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Abstract

Division of labor, outsourcing in manufacturing and just-in-time production require the provision of a good and sufficient road infrastructure system. The society is used to mobility, preference for it even increases, and the full benefit of competition can only be realized if special distances can be overcome at low cost of transportation. Since the 1970's, however, the negative aspects of an intensive extension of road infrastructure has dominated the political decision process.

The objective of this paper is to model the aspects of bottlenecks in road infrastructure, of congestion costs and of the effect of investment in infrastructure in a computable general equilibrium framework. A long-run "business as usual" simulation will show how congestion and its cost will develop over time. Given the necessity to act we will raise the fuel tax to partly finance infrastructure investment. We will then compare the cost of the addition in infrastructure with the savings in congestion costs in order to see whether this policy measure is self-financing.

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1. Introduction

Division of labor, outsourcing in manufacturing and just-in-time production require the provision of a good and sufficient road infrastructure system. The society is used to mobility, preference for it even increases, and the full benefit of competition can only be realized if special distances can be overcome at low cost of transportation. Since plans to extend infrastructure and to carry out this decision takes time, long run forecasts of traffic and the capacity of transportation modes are very important for an efficient economic development and for investment decisions of firms.[1] Transportation infrastructure is an essential factor for location decisions and is the source of growth and of employment opportunities.

Public opinion with respect to the benefits of road infrastructure is divided and fluctuates. This explains that since 1960 road infrastructure for the long distance traffic has increased by only ten percent whereas real GDP has increased by 200 percent. In the 1960's, high priority was given to the extension of the road network. Economic growth was seen to be correlated with infrastructure and mobility. Since the 1970's, however, the negative aspects of an intensive extension of road infrastructure has dominated the political decision process. The deterioration of the landscape in densely populated areas, air pollution, noise and global warming have slown down the construction of roads. The emphasis is more on the efficient use of the existing stock of infrastructure and on appropriate criteria for evaluating the benefit of infrastructure projects.

The insufficient provision of infrastructure is meanwhile considered to be a serious disadvantage of Germany as an economic location.[2] This assessment is underlined by estimated costs of congestion of 100 bill. € per year[3] and by waste of fuel on congested highways which has partly offset the improvement in energy efficiency. One therefore gets the impression that more infrastructure is necessary and, what is more important, could in principle be financed by savings in congestion costs. In view of the 40 bill. € which the German government collects per

[1] See e.g. Bundesministerium für Wirtschaft (1997).
[2] See BGL (1999), OICA (1995).
[3] Frank and Sumpf (1997).

year in terms of fuel tax and motor vehicle tax, the bottlenecks in road traffic could be less. However, taxation is not based on the benefit principle and revenues from taxing traffic enter the general government budget.

The objective of this paper is to model the aspects of bottlenecks in road infrastructure, of congestion costs and of the effect of investment in infrastructure[4] in a computable general equilibrium framework (CGE).[5] A long-run "business as usual" simulation will show how congestion and its cost will develop over time. Given the necessity to act we will raise the fuel tax to partly finance infrastructure investment. We will then compare the cost of the addition in infrastructure with the savings in congestion costs in order to see whether this policy measure is self-financing. The paper is organized as follows. In section 2 we explain the modification of a standard CGE model for incorporating the impact of congestion, infrastructure provision and the stock of transportation equipment on transportation demand, on transportation costs and on congestion costs. In section 3 we explain the data base and section 4 presents the simulation results. A section 5 concludes the paper.

2. Transportation and congestion costs within a CGE model

A CGE model is a system of linear and nonlinear equations that is solved to simulate market equilibrium. It includes equations describing consumer and producer supply and demand behavior that are derived explicitly from conditions for profit or utility maximization, as well as market clearing conditions in product and input markets. Unlike interindustry input-output models and other earlier economy-wide planning models, household factor income and expenditures are linked in a theoretically appropriate manner. A common methodological feature in CGE models is an activity analysis approach to model the exchange of commodities by agents. For methodological and data availability reasons, activity analysis is based on the input-output technology typically embedded in CGE models to characterize interindustry transfers. Next, appropriate mathematical specifications of production or cost function, and of utility functions at the level of the agents have to be chosen. The optimal demand for production factors (producers) and for commodities (consumers) are then derived through first order conditions of the optimum. In the case of the producer, the optimizing behavior may be respresented in the

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[4] Basic models about optimal investment in infrastructure are developed by Friedlaender and Mathur (1982), Keeler and Small (1997), Mohring and Harwitz (1962).

