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Spatial effects of Transeuropean Networks: preliminary results from a spatial computable general equilibrium analysis

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Spatial effects of Transeuropean Networks: preliminary results from a spatial computable general equilibrium analysis

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Abstract

This paper quantifies regional welfare effects of new transport links, which are going to be established in the framework of Trans-European Networks (TEN). It is confined to the regional welfare effects resulting from the use of the new links for trading goods and services. Effects from the construction phase, from financing and maintenance are not considered. Use of the links for other than trade purposes, such as commuting, tourism, leisure trips et cetera are not considered either. Welfare implications of new transport links are quantified by simulating effects of transport distance reductions in a spatial computable general equilibrium model. We model a static equilibrium for two sectors (local goods and tradables) and many regions. Firms in the tradables sector supply a large number of symmetrical product varieties under monopolistic competition. Trade between regions is costly, with costs depending on transport distances through a given transport network as well as on national trade impediments. The paper explains the formal structure of the model, the calibration procedure, and the data basis for implementing the model to a system of more than 800 regions covering the entire European space. Numerical results for several scenarios regarding regarding the establishment of TEN links are presented.

Keywords: transport infrastructure, computable equilibrium, spatial equilibrium, monopolistic competition.

1 Introduction

Ever since European integration started with the Rome Treaty, development of transport infrastructure bringing regions and countries closer together and offering the capacity for a rapidly increasing level of interregional flows has been a key issue on the community's

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agenda. The Maastricht treaty took a further step by formally installing the responsibility on the European level for planning a Transeuropean Network (TEN) for all modes of transport, communication and energy. Its aim is to support the completion of the internal market by emphasising the needs for international links within today's EU as well as the connections to central and eastern Europe. While the EU level shall set the guidelines for developing the European infrastructure, the subsidiarity principle is still to hold, levying the burden of finance for the projects on the national level, with minor exceptions cencerning the use of structural funds.

Though extensive research is already under way for assessing the infrastructural needs as well as costs and benefits of individual projects, very little is still known about the spatial distribution of the benefits. Traditional approaches to cost benefit and regional impact analysis are not really capable of taking account of the complex mechanisms by which transport cost changes affect the spatial allocation. This holds true already in a static framework, not to speak about the even more complex channels through which the transport system affects economic dynamics. The critical issue is to assign the benefits from using the transport links to regions. Assigning costs and benefits from construction and maintenance to regions is less of a problem, and traditional techniques like multiplier analysis are acceptable. Assessing the benefits from newly installed capacities and answering to the question where they accrue, however, is much more difficult. Four types of methods are used in practice.

The *first* is to assign benefits as measured by direct cost reductions or consumer surpluses gained on the links under study, to the place of investment itself. This method is applied in the official German manual for transport infrastructure evaluation [6], for example. Its shortcomings are so obvious, that a further discussion is not worth the effort.

The *second* method is to measure benefits by estimating rates of return on infrastructure investments in a production function approach, using cross section, time series, or panel data. Intricate econometric problems have to be solved for this type of analysis which, however, are not the subject of this paper. As far as the regional distribution of effects is concerned, however, the shortcomings of this approach are similar to those of the first one. While accessibility changes may affect many regions — possibly in a different way, depending on the pattern of interregional flows — all output effects are exclusively attributed to the region, where the investment is done.

The *third* method is to distribute benefits — however measured — to regions according accessibility changes, which are quantified by a potential type or any other kind of indicator. This is more convincing than the first two approaches, but still lacks a theoretical foundation. The way how accessibility changes are measured as well as the way how they are linked to regional benefits are arbitrary.

The *fourth* method is to establish an interregional demand driven input-output model with trade coefficients depending on transportation costs. Though this seems attractive because a lot of sectoral detail can be taken account of, it gives a theoretically unconvincing picture of the effects of changing transport costs. It is restricted to backward linkage effects. In this type of approach, it is difficult to simulate the cost effects and price effects stemming from a reduction in transport costs. To extend the picture to forward linkages generated by increased product diversity brought about by integrating the local markets is even more difficult.

The up to date alternative to the before mentioned approaches is to set up a multiregional computable general equilibrium, in which transport costs explicitly appear as an impediment to interregional trade. This is what we are going to do in this paper. It confines to the regional welfare effects resulting from the use of the new links for trading goods and services. Effects from the construction phase, from financing and maintenance are not considered. Use of the links for other than trade purposes, such as commuting, tourism, leisure trips et cetera are not considered either. Welfare implications of new transport links are quantified by simulating effects of transport distance reductions in a spatial computable general equilibrium model. We model a static equilibrium for two sectors (local goods and tradables) and many regions. Firms in the tradables sector supply a large number of symmetrical product varieties under monopolistic competition. Trade between regions is costly, with costs depending on transport distances through a given transport network as well as on national trade impediments.

Section 2 of the paper explains the formal structure of the model by describing the household sector, the production sector and the specification of transport cost and by derivating the equilibrium equations for the entire model. This section largely coincides with [2], where the same type of model is applied to estimating welfare effects of economic integration. Section 3 shows how the system is empirically implemented, section 4 presents comparative static simulations, and a concluding section gives some qualifications and hints to further research.

2 A spatial computable general equilibrium model

2.1 Overview

Our model is a static equilibrium model for a closed system of regions. The world is subdivided into 805 regions, of which 800 cover Europe, including the Asian parts of Russia and Turkey (see table 1). In addition, there are 5 non-European regions covering the rest of the world, namely North America, Latin America, Africa, Middle East, and Asia plus Australia and New Zealand. Each region shelters a set of households owning a bundle of immobile production factors used by regional firms for producing two kinds of goods, non-tradable local goods and tradables. Beyond factor services, firms also use local goods and tradables as inputs. The firms in a region buy local goods from each other, while tradables are bought everywhere in the world, including the own region. Produced tradables are sold everywhere in the world, including the own region. Free entry drives profits to zero; hence, the firms' receipts for sold local goods and tradables equal their expenditures for factor services and intermediate local and tradable goods.

Regional final demand, including investment and public sector demand, is modelled as expenditure of utility maximising regional households, who spend their total disposable income in the respective period. Disposable income stems from returns on regional production factors, which, by assumption, are exclusively owned by regional households, and a net transfer payment from the rest of the world. This transfer income can be positive or negative, depending on whether the region has a trade deficit or surplus. Transfers are held constant in our simulations. Introducing fixed interregional income transfers is a simplified way to get rid of a detailed modelling of factor income flows, and of all kinds

country	regions	correspondence to	mean population
Germany	99	Raumordnungsregionen	826960
France	89	Départements (NUTS 3)	652360
Italy	95	Provincie (NUTS 3)	602147
Netherlands	12	Provincies (NUTS 2)	1288333
Belgium	9	Provinces (NUTS 2)	1127333
Luxemburg	1		410000
United Kingdom	69	Counties/Local Auth. Reg. (NUTS 3)	848304
Ireland	8	Regional Auth. Reg. (NUTS 3)	448250
Danmark	14	Amter (NUTS 3)	372857
Greece	13	Development Regions (NUTS 2)	805154
Spain	52	Provincias (NUTS 3)	753827
Portugal	5	Comissaoes de coord. reg. (NUTS 2)	1985400
Finland	19	Maakunnat (NUTS 3)	268947
Norway	19	Fylker	229158
Sweden	24	Län (NUTS 3)	367917
Austria	9	Bundesländer (NUTS 2)	894889
Switzerland	26	Kantone	270731
Poland	49	Województwa	788000
Czech Republic	7	Kraje	1476000
Slovak Republic	4	Kraje	1342250
Hungaria	20	Megyék	511450
Romania	41	Regiuni	553610
Bulgaria	9	Okrâsi	934333
Slovenia	1		1992000
Croatia	1		4778000
Bosn. and Herzeg.	1		4383000
Yugoslavia	1		10518000
Macedonia	1		2119000
Albania	1		3260000
Estonia	1		1487000
Latvia	1		2516000
Lithuania	1		3715000
Russia	56	(different territorial units)	2646339
Belarus	6	Oblasti	1723167
Ukraine	25	Oblasti	2062000
Moldova	1		4344000
Georgia	1		5400000
Azerbaijan	1		7510000
Armenia	1		3760000
Turkey	5	Iller	12211600
Cyprus	1		734000
Malta	1		372000
Europe	800		1008934

Table 1: Delineation of regions

of interregional flows of privet and public funds. Households' expenditures for local and tradable goods equal their factor returns plus net transfers received. Thus, regional accounts of our system can be represented by a graph (see figure 1) with two nodes, firms

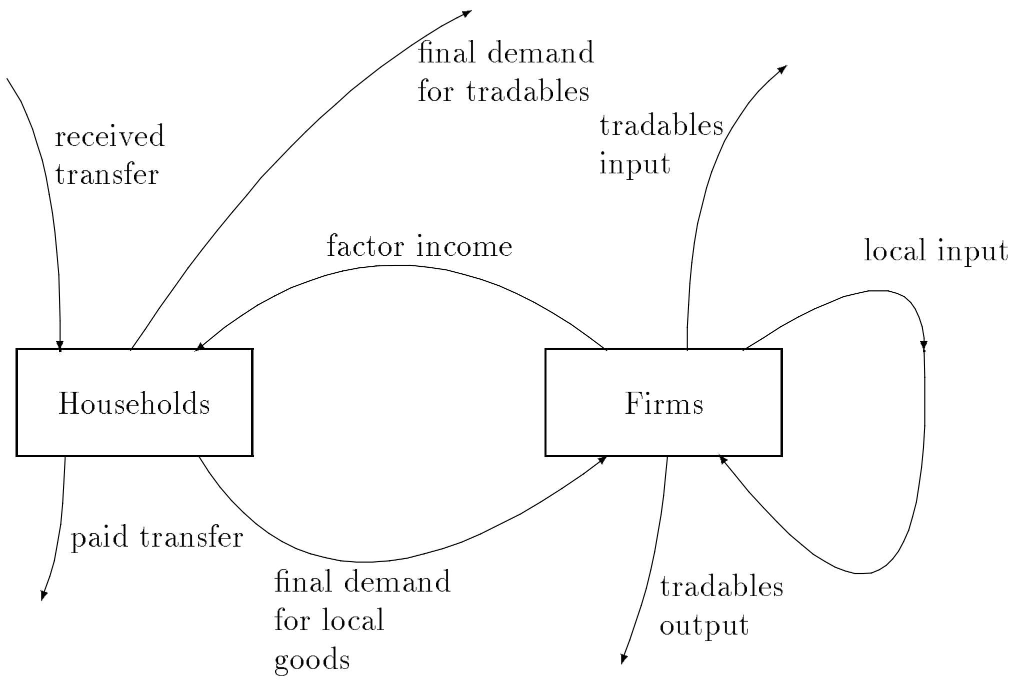

Figure 1: Regional accounts

and households. Arcs represent payments. Flows entering a node and flows leaving it add up to the same amount.

