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ETMOS – An Integrated Economic Transport Modelling System for Austria

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Abstract

The research project links together two regional models for Austria: a multiregional econometric input-output model at district level (MultiREG-D) and a multiregional transport and land use model (MARS). The combined model platform allows, on the one hand, for economic activities to influence transport flows and changes in land use patterns and, on the other, for changes in the transportation network and corresponding land use patterns to influence economic activities. Given such a model environment, various research questions can be addressed empirically, e.g., on the expected trends concerning spatial concentration, spatial dispersion or on the spatial, economic and environmental impacts of different policy instruments, such as road pricing, transport capacity changes, etc.

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1. Introduction

Economic and transport systems are interlinked in multiple ways: Trade between the different entities in an economy (producers, consumers, suppliers of labor, etc.) is often impossible without a minimum level of transport infrastructure. Consequently, changes in the transportation network of an economy that alter absolute and relative transport cost (in terms of direct cost, but mostly in terms of a reduction in transport time and therefore indirect cost) may have a significant impact on the economic system:

- In search for higher efficiency, firms may relocate to locations with a more favorable position in the network.
- Firms in given locations that now face better transport linkages to other firms and to consumers demanding their products and supplying labor may enhance their level of competitiveness;
- On the other hand, these firms may also face increasing competition from firms outside the region since a transport linkage always runs two ways.
- Economic welfare and improvements in the transportation infrastructure are interdependent: While economic growth and welfare are supported by a better transportation infrastructure, making public investments in the infrastructure a regional policy instrument, regions with a higher income per capita have more means to invest in their infrastructure and may therefore enhance their advantageous economic position.

The high relevance of transport cost and transportation systems is reflected by intensive research in this field. In the new economic geography (NEG) literature transport cost play a major role for the regional distribution of economic activity. Some NEG-models have also been empirically tested (for recent empirical work on the NEG see, e.g., Brakman, 2006). Unfortunately, transport models and economic models are often linked in imperfect ways: Traffic models frequently rely on exogenous information on economic variables (like regional product, income and/or employment) and estimate their results conditional upon these variables. In this way feedback from transport to the economy is disregarded. The effects of new or improved transport infrastructure, which certainly influences regional economic development, cannot be estimated this way and neither can the effects of traffic bottlenecks be evaluated.

By the use of economic models, on the other hand, one is able to estimate the effects of new transport infrastructure on the economy, if the model takes into account transport cost. However, in these models, the causal relation between economic development and transport and the expenditures for improving infrastructure is neglected (Van de Vooren, 2004).

The aim of the this research project was to link two existing models, MultiREG and MARS, within a comprehensive modeling framework which allows for

- economic activities to influence transport flows and changes in land use patterns;

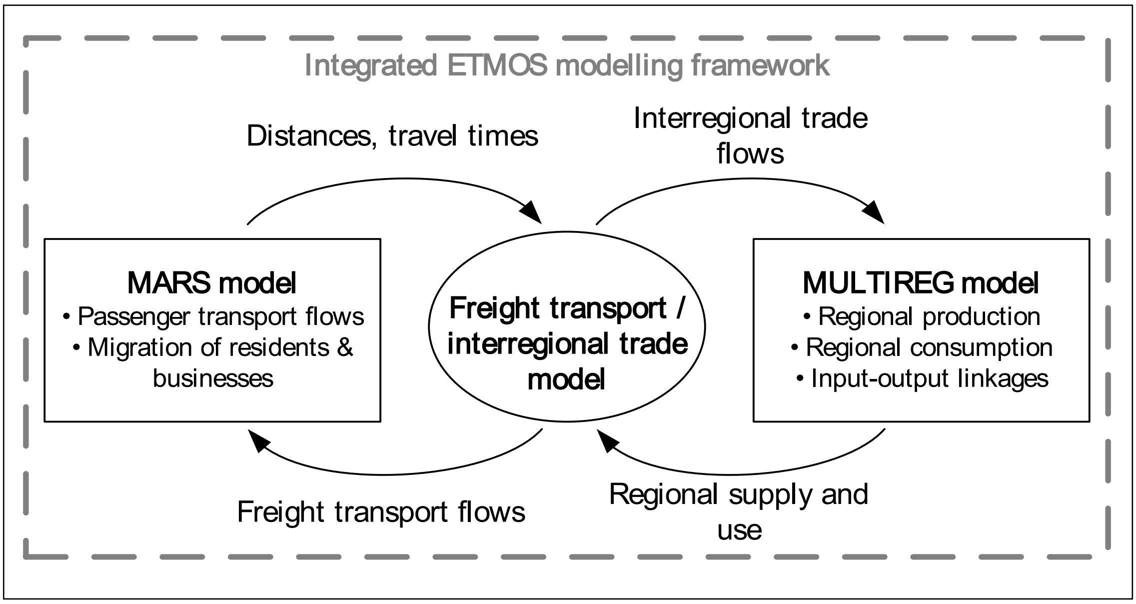
- changes in the transportation network and corresponding land use patterns to influence economic activities.

Given such a model environment, various research questions could be addressed empirically, e.g. on the expected trends concerning spatial concentration, spatial dispersion or on the spatial, economic and environmental impacts of different policy instruments, such as road pricing, transport capacity changes, etc.

When providing for an operational link between the MARS passenger and the MultiREG-D model, both the issues of freight transport distribution as well as the sensitivity of interregional trade to changes in transport costs were addressed. Freight transport and interregional trade are not closely related but can actually be considered two sides of the same coin: On the one hand, trade of physical goods necessarily requires transport. Freight transport, on the other hand, is a direct consequence of interregional trade.

Figure 1 gives an overview of the relation between the MARS, MultiREG-D and the model platform developed here.

Figure 1: MARS and MultiREG models and the new model link



Each separate model lacked one important component: In MultiREG-D, the trade matrix was purely static, i.e. it was not possible to simulate the trade effects of changes in transport costs. The MARS transport/land-use model focused on passenger transport only and completely abstracted from freight transport. The work carried out here not only extends each model by taking account of these components but creates additional value added in linking the models.

Within this research project, the following activities were carried out:

(1) Development and empirical estimation of a measure of freight transport costs which was then included in the combined transport/economic model. The basis for this measure is transport network data from the MARS transport model as well as information from various other statistical sources.

(2) Design and implementation of a freight transport / interregional trade model based on the gravity modeling framework.

(3) Compilation of a multiregional econometric input-output model at the level of Austrian political districts; this model was derived from MultiREG, a multiregional econometric input-output model for the Austrian Federal States ("Bundesländer").

(4) Implementation of an iterative simulation link between MARS and MultiREG-D

This report is structured as follows:

In the first two chapters the models that are to be linked together, MARS and MultiREG-D, will be described. Thereafter, following a short discussion on the modeling of freight transport and interregional trade, the way MARS and MultiREG-D are linked is illustrated and first simulation results are presented.

2. Metropolitan Activity Relocation Simulator (MARS)

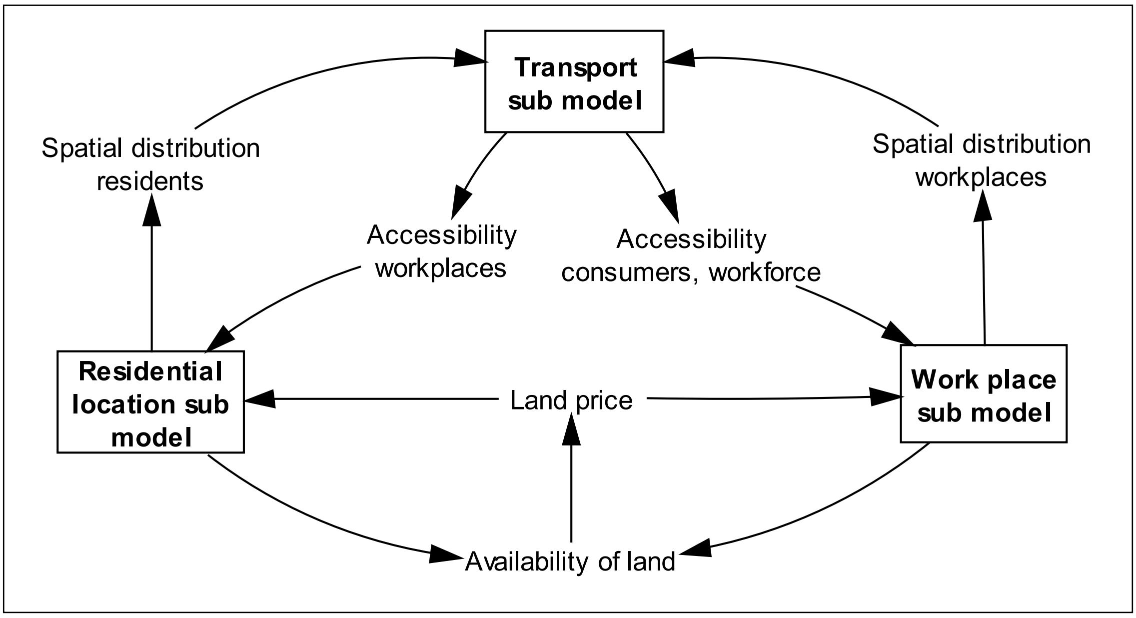
2.1. Introduction and general model description

The MARS model is a dynamic land-use/transport interaction (LUTI) model, which is based on the principles of synergetics (Haken 1983). To date MARS has been applied to 10 European cities (Edinburgh, Gateshead, Leeds, Madrid, Trondheim, Oslo, Stockholm, Helsinki, Vienna and Bari), 2 Asian (Hanoi, Ubon Ratchathani) and 1 South American (Porto Alegre) city. Ongoing projects cover setting up MARS for Hoh Chi Minh City in Vietnam and Washington D.C. in the US. Recently MARS has also been applied for a national case study of Austria (Emberger, Mayerthaler, and Haller 2010).

The model description in this report will focus on the overall model structure. For a more comprehensive presentation we refer the reader to Pfaffenbichler (2003).

The MARS model consists of sub-models which simulate passenger transport, housing development, household migration and workplace migration. Additionally separate accounting modules calculate assessment indicators and pollutant emissions. The overall structure of the model is shown in Figure 1. The main link between the transport model and the location choice model are accessibilities (formulated as potential to reach workplaces and shopping opportunities), which are passed on from the transport model to the location choice models and the spatial distribution of households and employment which are inputs from the location choice models to the transport model. The land price influences both the residential location- and the workplace sub-models whereas output from these two sub-models changes the availability of land.

Figure 2: MARS model structure - the three main sub models



2.2. Model structure

2.2.1. The transport sub model

The transport model in MARS simulates passenger transport and comprises trip generation, trip distribution and mode choice stages. Trip distribution and modal split are calculated simultaneously by a gravity (spatial interaction) type model.

The modes considered in the model are non-motorized transport (pedestrians and cyclists), private car transport as well as public transport by bus and by rail. The slow mode represents the non-motorized modes walking and cycling. Due to the zone size in MARS Austria, this mode is almost exclusively relevant for intra-zonal trips. The only significant exceptions are inter-zonal trips in Vienna where the model zones represent municipal districts.

The trip generation stage calculates the number of trips originating from a particular model zone. Trip distribution and mode choice in the MARS model are calculated per origin-destination (OD) pair.

For MARS Austria we implemented intra-zonal distance classes. Each of the 120 model zones is split into five distance classes and trips are allocated separately to each distance class.

2.2.2. The land-use sub model

2.2.2.1. The residential location model

The residential location model is implemented as a two stage migration model (Mayerthaler, Haller, and Emberger 2009): First, the number of out-migrants per zone is estimated. Second, a migration destination choice model distributes the out-migrants (which it takes as an exogenous input from the out-migration model) over the possible destinations based on characteristics of the destinations and the distance between two zones.

The model takes the form of the well-know gravity or spatial interaction model. In general terms, the number of migrants between origin i and destination j, M_{ij}, is modeled as

$$M_{ij} = O_i \frac{exp(\alpha_0 + \alpha_1 X_{1,j} + \alpha_2 X_{2,j} + ... + \alpha_n X_{n,j} + \gamma_n Y_{ij}) d_{ij}^{\beta}}{\sum_j exp(\alpha_0 + \alpha_1 X_{1,j} + \alpha_2 X_{2,j} + ... + \alpha_n X_{n,j} + \gamma_n Y_{ij}) d_{ij}^{\beta}}$$

where O_i represents the number of out-migrants of origin *i* (given exogenously to the distribution model); $X_{1,j} \ldots X_{n,j}$ a set of n attributes relating to destination *j* with the associated parameters $\alpha_0 \ldots \alpha_n$; Y_{ij} an origin-destination pair specific (dummy) variable with the associated parameter γ; d_{ij} the distance between origin *i* and destination j.

The choice of influencing variables considered (accessibility by car and public transport, level of housing costs and share of recreational green land) is based on several different lines of arguments: Firstly, they repeatedly rank among the most important determinants of migration in empirical migration research (ODPM 2002). Secondly, own empirical studies focusing on Vienna confirmed this importance (Pfaffenbichler 2003). Thirdly, each of the variables is highly endogenous especially from a land-use/ transport perspective.

2.2.2.2. Workplace location sub model

The workplaces migration sub module has a structure very similar to the residential migration model. In the current version it consists of two parts: one for the production sector and one for the service sector.

At the moment the relative attractiveness of a zone for potential workplace migration considers:

- The zone's potential for activity participation (accessibility);
- the abundance of building land;
- the cost for building in a zone and
- the average household income.

Access attractiveness, formulated as potential to reach workplaces and shopping opportunities, represents the zones potential for activity participation. The possibility to build in a zone is restricted by land availability in a zone. The cost of building in a zone is approximated by the land price. The average household income is a signal for firms whether there is consumption potential and is a proxy for labor cost.

The first empirical input required in the out-migration model is the average time between two business relocations, i.e. the average time a business stays at a given location. The reciprocal of this value is the share of businesses relocating in each period. The total number of relocating workplaces in the study area is calculated as the product of the total number of workplaces times the share of relocating businesses.

In a next step the attractiveness to move out of a certain zone is calculated with the above mentioned influencing factors, except for the land availability which of course is just relevant for the in-moving sub model. This is modeled again as exponential function of the form, separately for each sector:

$$Attr_j^{out} = e^{(\alpha_1 * ACC_i + \alpha_2 * Land\_price\_attr_{i,sector} + \alpha_3 * HHI_i)}$$

where

$Attr_j^{out}$	Attractiveness to move out zone j
$\alpha_1 \ldots \alpha_3$	Parameters
ACC_i	Access attractiveness in model zone i
$Land\_price\_attr._{i,sector}$	Land price attractiveness per zone i and sector (production/service)
HHI_i	Household income in model zone i

The total number of workplaces moving into the model zones is derived from the number of workplaces moving out. However, an external growth rate is added to capture the overall employment development in the case study region. This growth rate can be negative or positive and can differ between sectors. MARS then calculates the amount of space available for business use and allocates the total potential re-allocating and newly developed workplaces to the different locations using a LOGIT model (see equation above).

2.2.2.3. Housing development model

In MARS developers decide whether, how much and where to build new housing units. Their decision is based on four factors:

1. The rent they can achieve after the housing units are ready for occupation. It is assumed that this is the rent paid in the year of the development decision;
2. the land price in the decision year;
3. the availability of land in the decision year;
4. the demand from potential in-movers in the zones.