[5] For related CGE approaches about congestion and/or investment in infrastructure see e.g. Van den Bergh and Nijkamp (1996), De Borger and Swysen (1998), Mayeres and Proost (1997); for a CGE analysis with a multiregional transportation analysis see Liew and Liew (1991).

form of either the production or the cost function approach.[6] Our model is based on the cost function approach where the supplier is setting the market price of the commodity, he is supplying, by using the inverse supply function, i.e. price equal to marginal costs. The supplier receives the market price of the commodity from the inverse supply function, or, equivalently, from average cost pricing. Demand depends explicitly on prices and determines the quantity to be supplied. Supply enters marginal cost which influence the price. Our model is built around a flexible (price-driven technical coefficient) input-output framework and derives equilibrium prices of commodities directly from price (or unit cost) functions. Shephard's lemma is employed for obtaining factor demands (input coefficients). The unit cost pricing of equilibrium is equivalent to the zero-profit condition, which corresponds to one of the two forms of expressing Walras' law. Primary factor prices are, on the other hand, obtained through supply- demand interaction.

As a point of departure for extensions of this basic framework of a CGE model it might be useful to state it in mathematical terms. The structure of production of an industry j is characterized by its cost function $C_j\ (x_j; p_1, ..., p_N, p_K, p_L)$ where p_i are the prices for intermediate inputs and p_K and p_L are the prices for the primary inputs capital and labor. From price equal to marginal cost, assuming constant returns to scale, we obtain a system of N equations for the N unknown industry prices p_i:

$$p_j = MC_j\ (p_1, p_2, ..., p_N; p_K, p_L) \quad , \qquad\qquad j = 1, ..., N\ .$$

To make things easier for the time being, we assume the prices for the primary inputs to be exogenously given. Next, using Shephard's lemma, i.e. by partially differentiating the cost function, input demand or price dependent input coefficients can be derived:

$$\frac{x_{ij}}{x_j} = a_{ij}\left(\frac{p_j}{p_i}, s\ , t\right) \qquad\qquad i = 1, ..., N+2 \quad , \ j = 1, ..., N$$

where the input coefficients are functions of relative prices, of the elasticity of substitution σ, and of technical change t, represented by the time symbol. The input structure of an industry therefore depends on relative price changes, on the flexibility with respect to substitution, and on

[6] For a survey on the development of CGE modeling see Shoven and Whalley (1984), Bergman (1990) or Conrad (1999).

the bias of technical change. Finally, supply of an industry must be equal to demand for the product of this industry:

$$x_i = \sum_{j=i}^{N} x_{i\,j} + FD_i \quad , \qquad\qquad i = 1,...,N,$$

where FD_i is final demand (consumption (private and public), investment, and export). Since intermediate demand can be replaced by $x_{i\,j} = a_{i\,j}(\cdot)x_j$, this system of n equations can be solved for the n unknown industry output levels x_j. In order to obtain a basic structure of a CGE model, the above model has been extended by markets for capital and labor, by a model of consumers' behavior, by introducing import demand and export supply decisions, and by incorporating a variety of taxes.

We have augmented this basic structure of a CGE model by a transportation submodul in order to quantify the impact of infrastructure investment on congestion and its costs for the economy. The following figure shows the impact of congestion Z on the economy.

