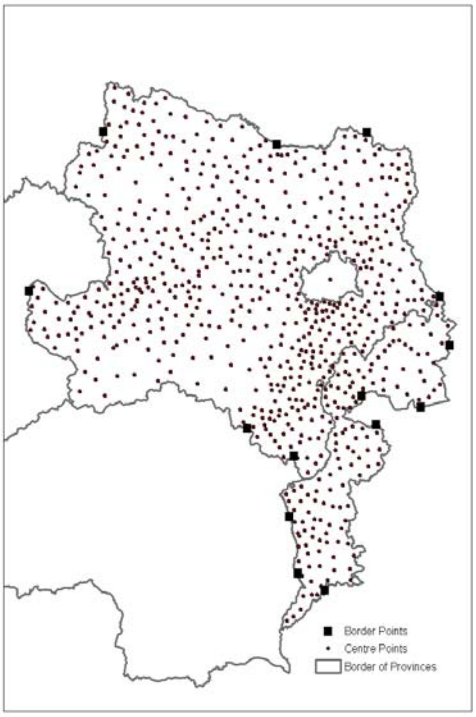

Figure 1: All sources and destinations

To have flexibility in the calculations the decision was to be able to change the source and target points from case to case. Thus routes had to be calculated from all sources (municipalities) to all targets. For the transports from abroad or all other provinces fill-in points on the main roads at the borders of the region of interest were created. From these points routes to all municipalities within the Region were calculated too.

Before starting the route calculation process the position of the starting sources and destinations have to be fixed. There are data about municipalities and districts available. In GIS municipalities are represented by polygons which mean that there is no single point standing for one place. At the same time there are sometimes several villages included in one municipality. To get a single point related to a 5-digit code of a

[4] The benefit from the savings of cost related to the lenght of time are smaller than the increased costs due to the roadpricing. This calculation is based on the assumption, that the utilization of the trucks is constant. In fact it is assumable, that in some cases the savings of time may lead to a higher average utilisation of the trucks an this may lead to a decreased cost rate.

municipality the decision was to choose the geometrical centre of the polygon as the representative point. These points are sources and destinations at the same time. Still, there was the problem that not all points were close enough to a road to be accepted by the road network. About 15 points had to be moved out of the centre to be able to take part in the route calculating process. Altogether there are 720 sources and aims. Hence, the route calculating process will result in a transport relation matrix with 518.000 relations.

The route calculating uses roads or road segments that can be found not only within the provinces Vienna, Lower Austria or Burgenland but some routes lead through parts of the neighbouring provinces Styria and Upper Austria.

As the basic road network motorways, national roads and major rural roads are used. During the years mainly motorways were extended and prolonged. Thus, in the road network only motorways were changed. In the following pictures the network of the years 1991, 2001 and 2015 are shown.

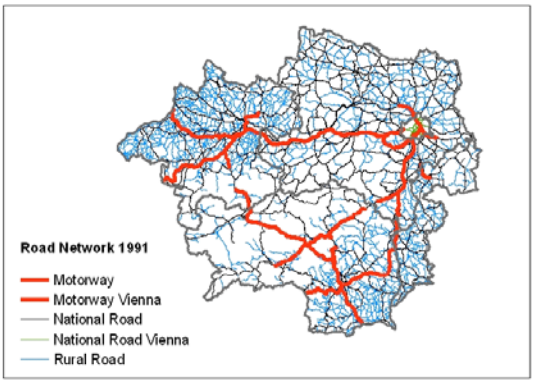

Figure 2: Road Network for the year 1991

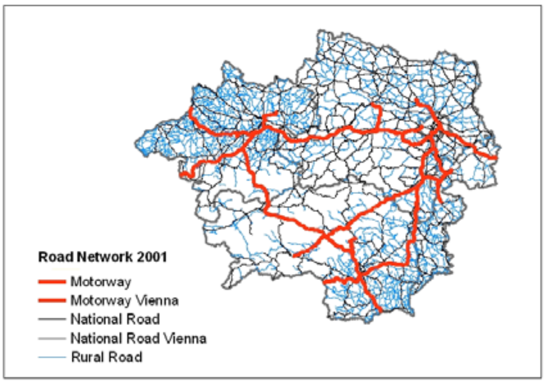

Figure 3: Road Network for the year 2001

The development of the road constructions is only changed within the area where roads are used for the routes from sources to destinations as described above.

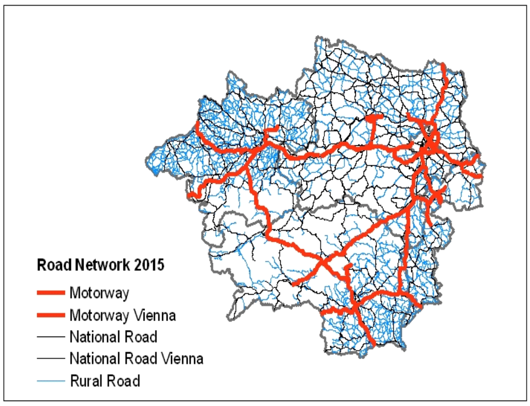

Figure 4: Road Network for the year 2015

For the route finding different attributes for each road segment were defined. As it can be recognized in the pictures roads within Vienna are specified especially. This gives the opportunity to assign extra attributes deviating from the other roads outside. It is important e.g. to lower the average speed for these roads.

For the route planning process basic information about average speed, status of the road (in Austria fees for the use of motorways have to be paid) is necessary. The resulting data about driving costs, driving time, etc. can be deduced from this. In Figure 5 the input possibilities are shown.

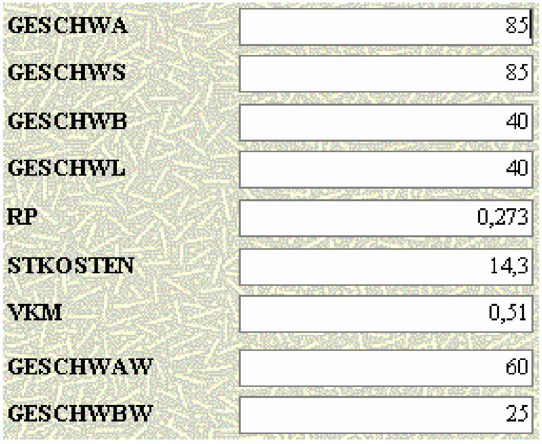

Figure 5: Data input for route calculation

Thereby, everything starting with *GESCHW-* describes the average speed on different road categories. *RP* is the roadpricing fee for the use of motorways per kilometre. *STKOSTEN* are the hourly costs of a truck and *VKM* are the variable costs considered per kilometre. In the route calculations the driving time is used as the impedance. This comes very close to the route chosen in reality. The result is a preference in the use of motorways.

6. Approaches to Introduce Accessibility Potentials into CGE Models

Alfried Braumann and Stefan Schönfelder

1 INTRODUCTION

In this chapter, an approach to conceptually link accessibility potentials to General Equilibrium modelling is introduced. We start with a brief overview of theory of accessibility potentials – a concept which has its origin in the classical theory of mass gravitation of physics. Section three outlines the basic formula used for calculating accessibility potentials, followed by an illustration of the development of the travel time matrix which is the input base for the calculation of accessibility potentials. In addition to that, further input data is described, that is, the characteristics of the region chosen and the socio-economic attributes used. In section five, final results are presented, and approaches for a possible introduction of the results into the CGE model framework are outlined. We conclude the chapter in section six.

2 THE THEORY OF ACCESSIBILITY POTENTIALS

The concept of accessibility potentials has its origin in the classical gravitation theory of physics and was adopted in a range of geographical studies since the 1940s (e.g. Stewart,1947 or Hansen, 1959). Gravity-based accessibility measures are still the most widely used general method for measuring spatial reach. Since its first applications, population potentials are the predominant focus of analysis. Thereby the potential of a given location is explained not only by its own endowment with a certain attribute, that is the population living in the location, but also by the endowment of location in the wider region, that is the population living outside the location yet still within a surmountable distance. In principle, the population is spatially weighted: Individuals living closer to the reference location contribute more to the location’s accessibility potential than those further away. The assignment of these theoretical potentials to existing locations is called „potential mapping“ (see Schumacher, n.a.).

Potential mapping is applied where a pattern of point related information is transformed into a continuous representation of space. In the literature, we find a variety of formulas to calculate potentials. For the present model, we assume that the accessibility potential of a location increases with the number of activities (i.e. the magnitude of supply) at the location itself and at all surrounding places. Furthermore, the contribution of a location towards the potential of the reference point decreases with increasing distance. Locations outside the scope of the analysis are not regarded due to their negligible effects on the location considered.