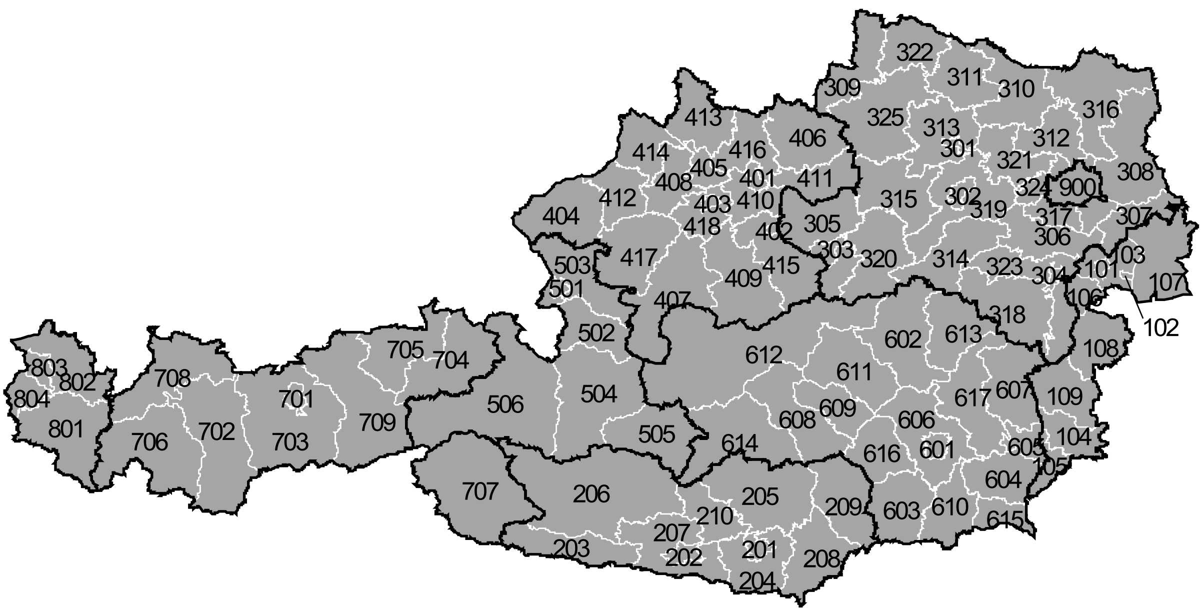
The potential for new residences is distributed to the zones according to the attractiveness to build in a zone, which is dependent on the above mentioned factors. These will be ready to be occupied after an externally defined time lag of three years. MARS checks whether there is enough land for the planned developments. If not, the number of developments in a certain zones is constrained. There is currently no redistribution process to other locations in the development sub model. Changes in the available land influence land price and rent.

3. The Economic Model (MultiREG-D)

3.1. Introduction

The economic model is based on the econometric Input-Output model MultiREG, a prototype of which was developed in 2002 in a different project funded by the OeNB's Jubiläumsfonds. In contrast to MultiREG, however, the new model MultiREG-D is more disaggregated both with respect to space and agents: where MultiREG distinguished between 32 sectors (and commodities) in the 9 Austrian provinces ("Bundesländer"), MultiREG-D sports the full complement of 57 NACE-2-digit sectors (and CPA-2-digit commodities) as covered by Statistic Austria's official Make-Use-Tables in a spatial framework of 99 political districts.[1]

Figure 3: A map of Austria's districts



The following list of districts also shows the "provincial affiliation" of each of the 99 districts; in the map above, the boundaries of the provinces are shown in black, whereas the district level is marked by white lines.

[1] In all, Austria is organized in 121 political districts; however, the 23 districts of Vienna are aggregated into a single "superdistrict", which seems more meaningful from both from an economic as well as from a (freight) transport point of view.

Table 1: Political districts in Austria

Code	Province	District Name
101	B	Eisenstadt (Stadt)
102	B	Rust (Stadt)
103	B	Eisenstadt-Umgebung
104	B	Güssing
105	B	Jennersdorf
106	B	Mattersburg
107	B	Neusiedl am See
108	B	Oberpullendorf
109	B	Oberwart
201	K	Klagenfurt (Stadt)
202	K	Villach (Stadt)
203	K	Hermagor
204	K	Klagenfurt (Land)
205	K	Sankt Veit an der Glan
206	K	Spittal an der Drau
207	K	Villach Land
208	K	Völkermarkt
209	K	Wolfsberg
210	K	Feldkirchen
301	N	Krems an der Donau (Stadt)
302	N	Sankt Pölten (Stadt)
303	N	Waidhofen an der Ybbs (Stadt)
304	N	Wiener Neustadt (Stadt)
305	N	Amstetten
306	N	Baden
307	N	Bruck an der Leitha
308	N	Gänserndorf
309	N	Gmünd
310	N	Hollabrunn
311	N	Horn
312	N	Korneuburg
313	N	Krems (Land)
314	N	Lilienfeld
315	N	Melk
316	N	Mistelbach
317	N	Mödling
318	N	Neunkirchen
319	N	Sankt Pölten (Land)
320	N	Scheibbs
321	N	Tulln
322	N	Waidhofen an der Thaya
323	N	Wiener Neustadt (Land)
324	N	Wien Umgebung
325	N	Zwettl

Code	Province	District Name
401	O	Linz (Stadt)
402	O	Steyr (Stadt)
403	O	Wels (Stadt)
404	O	Braunau am Inn
405	O	Eferding
406	O	Freistadt
407	O	Gmunden
408	O	Grieskirchen
409	O	Kirchdorf an der Krems
410	O	Linz-Land
411	O	Perg
412	O	Ried im Innkreis
413	O	Rohrbach
414	O	Schärding
415	O	Steyr-Land
416	O	Urfahr-Umgebung
417	O	Vöcklabruck
418	O	Wels-Land
501	S	Salzburg (Stadt)
502	S	Hallein
503	S	Salzburg-Umgebung
504	S	Sankt Johann im Pongau
505	S	Tamsweg
506	S	Zell am See
601	St	Graz (Stadt)
602	St	Bruck an der Mur
603	St	Deutschlandsberg
604	St	Feldbach
605	St	Fürstenfeld
606	St	Graz-Umgebung
607	St	Hartberg
608	St	Judenburg
609	St	Knittelfeld
610	St	Leibnitz
611	St	Leoben
612	St	Liezen
613	St	Mürzzuschlag
614	St	Murau
615	St	Radkersburg
616	St	Voitsberg
617	St	Weiz

Code	Province	District Name
701	T	Innsbruck (Stadt)
702	T	Imst
703	T	Innsbruck (Land)
704	T	Kitzbühel
705	T	Kufstein
706	T	Landeck
707	T	Lienz
708	T	Reutte
709	T	Schwaz
801	V	Bludenz
802	V	Bregenz
803	V	Dornbirn
804	V	Feldkirch
900	W	Wien

Province	
B	Burgenland
K	Kärnten
N	Niederösterreich
O	Oberösterreich
S	Salzburg
St	Steiermark
T	Tirol
V	Vorarlberg
W	Wien

Table 2: 57 sectors as covered by the Austrian Make-Use system

NACE	Description	NACE	Description
01	Agriculture, hunting	40	Electricity, gas, steam and hot water supply
02	Forestry, logging	41	Collection, purification and distribution of water
05	Fishing, fish farms	45	Construction
10	Mining of coal and lignite	50	Sale and repair of motor vehicles; retail sale of automotive fuel
11	Extract. o. crude petrol. a. nat. gas, min. o. metal ores (1)	51	Wholesale and commission trade
14	Other mining and quarrying	52	Retail trade, repair of household goods
15	Manufacture of food products and beverages	55	Hotels and restaurants
16	Manufacture of tobacco products	60	Land transport; transport via pipelines
17	Manufacture of textiles	61	Water transport
18	Manufacture of wearing apparel	62	Air transport
19	Manufacture of leather, leather products, footwear	63	Supporting a. auxiliary transport activities; travel agencies
20	Manufacture of wood and of products of wood	64	Post and tele-communications
21	Manufacture of paper and paper products	65	Financial intermediation, except insur. a. pension funding
22	Publishing, printing and reproduction	66	Insurance and pension funding, except social security
23	Manufacture of coke, refined petroleum products	67	Activities auxiliary to financial intermediation
24	Manufacture of chemicals and chemical products	70	Real estate activities
25	Manufacture of rubber and plastic products	71	Renting of machinery and equipment without operator
26	Manufacture of other non-metallic mineral products	72	Computer and related activities
27	Manufacture of basic metals	73	Research and development
28	Manufacture of fabricated metal products	74	Other business activities
29	Manufacture of machinery and equipment n.e.c.	75	Public administration; compulsory social security
30	Manufacture of office machinery and computers	80	Education
31	Manufacture of electrical machinery and apparatus n.e.c.	85	Health and social work
32	Manufacture of radio, television equipment	90	Sewage and refuse disposal,sanitation and similar act.
33	Manuf. of medical, precision, optical instruments, clocks	91	Activities of membership organizations n.e.c.
34	Manufacture of motor vehicles and trailers	92	Recreational, cultural and sporting activities
35	Manufacture of other transport equipment	93	Other service activities
36	Manufacture of furniture; manufacturing n.e.c.	95	Private households with employed persons
37	Recycling		

Table 3: Final demand components of the Austrian Make-Use system

	Components of Final Demand
Final consumption expenditure	by households by government by NPISH
Gross fixed capital formation	Dwellings Other buildings and structures Machinery Transport equipment Cultivated assets Intangible fixed assets
	Changes in valuables Changes in inventories Total exports, fob

3.2. The Data Base

The new model MultiREG-D – similar to MultiREG, with which it shares the basic outline – utilizes Make-Use tables, not an analytical version of (symmetric) Input-Output tables. The reason for this is flexibility: by explicitly distinguishing between commodities, producers and users, shifts in, say, the technology of production can quite straightforwardly be implemented in the Make-Use framework, but not so in the analytical tables. Such shifts come about by changes in intermediate inputs (as a share of output or as changes in the relative importance of intermediate inputs). Similarly, changes in the structure of final demand[2] can be consistently incorporated in the Make-Use framework. So, even if the present model is "incomplete" (although the Make-Use part is fully integrated the econometrically estimated behavioral equations could not be fully implemented in the prototype model) the basic structure can be easily expanded.

The data base at the district level was derived under the constraint that in the aggregate, the district tables must sum up to the Austrian Make-Use tables as published by Statistik Austria for the year 2005. The following chapter gives an overview of the steps involved in this derivation.

3.3. Make-Use tables

These tables describe the production structure (the commodities produced by each sector in each region) as well as the intermediate inputs used in their production process. The first step involved an analysis of the *Leistungs- und Strukturerhebung* LSE[3] for the year 2005 at the level

[2] In the case of private consumption, an AIDS model could be used to endogenously simulate the reactions commodity demand to changes in relative prices.

[3] This is an official survey of the (manufacturing) sectors.

of the 9 provinces. The result is provincial output, value added and employment by sectors. It has to be noted that at this level the production structure for a specific parameter (share of intermediate inputs, productivity) can be – and will be – different between the 9 provinces.

Further disaggregation to the district level is not possible on the basis of the LSE – sample sizes are simply too small (if there are fewer than 3 enterprises located in some area, Statistics Austria suppresses any survey data for reasons of confidentiality). Unfortunately, even employment data are not regularly published at the district level, much less output or value added. Therefore, breakdown of the production data was accomplished using data from the 2001 Census (*Volkszählung* and *Arbeitsstättenzählung*). Accordingly, below the provincial level, the production structure is assumed to be identical for all constituent districts.

In the case of Sector NACE 01 (Agriculture), district-level data on agricultural output, intermediate demand, employment (as well as investment) were available from another research project.

3.4. Final Demand

3.4.1. Public Consumption

National public consumption expenditures at the state level were regionalized with respect to each commodity in part directly by using regional public consumption data provided by Statistics Austria, in part indirectly by applying different regional indicators which were consistent with a place of consumption concept. Specifically, shares of regional population in total Austrian population were used as indicators for commodities that could be classified as public goods like national defense and parts of national government services. Education services were regionalized by the number of students at different levels of education, counted at the location of the educational institution. Public expenditures on health services and pharmaceuticals were first allocated to different (partly regional) health insurance carriers based on the number of insurants and then further regionalized if necessary. Since employees and their dependants are assigned to health insurance carriers based on the location of their employer and furthermore often stay in hospitals outside their home region adjustments for commuting (based on census data) and out-of-province hospitalization (based on data on regional hospital occupancy and the assumption of equal cost per occupied hospital bed across all regions) had to be made in order to comply with the place of consumption concept.

Further regionalization down to the district level could not proceed in the same way due to lack of data. For most commodities public consumption was broken down from the state level to the district level using population shares. For commodities CPA 22, 60 and 80 data on the number of students by school was applied.

3.4.2. Private Consumption

The estimation of private consumption at the district level proceeded in several steps:

1. First, data from the 2004/05 consumption survey of Statistics Austria by COICOP-categories, types of regions and types households by education level were used to estimate private consumption of residents at the local community level without their expenses for vacations. For this, all communities had to be assigned to three types of regions which differed according to population density; in addition data on the share of household by the level of education of the main household provider were used.
2. Private consumption by communities was then aggregated to the district level and transformed to CPA-categories, based on the matrix of private consumption by COICOP and CPA-commodities from the national input-output system 2005.
3. Relying on data on overnight stays of tourists by origin (states) and destination (districts) and estimates of tourism expenditures by states, consumption with respect to domestic tourism was added.
4. Proceeding in much the same way, consumption of foreign tourists was added as well.
5. The resulting private consumption of residents (without vacation expenditures) and of domestic and foreign tourists at the district level was then made consistent with total national private consumption of CPA-commodities, applying separate RAS-procedures for private consumption of residents including vacation expenditures on the one hand and foreign tourism expenditures on the other.

Each step of this estimation procedure was accompanied by plausibility checks.

3.4.3. Investment

For the disaggregation of investment demand, identical Investment-to-Output ratios were assumed for all districts (although some information on investment would be available from the LSE, resource constraints did not permit of its utilization). District-level investment by category and sector, therefore, exhibits identical structure in all Austrian districts.

As mentioned above, investment in the agricultural sector NACE 01 was available from an unrelated research project.

3.4.4. Changes in Inventories, Changes in Valuables

As *inventories* consist primarily of intermediate inputs their breakdown proceeds along the regional distribution of intermediate demand. Conversely, *Changes in Valuables* are assumed to reflect mainly private consumption patterns.

3.4.5. Exports

During development of MultiREG, a regional analysis of exports was performed, in which great care was aimed at resolving the enterprise-business problem: in the official statistics, exports are recorded at enterprise level. This poses problems with multi-business enterprises (i.e, most of the "big players" in exports), as often the headquarters of the enterprise is in a different region from the business units actually producing the exports.[4] Therefore, Vienna in particular is credited in the statistics with much more "exports" than is warranted (in many cases, exports from Vienna are much higher than can be satisfied by production in this region). To account for this discrepancy, official export statistics were corrected using a wealth of additional primary statistics (LSE; employment data at the enterprise and the business level; tax statistics).

An update of this exercise was not feasible within this project; therefore, we took provincial export shares from this exercise (which besides being based on the year 2000, was also restricted to the level of provinces), adapted them to the new Austrian export levels, and assumed them to be constant for all districts in each province.

3.5. Discussion

The quality of the derived district-level data is quite heterogeneous: whereas in the case of public and private consumption, the present work arguably represents the optimum of what can be done, the same cannot be said for the production side. Especially with respect to investment, there is still some work to be done on the way to a "definitive" version of the district data base. As for intermediate inputs and employment below the provincial level, the chosen path – though not wholly convincing – can probably not be much improved upon, as primary statistics simply cannot be utilized at this spatial level. In the case of investment and exports, however, such improvements are certainly possible.

Again, the main target of this exercise was to develop a "prototype" model, which, though probably not perfect, is at least consistent with (known) aggregates (the most important of which being the Austrian Make-Use matrices as published by Statistik Austria). Furthermore, the programs and algorithms used were developed under the guideline of "easy updateability"; consequently, results of future work on either (or all) of the parts of the Make-Use system can consistently – and quickly! - be implemented in new versions of the data base.

Also, the main application of MultiREG-D is not foreseen as a forecasting tool; too far-reaching are the assumptions which were made in the derivation of the present version of the data base (most likely, even "optimal" strategies would still have to rely on too many assumptions to make for a convincing forecasting model). Rather, it is simulations (and, more specifically, location and transport simulations) which might be the strong point of such a spatially disaggregated model – in which case a "perfect" data base is arguably of less importance than "getting the character of the linkages right".

[4] Often, but not always, headquarters are located in Vienna, whereas the producing businesses are located in Steiermark or Oberösterreich, for example.

3.6. Other tables (commuting, shopping, tourism)

At the sub-national level, a number of "regionally re-distributive" mechanisms have to be accounted for: apart from the inter-regional trade matrix (more on this in the next paragraph), we have to deal with

1. commuting (i.e., a re-distribution of disposable income from the work region to the region of residence)
2. shopping and
3. tourism (both constitute a re-distribution of private consumption from the region of residence to the region where the shopping or vacation take place).

The commuting data, again, are taken from the 2001 Census. As such, though slightly outdated, they arguably represent the most accurate description available. Inter-regional tourism is based on official statistics of overnight stays; using additional information and assumptions on daily outlays (relevant information comes from satellite accounts of the tourism industry), we derive a district-by-district matrix of financial flows originating in tourism activities (see the discussion of private consumption estimates above).

