Circular Causality in Spatial Environmental Quality and Commuting: A Spatial CGE Analysis within a NUTS III region

Birgit Friedl[1,2], Christoph Schmid[1] and Karl W. Steininger[1,2†]

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ABSTRACT: New economic geography has so far focused mainly on issues of interaction of location of production and transport costs. Building on a two-region (within NUTS III) spatial computable general equilibrium model of the core-periphery type, we extend the analysis to focus on the consumers´ decisions of location of residence. Centripetal forces originate from increasing returns to scale and the implied distribution of jobs, with consumers minimizing commuting effort, centrifugal forces from the spatial differentiation in land rents and environmental quality. Urban sprawl is triggered inter alia by environmental preferences, but resulting commuting levels and especially mode choice is counteracting environmental quality, predominantly in the centre (PM10), re-enhancing urban sprawl. Particular spatial planning elements (e.g. increasing living density in the periphery to support public transport feasibility) are found to foster development towards a social optimum.

KEYWORDS: spatial planning, spatial CGE, empirical new economic geography, settlement location modelling

JEL: C68, D58, D12

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1 INTRODUCTION

The explanatory focus of this paper 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

[1] Wegener Center for Climate and Global Change, University of Graz, Leechgasse 25, A-8010 Graz, Austria
[2] Department of Economics, University of Graz, Universitaetsstr. 15, A-8010 Graz
[†] corresponding author: Karl W. Steininger (phone +43 316 380 8441, fax +43 316 380 9830, e-mail: karl.steininger@uni-graz.at).

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 producer-consumer type, typically found in environmentally oriented CGE models, yet we model consumer-consumer (pollution, health) externalities.

This paper 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 paper 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).[3]

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.

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.

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

[3] 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.

$$\max\ U_r = \left(X_r, H_r, T_r\right) \quad (1)$$

subject to

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

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[4] 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 ($1\text{-}\alpha\text{-}\beta$); σ^C is the elasticity of substitution in preferences between any pair of goods.

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

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

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

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

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.

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 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.

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.

Dispersion and urban agglomeration [5]

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.

[5] Agglomeration and dispersion forces refer to the spatial distribution of *consumers,* not firms. Of course, firms may follow consumers or vice versa.

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 empirical model does help us to identify the relevance of centrifugal and centripetal forces at work in this interaction.

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.

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.

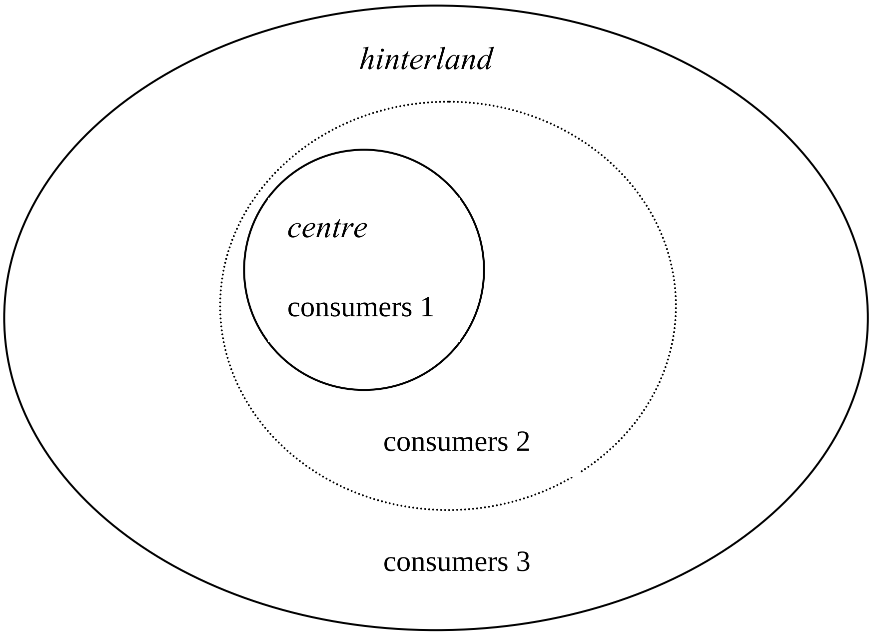

Figure 1: Residence Location of Consumer Types

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).