Factor service is modelled as the service of a single homogenous factor. The fixed factor supply is always fully employed due to the assumption of perfect price flexibility. The reader should be aware that we equivalently could regard factor supply as a vector of arbitrary length representing labour with different qualifications, capital, land etc. The factor price has then to be interpreted as a price for a composite factor service. The important assumption is that we don't have different sectors with different factor intensities, such that relative factor prices are not going to play a role in the solution.

Similarly, local goods are modelled as a single homogeneous good, though one equivalently may regard them as a given set of goods, such that the good's price is to be interpreted as the price of a composite local good. The market for tradables, however, is modelled in a fundamentally different way. Tradables consist of a large number of close but imperfect substitutes. The set of goods is not fixed exogenously, but it is determined in the equilibrium solution and varies with changing exogenous variables. Different goods stem from producers in different regions. Therefore relative prices of tradables do play a role. Changes of exogenous variables make these relative prices change and induce substitution effects.

Households act as price taking utility maximisers. They have a two-level nested CD-CES utility function. The lower CES nest represents their preference for consuming a diversified bundle of tradables. Firms maximise profits, taking prices for inputs as well as for local goods sold to households and other firms as given. The production function is a linear-homogenous two-level nested CD-CES function as well. The lower CES nest makes a composite out of the bundle of tradables. For the sake of simplicity it is assumed to be the same as the lower CES nest in the households' utility function. Due to linear-homogeneity the price of a local good equals its unit cost obtained from cost minimisation under given input prices.

Instead of directly selling their output as a local good, firms have a second option. They can take it as the only input required to produce tradables. The respective technology is increasing returns, with a decreasing ratio of average to marginal input. Firms are free to compete in the market for a tradable good which already exists, or to sell a new one not yet in the market. The latter turns out to be always the better choice. Hence, each good is monopolistically supplied by only one firm, which is aware of the finite price elasticity of demand for the good. The firm therefore sets the price according to the rules of monopolistic mark-up pricing. This choice, of course, is only made if the firm at least breaks even with this strategy. If it comes out with a positive profit, however, new firms are attracted opening new markets, such that demand for each single good declines until profits are driven back to zero. This is the well-known mechanism of CHAMBERLINian monopolistic competition determining the number of goods in the market as well as the quantity of each single good. Due to free entry the price of a tradable good just equals its average unit cost.

Certainly, assuming local markets to be perfectly competitive lacks empirical plausibility. Local goods producers may in fact exert some monopoly power, local goods might be diversified, just like tradables, et cetera. The reason why this assumption is nevertheless preferred is that this is the simplest way to get rid of the local sector which only plays a secondary role in an analysis focusing on interregional trade. Another choice without major technical problems would be to assume monopolistic competition for the local sector as well. This, however, is not recommended, because it introduces a size-of-region effect. Large regions in our system (like the Asian part of Russia, for example) would support a high diversity of local goods, generating an unrealistic low price of the composite local good, given the factor price and technology in the region.

The model gets a spatial dimension by the assumption that delivering tradables from one region to the other is costly. Two kinds of costs are involved, costs for overcoming geographic distance and costs representing tariff and non-tariff barriers in border crossing trade. Though tariffs may generate an income for the public sector, we completely neglect this income and deal with tariffs in the same way as with non-tariff barriers and costs resulting from geographic distance. They are all regarded as true costs spent for using up resources.

We assume that a certain amount of the tradable goods themselves is required for performing the transport service. This specification resembles the "iceberg-assumption" known from the literature [22], but our approach is in fact different. While according to the iceberg assumption, a certain share of the specific transported good itself is used up during transportation, in our approach a composite of all tradables is used up for transporting each single tradable good. The formal solution turns out to be particularly easily handable with this assumption. When we talk about "transport" and "transport cost" we have a broad concept of transport cost in mind, including costs of communication between producer and customer, travel costs in maintenance service and all costs usually covered by the notion of non-tariff barriers.

Summarising the basic philosophy of our approach, it obviously strongly relies on neoclassical ideas, even though it departs from the traditional computable general equilibrium approach by allowing for imperfect markets. In other respects, however, the strictness of neoclassical assumptions is retained: firms and households act perfectly rationally, prices are flexible, and markets are cleared, including labour markets. Though these assumptions are often criticised for contrasting with reality, there is no better choice. Even if households don't maximise utility subject to a budget constrained, it is not questioned that they react on prices and that the budget constraint must eventually hold. Neoclassical demand theory is just an easy way to represent these reactions consistently in a formal way. Similar comments apply to modelling reactions of firms.

The issue is not whether the model is close to reality — no model will ever be so. The issue is which is the best way to represent fundamental mechanisms detected by theory in a quantitative approach. In this context, marginal returns of making a model more complicated have to be traded off against marginal costs. More realistic models like large scale econometric or input-output models with many sectors might offer a more realistic description, but are much more expensive and offer less possibilities for studying the interaction between prices and quantities in a theoretically consistent framework.

2.2 Firms

We now describe the behaviour of firms in formal terms. The firms' technology for producing local goods (which are either sold or transformed into tradables) is a linear-homogeneous two-level nested CD-CES function, as illustrated by the substitution tree in figure 2.

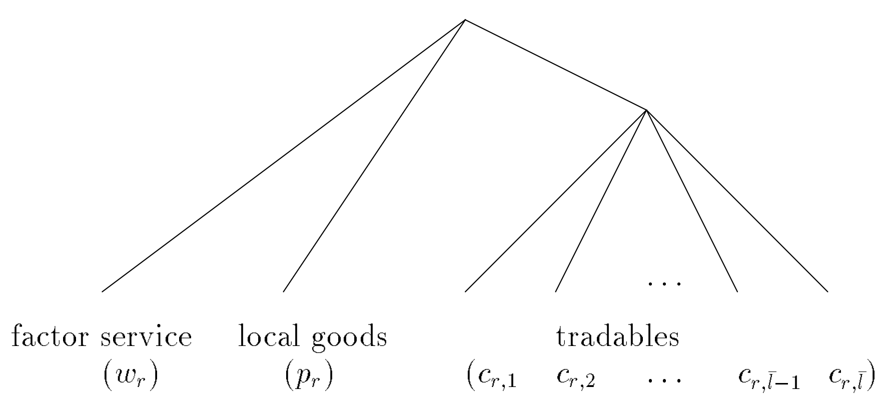

Figure 2: Substitution tree of firms

The lower CES nest aggregates the $\bar{l}$ tradables with prices $c_{r,1}, \ldots, c_{r,\bar{l}}$ to a composite tradable. As we have no specific information about specific tradables, we let all tradables enter symmetrically into the CES function. Hence, the unit minimal cost of a composite tradable, denoted by q_r, is given by

$$q_r = \phi \left(\sum_{i=1}^{\bar{l}} c_{r,i}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}, \tag{1}$$

with σ denoting the elasticity of substitution between different tradable goods. ϕ is an arbitrary scaling parameter fixing the unit of measurement for the composite tradable.

The upper CD nest transforms the factor service, local goods and the composite tradable into the output. Let α, β, γ, all positive, denote the constant cost shares of factor service, local goods, composite tradables, respectively, with $\alpha + \beta + \gamma = 1$. We have no information for calibrating region specific shares. Hence, the same shares shall apply to all regions. The output price p_r, which equals the minimal unit cost, is then

$$p_r = \frac{1}{\mu_r} w_r^\alpha p_r^\beta q_r^\gamma.$$

w_r is the price of the regional factor service, μ_r is the level of regional productivity. Introducing new parameters

$$\begin{aligned} \eta &= \frac{\alpha}{\alpha + \gamma} \\ \nu_r &= \mu_r^{-1/(\alpha+\gamma)}, \end{aligned} \tag{2}$$

and solving for p_r yields

$$p_r = \nu_r w_r^\eta q_r^{1-\eta}. \tag{3}$$

Now we have to determine the number of tradables produced in the regions as well as the price and the quantity of each good produced.[1] Remember that the local good is the only input into the production of tradables. This seems to be restrictive an assumption, but in fact it is not. It is just equivalent to assuming that tradables are produced by a composite of factor services, local goods and tradables, which are composed by a CD function with cost shares α, β, γ, the same as the shares in local goods production.