Potentials are theoretical indicators of the endowment of a location with regard to a certain attribute. Equally, the potential of a place may be considered as a field of attraction with its centre at the respective place. To better understand the potential approach, it may be described in several ways: First, it acts as an index of the nearness of attributes tied to a certain place to one another as well as a measure of the influence of people at a distance. Thereby the model is capable to represent the intensity of possible contact between people at location *i* and those at all other locations potentially accessible. Second, it may be seen as an indicator of relative position, i.e. as a measure of the accessibility of people in *i* to people in all parts of the area being examined.

3 THE MODEL

Accessibility potentials are calculated by a model consisting of two main components: an activity function and an impedence function. The activity function determines the attractiveness of any location considered to be contributing to the reference region's accessibility potential. In this chapter, attributes are population, number of workplaces and regional income. The impedance function in turn defines how distance curbs the effects that the attributes exercise on the location considered. To take an example: The effects that the population of Bratislava exercises on the city of Vienna shall be higher than the effects of the population of similar-size, but further away Dresden. The impedance function may take varying forms, with the negative exponential form most frequently used in literature. We thus construct our indicators of accessibility following equation (1).

$$P_i = \sum_{j=1}^{n} A_j * e^{-\beta * t_{ij}} \qquad (1)$$

P_i potential at location *i*
A_i activities attributed to location *j* (population, workplaces, regional income)
β impedance factor
t_{ij} Travel time between locations *i* and *j*

The impedance factor β practically calibrates the sensitivity of activities to travel time. A very high β close to 1 represents a highly degressive distance decay which means that places further away from the reference point are highly devalued. This will be used for studies of phenomena with purely local impacts, where effects can be felt only over a very short distance. Shifting β closer to 0 results in an ever more linear impedance function, with a β of 0 meaning that distance does not affect the influence of the activity at all. Thus, activities with global dimensions or repercussions (e.g. production sites of intermediary products) call for a very low β, while activities with local repercussions (e.g. commuters) need a rather high β. Table 1 shows selected reference values from earlier studies. For our model which is applied to a location on the border of two metropolitan areas (i.e. Vienna and Bratislava), we chose a β of 0,05, which implies a half life period of 13min 54sec.

Table 1: Use of in β in earlier studies

Source	β	Activities covered
BAK (2005)	0,0011	Global accessibility of Zurich
BAK (2005)	0,0051	Continental accessibility of Zurich
Schürmann and Talaat (2000)	0,03	Accessibility of European Regions by Lorry
Schürmann and Talaat (2000)	0,07	Accessibility of European Regions by Car
Schumacher (n.a.)	0,25	Commuters in Saxony

4 THE REGION

Our model was applied to the region of Parndorf, a community of 3.218 inhabitants (2001) located in the Austrian Bundesland of Burgenland. After the political changes in Eastern Europe that resulted in the fall of the Iron Curtain in 1989, Parndorf has experienced a rapid development. The community managed to attract new housholds and companies, and furthermore a vibrant retailing market emerged which annually attracts several million shoppers from Austria and the bordering countries. Additionally, being situated app. 30 km from the city limits of both Vienna and Bratislava, Parndorf is increasingly becoming subject to these cities' growing "urbanisational" pressure.

We calculated how accessibility potentials of Parndorf developed after 1988. Over the last 20 years, accessibility has mainly changed for two reasons: politics and road infrastructure extensions. Only shortly after the border between East (here: Hungary and the then CSSR) and West (here: Austria) became penetrable in 1989, a highway („A4“) first linked Parndorf with Vienna in 1991. Three years later, the same highway was extended into Hungary. Then, in 2004, the now Slovak Republic and Hungary became members of the European Union with implications for an even easier commercial exchange. Scheduled for opening in 2007, a totally new highway („A6“) will connect Parndorf with the Slovak Republic and thus the city of Bratislava. As final stage of the ongoing integration process, we assume the entry of Slovak Republic and Hungary to the Schengen Treaty to finally reduce border waiting times to zero. The entry will be probably in 2008.[1] Table 2 gives an overview of the different steps of development covered.

Table 2: Changes of accessibility of Parndorf

Date	Type of change	Change	Effects of Travel time
1988	-	Initial situation	-
1989	Political	Border opens between East and West	Border waiting time reduced
1991	Infrastructure	A4 Vienna – Parndorf opened	Highway travel time reduced
1994	Infrastructure	A4 Parndorf – Hungary opened	Highway travel time reduced
2004	Political	EU-enlargement	Border waiting time reduced
2007	Infrastructure	A6 Parndorf – Bratislava opened	Highway travel time reduced
2008	Political	Entry Schengen Treaty	Border waiting time reduced to 0

[1] Austrian Ministry of Foreign Affairs, July 2006.

The analysis included the whole of Austria, Hungary, the Slovak Republic and the Czech Republic. Thus every location within a travel distance of 120 minutes from Parndorf is covered. The first major agglomeration outside of these four countries would be Ljubliana (Slovenia) or Munich (Germany), both at a distance of app. 200 minutes. With β of 0.05, these cities would be weighted by a factor of app. 4,5*10-5 which renders them insignificant for the accessibility potential of Parndorf. In Austria, we used political districts as level of spatial aggregation. As for the other three countries, spatial aggregation was the same as used for the Austrian "Verkehrsprognose 2025+" project (traffic forecast 2025; see below). Here, it was organised along the lines of NUTS-III, yet in selected cases not wholly identical.

4.1 TRAVEL TIMES

Travel times between locations were calculated using the national Austrian transport model (using PTV VISUM software) which was developed within the framework of the „Verkehrsprognose Österreich 2025+" in the years 2004-2006. The study was carried out by a research consortium consisting of academic institutions and transport consultants[2]. The aim of the study – which was initiated and funded by the public Austrian transport/infrastructure authorities and providers[3] – was to forecast travel volumes up to the year 2025 and to test policies to control traffic. Car travel times between all pre-defined traffic cells in Austria and the rest of Europe were calculated for the above defined points in time (1988, 1989, 1991, 1994, 2004, 2007 and 2008). The calculation was based on free-flows, i.e. trips were assumed to be made at maximum permitted speeds.

4.2 BORDER WAITING TIMES

One of the critical points of the analysis is the assumption of border waiting times and their variations at the predefined points in time. This issue was discussed and implemented in other studies such as in Bröcker et al. (2002). Given the different clearing times and capacities at the border crossings to the East, entry and outward journey travel times varied significantly over time. In general, border processing and waiting times either way have decreased a lot since 1989 when freedom of movement was gradually introduced between East and West. We assumed that border waiting times have been reduced in steps since 1988 and will finally disappear with the entry of Hungary and the Slovak Republic to the Schengen

[2] Trafico Verkehrsplanung, Institut für Volkswirtschaftslehre der Universität Graz, Institut für Technologie und Regionalpolitik des Johanneum Research, Christian Grubits Verkehrplanung, Institut für Verkehrsplanung der ETH Zürich and WIFO (Österreichisches Institut für Wirtschaftsforschung).

[3] BMVIT, Asfinag, ÖBB and SCHIG (Schieneninfrastruktur Dienstleistungsgesellschaft).

Treaty, scheduled for 2008. Thus, transport times for journeys into and out of Austria have been augmented according to border waiting times shown in Table 3.

Table 3. Border waiting times in minutes for journeys into and out of Austrian, 1988 – 2008

1988	1989	2004	2008
60	30	15	0

Those waiting times act as a catch-all variable for a broader spectrum of phenomena which are not solely travel time related. They also account for (i) the low level of integration of national markets in the 1990ies, (ii) political decisions, such as the 7-year transition period which bar Eastern European workers from entering the Austrian labour market or (iii) the „cultural time-lag" that averted people from directly realising and exploiting the new (economic, cultural, social etc.) potentials outside their home country. Thus, the genuine waiting time at the Austrian-Eastern Europe border in, say, 2000, probably was not 30 minutes – as assumed in our model – but lower, maybe around 20 minutes. With this difference we try to account for the cultural and mental barrier which exist between the two sides of the border. This obstacle prevents many interactions from taking place - for example because people do not identify the newly arisen potentials.

4.3 ATTRIBUTES

Accessibility potentials of Parndorf were calculated along three attributes: population, number of workplaces and regional income.

Population. This indicator is one of the most widely used in relevant literature on accessibility. Population is taken as a proxy for almost any type of human activity. Its development over time promises to explain other changing patterns of development. As for input data, no timeline was used for population figures, as variation has been limited over the period covered. Due to reasons of availability and data-quality, we selected 2001 as base-year. Data used for Austria was taken from the Austrian 2001-census (Statistik Austria, 2006). Population figures for non-Austrian regions were taken from respective national statistic agencies. All data has been used and processed by Trafico for the preparation of the Verkehrsprognose 2025+ study.

Workplaces. The number of accessible workplaces influences the potential economic development of a location: Rising accessibility stands for a rise in possibilities on the spot, which can better be used for income generation (workplaces are near) or production (input factors are produced nearby). For the *New Economic Geography*, this indicator is of major importance as it denotes agglomerational effects. As with population, workplace figures have been processed for the year 2001, again from Verkehrsprognose 2025+.