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.

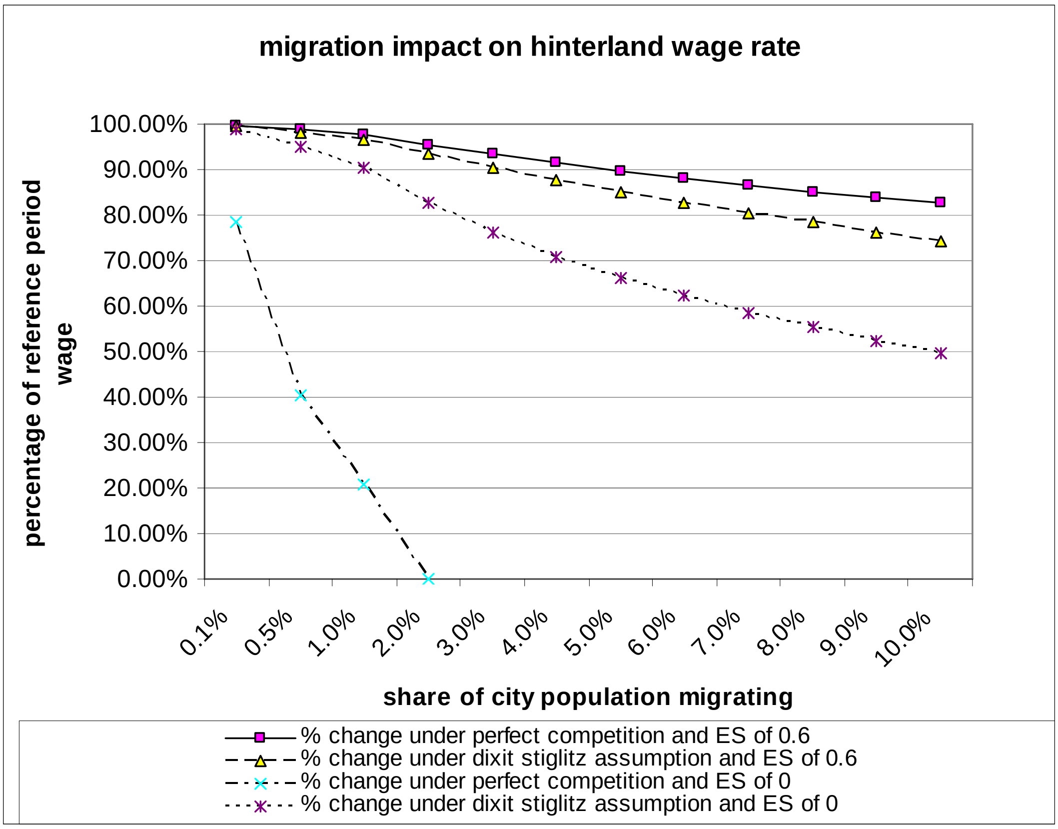

Figure 2: Migration of City Inhabitants to the Economic Sphere Hinterland – Impact on Hinterland Wage Rate

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 paper. 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 paper.

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, Figure 4 perfect competition).