Let x and $I(x)$ denote output and input of a specific tradable good, respectively. Dealing with all tradable goods symmetrically implies that the technology and, hence, the function $I(x)$ is identical for all tradable goods. If the number of tradables in the economy is large, and if the CES function in (1) also applies to households, then the price elasticity of demand for a single type of tradables can be shown to be $-\sigma$. Hence, by the Amoroso-Robinson relation, a profit maximising firm will set a price equal to marginal cost times the mark-up factor $\sigma/(\sigma - 1)$. We assume $\sigma > 1$, such that $\sigma/(\sigma - 1) > 1$. At the same time, the price equals average costs, due to free entry. This yields the equation

$$\frac{I(x)}{x} p_r = \frac{\sigma}{\sigma - 1} \frac{\mathrm{d}I(x)}{\mathrm{d}x} p_r.$$

[1] The formal structure applied in the following to modelling monopolistic competition is due to Dixit and Stiglitz [8] and has extensively been used in theoretical economic geography by Krugman and co-authors [16, 17, 18, 19, 20, 25, 10]. Its use in trade modelling originates from Ethier [9]. The applicability to spatial computable general equilibrium modelling has been shown in [1]. For a review of other fields of application see [21].

Therefore, solving

$$\frac{\mathrm{d}I(x)}{\mathrm{d}x}\frac{x}{I(x)} = \frac{\sigma - 1}{\sigma}$$

for x yields the profit maximising quantity x^* as a function of σ. As σ is a parameter, x^* and $I(x^*)$ are parameters themselves, identical for all r and not depending in any way on the equilibrium solution. Any variation of tradable output is a variation in the number of goods produced, while the quantity of each good remains unchanged.

Let l_r denote the number of tradable goods produced in region r. Then the output value of tradables in r, S_r, is

$$S_r = l_r I(x^*) p_r. \tag{4}$$

Thus, l_r is simply proportional to the real output of tradables, S_r/p_r. With a look at the accounting system in figure 1, S_r is easily related to regional income. Let Y_r denote regional factor income (i.e. the regional GDP) and let N_r be the value of final demand, which equals Y_r plus received net transfers. Furthermore, remember that households are assumed to have CD preferences w.r.t. locals and tradables. Let ϵ denote the constant share of local goods in consumption. Then gross regional output P_r equals Y_r/α, the value of final demand for local goods is ϵN_r, and the value of local inputs is βP_r. Thus we obtain

$$\begin{aligned} S_r &= P_r - \beta P_r - \epsilon N_r \\ &= \frac{1-\beta}{\alpha} Y_r - \epsilon N_r \\ &= \frac{1}{\eta} Y_r - \epsilon N_r. \end{aligned} \tag{5}$$

Y_r equals the fixed amount of factors, F_r, times factor price, w_r, which, by equation (3), can be related to p_r and q_r. Thus we obtain

$$Y_r = F_r \nu_r^{-\frac{1}{\eta}} p_r^{\frac{1}{\eta}} q_r^{1-\frac{1}{\eta}}. \tag{6}$$

If there were no transfers, l_r would be a constant-elasticity function of the price ratio p_r/q_r. The elasticity of l_r w.r.t. p_r/q_r would be $(1/\eta - 1) > 0$.

2.3 Households

As already noticed, households maximise a nested CD-CES utility function subject to the constraint, that expenditures for tradables and local goods equal disposable income, which is factor income plus received net transfer. The lower CES nest is the same as the one for firms. It aggregates the large number of tradables to a single composite tradable with price q_r (see figure 3). The upper CD function translates the quantities of the local good and the composite tradable into a utility, with expenditure shares ϵ and $(1-\epsilon)$ for locals and tradables, respectively.

In the comparative static analysis we want to measure welfare changes for households by Hicksian measures of variation. There are two standard measures of relative welfare change, the relative equivalent variation and the relative compensating variation. The

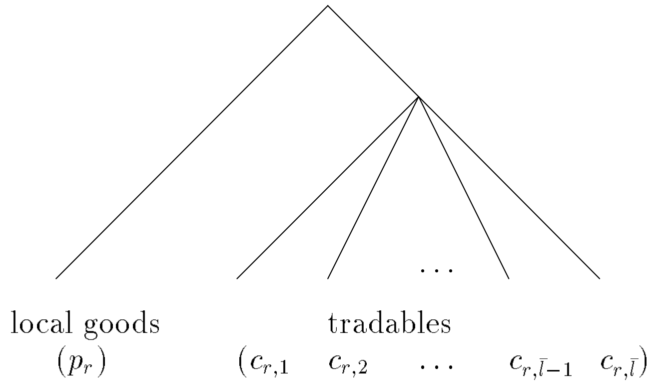

Figure 3: Substitution tree of households

former measures the relative ex-ante income change bringing about ex-post utility, while the former measures minus the relative ex-post income change bringing about ex-ante utility. For small changes both measures approximately equal the change of log real income, defined as

$$\Delta R_r = \log(N_r^a/N_r^b) - \epsilon \log(p_r^a/p_r^b) - (1-\epsilon)\log(q_r^a/q_r^b). \tag{7}$$

(see [2] for details). ΔR_r is the measure to be used in evaluating welfare effects of new transport links.

2.4 Transport

Now we show formally, how transport costs are introduced. Remember that the term "transport cost" is used as a short cut for any kind of cost related to interregional trade. Usually trade costs are assumed to depend on the quantity of goods traded. Some costs of interregional transfer, especially costs of information exchange and insurance costs, depend on the value rather than the quantity traded, however. Letting trading costs depend on the value of trade makes the model much simpler, and we therefore prefer this assumption. Then, if subscript i refers to a commodity stemming from region s and used in region r, the price in region r, including transport cost, is

$$c_{r,i} = \frac{I(x^*)}{x^*} p_s \tau_{sr}. \tag{8}$$

$\tau_{sr} \geq 1$ is the mark-up factor representing trade costs. τ_{sr} is equal to one, if trade costs are zero.

We introduce two kinds of trade costs: costs related to geographic distance, and costs for overcoming impediments to international trade. If region r belongs to country k and region s to country l, then the mark-up factor is

$$\tau_{rs} = f(g_{rs})\delta_{kl}. \tag{9}$$

g_{rs} denotes transport distance. f is the transport cost function with $f(0) = 1$. A plausible assumption is that f increases with increasing distance, but at a diminishing rate. An obvious specification would be

$$\tilde{f}(g_{rs}) = 1 + \zeta(g_{rs})^\omega,$$

with parameters $\zeta > 0$ and $0 < \omega < 1$. The problem with this specification, however, is the following. The parameters of the transport cost function will be estimated using observations on international trade. It turns out that the cost function appears in a gravity formula for interregional trade in the equilibrium solution. The gravity equation has the distance function $\left[\tilde{f}(g_{rs})\right]^{-\sigma}$, which has to be fitted to observed trade patterns. Unfortunately it is impossible to estimate the three parameters σ, ζ, ω, appearing in this function, because the effects of two of them, σ and ζ, are not separable from one another. Technically speaking, the level sets of the likelihood function are close to degeneration in (σ, ζ)-space. The reason is easy to see. If $\tilde{f}$ is sufficiently close to one (in the order 1.2, say), then

$$\tilde{f}(g_{rs}) \approx \exp\left[\zeta(g_{rs})^{\omega}\right]$$

and

$$\left[\tilde{f}(g_{rs})\right]^{-\sigma} \approx \exp\left[-\sigma\zeta(g_{rs})^{\omega}\right].$$

Here ζ and σ merge to a single parameter $\sigma\zeta$. Hence, we prefer the specification

$$f(g_{rs}) = \exp\left[\zeta(g_{rs})^{\omega})\right], \tag{10}$$

implying that the gravity distance function becomes exactly

$$\left[f(g_{rs})\right]^{-\sigma} = \exp\left[-\sigma\zeta(g_{rs})^{\omega}\right].$$

ω and the merged parameter $\sigma\zeta$ are now well estimable, and we need other sources of information to separate the estimates for ζ and σ. See section 3.1 for more on this.

f is not globally concave. It's second derivative is negative for small g_{rs}, but changes sign for a sufficiently large g_{rs}. For the specific parameters we are working with, however, f remains concave even for the longest distance in our system, and f and $\tilde{f}$ do not differ much.

$(\delta_{kl} - 1) \geq 0$ is a tariff equivalent of all costs stemming from the fact, that a good has to be exported from country k to country l. These include tariffs, but also, and more important, all costs stemming from non-tariff barriers, like costs due to language differences, costs for bureaucratic impediments, time costs spent at border controls and so forth. $\delta_{kl} = 1$ for $k = l$, of course, but it is suggested to be strictly larger than unity for $k \neq l$, even if countries k and l are both members of the EU (for a recent survey on international trade barriers see [13]).

In a general equilibrium one must specify, where trading costs are going. Any expenditure must appear as a proceed somewhere in the system. For the sake of simplicity, we assume that trading costs for goods arriving in s are paid to a "transport service", doing the job by consuming composite tradables, composed in the same way as the composite tradables consumed by households and firms. The transport service makes no profit. Hence, the value of goods going into the transport service equals transport cost. As a consequence, the value of tradables used for intermediate and final consumption (excluding transport), valued at c.i.f. prices, equals the value of all tradables (including those going into the transport service), valued at mill prices (see figure 4 as an illustration). Remember that we neglect tariff receipts, for the sake of simplicity.