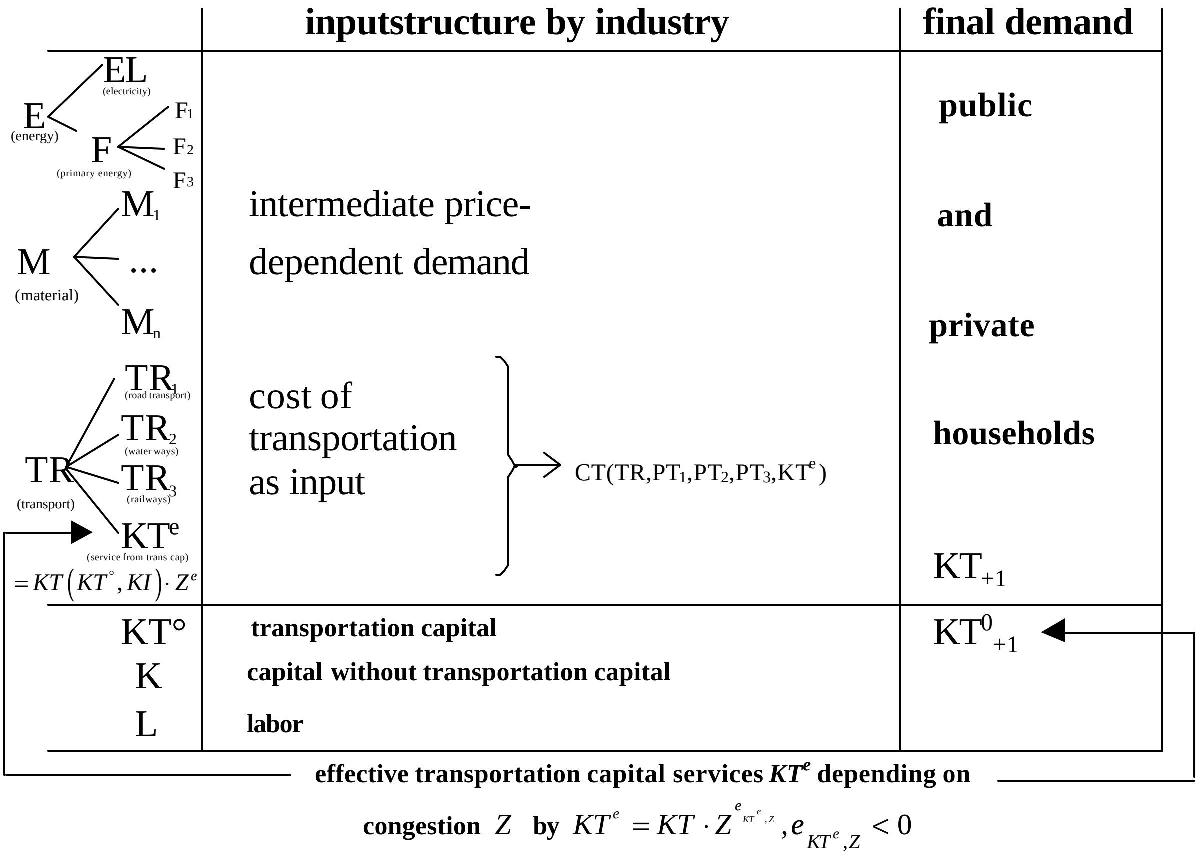

Fig. 1 The impact of congestion Z and infrastructure KI in a CGE framework

Our endogenous index of congestion, *Z*, reduces the profitableness of firms' transportation capital or of the provider of transportation services. Congestion affects the cost of production, investment decisions, and the level and structure of transportation inputs. Due to the non-optimal provision of infrastructure with congestion as a costly consequence, firms are compelled to keep a higher stock of transportation capital, KT^0, than required when there would be an efficient provision of infrastructure. In the latter situation less transportation capital is required to distribute a certain output volume within the regions.

In order to understand the modeling of the direct and indirect effect of congestion on the economy, we first assume that the service of transportation capital is proportional to the stock (we omit a factor of proportionality). It can be improved by a better provision of infrastructure, *KI*:

(1) $$KT = KT(KT^0, KI) = KT^0 \cdot \exp(-a / KI)$$

where $a > 0$ and $KI \to \infty$ implies a full utilization of the stock KT^0. Our index for congestion is

(2) $$Z := \frac{\prod_{k=1}^{N+1} \left(KT_k^0\right)^{b_k}}{\prod_{k=1}^{N+1} \left(KT_k^*\right)^{b_k}} \geq 1$$

where $k = 1,\ldots,N$ are the number of firms and $N+1$ represents the stock of transportation capital used by private households.[7] It is $KT_k^* = K\overline{T}_k^0 \cdot \exp(-a / KI^*)$. If $K\overline{T}_k^0 = KT_k^0$, the initial stock of transportation capital in the base year, then $Z = \exp(a / KI^*) > 1$ from (2). We use $K\overline{T}_k^0$ as a normalization of *Z*. $K\overline{T}_k^0$ is related to the present quality of the infrastructure, and the daily news on congestions show that actual number of vehicles $K\overline{T}_k^0$ should be less than the present one, KT_k^0, given the bottlenecks in the provision of infrastructure. This aspect then raises *Z* beyond $\exp(a / KI^*) > 1$. KI^* is an optimal provision of infrastructure, which minimizes transportation costs in the economy subject to a financial constraint; it will be

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7 We omit private households in our presentation of the model and refer to Conrad (1997).

determined later in this section. In the base case, KI^* is equal to the observed provision of infrastructure.

The functional relationship in (1) reflects as a capacity utilization index $CU(KI) = \exp\left(-a/KI\right) < 1$ the importance of a sufficient provision of infrastructure for a full utilization of the stocks KT^o. An extended network of roads between major industrial areas and cities and a better connection between the modes of transportation improves the efficiency of the stock of vehicles in terms of a factor augmenting effect. This aspect holds for any country, irrespectively whether there is congestion in terms of bottlenecks at certain times of the day. Besides this aspect we distinguish the impact of congestion, given KT from (1). In the model, cost will increase if there is congestion $Z > 1$. Since it is the objective of the government to reduce the cost of production in the economy by minimizing the bottlenecks in the existing road infrastructure network, it will invest in KI in order to lower the index of congestion *Z*. Therefore, KI in (1) reflects the direct effect of KI on capacity utilization whereas KI in (2) affects Z indirectly by balancing the cost-saving of less congestion for the economy and the cost of more KI for the government in reducing present bottlenecks (see the objective function (14) later in this section).

The effectiveness of transportation capital services is affected by congestion which we express as:

(3) $$KT^e = KT \cdot Z^{e_{KT^e,Z}}$$

where $e_{KT^e,Z} < 0$ is the elasticity of effective capital with respect to *Z*. The higher *Z*, the less productive is the transportation capital. This, in turn, has an impact on the cost of production where transportation costs are a more or less significant part of it. These transportation costs, *CT*, are expressed as a short-run, variable sub-cost function

(4) $$CT = CT(T, PT_1, PT_2, PT_3 KT^e)$$

where PT_i are the prices of the substitutes for transport services provided by firm-owned trucks ($i = 1$: road transportation, $i = 2$: water ways, $i = 3$: railways), T is the transportation volume, and KT^e the quasi-fixed transportation capital input in terms of firm-owned trucks. The benefit of having one more unit of the stock KT^0 can be calculated by the ex-post or shadow price of capital. It expresses the savings in the variable cost of transportation by having one additional truck given the transportation volume *T*.

