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Transport and Regional Development

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1. Introduction

The completion of the internal European market transforms the European regions and nations into a network economy with an open access to but also with a strong competition between major areas in this network. As a result of this competitive process, some regions will become losers and others winners. Thus the regional development issue is going to be a factor of critical importance in Europe. This is also witnessed by the new national and supranational plans in Europe to invest in sophisticated infrastructure in backward regions in order to ensure relatively equal competitive advantages for all regions. Thus transport infrastructure is a critical success factor for competitive performance and internationalisation of regional economies. Missing links - or even missing networks as a whole - mean a significant reduction in the potential productivity of a region or nation.

Regional development is not only the result of a proper combination of private production factors such as labour and capital but also of infrastructure in general and transport infrastructure in particular. Improving infrastructure leads to a higher productivity of private production factors. Conversely, a neglect of infrastructure leads to a lower productivity of the other production factors.

The desired balance between private and public infrastructure in regional development has been the subject of much theoretical and ideological debate. Hirschman (1985) has pointed out however, that is illusory to think that a balanced development is possible. Given the lumpiness of transport infrastructure projects, one will often have relatively long periods of excess supply or demand.

Governments have different options with respect to transport infrastructure. First, they may invest in infrastructure as a response to serious bottlenecks taking place due to an expansion of the private sector. This leads to a passive strategy: transport infrastructure is following private investment. Another option is that governments use transport infrastructure as an engine for national or regional development. This implies an active strategy where transport infrastructure is leading and inducing private investments. The latter strategy has a risky element however, because the response of the private sector to infrastructure improvement can be disappointing. In many countries one will find examples of infrastructure projects which failed because of an insufficient response from the private sector.

Doel: The purpose of the present paper is to give a review of studies which have been developed to assess the response of the private sector to transport infrastructure improvement.

It is important to note that in general the concept of infrastructure is used in a rather loose way in the literature. Most definitions include one or both of the following elements. First, infrastructure is mostly a capital good for which users do not pay a full market price: infrastructure is perceived as a source of external economies (cf. Youngson 1967; Lakshmanan 1989). Second, provision of infrastructure to an area leads to a very high cost for the first user, and a small

marginal cost for an extra user in the definition of infrastructure. This implies essentially that infrastructure is regarded not as a set of things but as a set of attributes.

The impact of infrastructure on the private sector consists of various elements. In the short run, direct effects will occur in the construction sector and indirect effects in all other sectors via intermediate deliveries. A negative effect, which is often overlooked, concerns the crowding-out effect: infrastructure must be financed, e.g., by means of government bonds, which may lead to higher interest rates and lower investments. In the long run one has operations and maintenance effects. In the present paper attention will mainly be focused on still another type of long-run effect: the programme (or spin-off) effects.

Programme effects refer to long-term indirect changes in income, employment or investment in the private sector which are induced by the new opportunities offered by the improvement or extension of infrastructure.

The organization of the paper is as follows. Some theoretical notions on infrastructure and regional development are discussed in Section 2. Section 3 is devoted to studies which focus on the impact of transport infrastructure on productivity in regions. In section 4 studies are reviewed which focus on the role of transport infrastructure as a location factor, influencing the location of private investment or employment. In Section 5 approaches are discussed where an integrated analysis is given of productivity and relocation effects of transport infrastructure on regional development. Section 6 offers concluding remarks.

2. Transport Infrastructure and Regional Development: Theory

Improvement of transport infrastructure influences both production and household consumption. It leads to a reduction of transportation costs and/or travel times. This may give rise to substantial redistribution effects among economic groups and also among regions. In order to analyze the differential effects of improvements of transport infrastructure on regional development, we will discuss the relationship between transport and interregional trade.

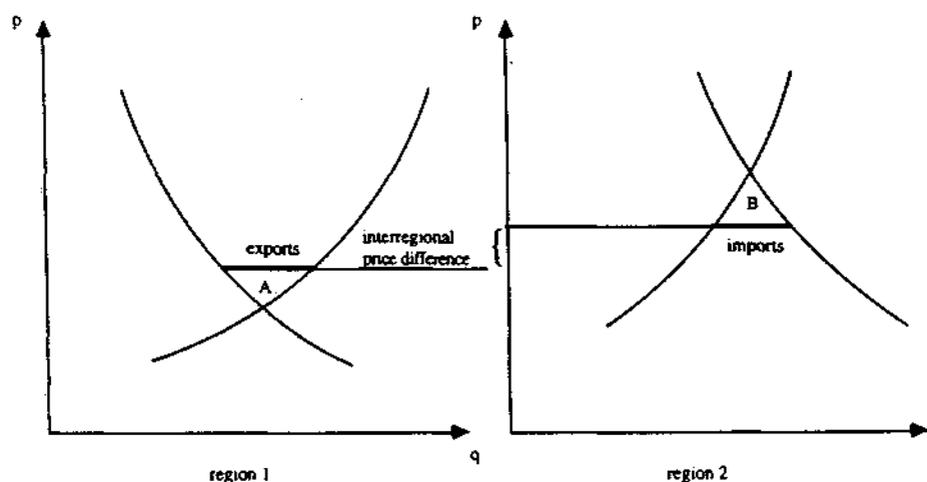


Fig. 1. Supply and demand in two regions

The standard model of interregional trade is illustrated in Fig. 1. Export takes place from region 1 to 2 when transportation cost is less than the difference in equilibrium price for a certain good in both regions. Compared with the situation without trade an additional surplus is created consisting of areas A (accruing to producers in region 1) and B (accruing to consumers in region 2). Thus, both regions benefit from trade according to the model.