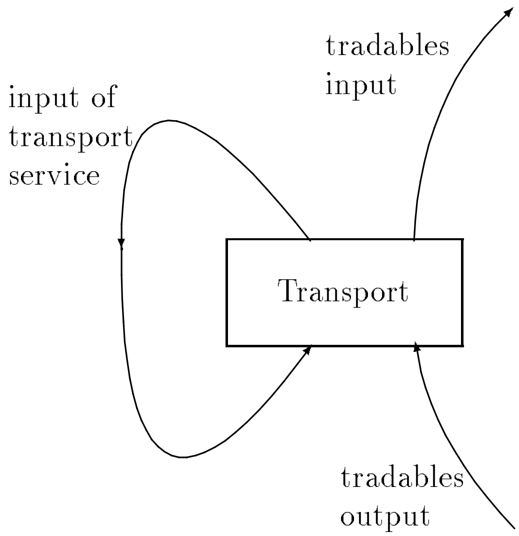

Figure 4: Accounts of the transport service

2.5 Equilibrium

Now the model is completely specified, and we are ready to find the equilibrium solution. The core of the model turns out to be a system of equations simultaneously determining interregional trade flows and the prices p_r and q_r for all regions. For a system of n regions there are $n(n+6)$ equations and the same number of unknowns, namely n prices p_r, n prices q_r, n values of tradables supply S_r, n values of tradables demand D_s (not yet introduced), n factor incomes Y_r, n disposable incomes N_r, and n^2 trade flows. The corresponding equations are n equilibrium conditions, n price equations derived from (1), $2n$ equations for S_r and D_r, derived from the accounting system, n equations for Y_r (see (6)), n equations for N_r resulting from an assumption about international transfers, and n^2 equations for trade flows derived from the demand behaviour implied by the CES form (1). The equilibrium conditions require equality between tradables supply in a region and demand for that tradables from the whole world. This equality must hold for each region. Precisely speaking there are $n(n+6)-1$ independent equations and the same number of unknowns; one equilibrium condition is redundant due to WALRAS' Law, and one price can arbitrarily be fixed as a numeraire.

We start with the equation for q_r. Have a look at equation (1) and note that for all goods i stemming from some region s the prices $c_{r,i}$ are the same, and are given by (8). As l_s is the number of goods produced in s, these prices appear l_s times in the sum in equation (1). Hence, (1) becomes

$$q_r = \phi \left[\sum_s l_s \left(\frac{I(x^*)}{x^*} p_s \tau_{sr} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} .$$

Now take equation (4) for region s, solve for l_s, insert into the last equation and gather all constants in a new parameter ψ. This yields

$$q_r = \psi \left[\sum_s S_s p_s^{-\sigma} \tau_{sr}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}. \tag{11}$$

Next, how S_r is obtained from the accounting system is already shown in equation (5) and repeated here for convenience:

$$S_r = \frac{1}{\eta} Y_r - \epsilon N_r. \tag{12}$$

A look at figure 1 shows that D_r, the value of households' and producing firms' demand for tradables (valued inclusive of transport cost), is (using the definition of η in (2))

$$\begin{aligned} D_r &= (1-\epsilon)N_r + \gamma P_r \\ &= (1-\epsilon)N_r + \frac{\gamma}{\alpha} Y_r \\ &= (1-\epsilon)N_r + (1/\eta - 1)Y_r. \end{aligned} \tag{13}$$

If there were no transfers, we would have $N_r = Y_r$, and therefore $S_r = D_r = (1/\eta - \epsilon)Y_r$. This would also imply that for each country trade must be balanced. But in reality it is not, for several reasons; there is trade in services not included in the trade data, and there are international transfers, capital flows and flows of factor incomes. As we want our equilibrium to reproduce observed trade flows, we have to account for these facts somehow. We take the most easy way assuming that surplus countries pay a transfer equal to the trade surplus to deficit countries, such that each deficit country receives an amount equal to its trade deficit. Transfers are distributed among regions in proportion to their GDPs.

Transfers are held constant in real terms in the comparative static simulations. Thus we have an equation for N_r,

$$N_r = Y_r + G_r, \tag{14}$$

with G_r denoting fixed net transfers into region r. For defining transfers in real terms we need a price index. The natural regional price index corresponding to the CD utility of households is $\bar{p}_r = p_r^\epsilon q_r^{1-\epsilon}$. As an overall price index we use the weighted average of $\bar{p}_r$ over all regions, the weights being the base year regional factor incomes. Fixing transfers in real terms is the same as fixing them in nominal terms and scaling prices such that the price index remains unchanged. This is how we proceed.

Next, Y_r has been derived as a function of prices already in equation (6), which we repeat for convenience:

$$Y_r = F_r \nu_r^{-\frac{1}{\eta}} p_r^{\frac{1}{\eta}} q_r^{1-\frac{1}{\eta}}. \tag{15}$$

Equations (12), (13), (14), and (15) give us S_r and D_r as functions of p_r and q_r. Note that the functions assigning the values of supply and demand to prices are linear-homogeneous, as they should be. Multiplying all prices by a common factor multiplies values by the same factor, and therefore leaves real terms unchanged.

Deriving the equations for trade flows is more complicated. Let $d_{r,i}$ be the demand for good i (offered in some region s) per unit of composite good bought in r. $d_{r,i}$ is in real, not in value terms. According to SHEPHARD's lemma [24, p. 74] $d_{r,i}$ is the derivative of the minimal unit cost w.r.t. price. Hence, by equation (1),

$$d_{r,i} = \phi^{1-\sigma}\left(\frac{q_r}{c_{r,i}}\right)^{\sigma}.$$

Let T_r be total demand in r for tradables in real terms (including demand for doing the transport service). Now calculate the value of trade from s to r, t_{sr}, valued at mill prices:

$$\begin{aligned} t_{sr} &= p_s l_s d_{r,i} T_r \\ &= S_s (p_s \tau_{sr})^{-\sigma} m_r. \end{aligned}$$

All variables with index r or without an index are gathered in m_r. For the last step use has been made of the fact that $l_s p_s$ is proportional to S_s according to (4), and $c_{r,i}$ has been substituted according to equation (8). The unknown m_r is easily found. A look at figure 4 makes obvious that the total value of flows to region r, valued at mill prices, equals the value of demand for tradables in r, valued at prices including transport cost but excluding demand for the transport service. Hence, the equality $\sum_s t_{sr} = D_r$ must hold. This gives our final equation

$$t_{sr} = \frac{S_s(p_s\tau_{sr})^{-\sigma}}{\sum_s S_s(p_s\tau_{sr})^{-\sigma}} D_r. \tag{16}$$

Finally, the equilibrium condition, written in value terms, simply requires equality of supply of tradables and demand for tradables stemming from a region r, both valued at mill prices:

$$S_r = \sum_s t_{rs}. \tag{17}$$

This completes our system, consisting of equations (11), (12), (13), (14), (15), (16), and (17) for determining the endogenous variables q_r, S_r, D_r, N_r, Y_r, t_{sr}, and p_r. Exogenous variables and parameters are F_r, G_r, τ_{sr}, ν_r, σ, η, ϵ, and ψ. As the scaling parameter ϕ is arbitrary, the same holds true for ψ. The parameter ψ just scales q_r for the base year by fixing units of measurement for the composite tradable.

3 Empirical Implementation

3.1 Calibration

Calibrating the model means to assign concrete numbers to each parameter and exogenous variable such that the equilibrium solution exactly reproduces the observed data or resembles them as close as possible. The list of exogenous variables and parameters has been given in the last paragraph of the preceding section.

We start with σ and τ_{sr}. According to (9) and (10), τ_{sr} depends on transport distance g_{sr} and the parameters ζ, ω and δ_{lk}. The measurement of transport distance is explained in subsection 3.2. In order to see how the other parameters appear in observed trade flows, insert f from (10) into (9) and τ_{sr} from (9) into equation (16) describing trade flows. Equation (16) is then rewritten in gravity form,

$$t_{sr} = A_s B_r \exp\left[-\sigma\zeta(g_{sr})^{\omega}\right] \delta_{lk}^{-\sigma}, \tag{18}$$

with

$$A_s = S_s p_s^{-\sigma}, \tag{19}$$

$$B_r = \frac{D_r}{\sum_s S_s (p_s \tau_{sr})^{-\sigma}}. \tag{20}$$

In fact we do not have sufficient observation on interregional trade for directly estimating equation (18). But let us assume for a moment we had such data. How to estimate (18)? First, we have to specify δ_{lk}. Let $\log \delta_{lk}$ be linearly dependent on a set of explaining variables gathered in a vector z_{lk}, that means $\log \delta_{lk} = \pi z_{lk}$ with parameter vector π.[2] Inserting this into (18) and expanding yields

$$\begin{aligned} t_{sr} &= A_s B_r \exp\left[-\sigma\zeta\omega\left(\frac{(g_{sr})^{\omega}-1}{\omega}\right) - \sigma\zeta + \pi z_{lk}\right] \\ &= \exp\left[a_s + b_r - \rho g_{sr}^{(\omega)} + \pi z_{lk}\right] \end{aligned} \tag{21}$$

with $a_s = \log A_s$, $b_r = \log B_r - \sigma\zeta$, and $\rho = \sigma\zeta\omega$. $(g_{sr})^{(\omega)}$ denotes the Box-Cox-Transform,

$$(g_{sr})^{(\omega)} = \frac{(g_{sr})^{\omega}-1}{\omega}.$$

.

According to (21) the logs of observed flows are linear in a set of explaining variables, among them row and column dummies (with parameters a_s and b_r) and one Box-Cox-transformed variable. Note that, with $\omega = 0$ and $\omega = 1$ we obtain the power form and the exponential form of the distance function as special cases. According to our assumptions, however, we should obtain $0 < \omega < 1$. Now we can add a random disturbance to the RHS of (21) and fit it to the observations by choosing a_s, b_r, ρ, ω and π maximising the likelihood.