Regional income. This indicator is relevant for any analysis with an economic background. It indicates the economic potential of surrounding regions and shows, if given in a timeline, the region's relative performance. For retail industries, a rising potential means a rise of purchasing power on the spot. Collecting reliable data on regional income is especially difficult, especially as incomes have been developing very dynamically in Eastern Europe after 1989 - both in absolute as in (territorially) relative terms. We constructed timelines of regional income from 1988 to 2008 for all regions covered. In order to have a common database, we opted for the Eurostat-Database, which is publicly accessible as well as free of charge. Timelines of regional income in nominal EUR were available from 1993 to 2003. For the years prior and after that period, values were constructed by extrapolating the average growth rate of each region over the period covered. Where the regional basis of the data was different to ours, we split up the regional income according to population of our smaller units.

4.4 INPUT MATRIX

Our input matrix thus was made up of the following data for all 138 regions:

- travel time by car from the region to Parndorf including border waiting times in 1988, 1989, 1994, 2004, 2007 and 2008
- size of population in 2001
- number of workplaces in 2001
- regional income for any year from 1988 to 2008 in Mio. Euro.

Table 4 shows selected data for the 15 regions which will be accessible from Parndorf in 2008 in less than 60 minutes.

Table 4. Selected data from the input matrix

		travel time [min]				reg. income [Mio. €]	
Region		**1988**	**2008**	**population**	**workplaces**	**1988**	**2008**
Neusiedl am See	at	22	21	52.019	17.283	522	1.101
Bratislava-Petrzalka	sk	93	29	121.637	72.305	410	2.252
Bruck an der Leitha	at	34	31	40.579	11.936	476	895
Bratislava	sk	95	32	479.245	284.879	1.614	8.872
Eisenstadt (Stadt)	at	44	43	11.496	15.831	499	1.052
Rust (Stadt)	at	44	43	1.742	685	18	38
Eisenstadt-Umgebung	at	45	43	39.281	9.054	315	665
Wien	at	56	44	1.570.604	826.375	42.633	71.568
Wien Umgebung	at	57	47	105.454	51.606	2.101	3.596
Györ	hu	117	47	315.605	129.364	585	2.439
Mödling	at	62	48	108.944	62.606	2.915	5.481
Sopron	hu	111	49	124.088	50.863	230	959
Mattersburg	at	56	53	38.013	11.467	435	917
Baden	at	65	56	129.936	45.425	2.356	4.430
Korneuburg	at	73	58	69.992	25.509	792	1.356
Trnava	sk	122	58	237.141	82.186	565	2.705

4.5 METHODOLOGICAL RESERVATIONS

Travel times were calculated for car travel only. For reasons of simplicity and the missing model implementation of rail and public transport timetables for the foreign countries, this methodological restriction was accepted. Improvements or degradations in the national rail and public transport networks could not be as easily traced and represented in detail by the transport model as it could be done for the road network. Clearly, for a considerable share of journeys to and from the reference region (Parndorf), car travel times do not provide a realistic picture of (overall) accessibility potentials and their development over time.
Due to the dependence of this study on the methodology of the available transport model, a different spatial resolution for the Austrian and the foreign "cells" needed to be tolerated. This lead to the consideration of fairly large cells for the neighbouring countries. As a consequence, the actual distribution of travel times to and from places belonging to those large cells are strongly aggregated to a single travel time to and from a suitably chosen "centre of mass or population". This equals a weighting or levelling of travel times and might bias the calculation of the accessibility potentials.
Another critical point to be mentioned is the assumption that there was no expansion and completion of motorways and trunk roads outside Austria. As such information was available only for Austria – due to the focus of the modelling on the Austrian traffic situation – accessibility potentials are likely larger than calculated. This might especially affect accessibility potentials towards the Eastern neighbours of Austria where a modernisation of road infrastructure has been taken place since 1989 and the opening of the borders.
Finally, the aggregation of single community travel times to district level slightly biases the accessibility results. The matrix operation does not take into account the actual location of the community within the district but only divides the given travel times by the number of communities associated with the upper administrative level.

5 RESULTS

Table 5 shows the results of our analysis. As we can see, indicators of accessibility increase dramatically over the period: the accessibility potential of population and workplaces roughly tripled from 1988 to 2008, while the indicator for regional income almost quadrupled.

Table 5. Development of indicators of accessibility

	1988	1989	1991	1994	2004	2007	2008
population	100	120	160	173	205	221	295
work places	100	121	164	178	211	228	307
regional income	100	106	163	194	274	326	387

5.1 ANALYSIS

Potential accessibility for Parndorf increased three- to four times between 1988 and 2008 (population and work places respectively regional income). This is obviously a result of three factors: (i) Dynamic economic growth, especially in Hungary and the Slovak Republic, raised level and volume of income. (ii) The construction of transport infrastructure generally reduced travel times, especially to the nearby urban areas of Vienna and Bratislava, thus raising accessibility of Parndorf. (iii) Political Changes in Europe decreased waiting times at the border and improved access of Parndorf to these regions with above-average economic development.

5.2 TRANSFORMATION

Indicators of accessibility changed as shown in Table 5. In this chapter we suggest three approaches to integrate these results into CGE-models with a focus on productivity, income levels and monopoly rent.

Thesis 1: Accessibility potentials of population and work places affect local productivity positively

Economic theory accepts a positive interrelationship between the density of labour markets and labour productivity: Dense labour markets permit a high degree of division of labour, which enables specialisation of the work force. This in turn allows for high labour productivity. More recent theories, mainly the various branches within the New Economic Geography, try to refine this argument by focusing on transport costs, division of labour and enhancing innovation (Glaeser, 2003, 83ff.).

We propose to exploit these connections to introduce accessibility potentials of population and work places into CGE-models. For this, we have to *interpret* changes of accessibility potentials as changes to the size of the population / number of work places of the location under examination – yet without actually *altering* the size of its labour market. We argue that this can be done because accessibility potentials describe phenomena that merely *affect* the local situation indirectly but do not directly *change* it. What can be observed is thus similar to a “free rider” phenomena: the location profits from changes that take place abroad, which it does neither initiate nor pay for. It does not account for them, but non the less is it affected by them.

For the case of Parndorf, we suggest to integrate accessibility potentials of population and work places into CGE-models via timelines of two new exogenous variables of the form displayed in Table 6. They should be integrated in the model as a positively influencing levels of productivity.

Table 6. Exogenous variables to influence levels of productivity

	1988	1989	1991	1994	2004	2007	2008
Accessibility potential of population	100	120	160	173	205	221	295
Accessibility potential of work places	100	121	164	178	211	228	307

Thesis 2: Accessibility potentials of regional income affect local mark-ups negatively

In CGE-models that assume perfect competition firms make no profit and prices equal total production costs. Yet if imperfect competition is modelled, prices can include a mark-up that is constituted by the difference between production costs and prices. One way to introduce this type of imperfect competition into CGE-models is to allow price mark-ups depending on the size of the local economy (for an overview over the variety of further techniques to include mark-ups into CGE-models see Roson, 2006).

If we interpret accessibility potentials of regional income within the setting described above – that is, as affecting indirectly the local economy as covered by the CGE-model but not changing it directly – we may assume that they exert a positive influence on the level of possible price mark-ups. To give an example: Let's imagine a small village in a remote area. Its market probably will be characterised by a relatively high level of monopolisation that allows local firms to pocket high mark-ups. If, e.g. by improving the area's access to a previously inaccessible agglomeration, more regional income becomes accessible, consumers will be confronted with a bigger market within a newly accessible distance. We assume that it is reasonable to expect, in such a situation, that mark-ups will come under pressure. Actually, in Parndorf this was the case over the past 15 years.

We therefore consequently suggest to integrate these relationships into CGE-models by integrating a new exogenous variable that represents accessibility potentials of regional income (Table 7 for the case of Parndorf). The would have to affect negatively the level of mark-ups that firms are able to obtain.

Table 7. Exogenous variables to influence levels of mark-ups

	1988	1989	1991	1994	2004	2007	2008
Accessibility potential of work places	100	106	163	194	274	326	387

Thesis 3: Accessibility potentials of regional income affect local income positively

Regional economics has developed a wide range of push- and pull factors, mostly based on the theories of cyclical development of Myrdal (e.g. Myrdal, 1957). They try to point out that for regional economies contact with other economies may result either in an influx of resources (they "pull" them in) or they are drained of resources (they are being "pushed" out). Lately this thinking has undergone a

revival through New Economic Geography, where those factors are labelled as centrifugal and centripetal forces.
As for Parndorf, we have been able to identify strong centipetral forces in the economic field. As mentioned above, a vibrant retailing industry has exploited the combination of relatively cheap and readily available land combined with rising accessibility of income, mostly from the neighbouring agglomerations of Vienna and Bratislava. Currently several million consumers are attracted annually that massively augment consumption on the location.
Consequently, accessibility potentials of regional income are interpreted as advancing local income directly and positively. We therefore suggest to integrate accessibility potentials as shown in Table 7 into the definition of local income. However, this specific approach is to a high degree dependent on the individual location and has to be further formalised in order to be generally applied.