Improvement of infrastructure leads to a decrease in transportation costs and hence to an increase in transportation volumes. The equilibrium price in region 1 will increase, and the price in region 2 will decrease. Thus, in region 2, consumers benefit from the improvement of infrastructure, whereas producer are negatively affected. In region 1 it is the other way around. In employment terms, region 1 benefits, but region 2 is hurt by the improvement of transportation infrastructure.

The two models sketched above are partial equilibrium models. They deal with the market for only one good. General equilibrium models are more adequate to analyze the effects of changes in infrastructure, but they are of course more complex (see for instance Labys and Takayama (1986; Takayama and Judge 1971; Tinbergen 1957). Figure 2 (which has been taken in adjusted form from Pluym and Roosma 1984) presents some of the main effects when more than one sector is considered. In this case the net effects are difficult to predict. Intermediate deliveries play a complicating role. In addition, there may be compensating forces in the regions in which employment was negatively affected by increased competition. Prices of the products concerned will decrease, so that consumers can spend more on other products, part of which will be produced in the same region.

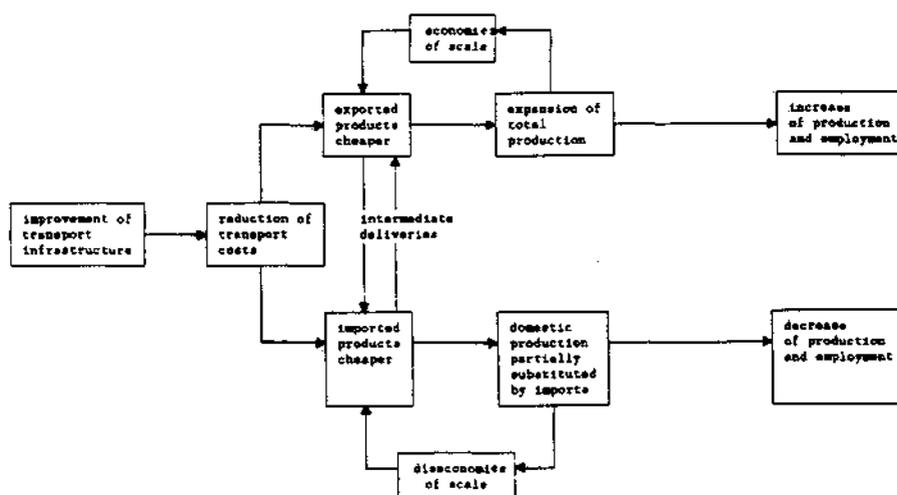


Fig. 2. Effects of improvement of transport infrastructure

Processes in the long term (relocation of capital and persons) caused by changes in transport infrastructure are even more difficult to predict. Thus, operational models have to be developed to trace the effects of changes in (transport) infrastructure on regional development. This will be the subject of the next sections.

3. Transport Infrastructure and Regional Productivity

In addition to production factors such as labour and private capital, transport infrastructure plays a role as an input in production processes. An improvement of transport infrastructure services implies that a regional economy can make use of its private production factors in a more productive way. Better transport infrastructure means: lower capital and labour needs to be able to reach the same production level.

There are essentially two ways for analyzing the productivity gains induced by transport infrastructure improvements. The first one takes place at the firm level by measuring carefully the reductions in (transport) costs which can be achieved by infrastructure improvements. The second one occurs at the aggregate regional level by investigating the contribution of the production factor infrastructure to regional production taking into account the contribution of other production factors. This entails the use of regional production functions.

3.1 Analysis at firm level

Micro analysis can be helpful in tracing behavioural determinants and responses of individual firms as a result of new infrastructure. An interesting example can be found in Forkenbrock and Foster (1990) who describe the results of various studies concerning the impact of infrastructure on regional development all using quasi-experimental control group analysis and macro-economic indicators (e.g., population, employment, income per capita etc.). It is remarkable that the results of these studies appear to be different: some authors find a positive relationship and others a negative or inconclusive one. Thus controlled micro experimentation does not necessarily guarantee satisfactory outcomes.

We will present two examples of a micro approach, taken from Dutch research in this field. A study by NEA (1990a) addresses the economic costs of inadequate infrastructure in the province of Noord Brabant on the regional economy. The study focuses on the congested S20 connection between Nijmegen and Eindhoven. Firms in the region were reported to suffer from excessive transport costs. A careful series of interviews with firms in the region led to the conclusion that firms with a regional orientation experience a increase in total transport costs of about 1.6% including both capital and labour costs. For firms with an international orientation this figure is 0.7%. For most firms the transport

costs do not exceed 30% of total costs (except for transport firms, of course).

Therefore the impact of the delays on productivity of firms is low, except for transport firms themselves. Thus the overall effect of inadequate transport infrastructure on regional productivity must be low in this case. Of course, the impact on the profit rate of individual firms will be higher; even much higher than certain individual cases. An interesting result of the study is that the actual time losses for firms are much smaller than the time losses as perceived by the firms themselves. This is also an important point for the impact of infrastructure on location decisions of firms. Perceptions deserve more attention in studies of firms behaviour than they usually receive.

A second case study was carried out by NEA (1990b) in the province of Zuid Holland. A difference with the former study is that the latter one is an ex-post study: it deals with a realized infrastructure improvement. In the 1980's an industrial area near The Hague received a much better connection with the national highway system. The time gains per car or truck operated by firms in this particular area varied from 2 to 10 percent. For firms located elsewhere the average time gains were of course much smaller. It appeared from the interviews that firms made little systematic effort to make use of the time gains. A rescheduling of trips did not take place, for example, so that part of the time gains were absorbed by an increase of slack in firms. The overall reduction in transport costs and the related productivity increase due to the transport infrastructure improvement were relatively small in this case study.