(5) $$-\frac{\partial\, CT}{\partial\, KT^0} = -\frac{\partial\, CT}{\partial\, KT^e} \cdot \frac{d\ KT^e}{d\ KT^0}$$

where $$\frac{d\ KT^e}{d\ KT^0} = \frac{\partial\, KT^e}{\partial\, KT^0} + \frac{\partial\, KT^e}{\partial\, Z}\,\frac{\partial\, Z}{\partial\, KT^0}$$

or,

$$-\frac{\partial\, CT}{\partial\, KT^0} = -\frac{\partial\, CT}{\partial\, KT^e} \cdot \frac{\partial\, KT^e}{\partial\, KT^0} - \frac{\partial\, CT}{\partial\, KT^e}\,\frac{\partial\, KT^e}{\partial\, Z} \cdot \frac{\partial\, Z}{\partial\, KT^0}\,.$$

KT^0 raises KT^e, given *Z*, and more KT^e reduces variable transportation cost due to substitution of KT^0 for other transportation inputs. The second term expresses the aspect that KT^0 raises *Z*, *Z* in turn lowers effective capital KT^e and this externality reduces the savings in variable costs. By making use of (2) and (3):

(6) $$-\frac{\partial\, CT}{\partial\, KT^0} = -\frac{\partial\, CT}{\partial\, KT^e} \cdot \frac{KT^e}{KT^0} - e_{KT^e,Z}\,\frac{\partial\, CT}{\partial\, KT^e}\,\frac{KT^e}{KT^0}\,b\,.$$

The first partial derivative represents the positive cost saving effect of more effective capital per unit of the stock KT^0 and the second partial derivative expresses the costs of the negative externality “congestion” from extending the firm’s own KT^0.

We define PKT^s as the savings in variable costs without the externality:

(7) $$PKT^s = -\frac{\partial\, CT}{\partial\, KT^e} \cdot \frac{KT^e}{KT^0}$$

and PKT^{net} as the savings in variable costs net of the externality. Then (6) means:

(8) $$PKT^{net} = PKT^s \cdot \left(1 - \left|e_{KT^e,Z}\right| \cdot b\right).$$

A unit of transportation capital is less valuable to the firm if it internalizes the contribution to congestion.

The endogenous ex-post price of capital is usually different from the given ex-ante price of capital due to short-run fixity of the stock. Let PKT^{ante} be the ex-ante price of capital which includes a motor vehicle tax and a gasoline tax. Using the envelope condition to find the optimal capital for a given transportation volume *T*, i.e.

$$\min_{KT_0} \quad CT(T,\cdot,KT^e) + PKT^{ante} \cdot KT^0 ,$$

we can solve the FOC for the optimal transportation capital $\hat{KT}^0$, given infrastructure *KI*:

$$(9) \qquad PKT^{ante} = -\frac{\partial\, CT(\cdot, KT^e(\hat{KT}^0))}{\partial\, KT^0} .$$

The property of $\hat{KT}^0$ is that more capital is required if congestion increases $(\partial\, \hat{KT}^0(\cdot) \big/ \partial\, Z > 0)$ and transportation capital can be saved if more infrastructure is provided $(\partial\, \hat{KT}^0(\cdot) \big/ \partial\, KI < 0)$. Finally, input coefficients for the transportation inputs road transport, water ways, and railways can be obtained from the cost function CT in (4) using Shephard's lemma.

We first want to know the optimal allocation of transportation capital in the economy when a central government wishes to minimize total cost of transportation, given the infrastructure:

$$(10) \qquad \min_{KT_1^0,\dots,KT_N^0} \quad \sum_{j=1}^{N} \left[CT_j(KT_j^e) + PKT_j^{ante} \cdot KT_j^0 \right].$$

The FOCs' are:

$$(11) \qquad PKT_l^s = PKT_l^{ante} + \frac{b_l}{KT_l^0} \left[\sum_{j=1}^{N} \left| e_{KT_j^e, Z} \right| \cdot PKT_j^s \cdot KT_j^0 \right] \qquad l = 1,\dots,N$$

with PKT_j^s as a function of KT_j^0 as defined in (7). This system could be solved for an optimal allocation of the stocks of transportation capital across the economy. The congestion externality is internalized by raising cost of capital per unit of KT_l^0, i.e. PKT_l^{ante}, by the cost of capital that a unit of KT_l^0 adds as congestion costs to all industries in the economy. The congestion cost term indicates the indirect effect of transportation capital KT_l^0 on other firms' capital costs. The benefits of an unit of transportation capital in industry j in order to reduce its variable transportation costs, PKT_j^s, weighted by the impact of Z on KT_j^e, increases costs of transportation for industry j, depending on the size of the externality b_l caused by industry l. Under an optimal allocation, (11) implies

(12) $$PKT_l^s \cdot \hat{KT}_l^0 = PKT_l^{ante} \hat{KT}_l^0 + C_l^{cong} \qquad , \qquad l = 1,...,N$$

where C_l^{cong} are the congestion costs caused by industry l.

