DIW

Diskussionspapiere
Discussion Papers

Discussion Paper No. 115

Public Infrastructure, Productivity and Competitiveness

analysis of relative differences and impacts with regard to U.S. and German industries

by
Georg Erber

Deutsches Institut für Wirtschaftsforschung, Berlin
German Institute for Economic Research, Berlin

Deutsches Institut für Wirtschaftsforschung

Discussion Paper No. 115

Public Infrastructure, Productivity and Competitiveness

analysis of relative differences and impacts with regard to U.S. and German industries

by

Georg Erber

JEL Classification: D24

Berlin, June 1995

Deutsches Institut für Wirtschaftsforschung, Berlin
Königin-Luise-Str. 5, 14191 Berlin
Telefon: 49-30 - 89 7 89 -0
Telefax: 49-30 - 89 7 89 -200

Public Infrastructure,

Productivity and Competitiveness

analysis of relative differences and impacts with regard to

U.S. and German industries.

by

Georg Erber

JEL Classification: D24

Berlin, June 1995

Paper presented at the conference on "Creating the Infrastructure for the Single Market: Planning and Promoting EU Investment Mega-Projects". Meeting of the Confederation of European Economic Associations (CEEA), Athens, Greece, 20 - 22 October 1994.
Authors address: German Institute for Economic Research, Königin-Luise-Str. 5, D-14195 Berlin, Federal Republic of Germany, Telephone: 049-30-89 789-697, Fax: 049-30-89 789-200.

Summary

The paper studies the impact of changes in the supply of public infrastructure on the cost structure, the changes in the cost efficiency and the relative efficiency levels of industries in the United States and Germany. The period covered by the empirical analysis is 1960 to 1985. The methodology applied is the bilateral cost function for industry level data of both countries which was first introduced by Jorgenson, Nishimizu (1978). The model allows for country specific differences in cost structures, in changes of cost efficiency and of cost efficiency levels. It includes non-constant returns to scales as a testable hypothesis which were found to be a significant property in a previous paper (see Erber, 1994). The model introduces national public infrastructure capital stocks as a positive externality to the cost function of an industry which is treated as a quasi-fixed factor of production to private producers. The economies of both countries are separated into 26 different industries. The implicit shadow price of public infrastructure contributing to cost savings of producers in the different industries is determined by the model as well. The estimated cost function models for the industries are used to test if the results obtained by Aschauer (1989) and others that a decline in the supply of public infrastructure in the industrialized countries contributed significantly to the productivity slowdown observed for these countries after 1973 are robust if studied at the level of industries by a translog cost function. Testing the hypothesis that changes in the supply of public infrastructure capital stocks have significant impacts to producers in the different industries in reducing private costs we found very little statistical support. Only in the motor vehicle industry significant impacts on the cost structure and the change in the cost efficiency are obtained. For finance, machinery and transport equipment some significant impacts are found. The magnitude of cost savings attributable to the supply of public infrastrucuture are even in these industries very low so that they are not an important factor in the overall costs of any industry. This result seems to lend support to the hypothesis that the observed decline in the real growth of public infrastucture capital observed in both countries did not matter in the observed process of productivity or respectively the dual cost efficiency growth during the years 1960 to 1985. Both countries seem to have had sufficient public infrastructure growth so that no bottlenecks causing a slowdown of cost savings or of productivity growth in the private sector industries emerged. This finding is in line with results and considerations made by Jorgenson (1991) and Gramlich (1994) that the methods applied by Aschauer and others to measure the importance of public infrastructure for producers give very little or at least very fragile empirical support for explaining the productivity slowdown by a shortage of public infrastructure capital.

Public Infrastructure,

Productivity and Competitiveness

analysis of relative differences and impacts with regard to U.S. and German industries.

by

Georg Erber

Introduction

A couple of years ago the public infrastructure hypothesis again attracted considerable attention following the publication of an article by Aschauer (1989a) who applied a simple aggregate production function approach to test its empirical significance. Aschauer proposed that a substantial part (up to 60%) of the productivity slowdown observed in the United States since the mid-1970s could be attributed to a decline in public infrastructure capital formation. Similar considerations were presented by Berndt and Hansson (1991) regarding the Swedish Economy.