6 CONCLUSIONS

In this chapter we tried to introduce the theory of accessibility potentials and applied the approach to an Austrian case study region. Furthermore, we developed a basic concept to integrate accessibility as a further model component into CGE-models. We think that the combination of these two approaches might inhibit possibilities to further explanatory capacity of CGE modelling, especially through integrating spatial characteristics that previously have been ignored. Parndorf proofed to be an expedient for this attempt, as it is in the centre of a dynamically changing region. Further endeavours should be undertaken to refine the calculation of accessibility potentials and especially to develop their integration into CGE-models.

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7. New Primary Road Transport Infrastructure and the Development of Spatial Distribution of Growth: A Spatial CGE Analysis for an Eastern Austrian Border Region

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1 INTRODUCTION

Substantial increases in transport infrastructure supply and transport flows in many countries over the last decades, both in freight and passenger transport, have enabled crucial growth in consumer benefits. But, as a recent OECD (2000, 13-15) report put it, "there have been costs – mostly environmental costs – that are eroding the benefits. […] The challenge for the 21st century is to maintain and even enhance transport's benefits while reducing its impacts to sustainable levels."

While transport services are crucial to economic activities, the transport sector in its current shape is connected to a range of substantial detrimental impacts. For example, mobility activities currently trigger the fastest increasing segment in fossil fuel emissions in many countries. In Austria, for example, while total CO_2 emissions increased by 14.4% between 1990 and 2002, emissions from road transport increased by 62% over this period. If Austria is to comply with its commitments within the European Union with respect to the Kyoto agreement, effective measures need to be prepared and implemented in due time. Similar demands for transport reorganisation arise from current noise and health impacts (e.g. respiratory illnesses triggered by particulate matter emitted or recirculated by transport).

In the set of instruments to govern environmental impacts of transport, both volume and mode, policy discussion focuses most often on the "narrow" transport sector, both on technological and management instruments. Long-term impacts on transport emissions, however, are much stronger governed by the way transport interacts within the broader social and economic system. In particular land use patterns, and transport infrastructure interacting with them, determine transport emission patterns for decades. In this chapter we thus focus on the interaction of new transport infrastructure and land use patterns.

[1] An earlier version of this chapter is also published in Ecomod Network (2006), *Proceedings of EcoMod International Conference on Regional and Urban Modeling,* Free University of Brussels, Brussels. The authors want to thank the participants of the EcoMod Conference 2006 for helpful comments on an earlier version of this paper. The authors also thank Laurent Franckx for inspiring discussions and comments.

Choices in land-use and in transport are mutually dependent. Any given pattern of activity location induces a specific trip pattern, and, reversely, the location choice for each activity is dependent on the transport system and the opportunities it offers, since it is the transport system which defines the cost associated with all future activities at any specific location.

Most modelling has chosen one of the above approaches of primary causation. Only few efforts at integration have been made, e.g. Martinez (2000). The developments within new economic geography, triggered by Krugman (1991; 1995), however, have provided a number of new theoretical modelling devices and possibilities for simulation which need to be employed in suitable areas of empirical application beyond illustrative modelling (probably best presented in the work of Krugman himself).

We will proceed as follows. In section 2 the methodological device used, spatial computable general equilibrium modelling (SCGE), is argued for. Section 3 discusses the interaction between new transport infrastructure, economic growth and environmental quality. Section 4 presents the model and its implementation for an Austrian region, while simulation results of the impacts of new infrastructure in this region within an imperfect competition setting are presented in the following section. A final section concludes by summarising the main results. This version of the chapter does present model structure and simulation results, sensitivity analysis is still ongoing and will be presented both in a later version and at the conference slot.

2 SPATIAL COMPUTABLE GENERAL EQUILIBRIUM MODELING

For modelling the interlinkage of land-use and transport, spatial computable general equilibrium (SCGE) models serve as basic starting point, as they

(i) inherently depict the simultaneous decision on both producer-producer and producer-customer distances, output levels, and structure and level of production input demands, each of which by sector.

(ii) inherently acknowledge transport costs (fixed and variable components), varying across locations

(iii) inherently depict production cost dependency on output levels (variable returns to scale)

(iv) respect budget constraints in the consumer, public and firm sectors

(v) include an initial spatial allocation of households (and thus spatial distribution of both labour and consumption potential), which is necessary to fix – in combination with explicit transport cost modelling – an efficient spatial distribution of production (without transport costs in models of variable returns to scale we can conclude that certain agglomerations will occur, but their location would be ambiguous, as we know from stylised models)

Implementing the monopolistic competition models of the Dixit-Stiglitz (1977) type into multi-region CGE-models, the few empirical examples of SCGE models available so far start from one of two ends: broad regional coverage with few economic sectors (Bröcker, 1998); or from a fully fledged sectoral structure, with regional diversity restricted to within a single country (Knaap et al., 2001; or in a later state of progress of the same model Tavasszy et al., 2003). In both cases the transport cost component is exogenously given by (separate) companion-models. The future issue, therefore, which the current project is seeking to contribute to, is to transfer transport cost to an inherently endogenous variable.

The CGE approach lends itself to transport analysis because of its focus on

- the long term
- the analysis of substantial policy changes with economy-wide feedback effects
- the analysis of pricing instruments

The extension of the long tradition in CGE to spatial CGE modeling for transport analysis involves two core issues to be solved

- the identification of transport costs by sector
- the specification of the type of transport costs

The simultaneity of modal choice and production-location/transport decisions requires a common set of indicators, in an SCGE model basically the so-called price of service indicator.
In supplying methods to solve these problems this chapter is meant to contribute to also empirically overcome the basic neglect of spatial aspects we found in mainstream economics prior to 1990 even on the theoretical side, that for Blaug (1985, 629) “remains one of the great puzzles about the historical development of economics”.

3 TRANSPORT INFRASTRUCTURE AND ECONOMIC GROWTH

GDP and transport volumes have generally developed in parallel in the past. This has been true for both developing and developed economies. Over the last two decades passenger transport (in terms of passenger-km) has grown at a rate slightly higher than income (GDP), freight transport (in terms of tonne-km) roughly at the same rate as output. Looking at this in slightly more detail, we find a roughly constant number of trips for passenger transport and a roughly constant time budget for travelling, but a significant increase in trip distance. In freight transport we find on the one hand that goods are transported further as market areas have grown in order to exploit economies of scale, but that the average weight of goods has declined, with the latter basically just offsetting the former in terms of transport volume (tonne-km).

This observation of parallel growth of GDP and transport in combination with the "strong belief among decision makers, transportation planners and economists, that transportation plays a vital role in enhancing economic growth" often leads to the conclusion that enabling growth in transportation unambiguously fosters economic growth, or even is a necessary prerequisite for it. Such a conclusion is, however, likely to be far too premature. Improvements in transportation can indeed improve productivity of labour and capital and thus enhance growth – but whether this is the case in any particular situation is a matter requiring much closer inspection (see below). The observation of parallel growth alone of course also does not reveal the direction of causality. Do increased transport volumes (and a growth in transport infrastructure) trigger economic growth, or does economic growth lead to a higher demand for and supply of transport? If the latter was true in the past, transport growth may still not need to be a necessary consequence of economic growth in the future.

To answer these questions let us look at historical experience first. The importance of transport and transport innovations for economic growth has been analysed for different transport systems focusing on different centuries. The result of many studies in this vein is that economic growth that has normally been attributed to a particular form of transport development has in fact generally had many sources. For example, de Vries (1981) looked at the economic impact of the development of the horse drawn barge and the canal network in the Netherlands, foremost in the 17th century. In spite of a tremendous growth in the canal network during this period, the author concluded that it may only have affected the level of economic performance at some locations, but not the overall rate of economic growth. Similarly, Fogel (1964), in his study on the impact of railroad development on American growth in the 19th century found that there was a multiplicity of innovations responsible for growth, and railroad development only shaped economic growth in a particular direction, but was not the prerequisite for it. There are more affirmative historical references in the literature indicating the relevance of transport investments for economic growth, which are then often directly contradicted by more critical research. In an overall evaluation Berechman (2002), for example, judges that as "[a] review of historical studies shows, it is difficult to conclude explicitly that transportation development necessarily induces economic growth even when the economy is in the developing stage."