A disadvantage of micro case studies of this type is that they only focus on productivity improvements for firms directly affected by infrastructure improvements. Indirect effects on other firms are usually not taken into account. Another disadvantage of these case studies is that only one type of infrastructure is taken into account. Therefore, it is interesting to combine these case studies with modelling approaches using aggregate production functions where such elements can be taken into account. This will be the subject of the next section.

3.2 Production function approach

A general formulation of a production function for sector i in region r , with various types of infrastructure is:

$$Q_{ir} = f_{ir} (L_{ir}, K_{ir}; IA_{r, \dots}, IN_r),$$

where:

- Q_{ir} value added in sector i , region r
- L_{ir} employment in sector i , region r
- K_{ir} private capital in sector i , region r
- $IA_{r, \dots}, IN_r$ infrastructure of various types in region r

Author	Country	Number of sectors	Number of types of infrastructure	Presence of:		Form of production function
				labor	private capital	
Biehl	E.C.	1	1	yes	no	Cobb-Douglas
Blum	F.R.G.	3	8	no	no	Cobb-Douglas
Andersson et al.	Sweden	1	7	yes	yes	Cobb-Douglas (with modification)
Snickars and Granholm	Sweden	21	5	yes	yes	Leonief
Nijkamp	The Netherlands	1	3	yes	no	Cobb-Douglas
Fukuchi	Japan	3	3	yes	yes	Cobb-Couglas
Kawashima	Japan	8	1	yes	no	linear
Mera	Japan	3	4	yes	yes	Cobb-Douglas

Table 1. Examples of the production function approach to infrastructure modelling

As far as transport infrastructure is concerned, it is not easy to take into account its network properties in the production function approach. The best thing one can do is to distinguish various types of transport infrastructure according to their spatial range: intraregional, interregional, and possibly international.

Another problem related to infrastructure is that its impact may transcend the boundaries of regions. A certain region may not have its own airport but still benefit from an airport nearby. This may be solved by using the concept of accessibility of certain types of infrastructure in the production function.

A summary of models using the production function approach is given in Table 1. It appears that in most of the models a simplified version of the above production function approach is used. The most complete ones are those developed by Mera (1973) and Fukuchi (1978) for Japan, and Snickars and Granholm (1981) for Sweden.

Sectorial detail is important in these studies. This is shown by Fukuchi (1978) and Blum (1982), who found that the productivity increase due to infrastructure may be quite different among different economic sectors. This is also confirmed by Biehl (1986), who found that an index of sectoral composition of regional economies explains much more of the variance in regional per capita income than infrastructure does.

The most detailed treatments of infrastructure are given by Blum (1982) and

Andersson et al. (1989). As far as transport infrastructure is concerned, Blum distinguished (in a regional study of the FRG):

1. long distance
2. all other roads
3. railroads
4. ports

For both types of roads and for ports, significant results were obtained. For railroads, Blum found zero and even negative effects.

Andersson et al. distinguished the following aspects of transport infrastructure for the Swedish regions:

1. main roads
2. railroads
3. airport capacity
4. travel time to major metropolitan area
5. interregional travel time

For 1970 Andersson et al. found that the impact of railroads on regional production was stronger than that of main roads. In 1980, this situation had reversed. Airport capacity itself does not have an influence on regional production, according to the estimates. However, if taken in conjunction with R&D, it can be shown to have a positive effect.

The form of the production function chosen is in most cases a Cobb-Douglas function. This implies a considerable degree of substitutability among production factors, e.g., between private and public capital. By investing in private infrastructure, regions can extend their production capacity, even when infrastructure is fixed at a low level. An interesting modification of the Cobb-Douglas function is used by Andersson et al. (1989) in order to allow for zones of increasing and zones of decreasing returns to scale. An entirely different approach is followed by Snickars and Granholm (1981). The Leontief structure they use implies that infrastructure imposes a limit on the extension of employment and private capital in a region.

4. Infrastructure and Factor Mobility

Provision of infrastructure in a certain region leads to an increase of productivity of private production factors such as labour and capital (see Section 3). This may in turn lead to expansion and relocation of these production factors into his region. This effect is the subject of the present section.

The response of labour and capital to changes in regional infrastructure could be studied by means of the production functions discussed in Section 3. These production functions can be used to derive demand functions for labour or capital with relative prices and infrastructure endowment as explanatory vari-

ables. In most empirical studies, this approach is not followed, however. Rather, the levels of employment and capital are studied in the context of a rather loose location theory in which relative prices and infrastructure play a role next to a series of other location factors. Among these factors are urbanization economies, sectoral structure, quality of labour, accessibility of markets, and particular regional policies.

Four approaches can be observed towards analyzing the influence of infrastructure on employment and private capital:

1. The role of transport infrastructure is modelled via its influence on accessibility.
2. The role of transport infrastructure is modelled via its influence on marginal transportation costs, which are computed by means of a linear programming transportation model.
3. Investments in infrastructure are directly linked to private investments in regional economic models.
4. The role of transport infrastructure is analyzed by means of surveys among entrepreneurs on the importance of infrastructure relative to other location factors.

4.1 Infrastructure and accessibility

Improvement of transportation infrastructure leads to a reduction of travel time or cost and hence to an improvement of accessibility of markets or inputs. This may in turn lead to a relocation of labour and capital. Accessibility of a certain variable Z in regions can be defined as:

$$ACC_r(Z) = \sum_{r'} Z_{r'} f(c_{r,r'})$$

where $c_{r,r'}$ is an index of travel costs between regions r' and r , and $f(c_{r,r'})$ is a distance decay function. The variable Z may refer to employment, production, inputs, etc. Botham (1983) uses the following relationship between regional employment and accessibility:

$$\Delta E_r = a_1 ED_r + a_2 w_r + a_3 LAPE_r + a_4 ACC_r(Z)$$

where ED , w , and $LAPE$ denote employment density, wage rate, and an index of labour availability. For Z , several variables mentioned above have been tried. Finally, ΔE is the differential shift in employment, as defined by shift share analysis.