(13) $$C_l^{cong} = b_l \left[\sum_{j=1}^{N} \left| e_{KT_j^e,Z} \right| \cdot PKT_j^s \cdot \hat{KT}_j^0 \right].$$

If $\left| e_{KT^e,Z} \right|$ is high, the congestion cost externality for the economy is high and stocks $\hat{KT}_l^0$ of transportation should be reduced.

In order to reduce congestion costs, the government could invest in infrastructure. This will reduce the ex-post shortage prices PKT_j^s of capital. Instead of an optimal allocation of the stocks as in (10) the government minimizes cost of transportation in the economy by investing in infrastructure subject to a financial constraint.

(14) $$\min_I \sum_{j=1}^{N} \left[CT_j(\cdot, KT_j^e) + (PKT^{ante} + t_E \cdot g_E) \cdot KT_j \right] + PI \cdot I$$

(15) s.t. $s \cdot PI \cdot I = t_E \cdot E$ and $KI = KI_{-1} + I - d \cdot KI_{-1}$.

It is I net investment in infrastructure and PI is the investment price index. We assume that replacement of infrastructure, $d \cdot KI_{-1}$, is included as expenditure in the budget of the government anyway. Net investment I has to be partly financed by a new tax t_E on energy E, or by an increase of the existing fuel tax, i.e. $t_E = \Delta t \cdot E$. E means fuel and is proportional to the services of the transportation capital, i.e. $E = g_E \sum_j KT_j$. The share $s \in [0,1]$ of investment expenditure, which has to be financed by the energy tax is exogenously given. The solution of (14) is (see Conrad (1997)):

(16) $$I^* = \frac{e_{KT,I}\left[\sum_j (PKT_j^s - PKT_j^{ante})KT_j^0 + \sum_l C_l^{cong}\right]}{PI \cdot (1+s)}$$

with C_l^{cong} as defined in (13). Congestion costs are now summed up over all industries since infrastructure investment improves productivity of transportation capital across industries. If these congestion costs are high, then more should be invested in infrastructure. If the shadow price of capital, PKT^s, is higher than the user cost of capital, more should be invested in infrastructure to remove the bottlenecks. The more investment has to be financed by energy taxes, the less will I^* be. The tax rate for financing I^* follows from (15):

(17) $$t_E^* = \frac{s \cdot PI \cdot I^*}{g_E \cdot \sum KT_j(KT_j^0, KI^*)}.$$

We have finally modeled consumer behavior by including the service flow of cars and the purchase of cars as part of the decision to spend the income. Expenditure by the government is exogenous, except for net investment for infrastructure, and revenue is generated by a variety of taxes on consumption, income and profits. Foreign trade is modeled in the small open economy framework. Foreign prices are exogenous, and demand and supply equations in relative prices clear the trade-offs between domestic production and imports, as well as between exports and production for the domestic market. In Fig. 2 we sketch the impact of transport policy on the economy for a representative industry.