When analysing the present situation many authors point out the importance of looking at the specific characteristics of the transport investment before concluding that transport development has a positive impact on economic growth. For example, there is the need to take account of the impact of different stages of economic development (advanced or low-income economy). Next, peculiarities of the project are crucial, such as whether the investment involves an elimination of a network bottleneck or simply an addition to capacity. Further, we need to consider the structure of the market of transport-using industries, in particular the prevailing degree of competition. When transport improvements lead to more intense competition, their potential contribution to growth is more relevant.

With respect to advanced economies, several major changes have been pointed out that make their growth less susceptible to transportation improvements. Berechman (2002) lists five of these: (a) a decline in the share of work related trips – transport improvements thus benefit leisure activity rather than labour productivity; (b) employment patterns become spatially more dispersed, making, for example, cross-commuting more important than commuting to city centres, resulting in fewer clear candidates for commuting transport improvements; (c) in postindustrial society the main source of profits and power has become knowledge and information, most of which is unrelated to transportation; (d) the proportion of the elderly in the population is constantly rising, and their use of transport is mostly for non-work trips and at off-peak hours; (e) narrowing limits of land resources and environmental uptake capacities require that transport systems become less resource intensive and thus allow for economic growth to be decoupled from transport growth.

What then are the ways that transport development can have an impact on economic growth? Let us look at the various potential causal relationships in turn.

3.1 TRANSPORT INFRASTRUCTURE INVESTMENT AND ECONOMIC GROWTH

The first and most often cited direct link is that between transport infrastructure investment and productivity. Infrastructure investment is frequently seen as both increasing the level of economic activity (which is true for any public investment in an economy running below full capacity) and enhancing the productivity of private capital (i.e. firms work better with better transport infrastructure). Aschauer (1989) triggered the empirical debate that has been evolving over the last decade by finding output elasticities of public infrastructure investments which implied social rates of return potentially well above 100%. His approach was questioned, however, on statistical and methodological grounds, and more recent studies suggest much smaller figures (see also Table 1).

In a growth accounting approach, Baum and Behnke (1997) and Baum and Kurte (2001) sought with this different methodological device to determine how much of economic growth can be associated with growth in transport. For Germany they found for the period from 1950 to 1990, that as much as half of German economic growth is attributable to transport, half of which in turn is attributable to road transport alone. While, again, this has been interpreted as a causal linkage repeatedly since, the studies themselves did not convincingly claim any such direction of causality. Furthermore, as Vickerman (2002) concludes, "even if there is some linkage of this type, it does not show, either that similar rates of growth could not have been obtained by other types of investment, or that there will be similar [reaction of] output [growth] to continued growth in the road transport sector." With respect to the last point he continues, that at certain stages of growth there is an argument that the expansion of transport capacity is essential, "but once a certain level of provision is reached there is very little overall impact from further growth in the transport sector. Continued increases in transport capacity may lead to activities being relocated, but it does not lead, of itself, to higher aggregate activity."

Table 1: Selected studies on transport infrastructure investment, productivity and economic output

Reference	Method	Selected Conclusions
Aschauer (1989)	Infrastructure is a (public good) additional factor in the aggregate production function, regression	Output elasticity of infrastructure investment is as high as 0.4 to 0.5.
Lau and Sin (1997)	-"-	Output elasticity of infrastructure input around 0.1.
Johansson et al. (1996), cited in ECMT (2000, 17)	Compilation of output elasticity results from studies on 12 different countries	Output elasticity of infrastructure input is found to range from 0.15 to 0.77. "Results from time series analyses […] are notoriously affected by spurious correlation, since many factors will grow fairly smoothly over time, and selecting any two of them always shows a strong statistical link. Time gaps between investments in infrastructure and economic growth also affect the reliability of results." (ECMT 2000, 17)
ECMT (2000)	Survey	"It has been shown consistently that the economic performance due to infrastructure investments varies by transport mode, by industry and by region. These variations are hidden when using highly aggregated data."
Baum and Kurte (2001)	Growth accounting approach	"Without the growth in transport [between 1965 and 1990] the productivity of labour [in Germany] would have been reduced by a fifth, national GDP by about a quarter."
European Commission (1997)	Analysis of the time savings – productivity gain – output growth link, regression	Implementation of the prioritised Trans-European Network (TEN) projects would increase EU GDP by ¼ % by 2025.
Berechman (2001)	Survey	"The results, which are statistically significant, range from very low to relatively high elasticity parameters. This contributes to the difficulty of establishing an acceptable level of transportation impacts to use for policy purposes."
Vickerman (2001)	Survey	"The best that can be said with any confidence is that infrastructure investment will have a modest positive contribution to economic growth, but the more accurately are the opportunity costs measured, the less attractive return infrastructure investment offers than other types of public investment, especially education and training […]."

Next, there are studies pointing out the time saving aspects of transport improvements, implying a gain in productivity – exploited in the form of higher wages or increased output. The European Union Trans-European Network (TEN) projects have been evaluated using such an approach (European Commission, 1997), resulting in estimates of up to a quarter percent extra GDP by 2025 if the priority TEN projects were implemented. These estimates have been questioned on methodological grounds and as a consequence are also considered to be most likely too high by some authors (e.g. Vickerman, 2002).

Finally, transport investment may not only have an impact on the level of GDP, but also on the rate of GDP growth. With reference to results from the trade liberalization literature (e.g. Baldwin, 1989), one may conclude that improvements in transport networks trigger income and efficiency gains that are re-invested, and thus trigger a higher growth rate of the capital stock. Further, the rate of innovation and technology transfer may increase. This reasoning rests on the assumption that the transport-using industries are characterized by monopoly, oligopoly, or monopolistic competition (i.e. that they are not acting in perfectly competitive markets, in which case potential gains would have been exploited already). In such a market structure the cited causal link can be present, but is subject to potential countertendencies. For example, high transport costs may have led to a spatial monopoly, and firms might have a vested interest in not seeking transport improvements. Where such improvements nevertheless occur, the economic impact of these depends on whether or not the firm can maintain entry barriers in the absence of transport cost barriers. There is also the case where a transport cost reduction increases competition and only initially erodes market power. Here, any subsequent development which takes advantage of any new economies of scale and rationalisation could again lead to fewer producers staying in business, thus increasing the market power of those remaining (and reducing growth benefits).

In an article weighing the various aspects of transport infrastructure impact on economic growth in more detail, Vickerman (2002) concludes that "[t]he best that can be said with any confidence is that infrastructure investment will have a modest positive contribution on economic growth, but that the more accurately are the opportunity costs measured, the less attractive return infrastructure investment offers than other types of public investment expenditure, especially education and training to enhance human capital (see also Transportation Research Board, 1997)".

3.2 ECONOMIC INTEGRATION, TRANSPORT, AND (REGIONAL) ECONOMIC GROWTH

Reduced transport costs (caused by technological improvement or transport infrastructure investment) enhance both exports and imports from and to a region or nation. While the rise in exports tends to raise production, increased imports will lower local production and thus economic growth. The threat of import competition, however, generally will also lead to efficiency increases and the lowering of production costs.

Further, each change in the volume of production has consequences for factor market demand. Changes in transport costs are thus also reflected in changes in factor markets, especially in the labour and land (or housing) markets. In general, factor market impacts will work in the opposite direction to the initial transport improvement. Let us illustrate this link. If the net effect of transport cost change is a rise in output, for example, and thus a rise in labour and land demand occurs, wages and rents will tend to rise, which offsets to some degree the initial production cost reduction triggered by transport improvements. Further, in the transport market itself counterbalancing feedback is also likely. If at the higher output level transport volumes are higher, congestion might be too, which feeds back to higher transport costs.

At the regional level impacts may be more pronounced. Transport cost changes will benefit specific sectors more than others; regions with a high sectoral exposure can thus be affected stronger than the overall economy. Also, the change in transport costs will trigger spatial relocation of industries and may lead to more pronounced agglomerations in some areas. As pointed out by Krugman (1995), three driving forces are at work. On the one hand, there are two agglomeration tendencies (centripetal forces): firms want to move closer towards their input markets (in order to take advantage of local external economies) and closer towards those customers (in the stylised models, employees in manufacturing) concentrated where the increasing returns to scale industries locate. On the other hand, firms want to move away from competitors when selling to those customers that are evenly distributed in space (in stylised models the example of farmers is often used) in order to establish some market power (centrifugal force). For any level of transport costs there is an equilibrium of these forces at a certain degree of concentration. Initially, lower transport costs in general tend to cause geographical concentration of production, while higher transport costs tend to cause geographical diversification (i.e. a more equal spreading of production costs across space).