As we in fact do not have the required data on a regional scale, we use international trade flows instead, assuming that (21) is also valid for aggregated flows crossing the border. The regression then reads

$$X_{lk} = \exp\left[a_l + b_k - \rho(\bar{g}_{lk})^{(\omega)} + \pi z_{lk}\right] + v_{lk}.$$

X_{lk} is the value of trade form country l to country k. a_l and b_k represent fixed effects of the export and import country, respectively. v_{lk} is a random disturbance. $\bar{g}_{lk}$ is the weighted average distance from regions in country l to regions in country k, with regional GDPs taken as weights. Regarding z_{lk}, we tried dummies for existence/non-existence of a common border (CB), existence/non-existence of a common language (LA), a dummy taking on a value of one if the respective flow crosses the former iron curtain (IC) and

[2] Remember that region r is in country k and region s in country l. $z_{lk} = 0$ for $k = l$.

zero otherwise, and a few more dummies. It turns out that the estimates for ρ and ω are stable. A typical result is given in table 2, obtained from 1995 trade between 37 European countries.[3] The estimate is based on the assumption that the errors are independent and have a variance proportional to the conditional expectation of the trade flows (see [3] for details). The values of the standard errors are WHITE's [28] heteroskedastic-consistent estimates. All parameter estimates are as expected. The former iron curtain roughly

	ω	ρ	IC	LA
Coefficient	0.582	0.021	-0.659	0.696
Standard error	0.056	0.008	0.067	0.072

Table 2: Regression results, international trade

halves, a common language roughly doubles trade, ceteris paribus. Both effects are highly significant. The distance impact is highly significant with the expected sign as well. The BOX-COX-parameter ω is significantly larger than zero and significantly smaller than one, as required. In other words, the power as well as the exponential form of the gravity distance function can be rejected with high certainty.

Now we can take $\hat{\rho}/\hat{\omega} \approx 0.036$ as an estimate of $\sigma\zeta$. Hence, our transport cost function reads

$$f(g_{rs}) = \exp\left(\frac{0.036}{\sigma}\left(g_{rs}\right)^{(\omega)}\right). \tag{22}$$

How to calibrate σ? A limit to the value of σ is given by the fact that, given $f(g_{rs})$ as in (22), the transport cost intensity C, defined as the average ratio of transport costs[4] to the value of trade, is decreasing in σ:

$$C = \frac{\sum_{rs} \hat{t}_{rs}\left[\exp\left(\frac{0.036}{\sigma}\left(g_{rs}\right)^{(\omega)}\right)\right]}{\sum_{rs} \hat{t}_{rs}}.$$

$\hat{t}_{rs}$ is the calibrated trade flow, which only depends on estimates of ρ and ω, not on σ. C is plotted over σ in figure 5.[5]

If we had an independent estimate of the transport cost intensity C, we could infer on σ. Estimates of transport costs and logistic costs, of which transport costs are a subset, can in fact be found in the literature. In a review of WEBER [26] logistic costs as a share of sales value vary between 12 percent and 22 percent, averaged over industries. Mere transport costs, however, are close to 5 percent of sales value. Logistic costs include several components which are not related to distance and therefore should not be included in our estimate. On the other hand, our notion of distance costs includes components like costs of transferring information, which are clearly related to distance and not included in transport cost.

[3] The countries are those in table 1, excluding Bosnia and Herzegovina, Yugoslavia, Cyprus, and Malta.

[4] Here we only talk about transport costs which depend on distance, not those depending on national borders.

[5] Only trade within and between the 37 countries mentioned before is included for calculating C in the figure.

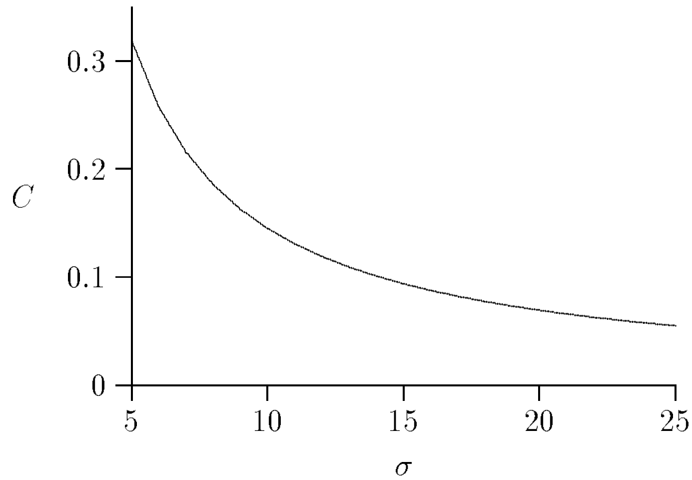

Figure 5: Transport cost intensity (C) and σ

Hence, distance cost intensity is probably in the order of 5 to 10 percent, which corresponds to σ somewhere between 15 and 25.

Another independent information for guessing σ is revealed by empirical studies on monopolistic price mark-ups. Note that, according to the AMOROSO-ROBINSON relation, $\sigma = 20$ would imply that the mark up is 5 % of the price. As an average over industries, this seems rather low, pointing to a guess of σ lower than 20. For now, however, we work with a guess $\sigma = 20$, which we feel to be at the upper bound of a plausible range. A sensitivity analysis shows, that varying σ in plausible ranges has a considerable effect on the level, but a negligible effect on the spatial distribution of estimated welfare effects. Figure 6 plots the total welfare gain of building autobahns through all "Crete-Corridors" (see section 4) over σ. Decreasing σ from 25 to 5 multiplies the welfare effect by a factor of 7.

For calibrating δ_{kl}, the following constrained gravity model is solved for A_s, B_r, and δ_{lk}, given ρ, g_{sr}, S_s, D_r, and X_{kl}:

$$
\begin{aligned}
t_{sr} &= A_s B_r \exp\left[-\rho (g_{sr})^{(\omega)}\right] \delta_{lk}^{-\sigma}, && (23)\\
\sum_r t_{sr} &= S_s, && (24)\\
\sum_s t_{sr} &= D_r, && (25)\\
\sum_{s\in\mathcal{K}, r\in\mathcal{L}} t_{sr} &= X_{kl}, \quad k \neq l. && (26)
\end{aligned}
$$

(23) is the gravity equation (18), (24) is the equilibrium condition (17), and (25) is implied by (16). (26) requires equality between observed trade from country k to country l and the estimate of this flow obtained from the benchmark equilibrium. $\mathcal{K}$ and $\mathcal{L}$ denote the sets of regions making up countries k and l, respectively. S_s and D_r come from equations (12) and (13). Starting from a base year estimate of Y_r for all regions we obtain N_r by

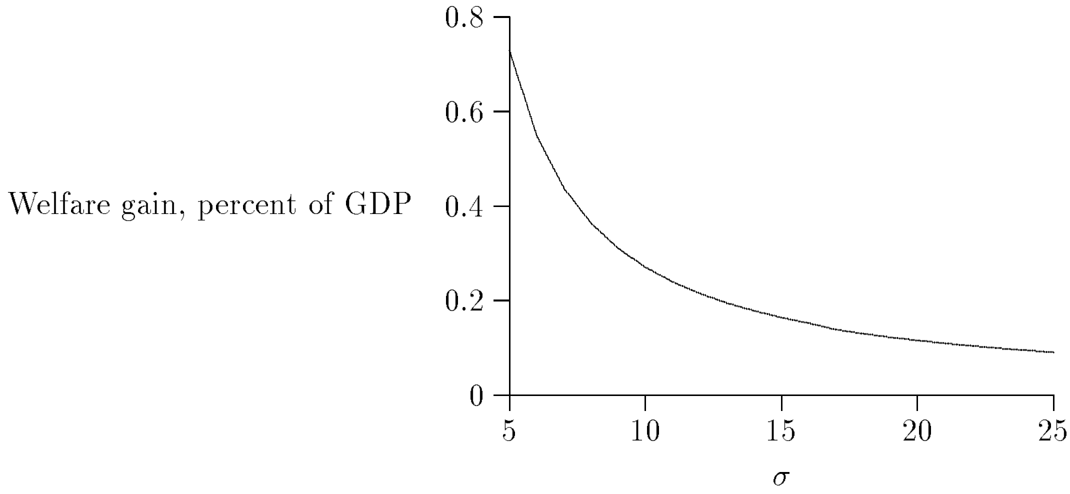

Figure 6: Aggregated welfare effect of "Crete-Corridors" and σ

distributing the observed national trade surplus or deficit among the regions of a nation proportional to Y_r.

There is a unique matrix of flows fulfilling equations (23) to (26). It can be calculated efficiently by iterative scaling [7]. Impediments to intranational trade are set to zero a priori. Unfortunately, however, the estimated impediments δ_{kl} are not unique. One may choose arbitrary numbers $h_k > 0$ for each country and gets a new solution (marked by a $\sim$) as follows ($r \in \mathcal{K}$): $\tilde{A}_r = A_r h_k$, $\tilde{B}_r = B_r / h_k$, $\tilde{\delta}_{kl} = \delta_{kl} h_k^{\sigma}$, and $\tilde{\delta}_{lk} = \delta_{lk} h_k^{-\sigma}$. Though it can be shown that our comparative static results are not affected by this non-uniqueness, we prefer a unique calibration. Therefore we introduce the plausible restriction that impediments are symmetrical, i.e. $\delta_{kl} = \delta_{lk}$. The natural modification of (26) is then

$$\sum_{s \in \mathcal{K}, r \in \mathcal{L}} (t_{sr} + t_{rs}) = X_{kl} + X_{lk}, \quad k \neq l. \tag{27}$$

Now equations (23) to (25) and (27) can uniquely be solved for δ_{kl}.

The parameter η has to be obtained from the value shares α, β, and γ, which are the shares of factor income, input of local goods and input of tradables in gross output value, respectively. According to German national accounts α is 0.4 and $\beta + \gamma$ is 0.6. We accept this as a proxy for all countries. National accounts do not tell, however, how to distribute the share $\beta + \gamma$ among local and tradable goods. In fact, what a local good is depends on the size of regions. We assume that local goods have a share of 0.6 in the value of intermediate inputs; and the share of local goods in final demand, the parameter ϵ, shall equal 0.6 as well. Then γ is 0.24 and η is $\alpha/(\alpha + \gamma) = 0.625$.