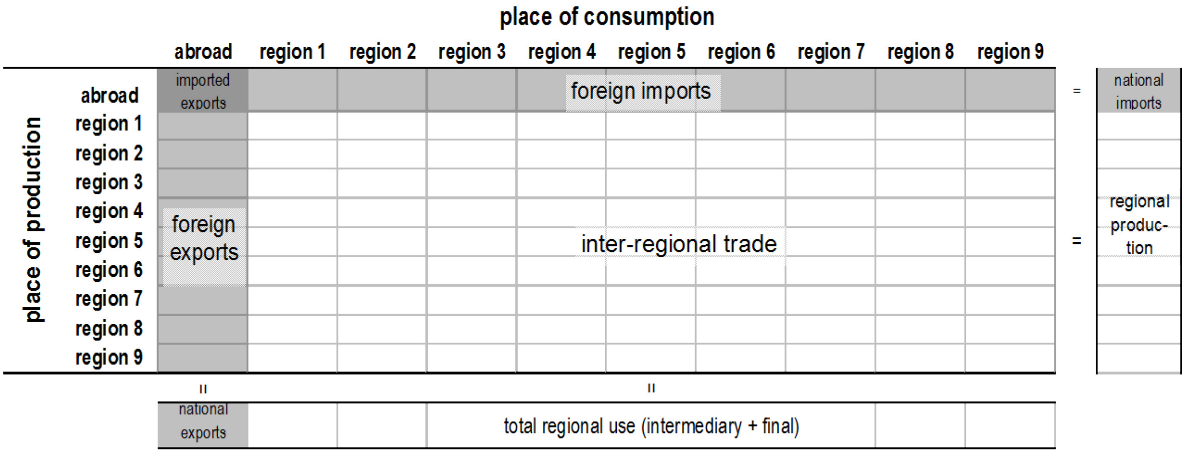
A similar (though conceptually distinct) matrix is derived for inter-regional shopping activities. Although taking place between essentially all districts, this is most pronounced between Vienna and its neighboring districts, most prominently exemplified in the Shopping City Süd, which, located just outside Vienna, draws (a major?) part of its clientele from Vienna, thus inducing quite large flows of "shopping linkages". Information on inter-regional shopping flows stems from various studies commissioned by regional Chambers of Commerce.

3.7. Trade matrices

The trade matrix serves a dual purpose: on the one hand, it is a representation of inter-district trade in the year 2005; as such, it should of course be as "accurate" as possible. On the other hand, in its function of "great balancer" – the trade matrix quite literally is derived via an algorithm designed to balance regional supply and regional demand – it is the main actor in ensuring consistency at the different regional levels (national, provincial, district). As such, the trade matrix "mops up" any problems and omissions on the part of the tables mentioned so far.

For each good, boundary values are given by regional values of total (final and intermediate) use and production: everything which is consumed in a region has to produced somewhere (in the same region, a different region, or abroad as imports); conversely, everything which is produced in a region has to be consumed somewhere (again, in the same region, some other region, or abroad as exports). Trade is described by the flows – the elements of this matrix – which bring about this balancing between regional demand and supply. Crucially, this approach allows for cross-hauling – the same commodity can both be exported and imported in any one region.

Figure 4: The balancing algorithm for the trade matrix



The boundary values, then, are given by the regional supply and use matrices. The flows, however, are unknown – no surveys are conducted which provide information on this matter. Nevertheless, we do have two sources of data at hand:

- For MultiREG, we conducted a dedicated survey among manufacturers (and wholesalers), inquiring about the main target regions for their output.
- Transport data are available for inter-regional transport flows.

The problem with the first data source has to do with coverage and base year: the original survey was conducted in 2002; additionally, the spatial dimension was not the district level, but the province – with a total of some 1800 responding manufacturers in about 15 sectors (and 500 wholesalers), a re-analysis at the district level was simply out of the question. The same holds for a new survey aiming at enough respondents to address the district level – infeasible not only on resource grounds, but positively impossible given the spatial level of districts; nothing short of a full survey would probably be sufficient to allow for such fine spatial resolution.

Here is where the second data source comes into play: transport data are collected (by Statistics Austria) on a regular basis with very fine spatial resolution. Of course, they are fraught with problems - from matters of sample size to the sheer cost of the data. Here, we could resorts to results of yet another research project, from which we could draw a "cleaned" version of the transport data at the district level. These data were used

- to "update" our trade survey (changes in inter-regional trade were assumed to follow changes in inter-regional transport); and
- to serve as starting values for the trade flows: transport flows were used as starting values for the trade flows in the diagram above; a bi-proportional algorithm (RAS) was then used to calculate trade flows which bring about a balance between regional demand and supply as described above.

The result is a series of trade matrices (one for each commodity), which ensure consistency between supply and demand at the district level – and, as the district supply and use tables add up to the Austrian Make-Use tables, by extension also ensure consistency of the whole system of regional data.

When using transport data to proxy trade flows, however, an additional obstacle has to be surmounted concerning classifications: whereas the economic tables use the CPA-classification, transport data are collected using NSTR nomenclature. This comprises the following list of transport goods:

Table 4: NSTR-Aggregates

NSTR24	Category	Description
1	A	Getreide
2	A	Kartoffeln, sonstiges frisches und gefrorenes Gemüse, frische Früchte
3	A	Lebende Tiere, Zuckerrüben
7	A	Ölsaaten, Ölfrüchte und Fette
4	B	Holz und Kork
5	C	Spinnstoffe und Textilabfälle, andere pflanzliche, tierische und verwandte Rohstoffe
23	C	Leder, Textilien, Bekleidung, sonstige Halb- und Fertigwaren
6	D	Nahrungs-und Futtermittel
8	E	Feste mineralische Brennstoffe
9	F	Rohöl
10	F	Mineralölerzeugnisse
11	G	Eisenerze, Schrott, Hochofenstaub
12	G	NE-Metallerze und Abfälle von NE-Metallen
13	H	Metallprodukte
21	H	Metallwaren, einschließlich EBM-Waren
14	I	Zement, Kalk, verarbeitete Baustoffe
15	J	Verarbeitete und nicht verarbeitete Mineralien
16	K	Natürliche und chemische Düngemittel
17	K	Grundstoffe der Kohle-und Petrochemie, Teere
18	K	Chemische Erzeugnisse, ohne Grundstoffe der Kohle-und Petrochemie und Teere
19	L	Zellstoff, Altpapier
20	M	Fahrzeuge, Maschinen, Motoren, montiert oder nicht montiert, sowie Einzelteile
22	I	Glas, Glaswaren, keramische und andere mineralische Erzeugnisse
24	N	Besondere Transportgüter

To get from NSTR to CPA, we had to construct a bridge matrix, which – due to a lack of data recorded in both NSTR and CPA nomenclature – was to a quite large extent "ad hoc". A special problem is posed by NSTR-good 24 ("special transport goods"), which primarily consists of container transports without regard as to the contents of the container – it could hold everything from electronic components to agricultural produce. So, while some of the NSTR goods can be bridged to CPA commodities in a quite straightforward way, this is not possible for this special transport good. This good, to make matters worse, is vastly increasing in importance, to the tune that in 2002, it made up some 15% of all transports; a share which is even larger when the two most important transport goods, building materials and minerals, which together account for almost 40% of transport volumes, are taken into account. Therefore, transport flows of NSTR 24 are used in the bridge matrix for most of the manufactured commodities. The following bridge matrix gives an overview of the mapping between NSTR and CPA.

Figure 5: The bridge-matrix from transport (NSTR) to trade (CPA)

traded Commodities - 2-digit CPA	Transport Goods - NSTR aggregates													
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
01	90%													10%
02		100%												
05	80%													20%
10					100%									
11						100%								
12														100%
13							100%							
14										100%				
15				90%										10%
16				20%										80%
17			70%											30%
18			70%											30%
19			70%											30%
20		100%												
21												80%		20%
22			66%											34%
23						100%								
24											95%			5%
25											66%			34%
26									95%					5%
27							95%							5%
28								90%						10%
29													80%	20%
30													33%	67%
31													70%	30%
32													33%	67%
33													33%	67%
34													90%	10%
35													90%	10%
36			66%											34%
37			75%											25%

As for trade in services, which are not transported (and therefore cannot be proxied by transport flows, leaving service trade without any statistical clues as to its volume), again an "ad hoc" heuristic was used: demand for such services is – to varying degrees – met primarily by production in the same region; then by production in neighboring regions; in the provincial capital; and, lastly, in Vienna, the national capital.

3.8. The treatment of imports

Although imports could in principle be included in the derivation of the trade matrix as described above, we refrained from doing so, because the above method does not allow for the different treatment of, say, trade in intermediates and in consumption goods. In the case of imports, however, the Austrian Make-Use tables give a very detailed description of import shares, allowing for all users (sectors and components of final demand) to exhibit different import propensities – as a result, import shares do indeed vary widely. To retain this level of detail, we chose not to include imports in the derivation of the trade matrix; however, to be able to do so, we had to make the assumption that for some user of some good, import shares are the same in all districts; consequently, import shares are different between users and commodities, but not between regions.

3.9. From Purchaser to Producer Prices – Margins, Subsidies and Taxes

As was the case with import shares, in the case of margins (wholesale, retail sale, and transport margins) as well as commodity subsidies and taxes, we assume that these are different for all commodities and all users (as given by the Austrian Make-Use tables), but identical in all districts.

3.10. Behavioral equations

MultiREG-D is intended to be an integrated econometric Input-Output model. So far, we have demonstrated the derivation of two of the three key elements: the IO-part and the trade matrix. Missing from the complete picture is the econometric part to capture, in an economically sound way, the behavior of economic agents. Among those are:

- total private consumption (as a function of disposable income)
- the commodity structure of private consumption (as a function of relative prices, for example via an AIDS specification)
- the "production block" describing factor demand (for intermediates and labor, possibly energy as a separate factor) and output prices
- investment demand (ideally as a function of shadow prices)
- the level of (foreign) exports and imports.

As such, these equations do not introduce new variables and parameters into the model. Rather, they serve to endogenize shares which in a pure IO-model would be calculated from the Make-Use tables and taken to be constant: for example, demand for intermediates is given by total intermediate use (by sector) divided by sectoral output (as given by the make matrix). In an IO-model, this share would be treated as given; the appropriate behavioral equation would alleviate this assumption by making the share dependent on other model variables (in this case, the price of labor and the price of intermediates would play a major role in this equation).

Within the duration of the present project, this plan proved too ambitious; consequently, MultiREG-D so far consists "only" of the regional make-use tables, linked by the trade matrices. Only (foreign) exports and imports, via Armington-type price elasticities, are fully endogenous even in the current model.

With one exception, however, this does not render the main aim of this project obsolete: to explore the feasibility of a combined economic-transport model. This one exception is the price equation: in the full EIO-model, output prices would be determined in the production block, and would react to changes in the output level (as well as changes in the factor prices, among others). Changes in output prices (which feed back to changes in commodity prices), however, are central to the simulations envisaged for the combined economic-transport model. So, in order to "simulate" such price reactions, we introduced an "ad hoc" specification for prices: it assumes that output prices react positively to the output level (i.e., rising output leading to rising prices, and vice versa). Via this venue, changes in output can feed back to changes in (foreign) exports and imports, as well as inter-regional demand. To dampen the effect of the price reactions (feedback mechanisms providing damping, from a numerical point of view, the model is in dire need of), we chose a sort of logistic function for the price reaction, effectively putting a ceiling over and a floor under allowable price levels (these are taken to be 1.2 and 0.8 times base prices, respectively). In the final simulations, which included gravity equations for inter-regional transport and trade (more on this below), this proved crucial for the "solvability" of the combined model.

3.11. The Model Structure

Attempts at the sequential description of a system of simultaneous equations are always fraught with the problem of where to begin. In the case of an EIO-model like MultiREG-D, a good starting point might be to stress the main roles of our three basic blocks: the regional make and use matrices, the behavioral equations (as envisaged) and the trade matrix.

3.11.1. The main blocks

In the full EIO-model, the behavioral demand equations (private consumption and investment on the one hand, factor demand on the other) serve to establish the level of total private consumption or total intermediate demand by sector (all at the regional level, of course). In this, these components of demand are driven by economic variables like income, prices, production levels (most of which are determined endogenously as well). Without behavioral equations, these levels are simply derived using (constant) IO-shares.

These total demand levels are broken down to demand for commodities using information from the regional use matrices (or, in the case of private consumption, from the AIDS model). After adding demand for foreign exports, which are determined on the basis of domestic commodity prices (the foreign price level is exogenous), using Armington elasticities this results in **regional demand for commodities**, i.e. demand which arises within a specific region. This is not to be mixed up with **demand for regional commodities**: after all, the demand within some region could be satisfied by imports, either from other regions (regional imports) or from abroad (foreign imports).

This is where the trade matrix comes into play: the task of this matrix is exactly the determination of commodities' region of origin. As an example, according to the trade matrix, almost half of Wien's demand for *food and beverages; tobacco* was imported from districts in Niederösterreich, almost a third was imported from abroad, while less than 10 % was produced in Wien itself. By summing the demand for commodities from some region over all regions (and abroad), total demand for commodities from this region can be calculated.

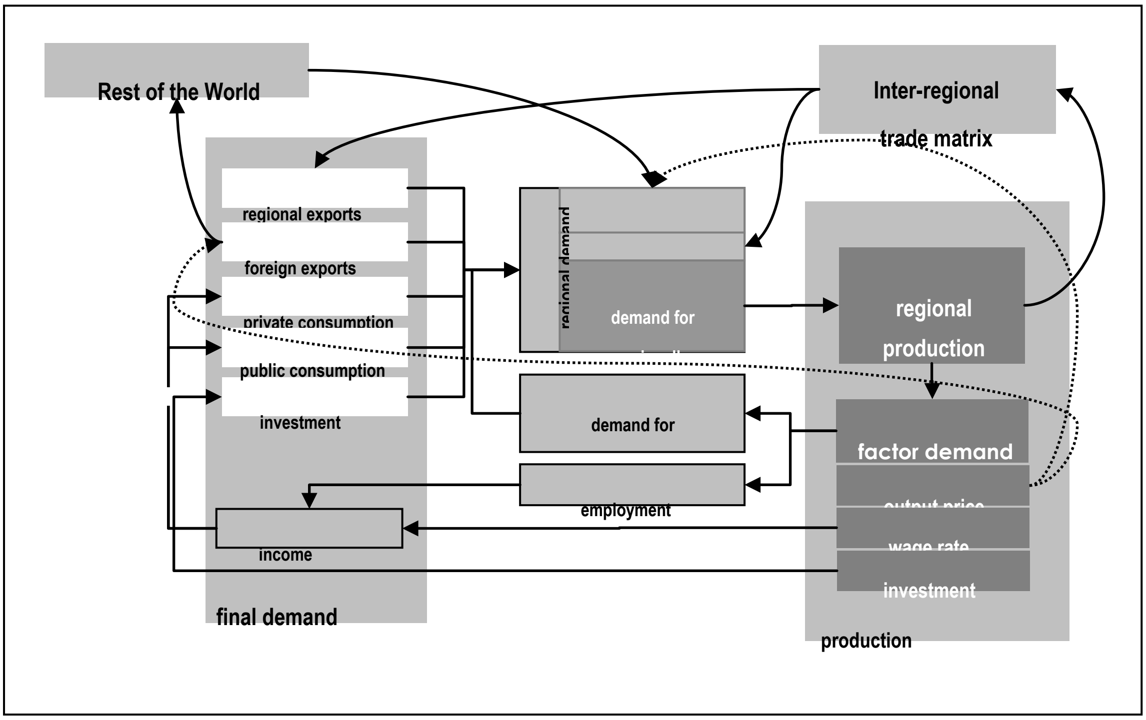
The next step involves sectoral production levels to meet this demand for regional commodities. As our regional make matrices allow for secondary production, a simple equation equating level of demand for some regional commodity to the necessary level of production of the respective sector (which would imply a primary production structure) is not sufficient. Instead, information from the make matrix has to be utilized. A possible approach would involve the matrix D of market shares (which is obtained by dividing each cell of the commodity-by-sector make matrix V by its respective row sum): sectoral output q_r necessary to meet the demand for regionally produced commodities g_r could be calculated by multiplying the vector of regionally produced commodities, g_r, with the matrix share matrix D_r:

$$q_r = D_r \times g_r$$

The drawback is the assumption of constant market shares: combined with changes in the relative sectoral production levels, this would imply changes in the make matrix (which, by the way, can be quite substantial). A better approach seems the assumption of a constant make matrix (and, implicitly, a variable market shares matrix). In this case, sectoral production is calculated more or less directly from the make matrix V_r: first, calculate $\overline{V}_r$ by dividing each element of V_r by its respective column sum ($\overline{V}_r$ then shows the commodity structure of each sector's output). Then, from $g_r = \overline{V}_r \cdot q_r$ (regional production of commodities is equal to regional sectoral output multiplied by the sectoral commodity structure), a level of production $q^0{}_r$ which is necessary to produce a given vector of commodities g'_r can be obtained from $q^0{}_r = \overline{V}_r^{-1} \times g'_r$.