Tatom (1991a) making a reference to Adam Smith for a third rational of governments, besides the provision of defence and justice, pointed out that governments supply public infrastructure which nowadays includes "highways, mass transit systems, airports, electrical and gas facilities, wastewater treatment facilities, water supply and distribution, in addition to the facilities and equipment used in governmental and judicial administration, police and fire protection and health and educational institutions (p.3)." By organizing the supply of public infrastructure they contribute to the living standard of their people and support the producers in their country by reducing private costs and improving productivity and international competitiveness (cf. e.g. Conrad; Seitz, 1994).

The European Commission which published its white paper on growth, competitiveness and employment in December 1993 again addressed the topic of the creation of public infrastructure with a view to the aim of stimulating European competitiveness (see EU, 1993). The legal basis for the development program is an intention to promote trans-European networks based on articles 130 ff. of the Maastricht Treaty. Not only in Europe and other industrial developed nations is public infrastructure considered to be vital for sustaining their future development but, for all developing nations too, where the need to create an appropriate public infrastructure is an even more important topic of their governments and international organizations supporting their development (see e.g. the most recent World Development Report 1994 with the subtitle "Infrastructure for Development", World Bank, 1994).

On the one hand it seems common sense to many people nowadays that creating public infrastructure has benefits exceeding its costs. On the other, economists have started to ask questions and are looking for criteria (see. e.g. Diewert, 1986 or Hulten, Schwab, 1991) on which to determine why services or commodities which constitute public infrastructure are not supplied by private companies and to what extend public investment is required for the creation of infrastructure. Well known economists such as Dale W. Jorgenson (1991) have pointed out that a unilateral perception of the benefits of the supply side of public infrastructure is myopic because it neglects the costs of providing this via higher taxes and distorting relative market prices.

Substantially differencing impacts of public infrastructure investment will also result from the way the investment is financed, whether by creating additional public deficits or leaving the government's position on deficits unaltered. Investments financed by an increase in public debt will accelerate at least transitory economic growth by its demand effects even if the supply effects may be negligible.

Furthermore, it would be necessary to explain why and to what extent private and social returns on public infrastructure investments deviate and constitute some kind of market failure, such as a resulting unwarrented low level of investment.

Supporters of substantial increases in government spending for public infrastructure often omit to explain why a certain spending level emerges i.e. whether it is a question of an equilibrium or a disequilibrium as others would claim. Also unsolved is the question of the net social benefits resulting from public infrastructure after taking into account their costs.

The present paper sets out to contribute to the development of a theoretical and empirical framework for an analysis of benefits to the producer of public infrastructure, based on ecomic theory (for an extensive theoretical study of this subject see Diewert, 1986). Its aim is not, however, to provide answers to all of the other fairly complex issues raised above. A thorough consideration of all problems related to the topic of the optimal supply of public infrastructure is beyond the scope of this theoretical model which will only deal with the single aspect of benefits for the producer resulting from it. This paper is therefore restricted to studying questions related to the extent that impacts of public infrastructure - expected to be beneficial in the beginning - are measurable against productivity growth, cost structures of industries, and the closing gaps in cost efficiency levels between industries of the United States and Germany. The period of time covered by the study is 1960 to 1985.

In order to study the more general questions raised above we limited ourselves to a confined framework of specific countries, some level of aggregated industries, and a specific time frame. This may constitute a certain degree of weakening to obtain more far reaching conclusions. As an empirical example, however, it will help us to assess whether this specific empirical framework lends support to a hypothesis whether public infrastructure matters or not. It tests if the aggregate statistical framework used by Aschauer (1989a, 1989b) and others (see e.g. Ford, Poret, 1991) is too fragile to hold its own implications if transformed into a more detailed analysis by providing a breakdown of the output of a national economy in 26 industries (see for a critical evaluation of the aggregate analysis, Jorgenson, 1991, or Munnell, 1990, 1991a). We have limited our analysis to the study of developments on the national level of industries and have not tried to account for the impacts of regional differences in development as have previous studies seeking the attempted impacts of public infrastructure capital (see Munnell, 1991b, Seitz, 1993, Seitz; Licht, 1993).