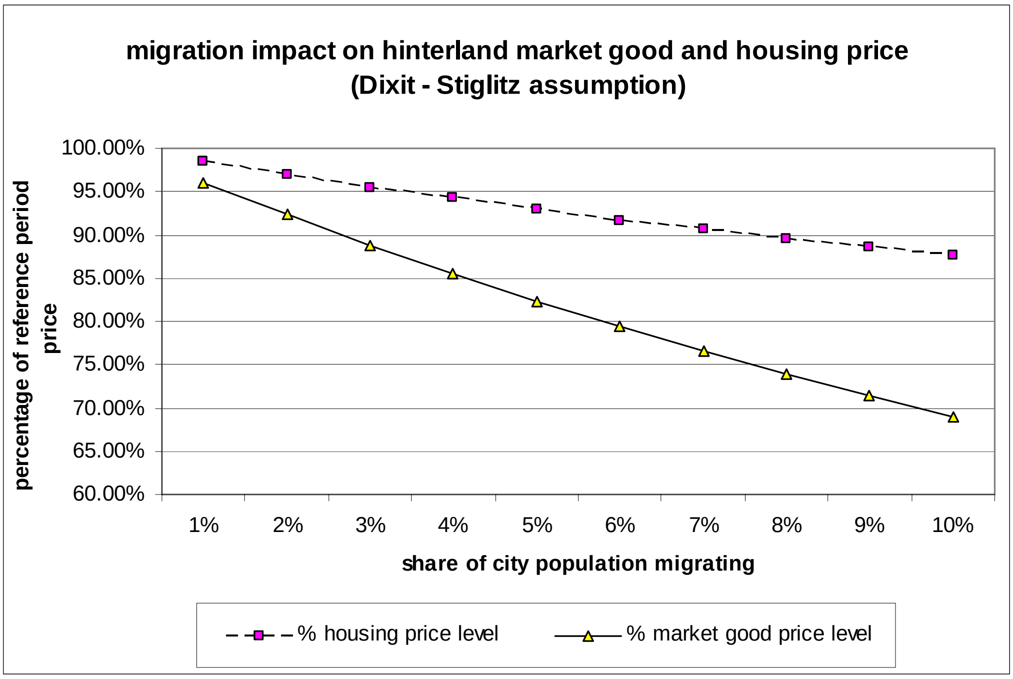

Figure 3: Migration of City Inhabitants to the Economic Sphere Hinterland – Impact on Hinterland Market Good and Housing Price under Dixit-Stiglitz-Production Assumption

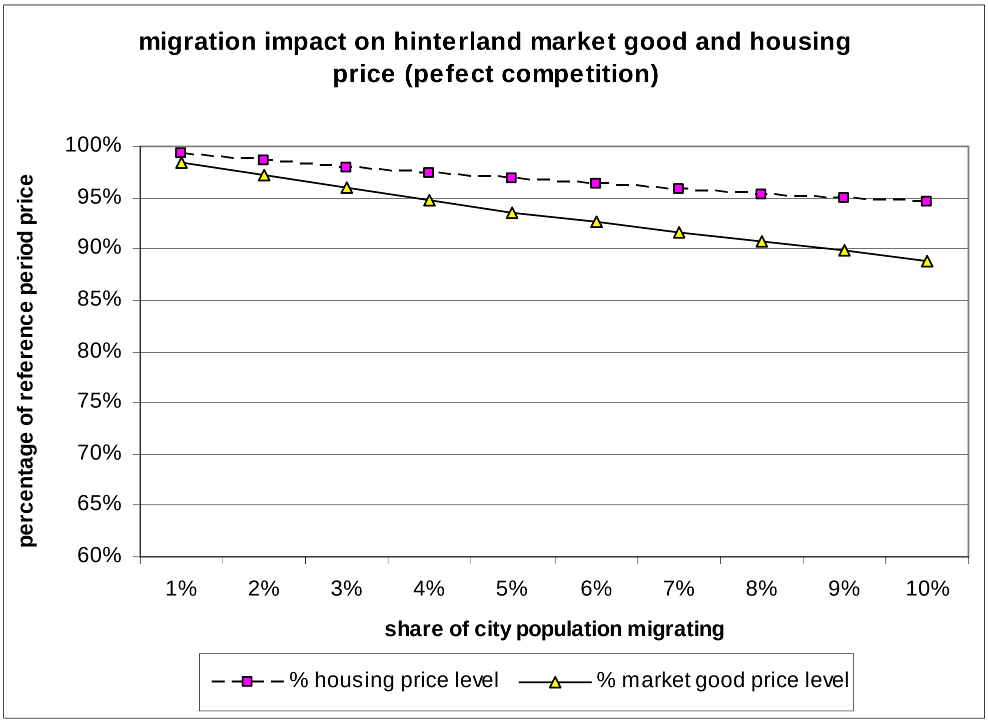

Figure 4: Migration of City Inhabitants to the Economic Sphere Hinterland – Impact on Hinterland Market Good and Housing Price under Perfect Competition Assumption

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 paper.

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