However, the impact of transport cost reduction also depends on the level of transport costs that we start from. This is shown in the seminal work of Krugman and Venables (1995) where they look at the impact of transport cost reduction on the worldwide distribution of production. Initially, transport costs are taken to be so high that each world region ("North" and "South") produces its own supply of all goods. When transport costs decline sufficiently, inter-industry trade occurs in order to take advantage of increasing returns to scale. If for any reason the North gains a larger share in the increasing returns to scale industry this region becomes more attractive for further location of production. Intermediate production will seek to locate closer to its market (´backward linkage´), thus lowering production costs and raising demand (´forward linkage´). The resulting circular process creates an industrialized North. If transport costs decline further, however, the importance of being close to one´s market declines. At some point the gain of taking advantage of lower real wages in the deindustrialized South outweighs the importance of transport costs. The increasing returns to scale industry then expands in the South and contracts in the North, thus reversing the earlier tendency and giving rise to a more similar structure of production across the world.

Thus, we find that a continuous reduction in transport costs (e.g. due to technological improvement) in an economic integration setting may give rise to both increasing and declining economic growth, and may do so in different world regions at different points in time.

4 THE SPATIAL CGE MODEL

4.1 PRODUCTION AND FOREIGN TRADE

There are two types of commodities produced in each region, goods produced for domestic markets and goods produced for export. In an Armington style modelling these goods are assumed to be imperfect substitutes produced as joint products with a constant elasticity of transformation. For output D_{ir} used domestically and exports Xir, total production Yir in region r for sector i is

$$Y_{ir} = \left[\alpha_{ir}^{Y} D_{ir}^{1+1/\eta} + \beta_{ir}^{Y} X_{ir}^{1+1/\eta}\right]^{1/(1+1/\eta)} \tag{1}$$

Inputs to production include primary factors labour *L* and capital *K*, as well as intermediate inputs (domestic and imported). Intermediate inputs are proportional to the activity level of the sector.

Intermediate demand ID_{ir} is a composite good of domestic intermediates *DI* and imported intermediate demand *M*

$$ID_{ir} = \left[\alpha_{ir}^{I} DI_{ir}^{\rho} + \beta_{ir}^{I} M_{ir}^{\rho}\right]^{1/\rho} \tag{2}$$

4.2 TRANSPORT

Transport costs are only acknowledged in interregional transport. Real transport costs T_{irs} in sector *i* are assumed proportional to bilateral trade flows between regions *r* and *s*

$$T_{irs} = \tau_{irs} M_{irs} \tag{3}$$

whereby transport services are supplied by the exporting region.

4.3 FACTORS OF PRODUCTION AND INCREASING RETURNS TO SCALE

The primary factors of production, capital and labour, are taken as region-specific supply, not mobile to migrate.
Following the approach of Dixit and Stiglitz (1977), production is characterised by monopolistic competition: an endogenous variety of *n* goods is produced in either region *r* and sector *i*. Different varieties of goods are imperfect substitutes in consumption. Each firm acts as a monopolist on its output market, taking the actions of the other firms as given. Again, imperfect competition arises due to the assumption of internal economies of scale at the level of the individual firm and the consideration of transport costs.
Based on empirical data for the regional structure presented below, production in either region and sector involves different marginal input requirements of labour *m* and capital and different fixed factor requirements *F*, independently of the quantity manufactured and assumed to comprise labour only: $l = F + m \cdot x$, where l is the labour required to produce any output *x*. Then, the production of a quantity *x* of any variety *i* in region *r*, with production coefficients *γ* and *δ*, involves

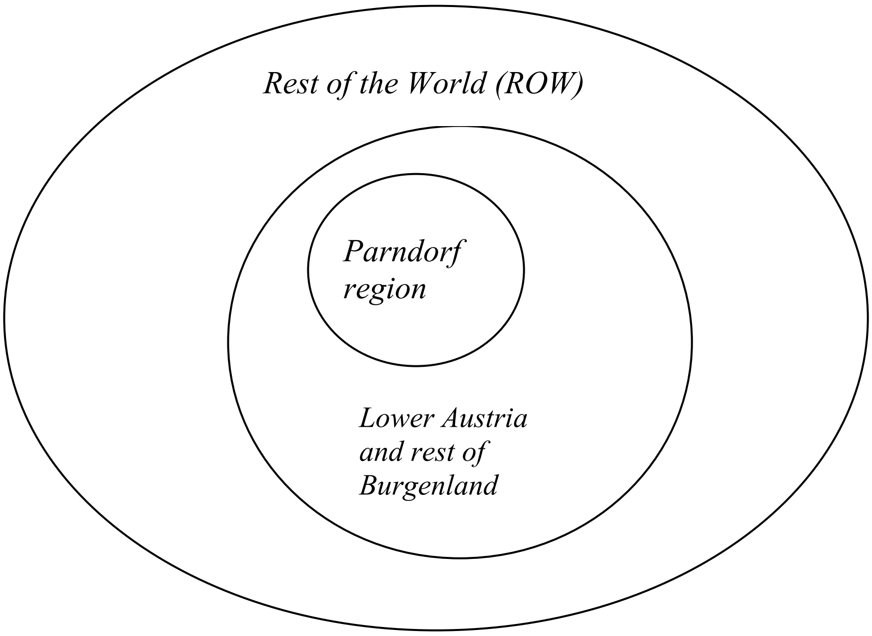
$$x_{r,i} = l^{\gamma_r} \cdot k^{\delta_r} \qquad \text{with } \gamma_r + \delta_r > 1 \tag{4}$$

inducing each firm to produce exactly one variety. Internal scale economies at the level of the individual firm and agglomeration externalities, accordingly, explain where production is located. More specifically, forward and backward linkages create an incentive for workers to be close to the production of consumer goods.

4.4 IMPLEMENTATION

A three-region model is implemented, focusing on the region of core analysis, Parndorf, close to the Austrian south-eastern border, a surrounding region (the remaining of the provinces of Lower Austria and Burgenland) and ROW (rest of Austria and abroad), see Figure 1.

Figure 1: Regional Structure



The model presented above has been implemented within GAMS (Brooke et al., 1998) using the modelling framework MPSGE (Rutherford, 1998) and the solution algorithm PATH (Dirkse and Ferris, 1995) in its – with Todd Munson – expanded version 5.6.04.

Using a three-regional split up of economic data of the provinces of Lower Austria and Burgenland, derived by using the provincial input output structure of these provinces, the focus region of Parndorf has been islolated. The model also requires further assumptions. Most importantly among these are transport cost shares in interregional trade as presented in Table 2, assumed uniform across sectors for the time being.

Table 2: Transport cost shares in interregional trade, initial estimation, uniform across sectors

		to region	
exports from region	Parndorf	LowerAustria/ Burgenland	ROW
	[% of total interregional trade expenses]		
Parndorf		8	12
Lower Austria/Burgenland	5		10
ROW	13	12	

We calibrate the model to the 2001 data set, including the 2001 reference split up of production in the three regions and interregional trade flows. Interregional trade balances are taken as fixed for the simulation scenarios. Increasing returns to scale are assumed to be present in all but one sector, the latter being “other industries”. This supplies us with a reference case for industries closer to the perfect competition assumption.

5 EXPLORATORY SIMULATION RESULTS

Our interest is in the spatial structure of growth, triggered by new infrastructure supply. Our first simulation thus introduces a reduction in interregional transport costs by a new infrastructure available to the core region of analysis, Parndorf. In fact in 1991 a new highway has been opened, shaping spatial economic growth structures that later will serve as a real world counterfactual to confront to model results.

Table 3 gives the results for a simulation of a 50% transport cost decline for all transport flows going into region Parndorf and leaving region Parndorf.

We find that sectors with strong dependence on interregional trade, such as Agriculture and Food, experience a significant increase in both domestic production and imports. Import prices decline by up to 7.5%. Also sectoral diversity increases in these sectors. The general equilibrium feedback implies that production factors shift to those sectors, and other sectors with lower dependence on interregional trade (and thus lower benefit of its real cost decrease) loose those production factors. Overall the real price of production factors slightly increases (relative to the production factor imports), and less trade dependent sectors, especially services, decline in output.

Table 3: Macroeconomic and sectoral impacts of a 50% interregional transport cost reduction for region Parndorf

Region Parndorf

Macroeconomic Variables		
Welfare	fixed	
Wage Rate [% change]		0.1
Capital Price [%change]		0.1

Sectoral Variables	Output	Import	Varieties [% change]	Domestic Prices	Import Prices
Agriculture	2.9	8	1.3	-0.2	-7.4
Other Industry	0.3	0.5	0	0.1	-0.2
Food	1.4	5.2	0.6	-1.4	-5.9
Construction	0.2	0.4	0.1	0.1	-0.3
Commerce	-0.5	1.7	-0.2	0.1	-3.4
Tourism	0.4	5.5	0.2	-0.5	-6.4
Transport	0	0	0	0.1	0
Puplic Administration	0.1	-0.9	0	0.1	1.9
Other Services	-0.1	-0.9	-0.1	0.3	2.3

Overall we do find both an increase in aggregate output and in transport volume.