Theoretical Framework

The model applied here is based on the economic theory of production. On the assumption of cost minimizing behavior, it follows from duality theory that production can be represented by its dual minimum cost function if certain conditions of regularity are maintained.[1]

Traditionally (cf. e.g. Solow, 1956) it is assumed that a technology will not differ from country to country, so the parameters of technology in one country are the same as for another. Recently, Pack (1994, p. 66) in a summary on current empirical evidence on endogenous growth theories commented that "regardless of whether one is using a neoclassical or endogenous approach, it thus seems necessary to examine one country at a time, insofar as there is no identical international production function along which changes in capital exert their effect." Jorgenson and Nishimizu (1978) already took this into account in their approach by introducing country specific parameters to the production or respective cost function to account for these differences and to be able to test if the data confirmed or rejected the assumption of the equality of technology between countries.

The empirical testing of this hypothesis for a number of countries (the U.S., Japan and Germany) at an industry level by a number of authors has shown that, statistically, significant differ-

---

1 Note, however, that for the translog function used later on the property of self-duality is not generally valid except for the Cobb-Douglas function which is included as a special case. A translog production function and a translog minimal cost function do not represent the same technology if the parameters of its quadratic terms are not all equal to zero.

ences between the technologies of these countries could be observed at a two-digit industry level, therefore lending support to the hypothesis that the capabilities of countries to apply technology efficiently differ. However, the reasons for the differences observed might be attributed to a number of different aspects such as environmental factors (climate, topography), infrastructure, institutional regulations, differences in the quality of input factors, in factor prices, in the composition of the industries or differences might be caused to some extent by variations in definitions and measurements which remain unsolved. To identify possible shortcomings of most studies currently avaiable, one would have to be able to break things down even further and study differences at a plant level for homogenous industries in different countries.[2]

In this study we introduce one of those aspects which were neglected in the traditional empirical analysis of production or cost functions and take into account the influence of the available public infrastructure capital stock as a positive externality for the production process. The total social costs of the production of a single industry, C^s_{Tot} can be separated into the private costs, C^s_{Priv} which have to be paid by the firms, and the public costs, C^s_{Pub} which are paid at first hand by the government if it supplies public infrastructure. The issue of how supply is financed by the government will be left aside at the present stage in our analysis.

$$C^s_{Tot} = C^s_{Priv} + C^s_{Pub} \tag{1}$$

The private costs of the production of a certain output level of an industry are divided into labor costs, private capital user costs, and intermediate input costs. The public costs are assumed to be simply the capital user costs of the supplied public infrastructure capital stock. The total private benefits or the cost savings, S^s for a single industry s are derived from the existence of the public infrastructure capital stock. The total savings for all industries of a national economy are therefore

2 For such an approach and its related problems especially in generating the necessary data cf. e.g. Mairesse, Hall (1993).

given by the sum of all individual savings for producers in the different industries whose activites are located in the respective country.[3]

$$\sum_{s=1}^{n} S^s = p^s_{K^{Pub}} \cdot K^{Pub} \tag{2}$$

Similarly one could derive the savings of private households from the availability of the public infrastructure capital, S^{HH}. Adding up the savings of the producers and the households in the economy we would end with a measure of the total benefits resulting from public infrastructure in an economy. If one calculates the respective social costs associated with the supply of the public infrastructure one is able to define a Lindahl equilibrium for the optimal stock of public infrastructure capital. As long as the costs associated with a particular level do not exceed the benefits, the level of public infrastructure might be increased. If the functions associated with the savings and costs functions behaved correctly a unique solution would be achieved. The present analysis, however, tries to measure only the benefits to the producers of the public infrastructure capital stocks observed. It does not set out to answer the question of whether the stocks obseved are the optimal ones or not.