Working with specific estimates for each country, which are based on empirical evidence, would be preferable, of course. But gathering the necessary information would be too costly. It is worth noting, however, that the expenditure shares could be similar in different countries even though the state of technology differs considerably. A comparison of national accounts for developed and developing countries would support this conjecture: even though technology differs markedly, factor shares are not too different.

Nevertheless, some idea about the impact of errors in the estimated share parameters is desirable. The smaller α is, ceteris paribus, the stronger is the reaction of output on prices (see equation (6)). Increasing α from .4 to .8, for example (which would be implausibly large), decreases the elasticity $1/\eta$ from 1.6 to 1.1 and the elasticity $1-1/\eta$ from -.6 to -.1. Furthermore, η has an impact on the multiplier translating price changes into welfare variations. Increasing α from .4 to .8 would double the welfare effect, ceteris paribus.

The last unknown to be calibrated is the exogenous amount of factor service F_r supplied in the regions. It is found as follows: From the solution of the constrained gravity model (23) to (25) and (27) we get A_s, unique up to an arbitrary scaling factor. Hence, we also have prices p_s, unique up to an arbitrary scaling factor, from equation (19). This scaling factor fixes the unit of measurement. It is chosen such that the weighted average price is equal to one. Then we calculate prices q_r by (11), fixing the arbitrary scaling factor ψ such that prices q_r are equal to one on average as well. The final step is to solve (6) for $F_r \nu_r^{(-1/\eta)}$.[6]

3.2 Data

For solving the calibration equations, given the parameters η, ϵ, σ, and ζ, we need data on transport distances g_{rs}, international trade X_{kl}, and regional GDP Y_r. All data refer to 1996.

Transport distances are shortest routes through a road network with 3606 nodes and 6213 links. There are 6 types of links:

- motorways,
- roads with four or more lanes,
- main roads,
- car ferries,
- border crossings, and
- shipping lines (only for connections to the rest of the world).

Distances along each type of link are translated to travel times (in minutes), taking average speeds, waiting times et cetera into account. Introducing border crossings as special links allows for modelling the time costs spent for border formalities. Link lengths are taken from auto atlases and additional information for ferries. Modes of transport other than road are neglected (except of overseas shipping). Each region is assigned to a node of the network, which is usually its administrative centre.

Regional GDP is estimated by distributing national GDP among regions of the respective country. National figures are from the world bank [27]. They are given in purchasing power parity dollars. They are broken down by region using regional GDP data from

[6]Note that F_r itself could only be calibrated, if the regional wage rate were also known. It is not required for our purpose, however.

EUROSTAT [15] and various national statistics [4, 12, 5, 23]. Regional GDP data are not available for most central and eastern European countries. For these countries, national figures are distributed among regions according to the index $Q_r = L_r V_r^{.07}$. L_r is regional population and V_r is regional population density. The density factor takes the fact into account, that GDP per capita is higher in more agglomerated regions. The exponent .07 is obtained from a regression analysis for countries with available regional GDP information.

Finally, data on international trade are from IMF [11], given in US dollars. For trade between reporting countries in the IMF statistic there is a double information, namely the import figure from the importing country and the export figure from the exporting country. Theoretically, both should only differ by the valuation. Exports are valued in f.o.b., imports in c.i.f. prices. As a consequence, import values should always exceed export values (though only slightly). Unfortunately, this is by no means true in practice. Both figures deviate from each other, more or less randomly in both directions. Comparing deviations for different countries shows that the statistics of different countries seem to be reliable to different degrees. Rather than just averaging export and import figures, it is preferable to give higher weights to the figures stemming from more reliable statistics. For that end, however, we need an estimate of the reliability of the statistics of the respective countries.

We solve this problem by assuming that export as well as import figures are randomly disturbed observations of the same, though unknown trade flow. The variance of the random disturbance is assumed to vary between countries. Formally, let H_{kl} denote the true (but unknown) trade flow from country k to country l, and let X_{kl} and M_{kl} be the corresponding observations from the export and import statistics of countries k and l, respectively. Then we make the following ansatz

$$\begin{aligned} X_{kl} &= H_{kl} + H_{kl}^{\lambda} \xi_k \varepsilon_{kl} \\ M_{kl} &= H_{kl} + H_{kl}^{\lambda} \chi_l \epsilon_{kl}. \end{aligned}$$

ε_{kl} and ϵ_{kl} are iid random variables. The factor H_{kl}^{λ}, $\lambda > 0$, implies larger errors for larger flows. The factor ξ_k scales the errors in the export statistic of country k. The factor χ_l scales the errors in the import statistic of country l. A statistic is the less reliable, the larger these factors.

The statistical problem is to estimate the flows H_{kl} and the parameters λ, ξ_k, and χ_l, given the observations X_{kl} and M_{kl}. We use a procedure iterating between the MLE for the flows, given the parameters, and the MLE for the parameters, given the flows. With GAUSSian errors the MLE for the flows solves the equations

$$\frac{X_{kl}}{\xi_k^2} + \frac{M_{kl}}{\chi_l^2} = \left(\frac{1}{\xi_k^2} + \frac{1}{\chi_l^2} \right) H_{kl}.$$

This is intuitively clear: The estimated flow is the weighted average of the export and import figure, with lower weights put on less reliable statistics. The parameters are estimated by regressing logs of estimated errors in the export and import statistics, as obtained in the before mentioned iteration, against logs of trade flows and country dummies (see [14, pp. 366-369] for a similar approach to estimating multiplicative heteroscedasticity). Stable and plausible estimates are obtained in a few iterations.

4 Simulation

How to simulate the effects of new transport links is quite obvious. After having calibrated the whole system, a counterfactual equilibrium is calculated with a changed distance matrix, which is calculated with the new transport links included in the network. In this way we can study the effects of a single new link, of a whole bundle of links or even of the entire TEN package. Welfare effects are then measured by relative variations defined in equation (7), section 2.3. Note that welfare effects of different packages are not additive, in general. Summing the welfare effects of two separate measures, each realised without the other, may sum to less or more than the combined effect of a package consisting of both measures.

In this paper we simulate the effects of new road projects which are part of the TEN programme. The entire TEN transport infrastructure programme launched in 1994 covered a network of 58,000 kilometer roads and 70,000 kilometer railways. An expert group was appointed in 1994 for suggesting priority projects ("Christophersen-Group"). A decision about 14 high priority projects and 21 further important projects was then made by the ministers of transport in 1995 in Essen. 5 projects of the former and 8 of the latter category are road projects. In addition to these internal EU projects the European Conference of Ministers of Transport (ECMT) in 1995 launched a further programme of transport corridors connecting the EU with central and eastern Europe (so-called "Crete-Corridors"), consisting of 8 combined road/rail corridors and the Danube inland water way. A further Balkan corridor has been added more recently.

We present simulations for the following road project bundles:

1. Crete-Corridors (figures 7 and 8),
2. Autobahn Lisboa–Valladolid (figure 9),
3. Nordic Triangle (figure 10),
4. Fehmarn-Belt link (figure 11),
5. Autobahn Dresden–Prague (figure 12).

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The autobahn Lisboa–Valladolid, connecting Portugal's capital with Spain and central Europe, is one of the high priority projects of the Christophersen-Group. The total length is 585 kilometer (363 kilometer in Portugal), partly already in operation. The project is going to be finished by 2004.

The "Nordic Triangle" with the edges Copenhagen, Oslo, and Stockholm is in the high priority list of the Christophersen-Group as well. It consists of multimodal corridors. We only consider the road component, however. The autobahns between the three capitals have a total length of 1,700 kilometer. The fixed link across the Øresund is an integral part of the triangle. Essential parts of the autobahns are already in operation. The total autobahn triangle shall be finished by 2003.

A Fehmarn-Belt crossing shall link the existing roads and rail connections on both sides of the Belt. A 19 kilometer distance has to be overcome, by a bridge or tunnel or a