The above equation has been estimated for 28 regions in the UK for the years 1961-1966, the period just before the construction of the UK national highway system. The equation was used for simulating the impact of the highway system as it developed on the distribution of regional employment. The reduction of transport costs induced by the highway system leads to an increase in accessibilities of the regions. The effects on employment shifts have been computed by means of this equation. The general conclusion reads that the impact of the highway system on the regional distribution of employment is rather small. A similar conclusion is also reached by Dodgson (1974) who used the same approach for the effects of the M62 in the UK. However, a similar study carried out by Kau (1976) in the USA gave rise to the conclusion that some regions experienced substantial positive impacts from an extension of the highway system.

Another application of the accessibility concept is given by Evers et al. (1987) in an ex-ante study on high speed rail connections in central and northern Europe. The study is more refined than the ones by Botham and Kau, in that some attention is paid to the problem of multiple modes of transport: focus on only one mode of transport may give a distorted view on accessibility as a location factor. It can be shown that the approach adopted by Evers et al. is (under certain conditions) consistent with a utility-based theory of the location of the firm (cf. Rietveld 1990). The result of the study was that employment relocation induced by the high speed rail connection would be quite modest.

Illeris and Jakobson (1991) used the accessibility concept to study the effects of a fixed link across the Great Belt in Denmark. Their conclusion is that the competitive position of the regions concerned will not change much by the fixed link so that relocation will remain of limited importance.

In other studies, accessibility is also included but in a much simpler way, i.e., by using travel time from a region to the economic core region in a country. This approach is a feasible option for countries dominated by a single center (see e.g., Folmer and Nijkamp 1987; Florax and Folmer 1988).

Still another approach to accessibility is followed by Mills and Carlino (1989). They measure accessibility by means of the density of the interstate highway network and find that it has a clearly positive impact on employment growth in US countries.

In the studies cited in this section, a positive relationship is found between accessibility and total employment. As discussed in Section 2, this result is by no means guaranteed by theory. In terms of Figure 2 it means that the balance between the sectors benefitting from a reduction in transport costs and the sectors hurt by a reduction is positive for the regions. At the level of specific sectors, one might still have negative effects on employment, but this is not reflected by the models discussed here, because a sectoral subdivision is not used.

4.2 Infrastructure and marginal transportation costs

The accessibility concept used in the previous section is closely linked to the gravity model. It allows for cross-hauling, and it yields spatial interaction matrices with a small number of zero interactions. An alternative approach to transportation modelling is the linear programming (LP) model, which does not allow for cross-hauling and which entails many zeros in the spatial interaction matrix (see Nijkamp and Reggiani, 1992). The model deals with the minimization of total transportation costs among a set of regions under constraints concerning total supply and demand. The dual variables of total supply and demand per region represent the marginal costs of receiving inputs and shipping outputs. As indicated by Stevens (1961) the dual variables can be interpreted as location rents.

Harris (1973, 1980) has developed a model on industry location in which the dual variables play a central role. Investments in infrastructure leading to changes in transportation costs give rise to changes in the dual variables. The dual variables in turn are determinants of industrial location. In this model, other factors influencing industrial location are: the cost of labour, the value of land, prior investments, and agglomeration variables. The model has been developed for the USA. It allows for a high degree of spatial detail (approximately 3000 counties), and also the sectoral detail is substantial (up to 100 sectors).

An interesting application of the model is discussed in Harris (1980). According to the model, investments in road and rail infrastructure in a rural county in the USA gave rise to substantial and positive direct effects on employment during the first 2 years. The structural spin-off effects of the infrastructure are negative, however, according to the model. After the fourth year, a negative, though modest, effect takes place on regional employment. This is an illustration of the lower part of Fig. 2: Regions may be negatively affected by an improvement of transport infrastructure.

4.3 Direct links between investments in infrastructure and private investments

The effects of government investments on the national economy and especially on private investments can be studied by means of standard macroeconomic models. Several types of effects have to be taken into account. Multiplier effects of public investments have a positive influence on private investments. On the contrary, crowding-out effects may occur which have a negative influence on private investments. Crowding-out occurs because financing infrastructure investments leads to higher interest rates for projects that are financed by means of government bonds. This implies a disincentive for private investors. Another type of effect consist of spin-off effects. These effects, on

which the present paper is focused, are usually not taken into account in the macroeconomic models, however (cf. Houweling 1987).

A possible approach to detect spin-off effects of infrastructure investments is the use of causality analysis. For example, in the approach of Pierce and Haugh (1977), statistical tests are developed for correlations between time series with different lag intervals. Using this approach, den Hartog et al. (1986) found for the Netherlands that there is indeed a causal relationship between public and private investments, taking place within an interval of 3 or 4 years. For the reverse relationship (i.e., public investments are caused by private investments), no statistical confirmation could be found.

This result is important in the context of Hirschman's (1958) notion of **unbalanced growth**. Unbalanced growth means that private and public investments do not follow parallel paths. Periods with a strong emphasis on public investments alternate with periods with a strong emphasis on private investments. The result of the Netherlands suggests that public investments are the leading variable in this process.