For the purpose of this study we assume that an industry level minimum cost function exists and that differences between industry in each country can be properly assessed according to country specific parameters and to he impacts of differences in the availability of public infrastructure. A general bilateral cost function for two countries, taking into account three input factors plus public infrastructure capital can then be represented for an industry s by:

$$C(Q^s) = G^s(p^s_K, p^s_L, p^s_M, Q^s, K^{Pub}, T, D_{US}) \tag{3}$$

where production cost (C^s) is a function of the factor prices of capital ($p_K{}^s$), labor ($p_L{}^s$), and intermediate inputs (p_{Ms}), the public infrastructure capital stock (K^{Pub}), the level of output (Q^s), time (T), and

[3] We assume here that no spillover effects exist from public infrastructure capital stocks between one country to another. An important extension of this theoretical framework for the analysis of impacts of transborder infrastructure systems would be to break down the overall benefit for a group of countries into the respective national savings and the corresponding spillover effects of savings resulting from the availability of public infrastructure in the other countries. The existence of public infrastructure reduces not only the costs for the producers in a particular country but makes trade between other countries and this country easier. It opens up the market for foreign producers who will save, for example, on transportation costs as well.

a dummy variable (D_{US}). This last variable is set at one for the U.S. and zero for Germany. Furthermore, we assume that factor markets are competitive. The current formulation of the cost function, however, avoids the assumption of constant returns to scale for an industry.

The derivative of the logarithm of the cost function (3) with respect to time provides us with a breakdown of the rate of change of total costs into its source components:

$$\frac{d \ln C^s}{d T} = \left[\sum_{i \in \Psi} \frac{\partial \ln C^s}{\partial z_i^s} \cdot \frac{d \ln z_i^s}{d T} \right] + \frac{\partial \ln C^s}{\partial \ln Q^s} \cdot \frac{d \ln Q^s}{d T} +$$

$$\frac{\partial \ln C^s}{\partial \ln K^{Pub}} \cdot \frac{d \ln K^{Pub}}{d T} + \frac{\partial \ln C^s}{\partial T} \tag{4}$$

$$with \quad i \in \Psi^s \equiv \{ K^s, L^s, M^s \}$$

$$\wedge \quad z_i^s \in \{ \ln p_K^s, \ln p_L^s, \ln p_M^s \}$$

Therefore the rate of change in total costs can be expressed as the cost elasticity weighted average of the changes in factor prices, plus the scale weighted rate of change in output, the cost elasticity weighted changes in the public infrastructure capital stock, and the rate of cost diminuition due to technical change.

Similarly the derivation of the logarithmic cost function with respect to the country dummy variable gives us a breakdown of the differences in cost efficiency levels.

$$\frac{d \ln C^s}{d D_{US}} = \left[\sum_{i \in \Psi} \frac{\partial \ln C^s}{\partial z_i^s} \cdot \frac{d \ln z_i^s}{d D_{US}} \right] + \frac{\partial \ln C^s}{\partial \ln Q^s} \cdot \frac{d \ln Q^s}{d D_{US}}$$

$$\frac{\partial \ln C^s}{\partial \ln K^{Pub}} \cdot \frac{d \ln K^{Pub}}{d D_{US}} + \frac{\partial \ln C^s}{\partial D_{US}} \tag{5}$$

$$with \quad i \in \Psi^s \equiv \{ K^s, L^s, M^s \}$$

$$\wedge \quad z_i^s \in \{ \ln p_K^s, \ln p_L^s, \ln p_M^s \}$$

The difference in cost efficiency levels between the two countries is generated by taking the sum of the cost elasticity weighted average of differences in factor prices, the scale weighted differences in outputs, the cost elasticity weighted differences in public infrastructure capital levels, and the differences in the rate of technological progress.

In this study the general bilateral cost function defined in (3) is approximated by a second order approximation in its logarithms. This form is known in the literature as the translog cost function (cf. Christensen; Cummings; Jorgenson, 1971). It was first introduced by Jorgenson and Nishimizu (1978) in the more restrictive form that constant returns always prevail.[4]

$$
\begin{aligned}
&\ln C(Q^s) = \sum_{i \in \Phi^s} \tilde{\alpha}_i^s \cdot z_i^s + \frac{1}{2} \sum_{i \in \Phi^s} \sum_{j \in \Phi^s} \tilde{\beta}_{i,j}^s \cdot z_i^s \cdot z_j^s \\
&\textit{with} \quad i,j \in \Phi^s \equiv \{ K^s, L^s, M^s, Q^s, K^{Pub}, T, D_{US} \} \\
&\wedge \quad z_i^s \in \{ \ln p_K^s, \ln p_L^s, \ln p_M^s, \ln Q^s, \ln K^{Pub}, T, D_{US} \}
\end{aligned}
\tag{6}
$$