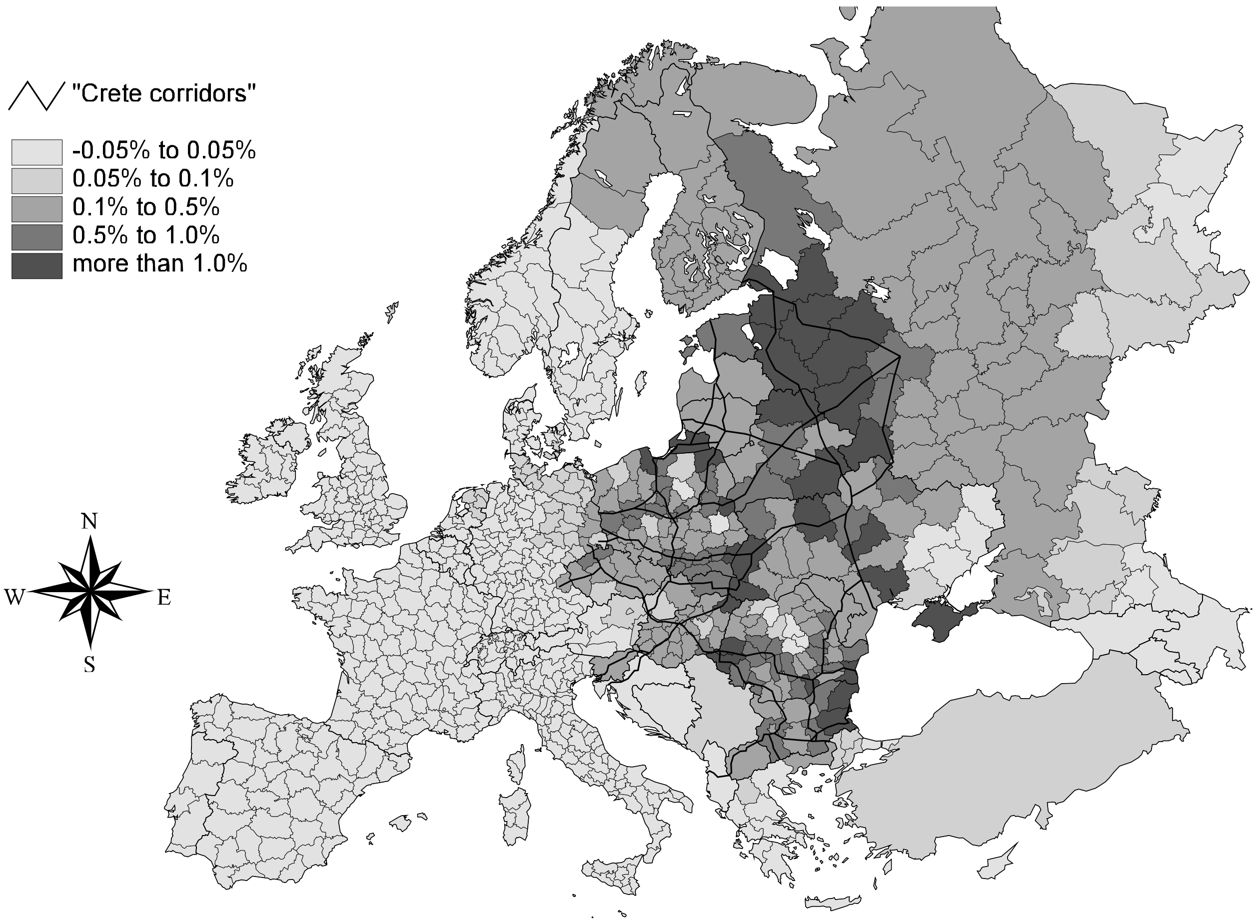

Figure 7: Crete-Corridors, welfare effects, percent of GDP

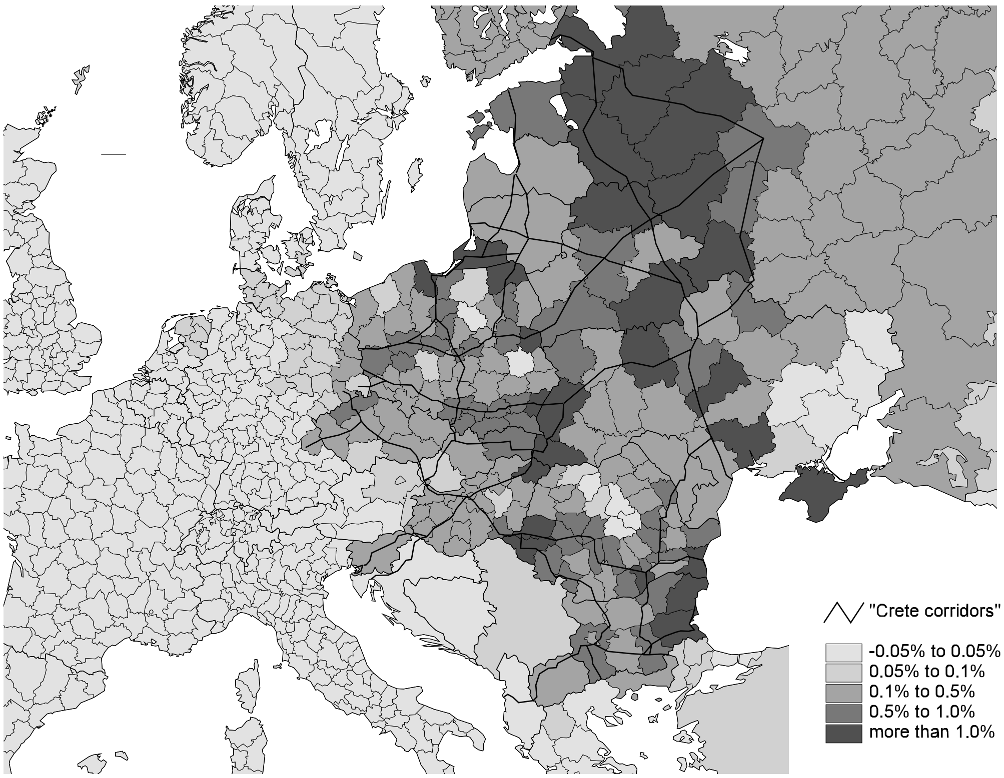

Figure 8: Crete-Corridors, welfare effects, percent of GDP (zoomed)

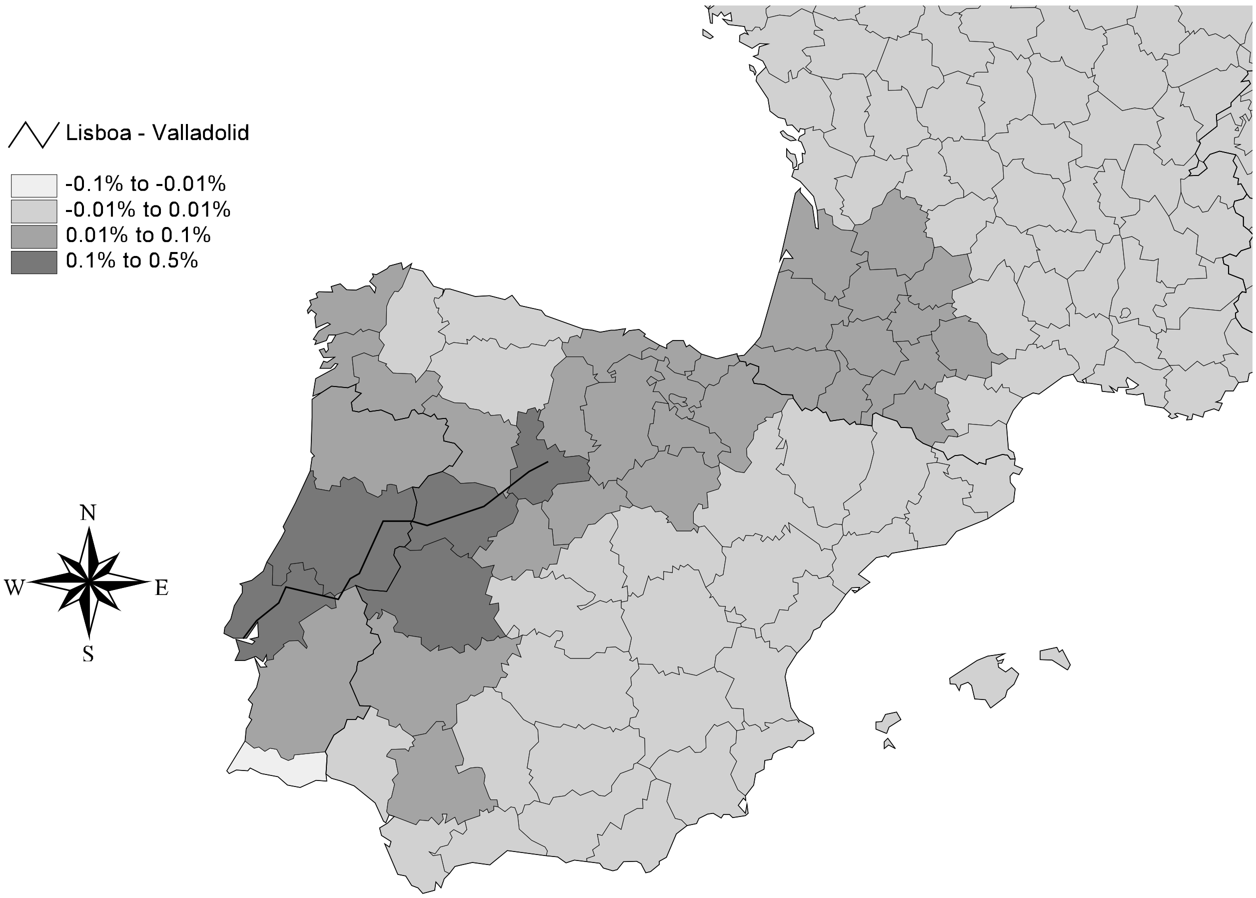

Figure 9: Autobahn Lisboa–Valladolid, welfare effects, percent of GDP

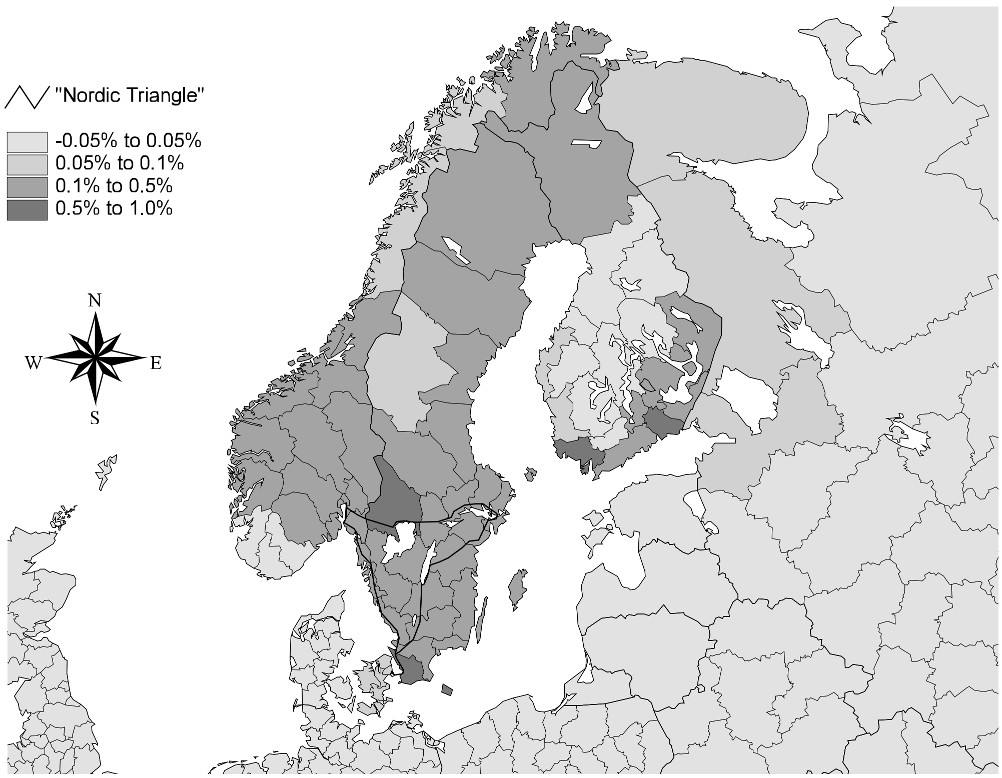

Figure 10: Nordic Triangle, welfare effects, percent of GDP

combination of both. The technical solution is not yet settled, and cost benefit studies are still under way. The project is in the second priority list of the CHRISTOPERSEN-Group. Currently, a road and rail ferry crosses the belt twice an hour, taking one hour's time.