To understand the solution process, it is best to have a second look at MULTIREG-D's structure:

Figure 6: The Structure of MultiREG-D



In the light of our previous paragraphs, the two blocks marked „final demand" and „production" are in terms of levels of "institutional" demand (total private consumption, total sectoral factor demand), whereas the block marked "regional demand" as well as the inter-regional and international trade blocks are in terms of commodities.

In more detail the procedure is as follows:

1. Initial estimates for the components of final (i.e., private and public consumption, investment) and intermediate demand;
2. Conversion of these "institutional" demands into demand for commodities (using fixed structures as given by the use tables; or, alternatively, using the endogenous coefficient matrix for intermediate demand, the AIDS results for final demand, and the assumption of constant commodity structures for public consumption and investment); demand for commodities as modeled in the AIDS part depend on the prices of consumption goods (which in turn depend on output prices);
3. Calculation of foreign exports by commodity according to the Armington assumption and of regional exports by commodity from the inter-regional trade matrix (which might also depend on the regional distribution of production); this results in regional demand for commodities;
4. Correction of the regional demand for foreign imports (which, like foreign exports, are endogenously determined, based on domestic prices and Armington elasticities) and

regional imports (again derived from the trade matrix), which yields demand for regionally produced commodities;

5. the structural make matrix $\hat{V}_r$ is used to determine regional production levels by sectors required to meet this demand;
6. with these sectoral production levels, the cost functions (if available; in the current version, this purpose is served by the logistic-type functions described previously) are used to derive output prices;
7. from these output prices and commodity prices are calculated (latter are a weighted sum of output prices, the weights being given by the relative share of each sector in the production of any one commodity).
8. The new level of output determines value added and employment; from this (correcting for taxes and transfers, yielding disposable income) new levels of private (and public) consumption are estimated, and investment demand and demand for intermediates also based on the new output levels, the procedure is iterated from step 2.

3.11.2. Numerical Aspects

The model as described above is implemented in GAMS. Although mainly known as an optimization engine, GAMS also offers solvers to deal with systems of (constrained) non-linear equations. This feature was used for the present model, allowing the utilization of GAMS's very flexible and powerful programming language. As a result, the model code itself fills only a handful of pages (apart from rather more pages, in which sets and variables are defined, matrices and parameters are read from excel-spreadsheets, calibrations are performed and – after solution – the results are saved to excel-spreadsheets). In all, the model contains some 9 Mio equations (although, to quote Peter Dixon's bon mot about his own multi-regional CGE-model of Australia, "most of them are very simple ones").

4. Modeling freight transport and interregional trade

4.1. Review of theories and modeling approaches

4.1.1. Introduction

This introductory section tries to provide a framework for the modeling work on the freight transport and regional trade model. To this end, it briefly reviews some of the reference models and theories, some empirical results on trade and freight transport (costs) as well as the specific issue of mode choice in freight transport.

In particular, different theoretical and empirical approaches to the modeling of the related issues of freight transport and interregional trade are reviewed, namely, (i) the gravity model, (ii) the four-stage approach towards freight transport modeling originating from transport planning and (iii) some theoretical models of trade from economic trade theory. The aims of the section are, first, to support the point made above about the close relation between freight transport and interregional trade, and, second, to motivate the approach used later on, a gravity model of freight transport / trade using an ad-valorem measure of transport costs as deterrence function.

4.1.2. The gravity model

The gravity model is a framework to describe the distribution of regional interactions in a series of fields. In very general terms, it can be formulated as follows:

$$I_{ij} = f(sc_i) \cdot f(sc_j) \cdot h(b_{ij})$$

The key assumption of the gravity model is that the size of the interactions between two regions i and j, I_{ij}, is a positive function of both regions' sizes and characteristics, sc_i and sc_j, as well as a negative function of some measure of barrier, b_{ij}, separating them.

The gravity model was initially conceived in analogy to the law of gravity in physics. The first application to a social or economic phenomenon was in the field of retail shopping but it has been applied to various other issues, including freight transport and interregional trade ever since (see e.g. Fotheringham and O'Kelly 1989; Sen and Smith 1995).

In all of these fields, the model has been an "empirical success" in that it succeeds in replicating observed interactions and flows with good to excellent model fits. However, the model has often been criticized for being a merely statistical relationship lacking sound theoretical underpinning. Over time, several scholars have shown that the gravity model is consistent with or can be derived from different theoretical models. Examples relevant here include Anas (1983), who proved that the gravity model can be derived from a discrete choice model; in the field of trade theory, others have shown that the neoclassical model of trade incorporating product differentiation boils down to a reduced form akin to the gravity equation (e.g. Deardorff 1998).

A key issue in formulating a gravity model is the choice of an appropriate deterrence function. The most straightforward solution, applicable in a variety of fields, is to use geographical distance as a proxy for the factors impeding interactions between any two regions. However, depending on the specific issue concerned, more appropriate measures are available.

4.1.3. The four stage approach

The complexity implied by its network nature and the multitude of options (mode, shipping time, routes, etc.) implies that (freight) transport demand cannot be estimated via a direct demand function. In order to address this problem, the so-called four-stage model emerged as the standard in transport modeling which formulates transport choices in a sequential manner (McNally 2000).

The four stages are (i) trip generation, (ii) trip distribution, (iii) mode choice and (iv) route choice. Trip generation determines, for each region within the study area, the overall amount of transport, i.e. the number of outgoing and incoming trips. In contrast to this, the remaining stages share models allocating the total from the generation model to successively more detailed options. The main determinants in this stage are structural characteristics of the individual regions. In trip distribution the transport potentials identified before are recombined to generate a matrix of transport flows. Distribution is essentially a destination choice model and the main influencing factor is some measure of transport impedance, usually captured by distance, travel times or the so-called 'generalized costs of transport'. Mode choice deals with the allocation of transport flows to alternative modes and route choice finally assigns the mode-specific flows to individual links of the transport networks.

As the stages are usually treated separately in the modeling process with little feedback, different modeling approaches can - and typically are – be used in the different stages. In the generation stage, the usual approaches are growth factor models (amounting in principle to trend extrapolation), the use of economic forecasts, category models (average trip regeneration rates are calculated for a number of categorical variables characterizing regions) and regression models (statistical relations between trip generation and structural properties of regions). For the trip distribution stage, the gravity model largely dominates as methodological approach, while discrete choice models are used only occasionally. As mentioned above, the main role of the gravity model is to determine the impact of the generalized costs of transport on the distribution of freight flows.

The four-stage model has its origins in passenger transport modeling. However, the framework can also be fruitfully applied to the modeling of freight transport (D'Este 2000) and has become the dominant approach in freight transport as well. A detailed treatment on how to apply the four-stage model to freight transport modeling is given by Cambridge Systematics (2007). An alternative to the four-stage model not based on gravity modeling are "strategic freight transport network" models (see e.g. Friesz 2000). These partial equilibrium models of the transport sector build on the spatial price equilibrium framework (Takayama and Labys 1986).

4.1.4. Trade theory: modeling international and interregional trade

In economics, trade theory and – to a somewhat lesser extent – urban and regional economics deal with the issue of international and interregional trade.

Four models dominate as (neoclassical) explanations of the question why nations and regions engage in trade with each other. The classical Ricardian trade model assumes that differences in labor productivity make countries fully specialize in the production of one good. The first contending alternative, the Heckscher-Ohlin model, pays more attention to the factor inputs used in production. It predicts that countries will specialize in the production of goods that make ample use of abundant input factors, while they will import goods that mainly use relatively scarce factors.

More recently, the "new" trade theory emphasized the role of increasing returns in production in shaping international trade, allowing for 'endogenous', self-reinforcing concentration of trade and production in individual countries or regions. In the earlier theories, concentration was the result of exogenous, given factors, such as physical geography or the availability of natural resources. The model also succeeds in explaining the empirical incidence of inter-industry trade, i.e. the cross-hauling of similar goods between countries with similar factor endowments (e.g. the exchange of cars between, say, Germany and France).

Even more recently, other authors suggest models that help to explain strongly increasing trends such as the above-average growth of trade in intermediate goods, the off-shoring of (parts of) production processes and the general tendency to (geographically) 'slice up the value chain' of formerly integrated production processes (e.g. Jones and Kierzkowski 2005; Grossman and Rossi-Hansberg 1997). By turning the assumptions of new trade theory on its head, assuming constant returns to scale in production and increasing returns in 'services links' (which they assume to include transport), Jones and Kierzkowski explain the ever-increasing fragmentation of regional and global production.

An interesting property of these quite distinct theories is that all of them generate trade patterns which are similar to those predicted by the gravity model. In particular, all models are consistent with the key premise underlying the gravity model, namely that the extent of bilateral trade flows (i.e. flows between two specific trade partners) is positively related to the economic sizes and characteristics of both trade partners and is negatively affected by barriers, spatial or otherwise, prevailing between them. Thus, the gravity model, despite being quite simple in its structure, seems to be quite generic and can be motivated by more profound theoretical arguments.

4.1.5. Conclusions from the literature review

From the brief literature review on trade theories, freight transport modeling and the gravity model, we draw some conclusions that will be relevant for our own work.

The first conclusion concerns the close relation between freight transport and trade modeling. Figure 7 juxtaposes the four-stage transport model with a rough structure of an interregional economic model. Even though the overall scope of models is obviously different, there is a significant amount of overlap in that both models address the questions of (1) how much goods are being transported in the economy and (2) how these total amounts translate into flows between specific origins and destinations. The difference between transport and trade analysis is mainly in the perspective taken: transport modeling deals with physical flows of vehicles (in trips) or commodities (tons), whereas trade models are formulated as trade flows in value terms (Euros).

The approach taken in this project is therefore to exploit this close relation to link the multiregional economic MultiREG-D and the transport model MARS into an integrated economic-transport modeling system.

The second conclusion addresses the methodological approach. In freight transport modeling, the gravity model is the workhorse in the traffic distribution stage of applied transport models on various scales. In the (international) trade literature, the gravity model has also been successfully used and, as has been shown above, can be motivated by more profound theoretical models and arguments. This leads us to conclude that the gravity model is indeed an appropriate framework for the purposes of this project.

The third conclusion concerns the choice of an appropriate measure of transport costs. The "new" trade theory can be used to derive an economically meaningful measure of transport costs, as will be demonstrated using the monopolistic competition trade model put forward by *Krugman* (1980).

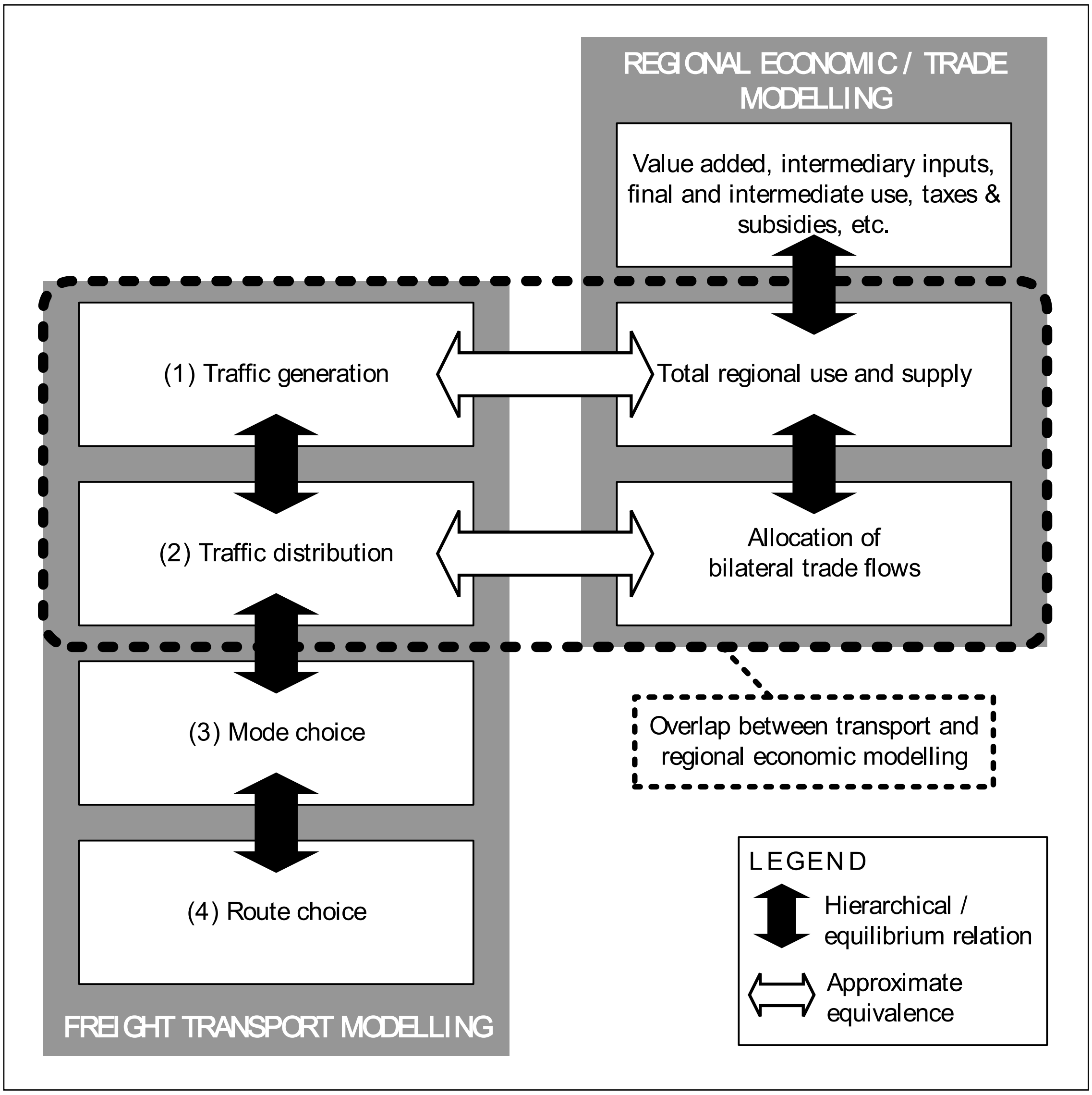
In this model, different varieties of the same good are produced by firms in different regions. Because intermediary users or final consumers value variety[5], they consume varieties from all other regions but the allocation over source regions is influenced by the extent of transport costs associated with goods from these regions. The demand of a user in region i for the output of region j, t_{ij}, can be derived as (see e.g. Hummels 1999):

$$t_{ij} = Y_i \left(\frac{c_{ij} p_j}{P_i^{-1/\sigma}} \right)^{-\sigma}$$

The trade flow will therefore depend on the mill price (net of trade / transport costs) price at the producers' location, the ad-valorem trade / transport costs c_{ij}, the elasticity of substitution between goods, s , and the prices in all regions as captured by the price index P_i .

[5] The utility function is a CES function over varieties of the good produced by a sector, $U = \left(\sum_j c_j^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$. For the purposes of the trade model, products originating from different source regions are interpreted as distinct varieties of the same good.

Figure 7: The overlap between freight transport and regional economic modeling



This demand structure is of course the result of assumptions underlying the model (yet quite plausible ones), and not an empirically identified characterization of real-world consumers' and intermediate users' behavior. However, accepting this reliance on (plausible) modeling assumptions, some conclusions as to the specification of a freight transport / interregional trade model can be drawn:

(1) The impact of trade / transport costs on trade / transport manifests itself not such much through the absolute level of transport costs, but through their importance relative to product values. This implies that the transport / trade flows of low-value goods will be

more strongly affected by the same absolute level transport costs than those of high-value goods.

(2) For rather homogenous goods[6], transport costs will have a stronger effect on the volume of trade than for more differentiated goods. This appears intuitively clear, as few users of a good will be willing to accept higher prices for goods from distant suppliers (due to transport costs), if in function, quality, or other properties they are comparable to products from closer suppliers.