Since the bilateral translog function is symmetric in all variables, the logarithmic partial derivatives with respect to factor prices, public infrastructure capital, output, time and the country dummy variable can be expressed as

$$
\begin{aligned}
&\frac{\partial \ln C(Q^s)}{\partial z_i^s} = \alpha_i^s + \sum_{j \in \Phi^s} \beta_{ij}^s \cdot z_j^s \\
&\textit{with} \quad i,j \in \Phi^s
\end{aligned}
\tag{7}
$$

Applying Shephard's lemma with respect to each input price, one obtains

4 The bilateral cost function under the restriction of constant returns to scale, was used in a couple of later studies. See for example K. Conrad; D. W. Jorgenson (1985); D. W. Jorgenson; M. Kuroda; M. Nishimizu (1987); K. Conrad (1988, 1989); D. W. Jorgenson; H. Sakuramoto; K. Yoshioka; M. Kuroda (1990) and G. Erber (1993). In some more recent studies the bilateral cost function was applied with weaker assumptions of homogenous returns to scale (see S. Nakamura, 1992) or in a general form of variable returns to scale (see G. Erber, 1994).

$$\frac{\partial \ln C(Q^s)}{\partial \ln p_i^s} = w_i^s = \alpha_i^s + \sum_{j \in \Phi^s} \beta_{ij}^s \cdot z_j^s \tag{8}$$

$$with \quad i \in \Psi^s \quad \wedge \quad j \in \Phi^s$$

Therefore the elasticity of cost with respect to the factor prices is equal to the corresponding cost share (w_i^s) of the total private costs.

The elasticity of cost with respect to output can be interpreted as a measure of static scale economies.

$$\frac{\partial \ln C^s}{\partial \ln Q^s} = w_Q^s = \alpha_Q^s + \sum_{j \in \Phi} \beta_{Qj}^s \cdot z_j^s \tag{9}$$

$$with \quad j \in \Phi^s$$

If w_Q^s equals unity, cost responds proportionally to changes in the output. This is the usual condition for constant returns to scale. If w_Q^s is less (greater) than unity, total costs increase proportionally less (more) as output increases, implying increasing (decreasing) returns to scale.

The elasticity of cost with respect to the public infrastructure capital stock determines the cost share of public infrastructure capital using an implicit shadow price of public infrastructure capital, p_K^{Pub}.

$$\frac{\partial \ln C^s}{\partial \ln K^{Pub}} = \frac{p_{K^{Pub}}^s \cdot K^{Pub}}{C^s} = w_K^{Pub} = \alpha_{K^{Pub}}^s + \sum_{j \in \Phi} \beta_{jK^{Pub}}^s \cdot z_j^s \tag{10}$$

$$with \quad j \in \Phi^s$$

The rate of cost diminuition is defined by the partial elasticity of cost with respect to time.

$$\frac{\partial \ln C^s}{\partial T} = - g_T^s = \alpha_T^s + \sum_{j \in \Phi^s} \beta_{Tj}^s \cdot z_j^s \tag{11}$$

It is equal to the negative value of the rate of technological progress. On the assumption of constant returns to scale, it would be equal to the negative rate of change of total factor productivity (TFP) growth. If however increasing or decreasing economies of scale at an industry level exist, the standard Törnqvist index of TFP growth will be a biased measure.[5]

The difference in cost efficiency levels is determined by the partial elasticity of cost with respect to the country dummy.

$$\frac{\partial \ln C^s}{\partial D_{US}} = - w^s_{US,G} = \alpha^s_D + \sum_{j \in \Phi^s} \beta^s_{Dj} \cdot z^s_j \tag{12}$$

As long as constant returns to scale prevail it can be measured by the standard Törnqvist index used by Jorgenson; Nishimizu (1978) and others. Under non-constant returns the standard measure will also be biased.

Note that in the bilateral translog cost function model, the rate of technological change and the differences in cost efficiency levels are partially generated endogenously by the development of relative factor prices and the levels of output demand. Furthermore, the model allows for time variable rates of technological change, which are different in both countries, and a time variable development in differences in the cost efficiency level of both countries. It also incorporates the possibility that technological change is factor augmenting. If relative factor prices in both countries develop differently the model also allows for differences in the factor augmentation process in both countries. However, since these differences in relative factor prices and output levels are exogenous to the model it fails to explain why these differences emerge.