A disadvantage of the approach above is that it is not possible to separate indirect, crowding-out, and spin-off effects. Since the lag interval is rather short (3 or 4 years), it is not clear whether the causal relationship refers to short-run (indirect or crowding-out) effects or long-run spin-offs. In order to overcome this difficulty, one may change the spatial level of analysis. An important part of the short-term effects of an infrastructure project will take place outside the region in which the project takes place. Long-run spin-off effects are likely to be concentrated in the project region, however. Therefore, den Hartog et al. (1986) also carried out an analysis at the provincial level. In each region, private investment IP as a share of the gross domestic product Q is explained by government investment IG as a share of the gross domestic product:

$$\Delta(IP/Q)_{r,t} = \sum_{i=0}^k a_i \Delta(IG/Q)_{N,t-i} + \sum_{i=0}^k \beta_i \{ \Delta(IG/Q)_{r,t-i} - \Delta(IG/Q)_{N,t-i} \}$$

The subscripts t and r refer to time and region. The national level is represented by N. Thus in the above equation, for each region private investments are explained by government investments at both the national and regional level with certain lags (see also Nijkamp and Blaas, 1992).

Spin-off effects can be detected by means of the β_i coefficients in a cumulative way ($\sum \beta_i$). Empirical results show that spin-off effects are indeed significant for an interval of 0 to 5 years. However, den Hartog et al. (1986) indicate that this positive result depends strongly on one particular province (Zeeland), which happened to attract high levels of government investment during the period considered. If this province is deleted, spin-off effects are no longer statistically significant. Thus, with the given approach, only when infrastructure investments are large is it possible to show that significant spin-offs take place in the regions.

4.4 Entrepreneurial statements about the importance of infrastructure as a location factor

As a complement to the above modelling approaches one may also make use of direct interviews among entrepreneurs in order to study the relative importance of infrastructure. An example of such an approach is given by Bruinsma (1990) who studied the impact of infrastructure improvements in three Dutch regions. About 15% of the entrepreneurs states that improved or new infrastructure has played a very important role in the development of employment in the firm. One should not exaggerate the importance of infrastructure however, since market developments and the availability of space for expansion played a more important role according to the entrepreneurs. A special category concerns firms which relocated recently: in about 35% of these cases, infrastructure is mentioned as an important or very important location factor. In each of the regions concerned there has been a major improvement of an existing highway or the construction of a new one. The average share of firms which reported that these activities had a positive impact on the firm's employment varied among the regions from 14% to 26%. In one of the regions the data available allow one to make an estimate of the (minimum) number of jobs created by a new highway per amount of investment. The outcome is that an investment of about Dfl. 650.000,- in highways (this is about US \$ 325.000) leads to the creation of one permanent job. As a contrast one may use the amount of investment which is needed to generate one man-year of work in the construction sector and related sectors: taking into account the multiplier chain, a Dfl. 100.000 investment in highways generates work for one person during one year. The difference between the two figures is of course that the first impact has a permanent character whereas the second impact only takes place in the short run.

An obvious disadvantage of the approach described here is that there is no guarantee that actual behaviour of the entrepreneur has been in agreement with his statements. Another disadvantage is that such an interview based analysis does not take into account indirect effects on other entrepreneurs, possibly located in entirely different regions (see also Vleugel et al., 1991). This raises the issue of generative versus distributive effects which will be discussed in the next section since it is of particular importance for our discussion.

4.5 Distributive versus generative growth

Improvement of infrastructure may lead to both distributive and generative effects. Distributive effects relate to a redistribution of economic activity among regions, the national total remaining constant. On the other hand, generative effects occur when the national total (or more generally the total in a system of regions) changes.

A difficulty is that the balance between distributive and generative effects depends on the demarcation of the system of regions. For example, improvement

of a national airport in a country may (apart from an interregional redistribution in the country) induce larger flows of air traffic in the country concerned. This might be interpreted as a generative growth effect, but it may also be the consequence of a redistribution of air traffic at a higher international level. In the latter case, the share of other countries would show a decline.

Thus, generative growth effects may simply be an illusion caused by a delimitation of a study area which is too narrowly defined. This does not mean to say, of course, that all generative growth effects are illusory. But one will often observe the tendency that generative growth effects will be smaller, the larger the system of regions studied.

In terms of the production function approach (Section 3), an increase in infrastructure leads to a higher productivity of private production factors. This will lead to lower prices of outputs and/or higher levels of value added. Both will have a generative growth effect on the regions concerned. However, in the case of footloose industries, generative growth effects will be very small. For these industries, the approach of section 4 may be more relevant. Improvement of infrastructure in a region may lead to redistribution of labour or capital from one region to the other.

5. An Integrated Analysis of Productivity and Relocation Effects of Infrastructure

In the preceding sections we discussed the productivity and relocation effects of transport infrastructure separately. Of course, it would be preferable to use models where the two effects are treated in an integrated way. We will discuss some interregional models which are suitable for this purpose.