Even though in what follows we do not build a CGE-type neoclassical model of interregional trade, we retain the notion that from a theoretical point of view, the most meaningful measure of transport (trade) costs is the specification as an ad-valorem transport cost rate (or, as in the example above, the ad-valorem rate plus one).

This way we capture both the inter-regional variability that transport costs introduce in final users' prices (and, thus, on sourcing decisions) as well as the inter-commodity variability (low-value goods are more strongly affected by transport costs than high-value goods).

[6] Those for which products from different sources are close substitutes as captured in the model by a high elasticity of substitution S

4.2. Barriers to trade and freight transport

The gravity approach illustrates that trade and transport flows are structured, besides the distribution of production and consumption of goods, by barriers that separate regions from each other. This section reviews the kind of barriers considered in transport planning and trade theory, gives some estimates of their quantitative extent and closes with some conclusions.

4.2.1. The measurement of trade and transport costs

The perspective of transport planners and transportation engineers is not surprisingly focused on barriers within the domain of transport. The concept of generalized transport costs, or GTC for short, allows both for the monetary and non-monetary costs of passenger and freight transport (Ortùzar and Willumsen 1994). Monetary costs are equal to freight rates charged by shippers for third-party transport or calculated bottom-up from detailed operating cost components (resource cost, taxes, insurance and infrastructure use charges) in the case of in-house transport. Non-monetary costs include capital costs and depreciation of the goods in transit. These can be estimated from industry- and commodity-specific studies (rates of return; depreciation rates) or by studies on the willingness-to-pay for transit time reductions.

The advantage of the GTC measure of transport costs is that due to bottom-up calculation procedure, they can be decomposed into different constituent parts. Combes and Lafourcade (2005) devise four criteria a useful measure of transport costs should meet and find that a GTC-style measure satisfies most of them. It should reflect (i) differences in itinerary [i.e. it should capture properties of the infrastructure], (ii) differences in the mode used, (iii) and the type of commodity and, finally, (iv) demand that the impact of each of these components should be decomposable in the overall measure. Moreover, they compare their measure with the cruder proxies (great circle distance, road distance and road travel time) often used in the empirical trade literature. They find that while the proxies perform well in capturing cross-sectional differences in transport costs, they are much less adequate to describe temporal changes in transport cost patterns.[7]

In economics, trade theory usually embraces a broader concept of "barriers to trade" which extends well beyond narrowly defined transport costs. Barriers to trade are categorized into transport rates, policy barriers (tariffs and non-tariff barriers such as quotas, different standards) and a host of other, largely immeasurable barriers such as differences in institutions, language, culture and the like.

Measuring barriers to trade is not a straightforward undertaking (Anderson and Wincoop 2004). Only those barriers that can be quantified in monetary terms, essentially transport costs and tariffs, can be measured directly.

The most common approach to measure the directly observable transport costs is to use data from national and international trade statistics. Typically, trade statistics record the value

[7] The most extreme example being great circle distances which cannot capture any changes in transport costs.

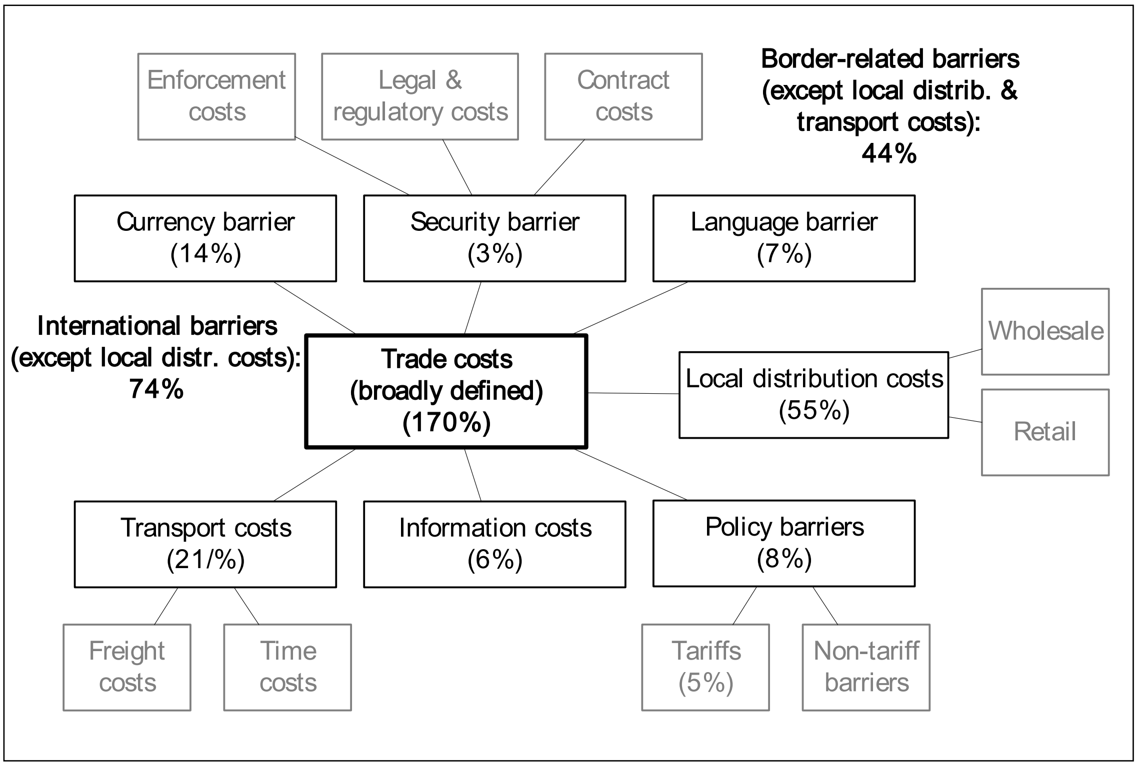
of imports in CIF and FOB measures.[8] The difference between these values is largely equal to the transport costs of international transportation. Therefore, the expression $(CIF/FOB) - 1$ provides an ad-valorem measure of transport costs.

In order to determine the extent of the other barriers, one has to resort to indirect inference from observed trade flows. The rationale underlying the approach is that if, controlling for other factors, observed trade flows between two regions are low, there must be some trade barrier separating them. The strength of the barrier can be estimated in a gravity model. The main explanatory variable in such models is usually the distance between trade partners, complemented by further proxy variables capturing features such as common border, same language, membership in the same free-trade-union, and so on. Ultimately, the effects of the proxy variables can be converted into an ad-valorem trade cost equivalent which allows comparisons of the significance of different trade barriers.

[8] The FOB (free on board) quotation of imports measures the value of imports at the "port" of shipment in the origin country , whereas CIF (cost, insurance, freight) measures the value at the port of reception in the importing country, i.e. it includes transport costs.

Figure 8 gives an overview of broadly defined trade barriers and shows estimates of the extent of these barriers. It appears that transport costs constitute a relatively minor share (21%) of the overall barriers to international trade ('typically' 170% on an ad-valorem base in an industrialized country). On the other hand, local distribution costs presumably include further transport costs.

Figure 8: Barriers to trade and their 'typical' ad-valorem tariff equivalent for industrialized countries.



Source: Anderson and Wincoop (2004)

4.2.2. The significance of transport costs

The significance of transport costs for the structure of the spatial economy, and thus for trade and transport flows, has been repeatedly called into question. This has led some to proclaim the "death of distance". In the scientific literature, Glaeser and Kohlhase (2004) take the radical stance that in modeling the spatial economy, the costs associated with physical transport of manufactured goods should be assumed to be zero.[9] They substantiate their claim with the concurrence of (i) a dramatic decrease in unit transport costs (due to technological progress) and (ii) the structural shift from manufacturing towards services which directly reduces the importance of freight transport costs and, indirectly, implies an increase in the unit values of the physical goods shipped (which reduces the ad-valorem cost of

[9] In contrast to passenger transport, where they suspect increasing costs in the past decades.

transport). They conclude that the vanishing importance will have profound consequences for economic geography.

Empirical estimates on the incidence of transport costs in total output value in the economy seem to support such arguments. Table 5 shows, for the specific case of Austria, the share of transport costs in total output value by industry. Estimates are differentiated as to whether transport costs embodied in intermediary inputs are taken into consideration or not, and whether own-account transport is included or only costs associated with third-party shippers are considered.[10]

Table 5: Transport cost as a share of product value in Austria 1976. Industry classification based on "Betriebssystematik 1968". Source: Otruba and Stiassny (1986, p. 29)

	Intermediary inputs			
	Excluding		*Including*	
Industry	Own-account transport *Excluding*	Own-account transport *Including*	Own-account transport *Excluding*	Own-account transport *Including*
Agriculture and forestry	1.7%	2.6%	3.4%	4.9%
Energy and water supply	2.0%	2.5%	4.4%	5.4%
Mining and quarrying	1.1%	1.6%	1.8%	2.1%
Man. of food products, beverages, tobacco	1.6%	2.6%	4.4%	6.4%
Man. of textiles, clothing, leather	1.7%	2.4%	4.5%	6.2%
Man. of wood products, sports equipment	3.0%	4.6%	6.3%	8.7%
Man. of paper, printing and publishing	2.9%	3.6%	6.3%	7.8%
Man. of chemical products	2.2%	3.1%	4.8%	6.4%
Man. of non-metal mineral products	3.9%	5.3%	7.2%	9.1%
Man. of basic metals	4.3%	5.2%	9.5%	11.4%
Man. of metal products	2.4%	3.2%	6.3%	7.9%
Man. of machinery and equipment	2.1%	3.1%	5.8%	7.7%
Man. of electrical equipment	1.8%	2.4%	4.9%	6.5%
Man. of transport equipment	1.3%	2.2%	4.3%	6.3%
Construction	4.5%	5.9%	7.6%	9.8%
Wholesale and retail trade, storage	3.5%	4.0%	5.2%	5.7%
Hotels and restaurants	1.6%	3.0%	3.6%	6.4%
Transport and communication	1.4%	11.7%	114.8%	115.8%
Financial intermediation	2.4%	2.5%	3.5%	3.9%
Real estate, business serv, priv. & pub. Serv.	2.6%	3.3%	4.8%	6.0%

Even in the most encompassing case (both embodied and own-account transport costs considered), the share of transport costs only exceeds the 10% mark in only one industry, manufacturing of basic metals (11.4%). Most other industries are in the 4 to 10 % range, with one outlier to bottom, mining and quarrying incurring a transport costs share of merely 2%.

There are, however, good arguments why the apparently low share of transport costs in overall production costs need not imply that transport costs are irrelevant for trading (transport) patterns and economic geography.

[10] Taking own-account transport into consideration requires rather strong (and potentially deceptive) assumptions. Therefore figures excluding own-account transport are reported as reference.

First, if transport costs are more variable than other production costs, such as labor, land and energy, small changes in transport costs imply large changes in profits. Changes in transport costs may thus have tangible effects on the locational patterns of certain industries or the economy as a whole (SACTRA 1999).

Second, transport costs may be low precisely because trade relations are organized so as to minimize transport costs (Hummels 1999). This implies that in industries where unit transport costs are high, trading relations are more local than in industries where costs are low. The fact that total transport costs are low does not mean that transport costs do not affect trade flows.

Third, if goods are close substitutes, even small differences in trade (transport) costs imply large effects on trade (transport) volumes (Hummels 1999). If goods produced in one country (region) are relatively close substitutes for those produced in another, then relatively minor changes in transport costs may have a significant impact on import and sourcing decisions.

Some of the arguments above can be illustrated by the figures in Table 5: The "mining and quarrying" industry is an activity producing distinctively low-value products (as measured in Euros per tonne) and would, thus, appear as a natural candidate for a high ad-valorem share of transport costs. However, it actually exhibited the lowest transport cost share of all industries in Austria. Obviously, sourcing decisions in this activity are made to keep overall transport costs low, even though unit-transport costs (transport costs per km) are high on an ad-valorem basis. Moreover, one of the main products of this industry, gravel and sand for construction purposes, is characterized by an arguably low product differentiation. As outlined above, the distance-deterrent effect of transport costs is magnified in such cases, helping further to explain the low share of transport costs in this industry.

4.2.3. Conclusions

The review of transport cost measures in the fields of trade theory and transport planning gives valuable clues on how to best measure transport costs for our purposes.

First, the choice of a transport measure is constrained by the availability of data. On a domestic level, information on actual transport expenditures is simply not available, particularly not on a relation-specific basis. Thus, we cannot use a CIF/FOB ratio-based measure of transport costs as in the international trade literature.

In any event, aggregate measures of transport rates like CIF/FOB ratios provide no information on the components of transport costs. However, a breakdown of transport costs is crucial for the policy sensitivity of the measure in policy simulation. The concept of generalized transport costs does provide this decomposability and is well-established in transport analysis. Unlike CIF/FOB ratios, GTC are not automatically expressed in ad-valorem terms. However, as we concluded earlier that transport costs are most appropriately measured in ad-valorem terms, we will use (approximate) unit value to do this conversion.

Finally, we restrict ourselves to transport costs and neglect other costs of or barriers to trade for now. While the trade literature shows that costs other than transport dominate within overall trade costs in international trade, transport costs presumably play a much greater role in the intra-national context. The reason for this is that many of the non-transport trade barriers, such as those related to language, currency exchange or differences institutional frameworks, simply do not exist within the same country. Therefore the use of transport costs only appears as a justified simplification to base our analysis on.

4.3. Transport cost and inter-modal competition

Modal choice is a central issue in transport modeling, illustrated not least by the fact that it represents a stage of its own in the four-stage transport model. However, in network-wide freight transport models, including modal choice is a serious challenge.

In passenger transport, differences in generalized transport costs between modes are a key determinant of modal shares. Generalized transport costs, in turn, are readily calculated from other "hard" variables, such as travel times and the costs of motoring. Passenger transport models therefore can build on a choice of readily quantifiable factors to model modal choice.

There are a few of reasons why things are more complicated in freight transport (Cambridge Systematics 2007).

First, qualitative issues, such as reliability, flexibility, and complementary services, are more important than travel times and costs. However, such issues are notoriously hard to quantify. Therefore, freight transport lacks reliable and tangible explanatory variables.

Second, less information is available in those fields were hard variables do matter. In particular for modes other than road, little information is available on actual travel times and transport rates. The latter is particularly problematic as due to strategic price setting, actual prices often deviate from costs but are kept secret for confidentially reasons (Puwein 2000).

Third, on a methodological level, the structure of decision making in freight transport poses problems. The most common type of mode-choice model, the discrete choice model, relies on the assumption that decision makers and shipping units are identical, an assumption that is typically valid in passenger transport. However, in freight transport, individual decision makers may be responsible for millions of tons of freight, thus undermining the validity of the model.

As a result, modal choice is rarely modeled explicitly in applied, network-level freight transport models (Cambridge Systematics 2007). For this reason, we, too, refrained from explicit modal choice modeling in this project.

5. Linking MARS and MultiREG-D

5.1. Overview

Above we tried to highlight the close relation between interregional trade and freight transport. In particular, Figure 7 identified an overlap including the generation and the distribution stages of the four-stage transport model which correspond to the determination of total regional use / supply levels and the allocation of bilateral trade flows in interregional trade models, respectively.

The approach of the model that will be developed here is essentially to build a model of freight transport distribution / bilateral trade flows. This model, to be based on the gravity framework, makes trade / transport flows sensitive (endogenous) to changes in transport costs. It effectively links the MultiREG and MARS models, both of which did not include such a model so far.