To estimate the parameters of the bilateral cost function we will use the bilateral factor demand system given by the equations (8) to (11). To be able to estimate it we have to rewrite it so that on the left we have the biased measures of the rate of cost diminuition and the differences in the cost efficiency levels obtained from the standard Törnqvist indices. To see how this can be accomplished we will rearrange the terms of equations (4) and (5) so that the traditional measures are on the left and the remaining terms on the right. In addition, we will also substitute the partial cost elasticities for their respective expression for the cost shares, static scale elasticity, etc.

For equation (4) we come up with

[5] cf. e.g. Luke Chan; Mountain (1983).

$$\frac{d \ln C^s}{d\,T} - \left\{ \sum_{i \in \Phi} w_i^s \cdot \frac{d \ln z_i^s}{d\,T} \right\} = w_Q^s \cdot \frac{d \ln Q^s}{d\,T} + w_{K^{Pub}}^s \cdot \frac{d \ln K^{PUB}}{d\,T} - g_T^s \qquad (13)$$

and equation (5) becomes

$$\frac{d \ln C^s}{d\,D_{US}} - \left\{ \sum_{i \in \Phi} \bar{w}_i^s \cdot \frac{d \ln z_i^s}{d\,D_{US}} \right\} = w_Q^s \cdot \frac{d \ln Q^s}{d\,D_{US}} + w_{K^{Pub}}^s \cdot \frac{d \ln K^{Pub}}{d\,D_{US}} - w_{US,G}^s \qquad (14)$$

In order to assess the model taking annual data into account, it has to be transformed in a form applicable to such variables. Instead of using Divisia indices for our calculation we can approximate them by the corresponding Törnqvist indices, which are exact if the production technology has the form of a translog function (see Diewert, 1976). The differentials are approximated accordingly by first logarithmic differences. We thus obtain

$$g_{TFP,t}^s = w_{Q,t}^s \cdot \left(\ln Q_t^s - \ln Q_{t-1}^s \right) + w_{K^{Pub},t} \cdot \left(\ln K_t^{Pub} - \ln K_{t-1}^{Pub} \right) - g_{T,t}^s \qquad (15)$$

and

$$\tilde{w}_{US,G;t}^s = w_{Q,t}^s \cdot \left(\ln Q_{US,t}^s - \ln Q_{G,t}^s \right) + w_{K^{Pub},t}^s \cdot \left(\ln K_{US,t}^{Pub} - \ln K_{G,t}^{Pub} \right) - w_{US,G;t}^s \qquad (16)$$

Equations (14) and (15) together with equation (8) form an equivalent factor demand system as equations (8) to (11) before. The difference is that now all necessary variables can be calculated.[6]

Substituting the parametric expressions the factor demand system now becomes

$$w_{i,t}^s = \alpha_i^s + \sum_{j \in \Phi} \beta_{ij}^s \cdot z_{j,t}^s$$

[6] This method of deriving a factor demand system was first developed by Gollop (1974) and later applied in an article by Gollop and Roberts (1981) to estimate non-constant returns to scales for the U.S. electric power industry. We extend their approach to include externalities given by the availability of public infrastructure capital.

$$g^s_{TFP,t} = \left(\alpha^s_Q + \sum_{j \in \Phi} \beta^s_{Qj} \cdot z^s_{j,t} \right) \cdot \left(\ln Q^s_t - \ln Q^s_{t-1} \right)$$

$$\left(\alpha^s_{K^{Pub}} + \sum_{j \in \Phi} \beta^s_{jK^{Pub}} \cdot z^s_{j,t} \right) \cdot \left(\ln K^{Pub}_t - \ln K^{Pub}_{t-1} \right) + \alpha^s_T + \sum_{j \in \Phi} \beta^s_{Tj} \cdot z^s_{j,t} \tag{15}$$

$$\tilde{w}^s_{US,G;t} = \left(\alpha^s_Q + \sum_{j \in \Phi} \beta^s_{Qj} \cdot z^s_{j,t} \right) \cdot \left(\ln Q^s_{US,t} - \ln Q^s_{G,t} \right)$$

$$\left(\alpha^{Pub}_K + \sum_{j \in \Phi} \beta^s_{jK^{Pub}} \cdot z^s_{j,t} \right) \cdot \left(\ln K^{Pub}_{US,t} - \ln K^s_{G,t} \right) + \alpha^s_D + \sum_{i \in \Phi} \beta^s_{Dj} \cdot z^s_{j,t} \tag{16}$$