Table 4, for comparison, reports the results for the surrounding region, i.e. Lower Austria and the remaining of Burgenland. Due to this surrounding region performing economic activity at a multiple level of Parndorf, impacts to this region are quite small.

Table 4: Macroeconomic and sectoral impacts of a 50% interregional transport cost reduction for trade to and from Parndorf – results for surrounding region

Surrounding Region

Macroeconomic Variables	
Welfare	-0.2
Wage Rate [% change]	-0.2
Capital Price [%change]	-0.2

Sectoral Variables	Output	Import	Varieties [% change]	Domestic Prices	Import Prices
Agriculture	0	-0.1		-0.2	0
Other Industry	0	0		-0.2	-0.2
Food	0	-0.1		-0.2	-0.2
Construction	0	0		-0.2	-0.1
Commerce	0	0		-0.2	-0.2
Tourism	0	0		-0.2	-0.1
Transport	0	0		-0.2	-0.2
Puplic Administration	0	0		-0.2	-0.1
Other Services	0	0.1		-0.2	-0.2

For analysing the counterfactual of real world development after the opening of the new highway in 1991, we also ask the question how sectoral structure and output levels would have been at higher transport costs than those observed in 2001. As an extreme case for a first idea on the type of effects occurring we use a doubling of transport costs for trade flows two and from region Parndorf relative to their actual level in 2001. Results are presented in Table 5.

Table 5: Macroeconomic and sectoral impacts of a doubling of transport costs for trade to and from Parndorf relative to transport costs observed in 2001

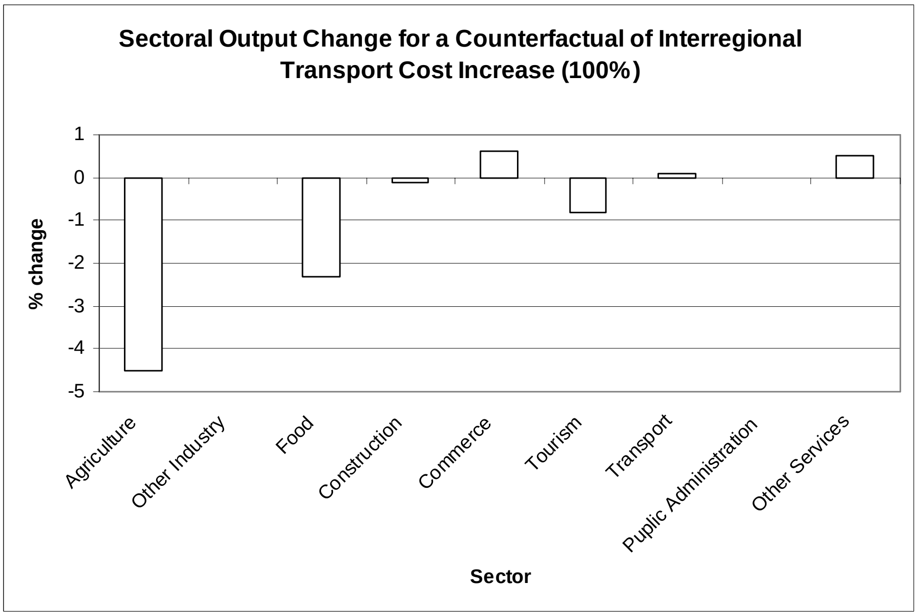
Region Parndorf

Macroeconomic Variables	
Welfare	fixed
Wage Rate [% change]	0
Capital Price [%change]	0

Sectoral Variables	Output	Import	Varieties [% change]	Domestic Prices	Import Prices
Agriculture	-4.5	-10.8	-2.1	3.2	12.4
Other Industry	0	-0.6	0	-0.1	0.7
Food	-2.3	-7.3	-1.1	2.2	9.8
Construction	-0.1	-0.5	0	0	0.8
Commerce	0.6	-2.4	0.2	-0.1	5.2
Tourism	-0.8	-7.2	-0.4	0.9	10.5
Transport	0.1	0.1	0	-0.2	-0.1
Puplic Administration	0	1.6	0	-0.2	-3.3
Other Services	0.5	1.9	0.2	-0.6	-4.3

We conclude that it was the sectors of Agriculture, Food and Tourism that benefited most from the new infrastructure (see also Figure 2).

Figure 2: Sectoral output changes for a 100% interregional transport cost increase for region Parndorf



6 SIMULATION RESULTS WITH OBSERVED FREIGHT TRANSPORT COST SHARES AND REDUCTIONS

As specified in Pichler and Schaffer, chapter 5, this volume, the actual transport cost reduction due to the opening of the A4 motorway extension in 1991 both strongly diverges across sectors and differs in level to the initial assumption given in Table 2 in section 4. Transport costs change substantially for agricultural goods and for food, and can be reasonably assumed to homogenously change only for the remaining sectors of the economy.

Table 6 presents the freight cost reduction due to A4 motorway opening by sector and interregional link.

Table 6 Freight transport cost reduction by sector and by interregional trade link

exports from region and sector	**to region**		
	Parndorf	**Lower Austria/ Burgenland**	**ROW**
	[% of total interregional trade expenses]		
Parndorf			
Agriculture		11.24	4.06
Food		8.12	2.33
Other Industry		6.32	2.85
Lower Austria/ Burgenland			
Agriculture	8.76		
Food	3.68		
Other Industry	7.11		
ROW			
Agriculture	8.11		
Food	5.11		
Other Industrie	8.21		

Further, from the analysis Pichler and Schaffer, chapter 5, this volume, we also get the actual transport cost shares by sector. The bilateral trade flows by sector and by political district (99 districts of origin by 99 districts of destination and by 24 NSTR goods, and foreign trade appropriately acknowledged) supply the relvant weights in this cost determination for the flows among the three regions as defined for our purpose.
Figures 3 and 4 report transport costs shares by sector and interregional trade link.

Figure 3: Transport cost shares region 1 to region 2, by sector

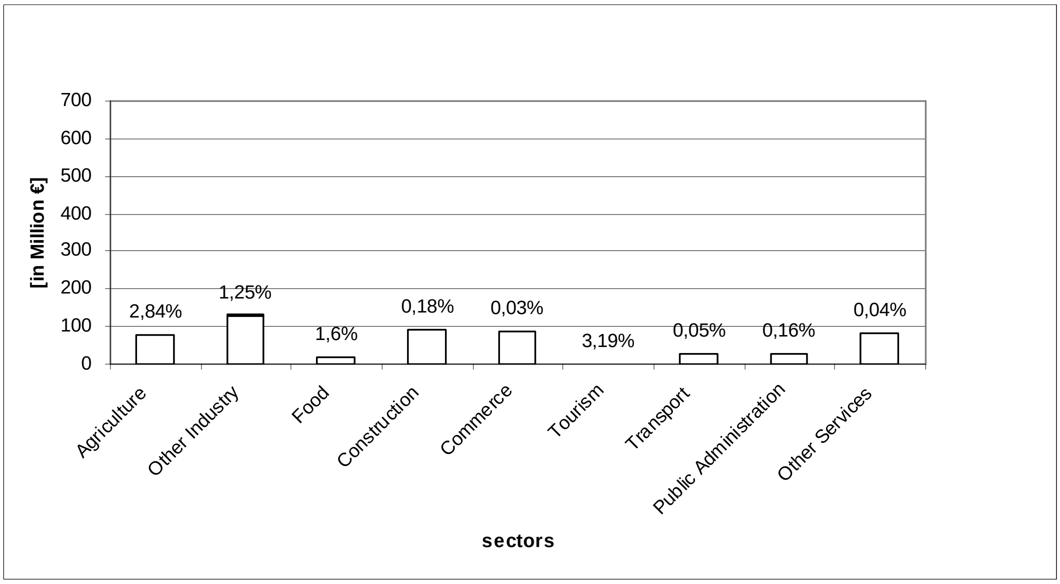
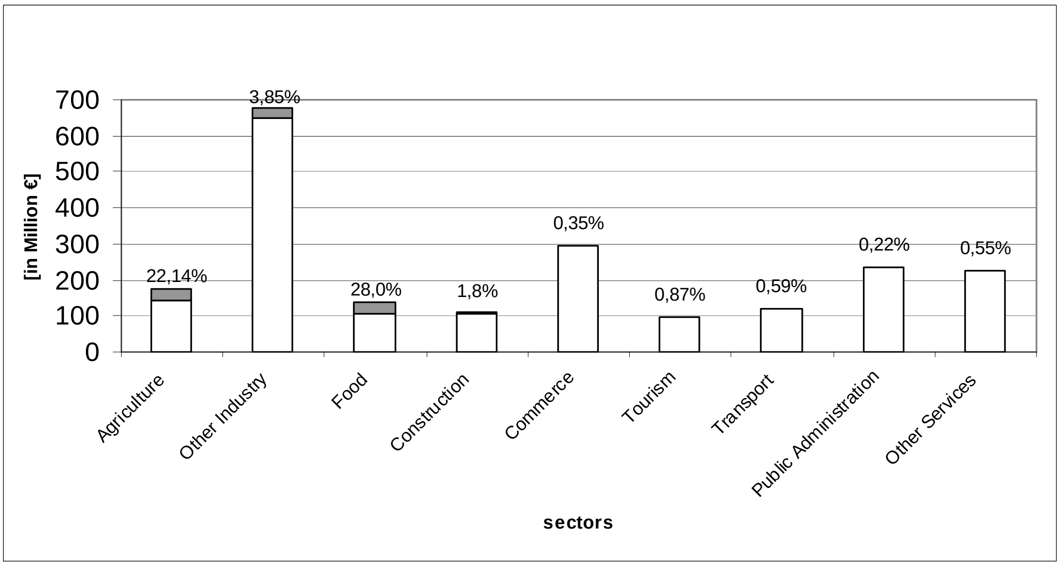