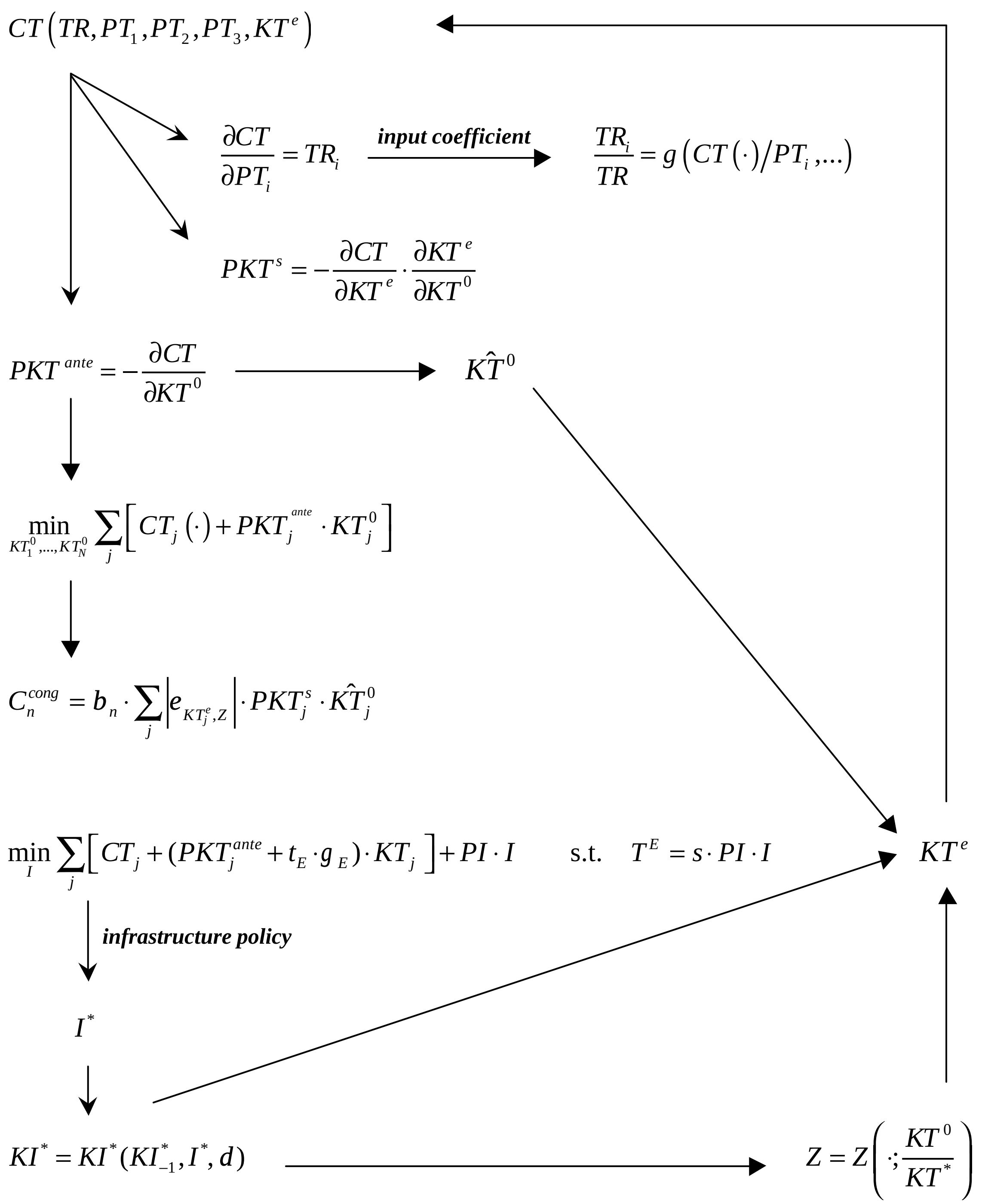

Fig. 2 Interdependency of transport costs, congestion and infrastructure in our CGE framework

3. Data

The Social Accounting Matrix consists of an input output table, the stock of trucks and of private cars[8] and of infrastructure. The capital stock of the highway system, *KI*, can be found in Verkehr in Zahlen. The number of trucks owned by manufacturing are published in the Statistical Yearbook. The same holds for the number of trucks owned by the truck-transport industry. The elasticities of substitution for the CES specification of the cost functions are taken from the GEM-E3 model. We assume that all industries (except railways and water ways) provide freight transport by themself using firm-owned trucks, and by outsourcing transportation services by purchasing these services from rail and / or truck transport firms. We have aggregated the 58 industries of the input-output table to 18. Industries which remained disaggregated are road transportation, water ways, railways, mineral oil, motor vehicle production, and construction. Based on Frank and Sumpf (1997) we assumed as initial cost of congestion 100 billion €. Using (13), this cost figure permits to calibrate $e_{KT^e,Z}$ which yields $e_{KT^e,Z} = -0.06$. For calculating the congestion index Z in (2) we assume that actual stocks of trucks $\bar{KT}^0$ should be less by ten percent given the actual size of infrastructure (*KI* = 72 bill. €). The elasticity of *Z* with respect to *KI*, $e_{Z,KI} = -\dfrac{a}{KI}$ is assumed to be –4 percent which implies $a = 13165$ in (1). This implies Z =1.2. For private households it is assumed that the budget share of expenditure on cars will be higher by 6¼ percent after 10 years.[9] World trade, finally, grows by 3% per year.

4. Simulation results

We first calculate a business as usual case (bau) as a reference scenario by running the model over 20 years. The figures for output x, transport costs CT and capital stock of transportation equipment KT^0 are given in growth rates for the first decade. As an approximation they could be divided by ten to get yearly growth rates although the model is not linear in its variables. The first bloc of columns in Table 1 shows a yearly growth of output x between 1.4 and 2.4 percent and growth rates for transportation costs CT which are somewhat higher for each industry due to inflation and congestion. The congestion index Z increases by 1.2 percent

[8] Source: Verkehr in Zahlen (1994).
[9] This corresponds to a projection by DIW (1994).