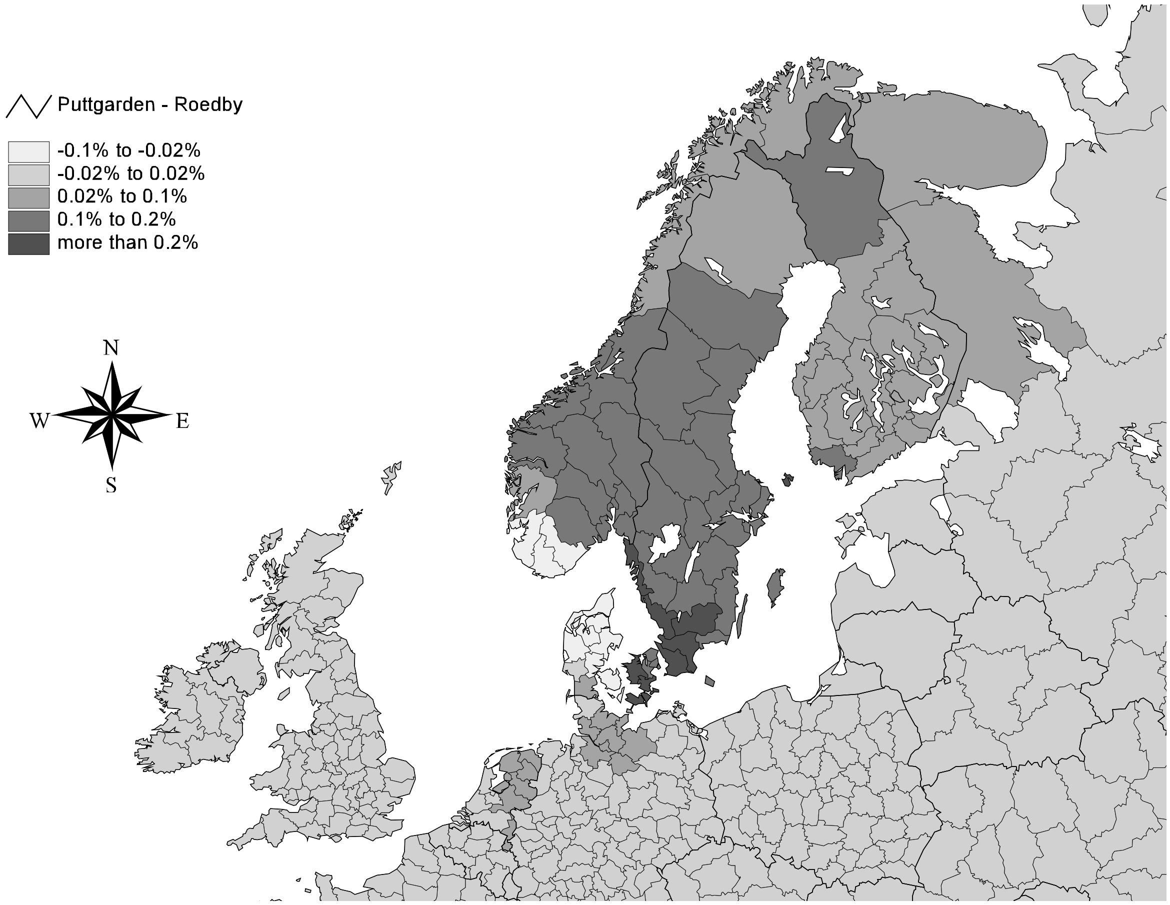

Figure 11: Fehmarn-Belt link, welfare effects, percent of GDP

Finally, the Dresden–Prague autobahn is included in our study, a project hotly debated in the author's home city. It is part of one of the Crete-corridors (corridor IV), closing a missing link along the Scandinavia–Berlin–Dresden–Prague–Vienna/Budapest connection. It's length is 136 kilometer (46 in Germany, 90 in Chech Republic). Construction started in 1995 on the Chech side and in 1998 on the German side. It is planned to be finished by 2004.

Regarding the general spatial pattern of effects, three observations are worth mentioning. First, the largest part of the gain accrues to regions close to the established link itself. Second, gains in more distant places are concentrated on a band prolonging the respective link in both directions. This striplike pattern is particularly strong for the Dresden-Prague link. Third, new links throw a shadow on the sides right and left of the winners' band. Welfare may decrease in the shadow of the new link. Cases in point are the shadows thrown on Northern-Jutland by the Fehmarn-Belt link, on parts of Spain by

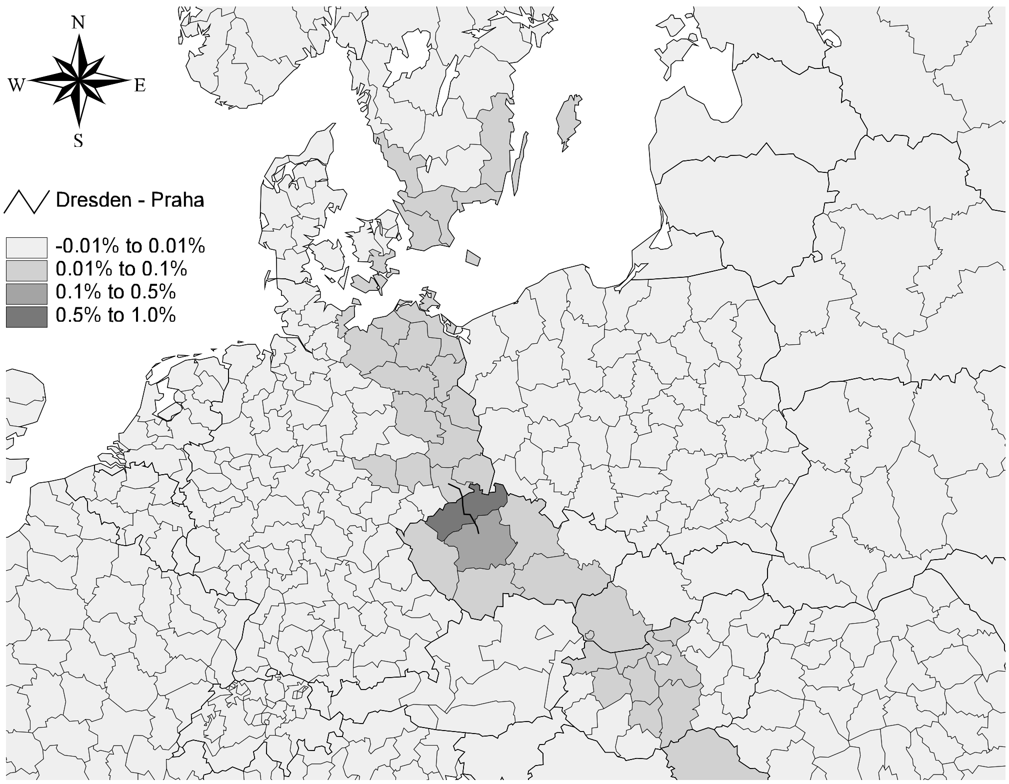

Figure 12: Autobahn Dresden–Prague, welfare effects, percent of GDP

the Lisboa-Valladolid link, or on Transylvania by some Crete-Corridors.[7]

5 Concluding remarks

The approach presented in this paper has several advantages over traditional methods applied to transport project evaluation. Most importantly, it is well founded in microeconomic theory. Spatial interaction, regional allocation and regional welfare measurement are all derived from the same consistent theoretical framework. Furthermore, economies of scale on the firm level and economies of agglomeration on the regional level, which have always been regarded as vital to transport project evaluation, are well integrated into the CGE analysis by the monopolistic competition assumption. A nice by-product of the model is that familiar concepts in empirical regional science like gravity models and potential measures reappear in our system, though in a modified form and with a new theoretical underpinning.

The shortcomings of our approach, however, are also obvious. Two of them are the most important, namely the high level of sectoral aggregation and the lack of dynamics. Industries in the real world differ in many respects, which are all averaged out by merging them into just two sectors (tradables and non-tradables). Three main dimensions of sectoral differentiation are vital to transport project evaluation: (1) factor intensity, (2) transport cost intensity, and (3) degree of monopoly. Varying factor intensities of industries and varying factor abundance over regions give rise to comparative advantage effects of integration, which are excluded from our aggregated approach by assumption. Furthermore, regions might also be differently affected due to differing transport cost intensities and degrees of monopoly of their industries. These spatial differentials are also excluded from our analysis by assumption.

The other important drawback is neglecting dynamics. Decreasing transport costs could affect regional rates of growth through their impact on factor flows and, more importantly, on knowledge flows and rates of innovation. The theoretical study of these aspects in the context of new growth theory is still in its infancy, and there is a long way to go, until they can be implemented into an operational empirical analysis. Here is the most challenging field of future research in transport project evaluation.

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