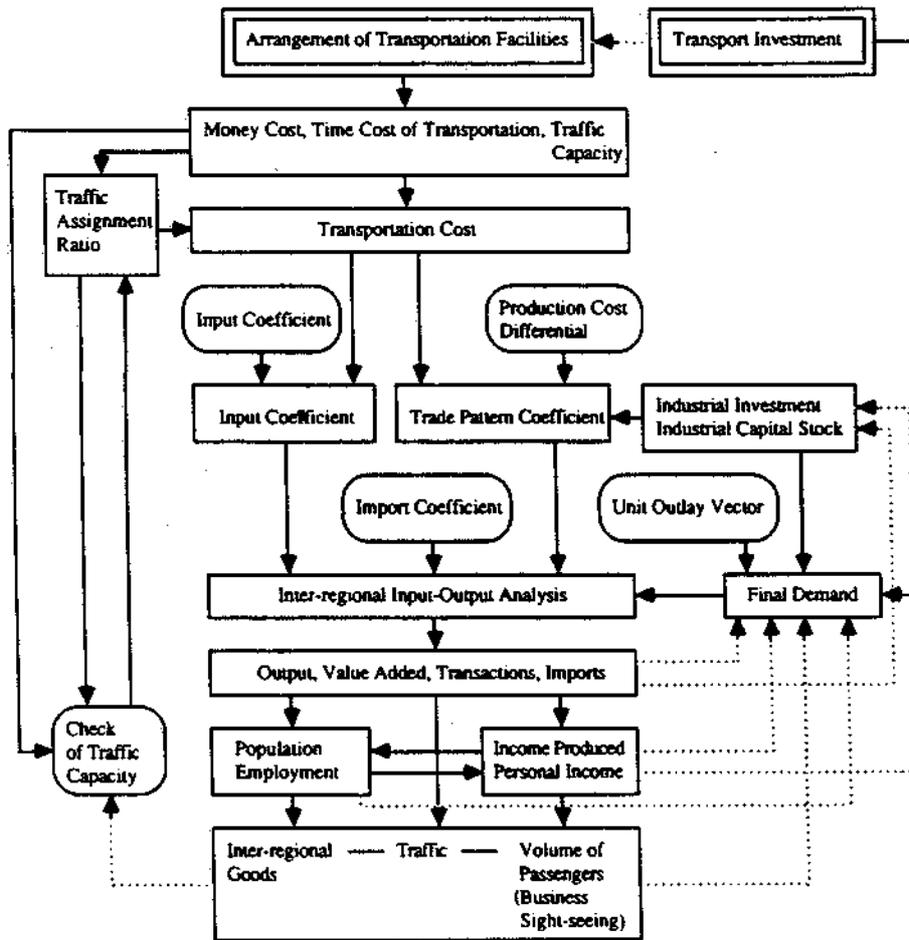
Figure 3 gives a schematic example of a model of this type (derived from Amano and Fujita 1970).

For an appropriate analysis of transport costs one needs a detailed treatment of transportation networks, route choice and modal choice. This leads to a degree of spatial detail which is difficult to meet in other parts of the model. Los (1980) proposed solving this problem by linking models with different degrees of detail, i.e., by using a transportation model with a high sectoral and spatial detail. This approach has not become very common, however. Most operational models in this field give a rather crude treatment of networks, route choice and modal choice.

In this paper we will focus on the relationship between transportation costs and trade flows.

Amano and Fujita (1970) put forth the following formulation for a Japanese interregional model:

$$t_{irs} = K_{ir} \exp [-\beta_i(p_{ir} + v_{irs})] / \sum_q K_{iq} \exp [-\beta_i(p_{iq} + v_{iqs})]$$



Note: Dashed lines denote a time lag of one year

Fig. 3. System chart of the Amano-Fujita interregional model

where the subscripts q , r and s refer to regions, and i refers to sectors. K_{ir} and p_{ir} denote capacity and price level in sector i of region r . Furthermore, v_{ir} is transportation cost per unit of i between r and s , and t_{irs} is the share of regions r in the deliveries to region s for goods produced in sector i . As indicated by Bröcker (1984), this formulation can be based on theories of stochastic choice.

A simple illustration of this equation on the sensitivity of interregional trade flows for changes in transportation costs is given in Fig. 4. In a system consisting of regions A, B and C, infrastructure between A and B is improved, leading to a decrease in transportation costs between A and B for all goods in both directions. The effect on the trade share of region C (the region not directly involved) is unambiguously negative according to this equation. For the regions directly involved, the effect on trade shares is not clear, however. The loss on the home market has to be traded off against an increased penetration on the market of the other regions. One thing is clear, namely that the sum of trade shares for A and B together will increase as a consequence of the improvement of infrastructure. The conclusion reads that although it is not obvious which of the regions

directly involved in the improvement of transport (infrastructure) will be the winner, the regions not involved will certainly be losers.

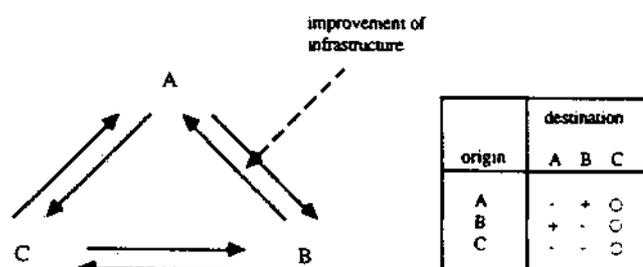


Fig. 4. Response of trade flows to transport cost reduction in a three-region framework

According to the formulation above improvements of infrastructure lead to a zero sum game: $\sum_r t_{irs} = 1$ for all i and s . However, as can be understood from Figure 1, it is not only trade shares which change but also total trade volumes. Improvement of infrastructure does not only redistribute existing trade flows but may also generate larger trade volumes. Taking into account this generation effect and other indirect effects it is no longer obvious that a zero sum result will arise. In the Amano-Fujita model, generation effects occur among others because the reduction in transportation costs leads to an increase in value added which leads in turn to an increase in labour supply and investments.

Liew and Liew (1985) propose another modelling procedure. Their point of departure is a Cobb-Douglas production function with capital, labour and intermediate purchases for each sector and each region. Liew and Liew assume that consumers fully absorb the advantage of a decrease in transportation costs: the equilibrium purchase price in region s is the sum of the equilibrium price of the good in region r plus the cost of shipping it from region r to s . Another assumption is that in equilibrium, transportation costs are a constant fraction of the equilibrium price. Using a profit-maximizing approach, Liew and Liew derive a linear logarithmic system of price frontiers. Changes in transportation costs give rise to changes in equilibrium prices in the various regions. These in turn give rise to substitution effects in the production process. Thus, it is not only interregional trade shares which change as a consequence of changes in transportation costs, but all input-output coefficients may change as a result of it. In this respect, the model of Liew and Liew is more general than the model of Amano and Fujita where input-output coefficients are assumed to be constant.