Figure 4: Transport cost shares region 1 to ROW region, by sector

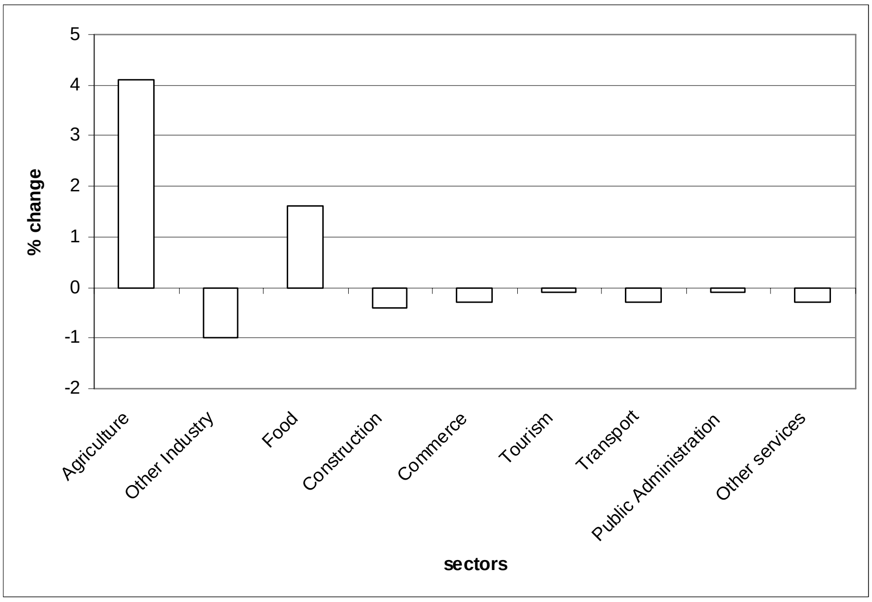


Using the model presented in section 4 with this empirically relevant freight transport cost data in terms of both cost shares and cost reductions due to the opening of motorway A4 we can exert an ex-post analysis to explore which quantitative economic development of regional redistribution of the past was due to this motorway opening.

We shock our 2001 reference case backward looking by a transport cost increase. For ease of interpretation we report results reversely, i.e. as impacts 1991-2001, thus in usual historical sequence. Transport cost reductions will thus increase output in sectors characterized by high export shares and initially high transport cost shares.

Our empirical analysis allows to quantify the dimension of interregional redistribution of economic activity by sector. Figure 5 reports simulation results of this analysis.

Figure 5: Sectoral Output Change due to A4 motorway opening, Parndorf region, actual freight transport cost data



We measure a welfare benefit connected to this new infrastructure for the Parndorf region due to freight transport cost reduction at 0.1% (Hicksian welfare index). The welfare benefit of this single infrastructure project to both region 2 and ROW are negligible.

7 SIMULATION RESULTS WITH OBSERVED CONSUMER ACCESSIBILITY IMPROVEMENT

However, freight transport cost reductions are not the only relevant impact to be acknowledged when new infrastructure, such as the A4 motorway, are considered. We also find high retailing investments in the Parndorf region, indicating that consumer access is a crucial parameter in the further economic development induced by new transport infrastructure. Braumann and Schönfelder, chapter 6, this volume, developed an indicator for accessibility improvement, taking account of both new infrastructure and other exogenous developments, such as the opening of the border to the east in particular (cf. Table 8).

Table 8: Change in accessibility for Parndorf region

	1988	1989	1991	1994	2004	2007	2008
Accessibility potential of population	100	120	160	173	205	221	295
Accessibility potential of work places	100	121	164	178	211	228	307

Source: Braumann and Schönfelder, chapter 6, this volume, Table 6

A doubling of the accessibility potential in our analysis is translated into a 5% increase of labour productivity (efficiency labour). We use the change in accessibility between 1989 and 2004 from table 8. Table 9 presents the results of this policy simulation.

Table 9: Regional economic impact due to accessibility increase after A4 motorway opening, Parndorf region, 1990-2004

Macroeconomic Variables [% change]	
Efficiency Wage	-0.8
Capital Price	0.8
Welfare	4.4

Sectoral Variables	Variety Index per sector [% change]
Agriculture	-1.3
Other Industry	1.3
Food	-0.8
Construction	0.8
Communication	0.6
Tourism	-0.1
Transport	0.6
Public Administration	0.5
Other Services	0.2

We find that the overall regional macroeconomic impact is dominated by the accessibility effect. Regional welfare increases by 4.4%, while it increases only 0.1% due to freight transport cost reduction. For some particular freight transport cost intensive sectors, however, it is well the former impact that dominates. For agriculture, for example, freight transport cost reduction induces a 4.1% output increase, while accessibility gains favours other sectors, thus exerting even a negative impact on agricultural output as a consequence of improved accessibility.

8 CONCLUSIONS

In this chapter we started from the assertion that transport infrastructure in mature economies does not really have an impact on overall growth, but does have an impact on both the structure and level of the regional distribution of economic activity. We develop a three-region spatial computable general equilibrium with Dixit-Stiglitz imperfect competition production to test for this assertion empirically. Implementing the model to the Parndorf region in eastern Austria supplies us with a first quantitative result, indicating which sectors benefit from new transport infrastructure, which loose. This serves as the basis for a calibration of the model also in terms of observed sectoral transport cost shares. We use this model to quantify the impacts of both freight transport cost reduction and accessibility increase for consumers (and labour) due to new transport infrastructure opening, using the example of the motorway A4.

We find that freight transport cost reduction even for a small region, such as our simulation was carried out for the core region of two political districts, does have negligible overall economic impacts. However, it is a few transport intensive sectors that show substantial impact in interregional trading prices and regional output.

For the implications of accessibility increase, the regional economic impacts are quite larger. For the A4 motorway opening, for example, we find a welfare increase for the core region at the order of magnitude of 4%. The causation here runs via both lower efficiency wages and increased consumer demand due to lower prices.

Overall, we thus do find a confirmation of the dominating view in the literature, that new transport infrastructure in mature economies hardly increases overall economic output, but may have a significant impact on its regional distribution. In particular our findings point out, that locally specific sectoral shares in production, freight transport cost shares, and – most of all – accessibility determine the order of magnitude of regional economic impact.

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Abstract:
Within this project the method of spatial computable general equilibrium (SCGE) has been developed for Austria in order to

- depict the simultaneity of decisions on producer-producer/producer-consumer distances, settlement structures and sectoral output levels
- analyse the long-term impact of new transport infrastructure on spatial distribution of production and transport flows
- supply an improved evaluation instrument for transport and spatial policy.

The theoretical model has been empirically implemented for two Austrian regions. In the urban context, we analyse driving forces and policy options in urban sprawl. In the interregional context, we investigate the importance of new transport infrastructure for the explanation of regional economic development differentials.

Zum Inhalt:
Innerhalb dieses Forschungsprojekts wurde die räumliche angewandte allgemeine Gleichgewichtsmodellierung (spatial CGE (SCGE) modeling) für Österreich eingesetzt, um

- die simultanen Entscheidungen über Produzenten-Lieferanten bzw. Produzenten-Konsumenten-Entfernungen, Siedlungsstrukturen und sektorale Outputniveaus abzubilden
- den langfristigen Einfluss neuer Verkehrsinfrastrukturen auf die räumliche Verteilung von Produktion und Verkehrsströmen zu analysieren und
- ein verbessertes Evaluierungsinstrument für Verkehrs- und Raumordnungspolitik bereitzustellen.

Das theoretische Modell wurde für zwei österreichische Regionen empirisch implementiert. Im städtischen Kontext analysieren wir die Anreize und Politikoptionen im Hinblick auf die wachsenden „Speckgürtel“, im interregionalen Kontext die Bedeutung neuer Verkehrsinfrastruktur für ökonomisch differenzierte regionale Entwicklung.

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