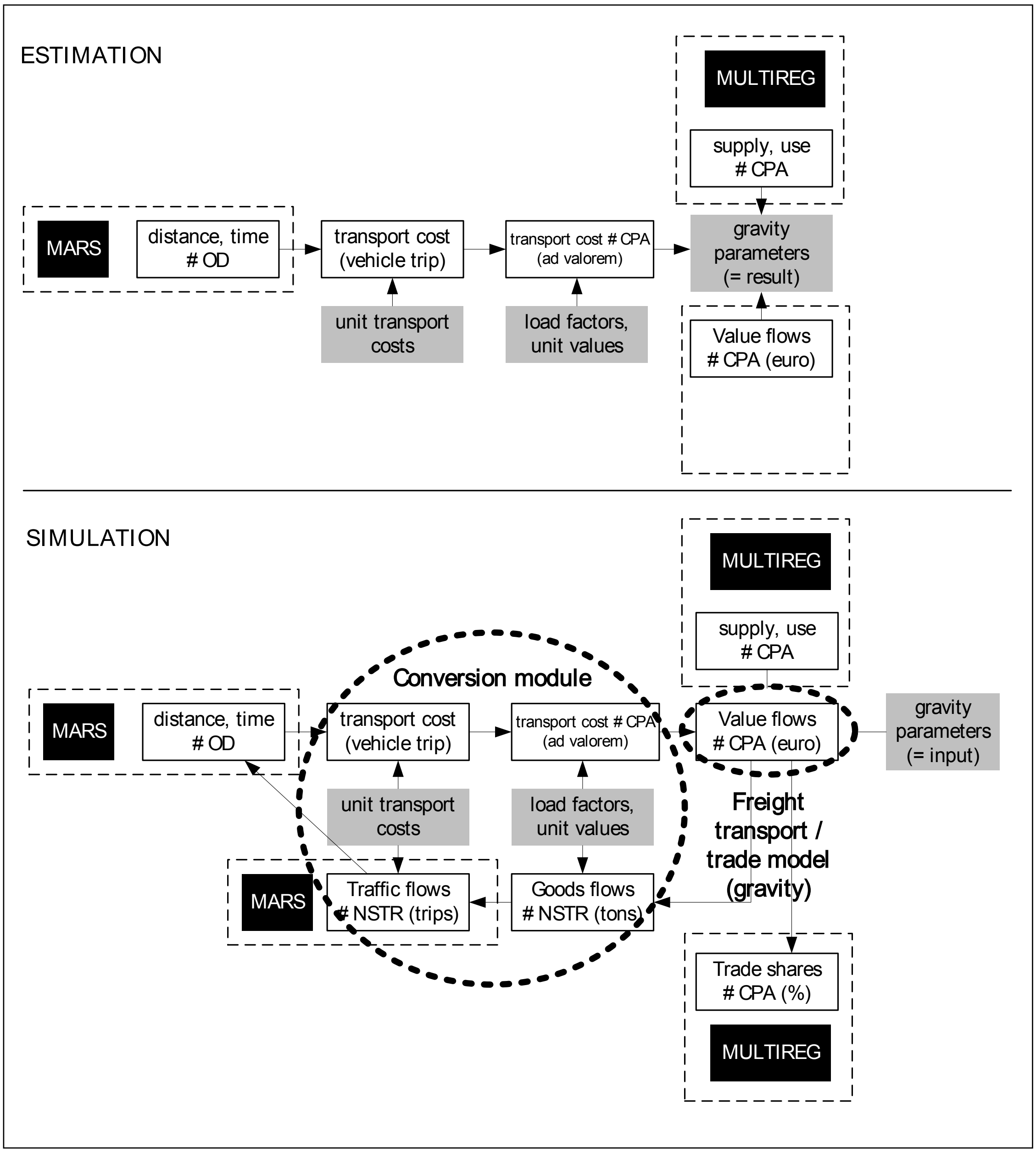
In terms of the four-stage framework, the generation stage is taken over by the MultiREG economic model. This is in line with the common practice in freight transport modeling to use economic forecasts instead of an explicit generation model. However, contrary to this practice, the economic model is fully integrated in the modeling framework. This allows for feedbacks from the transport to regional economic development instead of the usual one-way causality where economic development only influences transport. The link to the MARS (passenger) transport model consists in the endogenous, traffic-flow dependent determination of travel times on an aggregated network (OD-based). Again, there is full feedback between the network, the freight transport / trade, and the economic model.

In addition to the gravity model, some conversion procedures are developed. Notwithstanding the close relation between trade / freight transport, the difference in perspective between transport (physical vehicle or commodity flows in physical terms) and trade (commodity flows in value terms) requires a module for the transition between the transport and trade / economic models.

5.1.1. Model outline

Figure 9 details the way the trade / transport gravity model links the MARS and MultiREG models as well as the main components of the additional conversion modules. Moreover it illustrates the sequence of calculations and estimations during estimation and simulation, respectively.

Figure 9: The overall model structure for estimation and simulation: transport model (MARS), economic model (MultiREG), the freight transport / trade model and the conversion module.



The transport cost implications of various policy measures and external scenarios are captured through changes in travel distances and times (e.g. for transport infrastructure construction policies), or, alternatively, through changes in unit vehicle costs (e.g. following an exogenously triggered or policy-induced increase in fuel costs). The initial change in transport costs makes its way through the transport cost calculation module and influences the spatial distribution of interregional trade through the gravity model. Within the economic model, the transport-cost induced change in trade patterns is overlaid with reactions of intermediary users and final consumers within the input-output model. After convergence of the combined gravity and input-output model, the equilibrium reaction to the initial trigger need not be the same.

The trade reactions of the gravity and input-output models are then fed back into the network model of MARS where travel times change according to the changes in transport patterns. In this process, changes in trade flows are re-converted to equivalent changes in traffic (vehicle) flows.

Table 6 details the interfaces between the MARS, MULTIREG-D and the freight transport model developed here.

Table 6: Interfaces of the freight transport / trade model with the existing MultiREG and MARS models

1. **Model**	2. **Input to trade / freight transport model**	3. **Output from trade / freight transport model**
4. **Passenger & network transport model (MARS)**	5. Distances and travel times by origin-destination pair	6. Freight vehicle flows by origin-destination pair
7. **Interregional input-output model (MultiREG)**	8. Supply and use of goods by origin / destination region	9. Distribution of interregional trade flows by origin-destination pair

5.1.2. The transport cost measure and the conversion modules

It has been shown above that the most economically meaningful measure of transport costs is the ad-valorem transport rate. At the same time, aggregate ad-valorem measures usually used in economics (such as cif/fob price ratios from customs statistics) lack the policy sensitivity required in our model because these cost indicators cannot be decomposed in constituent, policy-dependent components.

We therefore opted for a transport cost measure that combines the bottom-up approach inherent in the concept of generalized transport cost, as used in transport planning / modeling , and the ad-valorem measures as customary in economic trade analysis. The first property guarantees the decomposability of our measure while the second ensures its economic content.

Linking the both levels requires a conversion module which takes over the transition between the transport and trade perspectives (see Figure 9). This conversion module operates in two directions: first it translates transport costs at the vehicle level (transport perspective) into ad-valorem transport cost rate (trade perspective) and, vice versa, converts monetary trade flows (trade perspective) into the physical flows (transport / traffic perspective, measuring commodity flows in tons and vehicles flows in trips, respectively).

5.1.3. The gravity model

Due to the allocation of duties between the MARS, the MULTIREG-D and the gravity model (see Figure 9), the focus of the gravity model is exclusively capture the effect of changes in transport costs on the distribution of interregional trade. The calculation of total supply and use by regions is done entirely within the MultiREG model. This obviates the need to model the total amount of freight (trade) supplied (demanded) in source (origin) regions conditional on structural characteristics of regions. Most applications of gravity modeling not only estimate the sensitivity of trade to transport costs (or proxies thereof) but also estimate the total extent of flows from variables such as population, economic output (GDP) or the like.

The value of commodity c traded between regions i and j, T_{ijc} is estimated according to the doubly-constrained gravity model:

$$T_{ijc} = \exp\left[a_c \cdot tcs_{ijc} + b_{ic} + c_{jc} + d_c \right]$$

The variable tcs_{ijc} is the ad-valorem measure of transport costs described in section 5.1.2.

The origin- and destination-specific balancing factors b_{ij} and c_{jc} ensure that the estimated trade matrices satisfy the row and column sum constraints. In other words they guarantee that for each commodity the sum over all destination regions of outgoing trade flows equals the total supply in each region and that the sum over all source regions of incoming trade flows equals the total use in each region.

The balancing factors incorporate all factors that determine the level of total supply and total use of commodities in a region, such as the size of the region, its sectoral structure and its comparative advantage relative to other regions (e.g. natural resources, educated labor, etc.).

Freight transport models often incorporate a preliminary model stage which explicitly models the generation and attraction of freight transport (trade) from such structural indicators, i.e. the generation / attraction stage in the four-stage transport model.

However, within the ETMOS modeling framework, the generation as well as the attraction of commodity flows is given by the total regional commodity supply and use determined in the input-output model MultiREG-D.

Instead of estimating a separate generation / attraction model that would necessarily collide with the economic model, the role of the catch-all balancing factors is simply to ensure the consistency between the economic and the freight transport / trade model.

The inclusion of these balancing factors in the econometrically estimated model implies that this consistency is explicitly reflected in the trade cost sensitivity parameters a_c.

5.2. Estimating freight transport costs

5.2.1. Spatial scope and differentiation of the model

The model is implemented at the spatial level of so-called 'politische Bezirke' (political districts). This level of disaggregation is in line with both the MARS and MultiREG models. The model covers the Austrian territory; foreign zones are not explicitly considered in the model for the time being. A map of Austria and its districts (including district codes) can be found in the chapter on the economic model.

As to the goods classification, the transport costs estimates as well as the gravity model follow the same (Ö)CPA 2-digit level as the economic model.

5.2.2. Calculation of the transport cost measure

Based on the distances and travel times by origin-destination (OD) relation taken over from the MARS transport model, the calculation of the ad-valorem transport cost measure proceeds in the following stages (see also Figure 9):

(1) Distance- and time-based unit costs on the level of the vehicle (lorry) yield absolute per-vehicle transport costs by OD pair (Euros per lorry trip)

(2) Commodity-specific load factors result in specific transport costs by OD pair and commodity (Euros per ton)

(3) Finally, unit commodity values yield ad-valorem transport costs by OD pair and commodity (transport costs as a share of product values)

Accordingly, the ad-valorem transport cost rate for commodity c between regions i and j, TCS_{ijc}, is calculated as follows:

$$TCS_{ijc} = \frac{TCV_{ij}}{LF_c \cdot UV_c}$$

where LF_c denotes commodity-specific average loading factors (tons per vehicle) and UV_c unit commodity values (Euro per ton). TCV_{ij} are the per-vehicle transport costs between regions i and j (Euros per lorry trip).

5.2.3. Cost components

This section details individual steps in the calculation of the ad-valorem transport cost measure as well as the data sources and assumptions to estimate them.

5.2.3.1. *Freight transport costs at the vehicle level and their components*

The basis for our transport cost measure is a detailed breakdown of the fixed and variable costs of lorry operation in Austria. Such data lie within the domain of freight haulers and their associations. Indeed, the most detailed scheme to has been developed by Prognos AG (1998).

The method distinguishes fixed vehicle-related costs (depreciation, capital cost, taxes and insurance), variable vehicle-related costs (maintenance, fuel, tires and other expendable materials), payroll costs and infrastructure charges.

As an approximation, fixed costs have been converted in variable costs by dividing them through characteristic operation duration (hours per year). Thus, our measure captures average not marginal costs of trucking in Austria. The resulting unit transport cost figures are shown in table 3 which has been aggregated from more detailed information provided by ProgTrans (2005).

The figures in the table reflect the costs associated with a articulated lorry with a total gross weight of 40 and a payload of 26 tons. The service life is assumed to be 7 years, with an average mileage of 140.000 kilometers per year.

Table 7: Values of distance and time related unit transport cost

Cost Category	Euro/veh-km*	Euro/veh-hour
(A) DISTANCE-RELATED		
Tire & maintenance	0.07	
Tire	0.02	
Semi-trailer axle	0.01	
Drive axle cost	0.01	
Steering axle cost	0.00	
Maintenance & operating cost	0.05	
Tolls	0.33	
Regular toll (...)	0.33	
Special tolls	0.00	
Fuel cost	0.33	
Total	0.73	
(B) TIME-RELATED		
Depreciation	0.08	4.5
Charges, taxes	0.19	11.6
Insurance	0.05	3.1
Driver's wage	0.21	12.6
Total	0.53	31.83

* Based on a speed of 60 km/h for time-related costs
Source: ProgTrans AG (2005)

Because the scheme distinguishes distance and time related transport costs, it can capture differences in the quality of the road infrastructure. Trips on high-level infrastructure, such as motorways or grade-separated dual carriageways, thus incur lower cost per kilometer than trips on ordinary roads.

Left aside in this calculation scheme are haulers' overhead costs at the level of the establishment or firm (administration, management, etc.). As these are fixed costs vis-à-vis an individual shipment, considering these could be used to consider economies of scale in haulage at the firm level. However, as this would require a host of additional information (or assumptions) on the shipping industry and a much more sophisticated model of the transport industry, we refrain from this for the time being.

The cost figures capture a 40 ton lorry which is used in international and domestic long-distance transport. A potential improvement in the future would be to consider the use of smaller vehicles with higher unit transport costs for local short-distance transport. This would capture transport cost economies with respect to distance.

5.2.3.2. Loading factors

Loading factors of individual shipments may vary due to a host of reasons. On physical level, high-density goods (in a physical sense), such as building materials, are mass-constrained while lower-density goods, such as apparel, are constrained by volume. Differences in load factors also result from the high and low capacity utilization. The frequent occurrence of less-than-truckload (LTL) shipments may be due to irregular temporal patterns of transport flows which cannot be absorbed by lower shipping frequencies or smaller vehicles. Vehicle sizes are limited in the local distribution or pick-up of freight within urban areas; large vehicle are more economic on long distance routes where it is possible to bundle freight flows.

To capture at least a rough aggregate of all these effects and their variation between goods, we consider the aggregate load factors by commodity. The values are derived from the official Statistics Austria survey on road freight transport (Statistik Austria 2004). As transport statistics are classified according to the NSTR classification of goods, these had to be converted to the (Ö)CPA classification used in the economic and freight transport / trade models. This was done based on an expert estimate as to the composition of (more detailed) ÖCPA in terms of NSTR transport goods. Table 8 shows the resulting load factors (tons per shipment).

The highest loading factors exceed the lowest ones by a factor of 2.3. The pattern across goods appears to be fairly plausible, with commodities showing relatively high load factors (e.g. timber / ÖCPA 02 and crude oil / ÖCPA 11) and manufactured goods, such as computer equipment, apparel and the like, relatively low ones. Somewhat surprisingly, cars and car components appear at the bottom end of the range – this may be due to the logistical strategies of the car component industry which presumably strongly relies on frequent (and consequently small) just-in-time shipments.

Table 8: Load factors for commodities

Good (CPA2003) Code	Title	Load factor (tons/trip)
01	Landwirtschaft, Jagd	10.5
02	Forstwirtschaft	15.3
05	Fischerei und Fischzucht	10.2
10	Kohlenbergbau, Torfgewinnung	7.5
11	Erdöl- und Erdgasbergbau	15.4
12	Bergbau auf Uran- und Thoriumerze	8.2
13	Erzbergbau	9.5
14	Gewinnung v. Steinen; sonst. Bergbau	14.8
15	H.v. Nahrungsmitteln und Getränken	8.8
16	Tabakverarbeitung	8.3
17	H.v. Textilien und Textilwaren	8.2
18	H.v. Bekleidung	8.2
19	Ledererzeugung und -verarbeitung	8.2
20	Be- und Verarbeitung v. Holz	15.3
21	H.v. Papier und Pappe	9.9
22	Verlagswesen und Druckerei	8.2
23	Kokerei und Mineralölverarbeitung	15.4
24	H.v. chemischen Erzeugnissen	11.5
25	H.v. Gummi- und Kunststoffwaren	10.5
26	H.v. Glas/-waren, Stein- und Erdwaren	12.6
27	Metallerzeugung und -bearbeitung	9.4
28	H.v. Metallerzeugnissen	9.1
29	Maschinenbau	6.8
30	H.v. Datenverarbeitungsgeräten	7.6
31	H.v. Geräten der Elektrizitätserzeugung	7.0
32	Rundfunk- und Nachrichtentechnik	7.6
33	Medizin-/Messtechnik; Optik	7.6
34	H.v. Kraftwagen und Kraftwagenteilen	6.6
35	Sonst. Fahrzeugbau	6.6
36	H.v. sonstigen Erzeugnissen	8.2

Source: Own calculations based on Statistics Austria (database ISIS)

5.2.3.3. Unit values

Unit commodity values are a key input to our measure of freight transport costs. However, sensible estimates of unit values are generally hard to obtain since economic statistics focus on transaction values, not on (physical) quantities. First attempts at physical input-output accounts have been made by Statistics Austria (Statistik Austria 2004) but so far have not been elaborated to an extent to yield useful information for our purposes.

The remedy was to resort to foreign trade statistics which traditionally record trade in value as well as physical volume terms (tons for most goods). Table 9 reports the unit values (Euros per ton) by CPA goods derived from the published trade statistics based on 2-digit CN goods (Statistik Austria 2004) as well as an analysis of more disaggregate data by WIFO and Joanneum Research.