6. Concluding remarks

A wide variety of approaches towards analyzing infrastructure can be observed. For another recent review of studies we refer to Vickerman (1991). Some of the findings of this survey can be summarized as follows (cf. Evers-Koelman et al. 1987)

It should be noted that transport infrastructure is a generic term which would deserve much more detailed qualification in order to render itself appropriate for focused policy analysis. It is, for instance, noteworthy that the impact of infrastructure on locational decisions of firms depends also on its uniqueness. An increase in an ubiquitous infrastructure category does not exert a major additional influence on a region. For example, road expansion in an industrial area with a highly developed infrastructure network will have a lower effect than that in an underdeveloped area (i.e., a case of decreasing marginal benefits). Thus infrastructure is a sine qua non, but not a panacea for growth. Besides, infrastructure will only have a positive impact if the region at hand has already a favourable existing potential for new development.

Another basic and often neglected transport policy question concerns the relationship between transport infrastructure and land use patterns: are large-scale geographical concentrations of public and/or private activities (e.g., offices, warehouses, facilities) a response to existing transport infrastructure, or have transport developments merely help to mitigate what would have occurred anyway? Thus the assessment of economic impact of infrastructure requires a clear specification of causality mechanisms.

Infrastructure is also subject to decreasing marginal productivities. When a region is already well provided with infrastructure, adding infrastructure of the same type is of little value (cf. Section 3). The provision of an extensive network of highways makes more and more industries footloose. As a result, the importance of road infrastructure as a location factor decreases (cf. Wilson et al. 1982). It is in developing countries with low infrastructure qualities that one expects the highest impacts of infrastructure investments on regional development.

As a corollary to the above, it is important to assess the potential effects of new types of infrastructure versus existing types (e.g., telecommunication versus roads). Infrastructure types clearly have their life cycles. Life cycles must not be used in a simplistic way, however. For example, rail traffic is regaining momentum after a long period of decline in Europe by the introduction of high speed trains.

Consider an improvement of a link in a transportation network. The program effects tend to be largest in the regions connected by the link concerned (and other regions for which the link is important). The effect is not necessarily positive for all of these regions. Some of them may be negatively influenced, for example, by the loss of markets due to increasing competition. The effect on the other regions, for which the improved link is not important, is much smaller, but it tends to be negative (cf. Section 5).

Improvement of infrastructure is not a sufficient condition for regional development. Many other intermediary factors play a role. The interplay

between infrastructure and other relevant factors is often only formulated in a superficial way in the studies surveyed. Especially for studies on specific infrastructure improvements, it is advisable that model-based studies be complemented with micro studies based on interviews with actual and potential users of infrastructure.

Improvement of infrastructure gives rise to both distributive and generative effects (Section 4). Distributive effects tend to be small when in all regions improvements of infrastructure take place at the same speed.

Distr. eff^s

Generative effects of infrastructure can easily be overestimated when the spatial delimitation of the area of study is too narrow. Part of the effects may simply result from an unobserved redistribution at a higher spatial level (Section 4).

Gener. eff^s

Improvement of transport infrastructure leads to a decrease of transportation cost. This advantage may be absorbed by entrepreneurs or land owners in the form of profit or rents; it may also be absorbed by employees (via wages). Another possibility is that the advantage is passed over to consumers in the form of lower prices. This distribution issue receives little systematic attention in the models surveyed, which is regrettable since the regional incidence of infrastructure improvements depends strongly on it.

Infrastructure is a multidimensional phenomenon. The importance of synergetic effects between various types of infrastructure has been recognized at the theoretical level. In the present generation of operational multiregional economic models however, the occurrence of such synergetic effects is usually neglected.

Models on infrastructure tend to focus on its use for firms. The use for households must not be neglected, however. Infrastructure is an important location factor for households when relocating. In the long run, this will also have implications for the location behaviour of firms.

Most of the models have been formulated as tools for impact studies: A change in infrastructure is supposed to lead to a change in the private sector. Infrastructure is an exogenous variable in the models. This is not necessarily an adequate way of modelling infrastructure. As indicated in Section 1, infrastructure may not only lead the private sector, it may also follow. It is challenging to broaden the scope of models by introducing the possibility of this two-sided relationship.

References

- Amano K., Fujita M. (1970) A long run economic effect analysis of alternative transportation facility plans - regional and national. *Journal of Regional Science* 10:297-323
- Andersson A.E., Anderstig C., Harsman B.(1989). Knowledge and communications infrastructure and regional economic change. University of Umea, Umea
- Biehl D. (1986) The contribution of infrastructure to regional development, regional policy division. European Community, Brussels
- Blum U. (1982) Effects of transportation investments on regional growth. *Papers of the Regional Science Association*, pp 151-168
- Botham R. (1983) The road programme and regional development: the problem of the counterfactual. In: Button K.J., Gillingwater D. (eds) *Transport, location and spatial policy*. Gower, Aldershot, pp 23-56
- Bröcker J. (1984) How do international trade barriers affect interregional trade? In: Andersson AE, Isard W, Puu T (eds) *Regional and industrial development theories, models and empirical evidence* North Holland, Amsterdam, pp 219-239
- Bruinsma F. (1990) *Infrastructuur en werkgelegenheid*, OSA, The Hague
- Diewert W.e. (1986) The measurement of the economic benefits of infrastructure services. In: *Lecture Notes in Economics*, vol 278. Springer, Berlin, Heidelberg, New York
- Dodgson J.S. (1974) Motorway investment, industrial transport costs and sub-regional growth, a case study of the M62. *Regional Studies* 8:75-80
- Evers G.H.M., Meer P.H. van der, Oosterhaven J., Polak J.B. (1987) Regional impacts of new transport infrastructure: a multisectoral potentials approach. *Transportation*, 14:113-126
- Evers-Koelman I. Gent H.A. van, Nijkamp P. (1987) Effecten van de aanleg of verbetering van verkeersinfrastructuur op de regionaal-economische ontwikkeling. *Tijdschrift voor Vervoerswetenschap* 23 (No 1):33-60
- Florax R., Folmer H. (1988) regional economic effects of universities. Twente University, Enschede