per year and congestion costs by 0.8 percent. This is an increase of 0.8 bill. € per year. Within the bau-simulation run we calculate the optimal road infrastructure investment I^* and the fuel tax rate t_F^* according to (16) and (17). Investment I^* is net investment to extend the capacity of the road system and t_E^* is an additional fuel tax to finance 40 percent $(s = 0.4)$ of investment expenditure. The yearly figures of I^* and t_E^*, calculated in the bau-run, had no impact on the bau-results. Now we use these figures as policy instruments which enter the equations of the model as exogenous variables. Column bloc 2 of Tab. 1 contains the results of this tax financed extension of infrastructure. Growth in real output is slightly higher in some industries since we have modeled a smooth policy and not a shock to the economy. Growth is lower for railways, as expected, and also lower for road transport because the need to outsource transportation services is reduced due to the improved efficiency of firm-owned trucks. As shown by the KT^{o} column, the stock of trucks required to transport the production volume of the economy declines due to this improvement in efficiency. The congestion index increases now by only 1 percent per year compared to 1.2 percent in the bau-case. Congestion costs are higher by only 0.4 percent per year which is a saving in congestion costs of 0.4 bill. € per year. Since $PI \cdot I^*$ is about 0.33 bill. € per year, the benefit of this policy outweighs the costs by far. A percentage of $s = 0.4$, i.e. $0.4 \cdot 0.33 = 0.132$ bill. €, has been financed by the additional fuel tax and $(1-0.4) \cdot 0.33 = 0.198$ bill. € comes out of the standard government budget. Since it is not possible to draw the savings in congestion costs into the financial calculation of I^*, a tax is required in order for the economy to benefit from a better provision of public infrastructure. Due to the additional tax burden, costs of transportation CT are somewhat higher compared to the bau-case, and the stock of private cars has grown less.

A measure, only weakly related to a more effective usage of infrastructure provision, is to raise the fuel tax in order to get cars off the streets. We have simulated such a measure, given the unchanged infrastructure of the bau-case (3rd. bloc of columns of Table 1). Growth in Z and C_{cong} is below the bau-case, but higher than in case 2. Private cars increase less than in the bau-case due to the higher fuel tax. Z is still high because the industries need more trucks to transport the production volume on the insufficient infrastructure. Finally, in a fourth simulation, infrastructure increases along KI^* as in case 2, but the financial means come out of the ordinary government budget.[10] This policy is more effective than higher fuel taxes

[10] This is not a policy with $s = 0$ in (15), which would imply a higher KI according to (16).

because the saving in congestion costs is higher and the industry requires a lower number of trucks due to better infrastructure.

Table 1

Variable	**Bau** **Growth after 10 years in %**			**Optimal** KI^* **financed by a fuel tax** t_E^* **Growth after 10 years in %**			**Higher fuel tax** t_E^* **Constant** KI **Growth after 10 years in %**			**Higher** KI **Constant** t_E **Budget deficit Growth after 10 years in %**		
***Z*, congestion index**	12			10			11			11		
C_{cong} **, congestion costs**	8			4			7			5		
	CT	*KT*°	*X*	*CT*	*KT*°	*X*	*CT*	*KT*°	*X*	*CT*	*KT*°	*X*
3 **Petroleum**	19.4	17.3	18.2	19.7	14.8	18.2	19.6	17.2	18.1	19.6	15	18.2
6 **Energy int. ind.**	24.2	21.9	23.2	24.6	19	23.3	24.5	21.8	23.2	24.4	19.1	23.3
8 **Investm. goods**	25.6	23.0	24.4	26.1	20	24.5	26	22.8	24.5	25.8	20.2	24.5
10 **Consumption goods**	21.	18.8	19.4	21.6	16.3	19.5	21.4	18.7	19.4	21.3	16.4	19.6
13 **Motor vehicle**	25.6	23	24.6	26	20.1	24.7	25.9	22.9	24.6	25.7	20.2	24.7
14 **Waterways**	14.5	-	14.4	14.6	-	14.5	14.5	-	14.4	14.6		14.5
15 **Railways**	19.5	-	18.1	19.9	-	18	19.8	-	18	19.6		18.2
16 **Road transport**	17.8	15.8	16.4	18	13.2	16.1	17.9	15.4	16	17.9	13.5	16.5
17 **Services**	18.3	16.2	16.8	18.8	13.8	16.8	18.7	16.1	16.7	18.5	14	16.8
Fuel tax t_E	0			0,01 €/year			0,01 €/year			0		
Investm. **(nom.)** $PI \cdot I$	0			333 mill. €/year			0			333 mill. €/year		
Infrastruc. KI^*	0			4			0			4		
Private cars	7.7			6.8			6.8			7.7		
$\exp\left(-a/KI\right)$ (index)	*0.9167*			*0.9195*			*0.9167*			*0.9195*		

Simulation results: For the business as usual case (Bau); a fuel financed extended infrastructure $(s = 0.4)$; a higher fuel tax; an extended infrastructure.

In Fig. 3 we have summarized our results with respect to Z and C_{cong} by doing the simulation over 20 years. As the figure shows, congestion costs increases more than proportional. Even in the case of tax financed infrastructure C_{cong} will increase. However, compared to the bau-case, the accumulated yearly saving in congestion costs adds up to a total saving potential of 100 bill. € within 20 years. In the 20th year, by itself, congestion costs differ by 13 bill. €.