The unit values derived from both sources differ significantly. None of both sources seems to deliver more "plausible" results overall – some of the CN/CPA results appear rather excessive (e.g. CPA 34 as the most striking example) while others seems to be too low in the WIFO / JR study (e.g. CPA 16 tobacco). In the end, we opted for the values calculated by WIFO / JR which seem to be less [volatile] overall.

Table 9: Unit commodity values by CPA goods (Euros per ton)

Good (CPA2003)		CN/CPA	Detailed WIFO /
Code	Title	equivalence	JR study
01	Landwirtschaft, Jagd	6,022	1,471
02	Forstwirtschaft	5,356	501
05	Fischerei und Fischzucht	1,892	31
10	Kohlenbergbau, Torfgewinnung	1,152	195
11	Erdöl- und Erdgasbergbau	253	3,386
12	Bergbau auf Uran- und Thoriumerze	51	1
13	Erzbergbau	51	455
14	Gewinnung v. Steinen; sonst. Bergbau	519	227
15	H.v. Nahrungsmitteln und Getränken	4,454	3,330
16	Tabakverarbeitung	4,134	51
17	H.v. Textilien und Textilwaren	33,861	2,100
18	H.v. Bekleidung	19,858	2,413
19	Ledererzeugung und -verarbeitung	20,173	1,152
20	Be- und Verarbeitung v. Holz	26,807	1,130
21	H.v. Papier und Pappe	7,083	2,334
22	Verlagswesen und Druckerei	5,001	855
23	Kokerei und Mineralölverarbeitung	3,111	1,778
24	H.v. chemischen Erzeugnissen	8,339	7,481
25	H.v. Gummi- und Kunststoffwaren	8,731	2,729
26	H.v. Glas/-waren, Stein- und Erdwaren	4,552	1,539
27	Metallerzeugung und -bearbeitung	47,155	4,603
28	H.v. Metallerzeugnissen	7,433	3,183
29	Maschinenbau	13,078	8,138
30	H.v. Datenverarbeitungsgeräten	29,786	2,808
31	H.v. Geräten der Elektrizitätserzeugung	20,001	3,807
32	Rundfunk- und Nachrichtentechnik	11,229	5,577
33	Medizin-/Messtechnik; Optik	26,045	2,195
34	H.v. Kraftwagen und Kraftwagenteilen	7,792	9,867
35	Sonst. Fahrzeugbau	78,227	2,520
36	H.v. sonstigen Erzeugnissen	14,915	2,792

5.2.4. Assessment of the approach – strengths and shortcomings

This section briefly summarizes strengths and shortcomings of our transport cost measure.

The first strength is that by relating the monetary costs of transport to the value of the goods being shipped, we explicitly take into account that it is not so much the absolute level of transport costs but the (relative) markup that transport costs impose on product values that influences the spatial range of sourcing and sales of firms and the consumption of individuals. Considering the ad-valorem equivalent and not absolute transport costs is also in line with theoretical trade models, as demonstrated above.

Second, the bottom-up calculation procedure makes our transport cost measure very well suited for policy analysis. In particular, it permits to vary rather detailed components of the cost of trucking and it can capture transport cost effects of changes in the transport infrastructure.

One major shortcoming of our measure is that for the time being, the distance-dependency of unit transport costs is not considered in our transport cost measure. The problem here is that it is difficult to build a bottom-up measure of transport costs and capturing distance-dependency at the same time. Typically, studies which do consider the distance-dependency of transport costs are based on aggregate data on transport rates and haulage distances and are, therefore, unable to distinguish the components of transport costs.

A rather crude way to introduce some distance-dependency in the transport rates would be to assume loading and unloading times associated with time costs for each individual trip. We did calculate our transport cost measure with different assumptions on this loading / unloading times (15, 30 or 60 minutes per trip). However, lack of time prevented us from carrying this through in the overall model. In any event, the resulting relation between trip length and transport rates did not look too realistic either: The presence of fixed cost does increase transport costs rates for very short relations; however, the effect levels off rather fast, such that the variability between medium and long distance transport (say, 50 vs. 500 km trips) cannot be captured by fixed terminal costs alone. In order to produce a "smoother" transport cost profile, one would have to consider differences in the trucks being used for short, medium and long distance transport.

5.3. Estimation of the gravity model

This section summarizes two papers suggesting an alternative estimation approach for gravity models, goes on to describe the approach adopted for our model and, finally, reports estimation results.

5.3.1. Approaches to estimating gravity models

The most straightforward and most frequently used approach to estimate the parameters of a gravity model is to make the model linear by taking the logarithm on both sides. If one assumes that the trade flows T_{ij} between two regions i and j, with GDPs of Y_i and Y_j and separated by a distance of D_{ij} are given by

$$T_{ij} = Y_i^{\alpha} \cdot Y_j^{\beta} \cdot \exp(\gamma D_{ij})$$

The following linear model can be generated by taking logs on both sides:

$$\ln(T_{ij}) = \alpha \ln(Y_i) + \beta \ln(Y_j) + \gamma D_{ij}$$

This model can be estimated using standard OLS regression. However, this approach has been shown to produce biased parameter estimates and unreliable diagnostic statistics.

Flowerdew and Aitkin (1982) first proposed the use of Poisson regression in the context of estimating a gravity model modeling interregional migration flows in Great Britain. In their specific case, they identify four key problems with OLS estimation of the logarithmized gravity model: (i) The bias introduced by estimating the logarithms of the independent variables not the variable themselves; (ii) the inadequacy of the assumption that error terms are normally distributed; (iii) the unequal variance of the error terms and, finally, (iv) the sensitivity of the model estimates to the treatment of zeroes in the dependent variable. The last problem is particularly relevant as interregional migration, and spatial interaction matrices in general, contain a significant share, or even a majority, of zero entries. This poses a problem in the usual OLS estimation approach, as the logarithm of zero is not defined. The two possible remedies used in the literature are to drop these observations or to add a small constant factor to all observations.

In the context of modeling of interregional migration flows, the dependent variable (the number of individuals migrating between any two regions) and, concomitantly, the error terms can only take non-negative integer values. Assuming a given probability for individuals in region i to migrate to a destination region j, a sufficiently large population in i and independence between migration decisions yields the discrete Poisson distribution for the number of migrants between i and j. Flowerdew and Aitkin go on to demonstrate that the Poisson model is superior in terms of model fit and interpretability of the residuals.

Recently, Westerlund and Wilhelmsson (forthcoming) put forward similar arguments relating to the superiority of the Poisson regression approach when using the gravity model to estimate trade flows. In a Monte Carlo simulation they show that OLS estimates produce biased estimates and deceptive t-statistics in both possible cases, i.e. when zero trade flows are dropped from the sample and when a constant factor is added to the dependent variable for all observations. The Poisson maximum likelihood estimator is shown to be superior to the OLS estimators. Moreover, they advocate the use of panel data in order to control for region-pair fixed effects. This was, however, beyond the scope of the data available to us as building an interregional database for even one year was already a major task (see the chapters on the estimation of the interregional trade matrix).

5.3.2. The estimation approach adopted for our model

To estimate this gravity model we followed the approach suggested by the studies summarized above, adopting a maximum likelihood estimator of a Poisson regression model.

The model parameters are determined in a cross-section estimation, as due to data limitation we only have trade matrices for one year available (and even that required a major effort and a series of heroic assumption; see the section on the building of the trade matrices at district level). This data setting effectively prevented the estimation of region-pair specific effects as suggested by Westerlund and Wilhelmsson (forthcoming).

The econometric estimations were calculated out in the econometric software package Eviews. For each commodity, we estimated an individual gravity model according to the specification (equivalent to the doubly constrained gravity model put forward in section 7.3).

$$T_{ijc} = \exp\left[a_c \cdot tcs_{ijc} + \sum_m b_{ic} x_m + \sum_m c_{jc} y_j + d_c + \varepsilon_{ijc} \right]$$

Technically, the balancing factors b_{ic} and c_{jc}, which ensure the equality between the estimated and observed regional supply and use of commodities (i.e. the row and column sum constraints), were estimated as the parameters on dummy variables x_i (y_j) that were equal to 1 when $m = i$ ($n = j$) and 0 otherwise; e_{ijc} is origin-destination pair-specific error term with $\mathrm{var}(e) = \mathrm{E}(T_{ijc})$ as assumed in the Poisson model.

5.3.3. Estimation results

Table 10 reports the results of the model estimation as described in the section above.

As the model is specified in exponential form, the estimates cannot directly be interpreted as elasticities. The first column from the right provides the implied transport cost elasticities of trade flows with respect to (ad-valorem) transport costs evaluated at the unweighted average of ad-valorem transport costs over all origin-destination pairs. Overall, the elasticities (in absolute terms) are rather low with only two goods exceeding 0.5, a majority of goods (13) in the range between 0.1 and 0.4 and six goods below 0.03. These estimates are clearly rather low; however, it has to be taken into consideration that the reported values are point elasticities and will vary over the range of observed transport cost values.

Clearly, some of the estimates would require more attention as for example the parameter on the ad-valorem transport rate for fish and fishery products (05) which deviates from the other estimates by two orders of magnitude. This specific case may be due to the rather suspicious unit value estimated for this good (see Table 9). Moreover, the above mentioned implausibly low transport costs elasticities of trade flows do warrant attention.

Table 10 : Parameter estimates and diagnostic statistics of the gravity trade models

CPA good		Ad-val. transport rate		Equation		Transport cost
Code	Title	Estimate	Std. error	R^2 (adj.)	Log-likelih.	elasticity of trade[1]
01	Agricultural product	-201.9	0.1	0.41	3,573,583	-0.47
02	Forestry products	-121.3	0.1	0.30	1,884,196	-0.50
05	Fish and fishery products	-4.0	0.0	0.48	21,363	-0.59
15	Food, foodstuff, beverages	-297.6	0.1	0.88	4,940,749	-0.59
17	Textiles	-96.8	0.2	0.62	322,278	-0.15
18	Clothes	-176.7	0.7	0.80	63,509	-0.22
19	Leather and leather products	-71.6	0.2	0.74	82,641	-0.08
20	Wood and wood products	-260.4	0.2	0.56	2,353,426	-0.29
22	Printed matter, data media	-63.2	0.0	0.97	1,552,943	-0.19
23	Mineral products	-214.1	0.5	0.91	1,166,134	0.00
24	Chemical products	-572.3	0.6	0.76	1,260,117	-0.15
25	Rubber and plastic products	-215.5	0.2	0.77	848,101	-0.31
26	Glas, ceramics	-242.3	0.1	0.56	2,384,679	-0.33
27	Metals, semifinished metal prod.	-346.7	0.2	0.63	3,118,858	-0.04
28	Metal products	-271.2	0.1	0.52	3,702,524	-0.39
29	Machinery	-494.1	0.3	0.88	2,033,455	-0.39
30	Office and data processing equipm.	-178.3	0.6	0.94	46,592	-0.01
31	Electric equipment	-226.1	0.2	0.95	910,753	-0.13
32	Information & communication eq.	-247.5	0.3	0.93	553,347	-0.04
33	Medical, optical equipm., watches	-164.3	0.2	0.93	626,747	-0.15
34	Transport equipment	-718.1	0.7	0.96	537,231	-0.03
35	Other transport equipment	-197.6	0.2	0.97	364,402	-0.02
36	Furniture, toys and other products	-253.3	0.2	0.86	1,392,763	-0.45

Note: [1] Evaluated at the (unweighted) mean of ad-valorem transport costs and trade flows

A comparison of the models based on distance (as a proxy for transport costs) and based on our detailed transport cost measure shows that for most commodities the model fit (R^2) is similar or even slightly better in the case of the distance-based models. This confirms the observation of Combes and Lafourcade (2005) that on a cross-section basis, distances are good proxy for transport costs (highly correlated with transport costs). However, the main advantage of our transport policy measure for model simulations is sensitivity to policy measures.

6. Simulations combining MARS and MultiREG-D

To explore the simulation potential of the combined model, we ran three simulation exercises:

1. An exogenous shock to output prices in district 101;
2. A general increase in variable transport costs by 10% (as might be brought about for example by a network-wide toll system);
3. An extension of the existing motorway system by an alpine east-west connection.

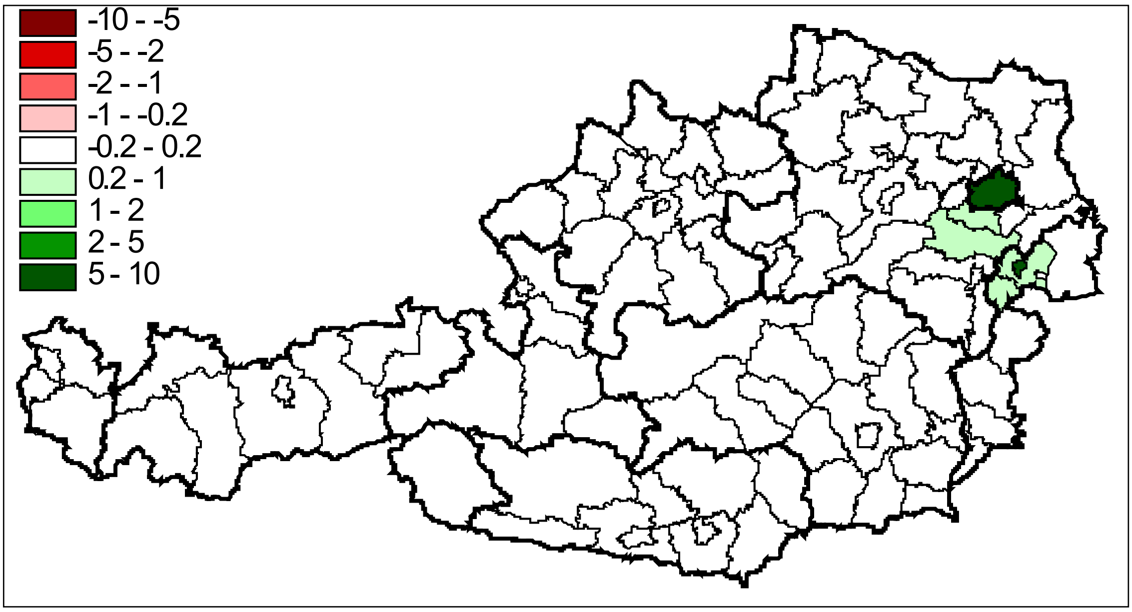
The first simulation serves to show the reaction to a pure price shock; in contrast, the second exercise starts out with a shock to transport costs (here, output prices will react to ensuing changes in regional output as well, whereas in the first case, transport costs remain unaffected by the price shock; this is to demonstrate the possibility of distinguishing, in the trade model, between pure price effects on the one hand and transport cost effects on the other). The third demonstrates tentative effects of a (major) transport infrastructure project.

In all 3 scenarios, the results must not be taken as "definitive": the price forming mechanism as implemented in the economic model (see above) simply is not up to the task of simulating "realistic" price reactions. However, even if the magnitude of the simulated economic reactions might be unreliable, their direction should convey some economic meaning. Thus, besides being a "proof of principle" of the numerical feasibility, it should also be a "proof of principle" of the combined model's simulation potential.

6.1. Exogenous shock to output prices in district 101

In this scenario, we introduce an initial shock to output prices in district 101 (*Eisenstadt*); this initial shock is – uniformly across all sectors – a price reduction of -10%. In the model solution, however, this 10% reduction will show up only fractionally: this initial reduction will drive up demand for district 101's output, thus leading to rising prices. In equilibrium, therefore, prices will be lower than in the baseline, but not by the "full" amount (in fact, the average reduction in prices turns out to be -4%, which, however, is quite unevenly distributed across sectors: the manufacturing sector, where price reductions exert the largest influence on trade, and therefore output in district 101, the price effect averages only -3%. On the other hand, the service sectors, in which trade across district borders – and international trade – is much less pronounced, the eqilibrium price effect is in the range of -6% to almost the full amount of the original shock of -10%).

Figure 10: Effect on Value Added by district to an exogenous price shock in district 101 [million Euro]



Source: own calculations

As can be seen, both total value added and employment are higher in district 101; in addition, other regions can profit from this development as well, predominantly the neighboring regions (district 101 is the city of Eisenstadt, the capital of the province Burgenland; neighboring districts, therefore, profit not least from commuting into 101).