- Folmer H., Nijkamp P. (1987) Investment premiums: expensive but hardly effective. *Kyklos* 40:43-72
- Fukuchi T. (1987) *Analyse Economie-Politique d'un Développement Régional Harmonisé*. Collect INSEE 61:227-253
- Harris C.C. (1973) *The urban economies 1985*. Heath, Lexington (Mass)
- Harris C.C. (1980) New developments and extensions of the multiregional multi-industry forecasting model. *Journal of Regional Science* 20 9No. 2):159-171
- Hartog H. den, Heineken K.A., Minne B., Roemers R.J.J., Roodenburg H.J. (1986) *Investeren in Nederland*. Onderzoeksmemorandum 17, Centraal Planbureau, The Hague
- Hirschman A.O. (1985) *The strategy of economic development*. Yale University Press, New Haven
- Houweling A. (1987) Bereken zelf de macro-economische effecten van een investeringsprogramma. Onderzoeksmemorandum 33, Centraal Planbureau, The Hague
- Illeris S. and Jakobsen L. (1991) The effects of the Fixed Link across the Great Belt, in: R.W. Vickerman (ed.), *Infrastructure and regional development*, Pion, London, pp. 75-85
- Kau J.B. (1976) The interaction of transportation and land use. In: Wendt P.F. (ed) *Forecasting transportation impacts upon land use*. Martinus Nijhoff, Leiden, pp 112-134
- Kawashima T. (1978) Regional impact simulation model BALAMO. In: Straszak H., Wagle B. (eds) *Models for regional planning and policy making*. Proceedings of the Joint IBM/ILASA Conference, Vienna
- Lakshmanan T.R. (1989) Infrastructure and economic transformation. In: Andersson A.E., Batten D., Johansson B., Nijkamp P. (eds). *Advances in spatial theory and dynamics*. North Holland, Amsterdam, pp 241-261
- Liew C.K., Liew C.J. (1985) Measuring the development impact of a transportation system: a simplified approach. *Journal of Regional Science* 25:241-257
- Los M. (1980) *A transportation oriented multiregional economic model for Canada*. Centre de Recherche sur les Transports, Université de Montreal, Montreal, publication 178

- Mera K. (1973) Regional production functions and social overhead capital. *Regional and Urban Economics* 3:157-186
- Mills E.S., Carlino G. (1989) Dynamics of county growth. In: Andersson A.E., Batten D., Johansson B., Nijkamp P. (eds) *Advances in spatial theory and dynamics*. North Holland, Amsterdam, pp 195-205
- NEA (1990a), congestie en het functioneren van bedrijven, een case-study rondom de S20 in Noord Brabant, Rijswijk
- NEA (1990b), Plaspoelpolder bedrijfsonderzoek, Rijswijk
- Nijkamp P. (1986) Infrastructure and regional development; a multidimensional policy analysis. *Empirical Economics* 11:1-21
- Nijkamp P. and A. Reggiani (1992) *Interaction, evolution and chaos in space*. Springer, Berlin
- Nijkamp P. and E. Blaas (1992) *Impact assessment and decision support in transportation planning*. Kluwer, Boston
- Pierce D.A., Haugh L.D. (1977) Causality in temporal system, characterizations and a survey. *Journal of Economics* 5:265-293
- Pitfield D. (1983) The useful interpretation of freight transport models for regional investment policy. in: Button K.J. Gillingwater D. (eds) *Transport, location and spatial policy*. Gower, Aldershot, pp 122-153
- Pluym W.K. Roosma S.Y. (1984) *Economische Betekenis van Transportinfrastructuur*. Federatie van Noordelijke Economische Instituten, Groningen
- Rietveld P. (1990) Employment effects of changes in transport infrastructure: methodological aspects of the gravity model. *Papers of the Regional Science Association*, vol. 66, pp 19-30
- Stevens B. (1961) Linear programming and location rent. *Journal of Regional Science* 3:15-26
- Takayama, T. and W.C. Labys, (1986) Spatial equilibrium analysis, *Handbook Regional Economics* (P. Nijkamp, ed.), Elsevier, Amsterdam pp. 171-199
- Takayama, T. and G.C. Judge, *Spatial and temporal price and equilibrium models*, North-Holland Publishing Co., Amsterdam, 1971
- Tinbergen, J. (1957) The appraisal of road construction, *Review of Economics and Statistics*, vol. 39, pp. 241-249

- Vickerman R.W. (1991) Infrastructure and regional development, Pion, London
- Vleugel, J., P. Nijkamp and P. Rietveld (1991) Network infrastructure and regional development. In: M. de Smidt, A. Granberg and E. Wever (eds.) Regional development strategies and territorial production complexes. Netherlands Geographical Studies, Amsterdam, pp. 189-208
- Wilson F.R., Stevens A.M., Holyoke T.R. (1982) Impact of transportation on regional development. Transportation
- Youngson A.J. (1967) Overhead capital. Edinburgh University Press, Edinburgh

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