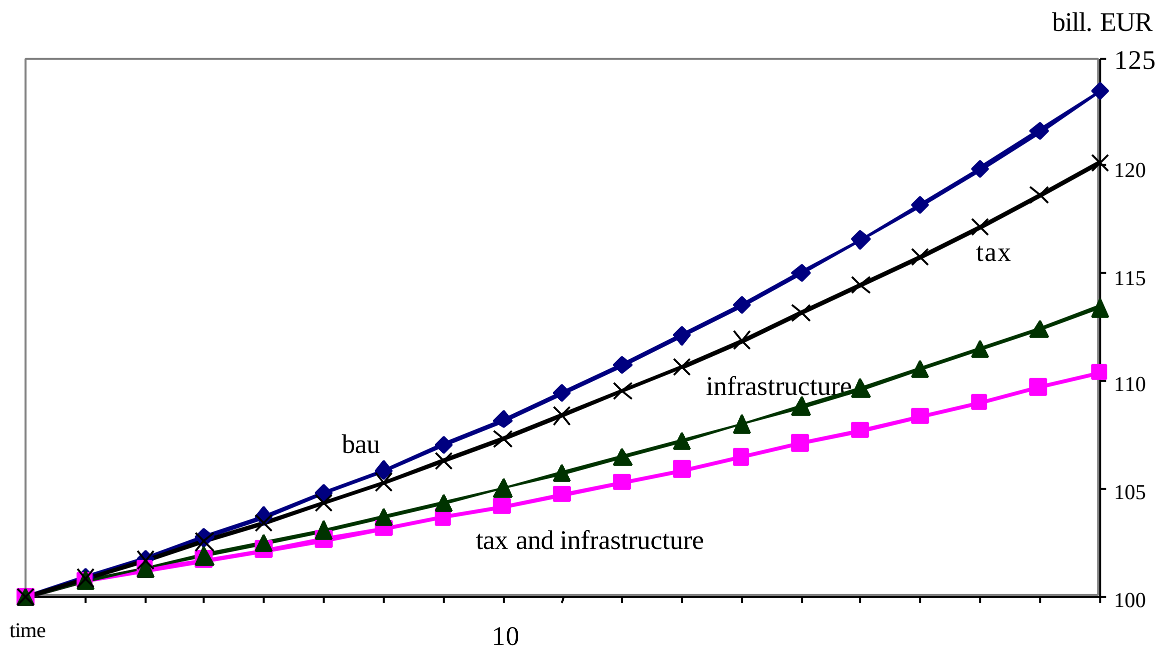

Fig. 3: social cost of congestion over 20 yaers

5. Summary and Conclusion

The costs of the benefit “mobility” are a collection of negative externalities like air-pollution, noise and congestion.[11] Given the enormous cost of congestion in some European countries, we have concentrated in this paper on measures to reduce congestion. This would also improve the emission account of traffic because less fuel would be wasted. Although our model could easily have been linked to all sorts of emission from traffic because it calculates the stock of motor vehicles and fuel consumption, we have concentrated on simulating the congestion problem. Modeling congestion and its impact on the economy is not without risk

[11] See e.g. Bickel and Friedrich (1995).

because congestion is a local phenomenon, depends on time, days and seasons,[12] and its costs could be measured in different ways.[13] As congestion is easy to forecast in Germany because it happens every weekday and everywhere, we decided to measure it as an index which affects each driver irrespective of time and place. The cost of congestion are measured as the cost of the substitutes for the transport services, normally carried out with firm-owned trucks but blocked up by the congestion externality. Trucks of each industry and private cars contribute to congestion, and the resulting inefficiency of firms' transportation capital compel them to spend extra money to get the output transported.

We have employed a CGE model with 18 industries and have simulated in a reference case the output, transportation capital, transport cost and congestion and its costs over a period of 10 years. Over these 10 periods of the business as usual (bau) case, congestion will increase and will add up to 16 bill. € more in comparison with present congestion costs. In order to improve the efficiency of transport capital, the government invests in infrastructure subject to the financial restriction that 40 percent of the expenditure has to be financed by an increase in the fuel tax. We found that potential savings in congestion costs sum up to 15.5 € in ten years whereas investment for improving infrastructure would only cost 7.5 € in the same stretch of time. Therefore savings in congestion costs will exceed by 50 percent the costs of the addition in infrastructure investment. No matter where the means for infrastructure investment come from, it is self-financing because the willingness to pay in order to save congestion costs exceeds the cost of the investment project. We have, however, ignored the fundamental law of congestion by Downs (1962, 1992), which states that congestion is constant because a better infrastructure provision will generate additional traffic. This could be a justification for politicians to do nothing, an attitude we do not accept in view of the waste in time, fuel and production inefficiencies.

[12] See e.g. Small (1992).
[13] See e.g. Aberle (1972).

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