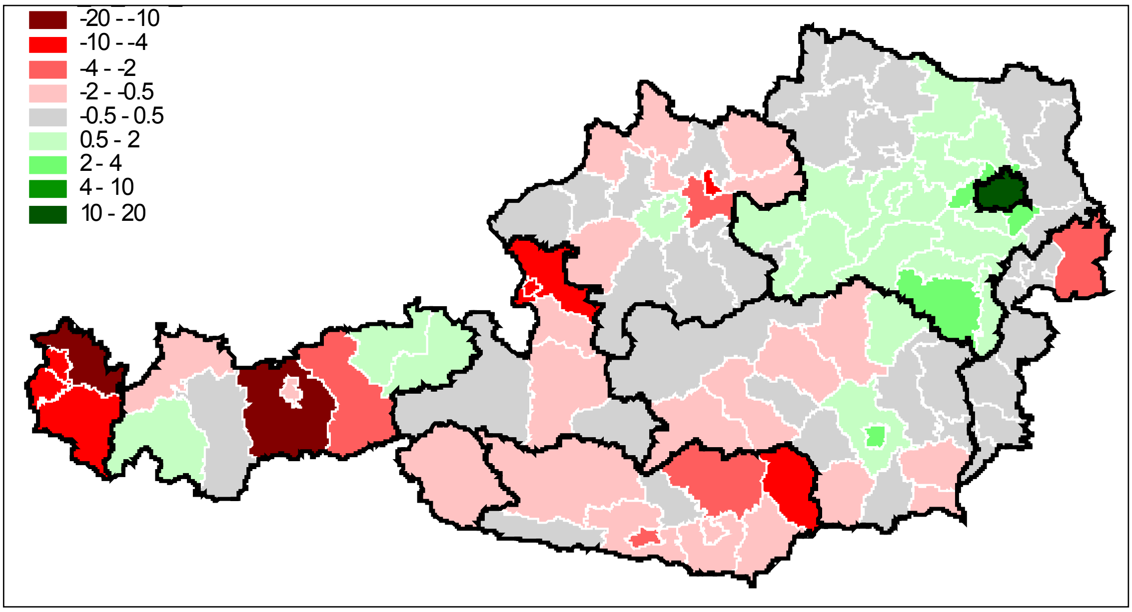
Most districts are quite unaffected by district 101's positive development; but, there are some losers (if in this case, it is only a very few): economically, this is quite plausible, as at least part of the additional output in 101 crowds out output in other regions. The only "unambiguously positive effect" of the positive price shock on total GDP in Austria is due to additional exports from (and reduced imports to) district 101 brought about by the increase in this district's competitiveness; conversely, changes which only affect inter-regional trade have ambiguous effects: at least partially, one district's gains can (and will) be another district's loss. At the national level, the net effect amounts to a slight increase in GDP, by +19 Mio. € (or +0.009%). About half of this increase accrues to district 101 (+9 Mio. €), which for district 101 constitutes an increase in its GRP of roughly +1%.

6.2. A general increase in transport costs

Here, we assumed variable transport costs to increase by 10%. This might be caused, say, by an increase in fuel prices or by the introduction of a general toll on freight transport. In the model, or, specifically, in the gravity equations, this can be introduced by increasing the parameter describing the *ad valorem transport cost rate* (i.e., the share of transport costs in the total value of the commodity transported; see the chapter on the gravity equations).

The results could be described as "concentration": peripheral regions lose somewhat, whereas central regions (or, rather, regions in the proximity of major agglomerations) tend to win in this situation (the effect is perhaps best visible in the area surrounding Vienna). At the national level, the net effect is negligible, with a reduction of GDP totaling some -61 Mio. € (less than -0.03% of GDP). The regional distribution of the effects is shown in the following diagram.

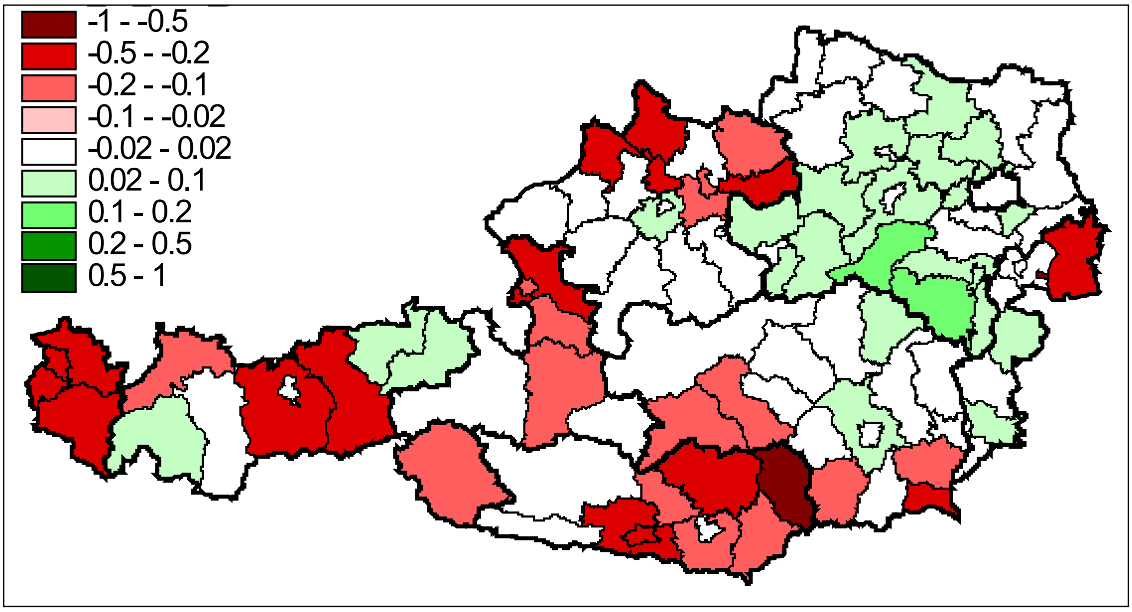
Figure 11: Absolute Effect on Value Added by district to a general increase in transport costs [million €]



Source: own calculations

The distribution of relative effects on value added (i.e. as a percentage change relative to the base scenario) is even more pronounced with respect to the "center-periphery" concentration: here, it is mainly the central region to the west of Vienna which exhibits gains; losses are estimated for the south, the "far west", and the north-western districts. Both gains and losses, however, are rather moderate, rarely exceeding the +/- 0.2%-range.

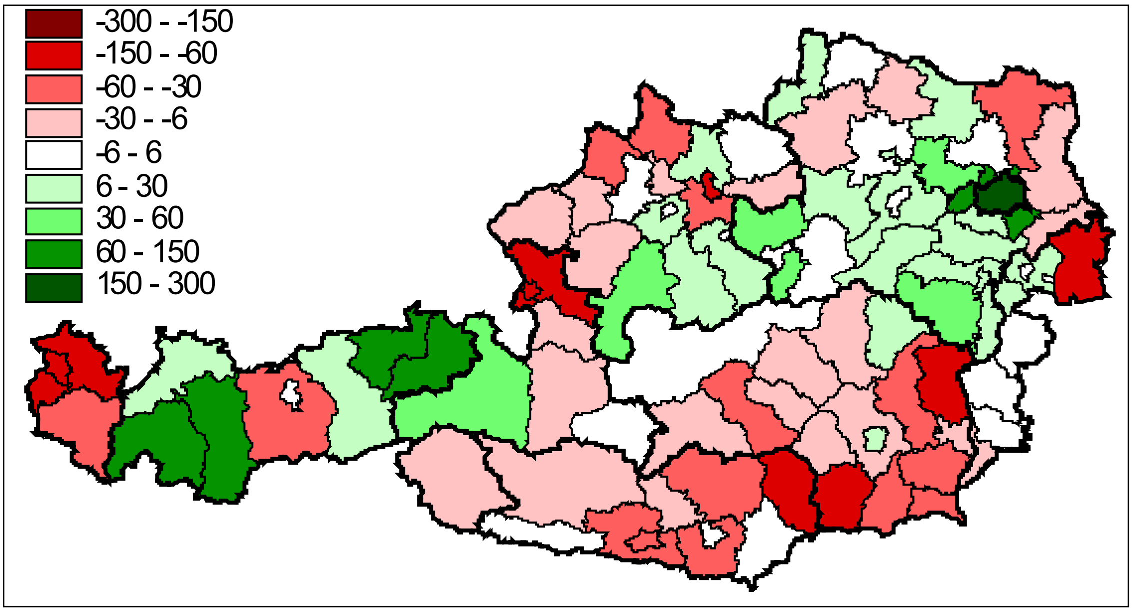
Figure 12: Relative Effect on Value Added by district (percent)



Source: own calculations

Though not markedly, the regional pattern of the employment effects is somewhat different from the value added-effects:

Figure 13: Effect on Employment by district to a general increase in transport costs [FTE]

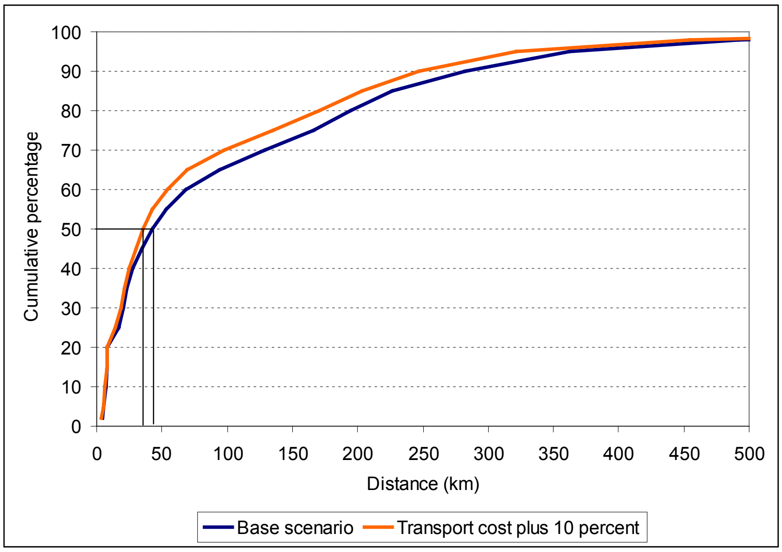


Source: own calculations

Of course, the reason is that not all sectors are equally affected by the increase in transport costs: the manufacturing sectors are much more affected than the services sectors (which, to a large extent, are not affected at all, as their "products" are not transported). Therefore, value added-effects and employment-effects can differ, depending on a district's sectoral structure.

The main effect of the scenario on trade and freight transport is a reduction in the distances:

Figure 14: Cumulative distribution of transport distances (all commodities)



Source: own calculations

Transport distances decrease quite markedly, from an average of 103 km (in the base run) to 90 km (the median distance was 42 and 36 km, respectively). The bulk of this reduction seems to stem from transport distances in the range of 40-80 km. Total freight transport volume (in tons) decreases by -0.3%, with a similar reduction in the number of trips. However, transport performance (in ton-kilometers) decreases by -12%, reflecting the marked reduction in average transport distance.

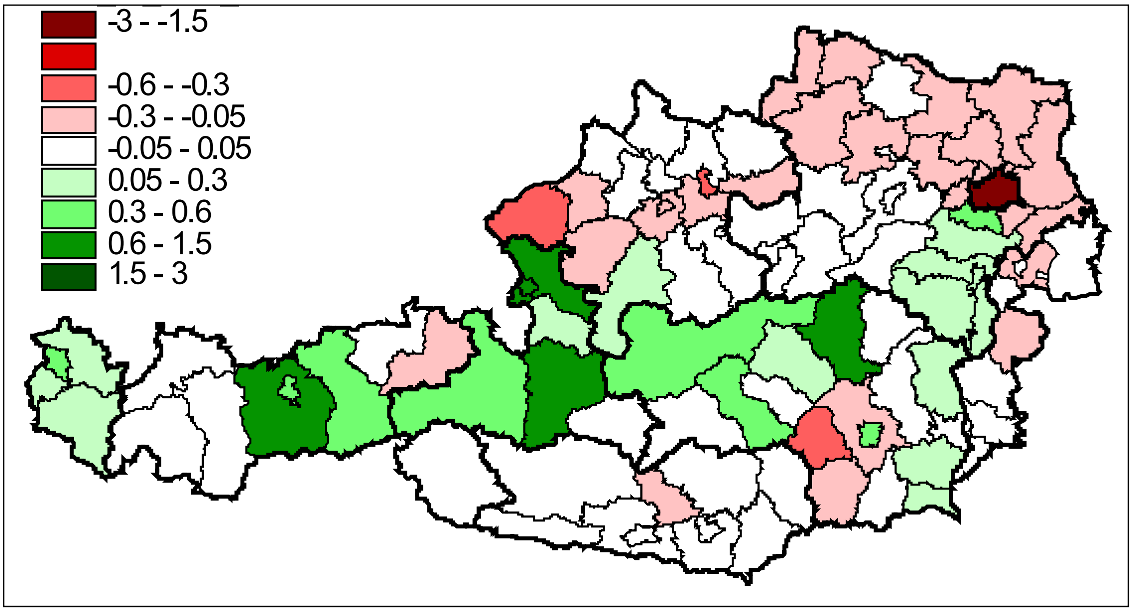
6.3. Implementation of an additional alpine connection

As a complement to the first two scenarios, which covered the influence of changes in prices and transport costs, the last scenario is designed to highlight possible effects from changes in transport infrastructure, by introducing a new east-west connection in the central alpine region.

At the national level, the estimated total effect on GDP amounts to a modest +4 Mio. € (or +0.002%). Of course, the regional distribution shows winners and losers, although even here, effects are quite subdued (in absolute terms, the largest loss and gain are -2.6 and +1.3 Mio. €, respectively; in relative terms, the range is from -0.03 to +0.06% of district GRP).

Again we emphasize that these tentative results are to be considered as a proof of the modeling concept and not as an actual evaluation of the specific project.

Figure 15: Effect on Value Added by district to a change in the transport network structure



Source: own calculations

7. Discussion of results, applications, further research

In our opinion, this paper demonstrates the feasibility of modeling – at very disaggregate regional level – the interaction between economic processes and transport activities. Although at the present stage, both the economic and the transport parts of the model are still far from being perfect, we think that it provides enough ground for optimism concerning the potential of a full-fledged version of a combined economic-transport model.

So, in a nutshell, what are the main ingredients still missing from such an "optimal" version?

First and foremost, it is the econometric part of the economic EIO model, with the equations describing the price model as probably the most important task. Here, work is underway in a different, unrelated project, which aims at constructing an EIO model at the national level. The idea is that the parameters of the behavioral equations derived at the national level will be used to calibrate the respective equations to the district level. Of course, this will imply that elasticities are identical for all regions. Although true, this criticism cannot easily be avoided – due to data reasons (remember, the only key economic variable officially available at the district level was employment – and this only for the census years!), econometric estimation simply cannot be performed at this level of regional disaggregation. Some equations, however, might conceivably be estimated at the level of provinces, where data are not nearly as scarce as at the district level; calibrating these provincial equations to the district level would alleviate the problem of "identical elasticities", as now, only district within one province would exhibit such identities.

At a more "philosophical" level, this problem of identical elasticities is arguably not so problematic to start with: after all, computable general equilibrium (CGE) models use such assumptions all the time (and they usually do not even use econometrically estimated elasticities, but rather take them from the "literature"). Also, as discussed in a previous chapter, the natural application for the combined model will not be forecasting (where subtle differences in elasticities might prove decisive), but rather simulation exercises, where, arguably, such concerns have less validity.

In the transport part, modal split (in the case of Austria primarily between road and rail) should certainly command much more attention. In the present version, modal is split is treated as constant. Modal split, however, is quite difficult to treat in an economically (and technically) sound way:

the impact of (relative) transport costs is not as dominant in the case of modal choice as it is in the determination of the spatial distribution of transport flows (as modeled by the gravity model). Shippers' preferences for one mode or another are influenced to a large extent by qualitative variables that are more difficult to capture (and quantify) in a model. These include factors such as the reliability of delivery dates, flexibility to react to short-term changes in production schedules, the availability of shipment tracking information. Nevertheless, any "definitive version" of the combined model will have to afford much more attention and rigor to this question – not least with the policy relevance of the model in mind, as modal shift continues to feature centre stage in many national and EU transport policies.

In the gravity model, the fixed costs of transport (e.g. terminal costs and short- to medium-term fixed costs of carriers) should be more conceptually distinguished from variable transport costs. For the moment, they are somewhat tangled up in a "common" parameter; an improved version of the gravity equations has already been developed, although too late for inclusion in the current version of the combined model.

In the combined run, some of the results seem rather large, e.g. the effect of the 10% increase in transport costs on average transports distance. Clearly, the "unrealistic" price mechanism implemented in the combined model plays a part; however, this result highlights the need to look into all parts of this prototype model.

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