To satisfy the adding-up condition (17), one cost share equation given by (8) has to be omitted in the estimation. We decided to use the capital and intermediate input cost share equations and discard the labor cost share equation.

$$\sum_{i \in \Psi^s} \tilde{\alpha}^s_i = 1 \quad \wedge \quad \sum_{j \in \Psi^s} \tilde{\beta}^s_{ij} = 0 \tag{17}$$

Furthermore, to ensure linear homogeneity (18) and symmetry (19) in factor prices of the cost function the factor demand system had to satisfy further parameter restrictions.

$$\sum_{j \in \Psi^s} \tilde{\beta}^s_{ij} = 0 \tag{18}$$

$$\tilde{\beta}^s_{ij} = \tilde{\beta}^s_{ji} \quad \textit{for all} \quad i, j \in \Phi^s \tag{19}$$

Following the estimation of the parameters of the factor demand system, it is then possible to calculate the unobservable scale elasticity from equation (9), the implicit adow price of public infrastructure capital from equation (21) as well as the unbiased rate of cost diminuition from equation (10).

$$p^s_{K^{Pub}} = \frac{C^s}{K^{Pub}} \cdot \left(\alpha^s_{K^{Pub}} + \sum_{j \in \Phi} \beta^s_{jK^{Pub}} \cdot z^s_j \right) \tag{20}$$

$$with \quad j \in \Phi^s$$

Data

The data of real public infrastructure capital stocks are taken for the United States from a publication by the U.S. Department of Commerce, Bureau of Economic Analysis (1987). We excluded from the total fixed non-residential government capital the federal military equipment and military facilities as a part of federal structures. For Germany the respective data are taken from an accounting system of fixed non-residential government capital by the German Institute for Economic Research calculated in 1987.[7] From the total real public infrastructure capital stocks of Germany, we excluded all stocks of equipment and structures related to defence. The price base of the German data is 1980 while that taken for the United States data is 1982. The price base of the United States data was equalized to 1980. The German real public infrastructure capital stock time serie was converted by using the purchasing power parity of government capital of 1980 in U.S. dollars.[8]

For the other data required in our study we used data for the U.S. from Jorgenson. However, given that we are unable to account for quality changes in the three factor inputs for Germany, we adjusted the U.S. data so that quality changes were no longer separated from the real input quantities. We hope to be able to compensate for this at a later stage in our research.

In addition, we adjusted the capital stocks of the U.S. data to exclude land and inventories because of the unavailability of corresponding data from Germany (for a detailed description of the U.S. data see Jorgenson; Gollop; Fraumeni, 1987).

The German database uses data published by the German Federal Statistical Office, the Institute of Labor Market Research (number of employees and effective working hours), capital stock data calculated by the German Institute for Economic Research (for a more detailed description of the database see G. Erber, 1993).

---

7 The complete detailed data sets have not been published by the German Institute for Economic Research. For a publication based on a previous data set and the methodology applied see e.g. Frank Stille (1981) and the publications cited there. The investment data of the capital stock accounting model are taken from the sources of the Federal Statistical Office in Germany.

8 For more detailed information see Conrad, 1985, and Erber, 1993.

In order to express both data sets in a common currency the German data were converted by purchasing power parities (PPP) taken from Conrad (1985). For the method used to calculate specific PPPs for output and all three factor inputs see again Conrad (1985) or Erber (1993).

Since the base years for the price statistics differ between the U.S. and Germany they have been adjusted to a common base year. We have chosen 1980 for both countries so that the U.S. price deflators were adjusted to have the same base as the German data.

The original data for the U.S. identifies 35 industries which are very similar to the SIC sectoral breakdown of the officially published data. For Germany the sectoral breakdown available identifies between 51 industries. Since some sectoral definitions in the U.S. and Germany are overlapping the corresponding industries were combined to achieve homogenous coverage for both countries. This process led to a 26 industry classification (see Erber 1993).

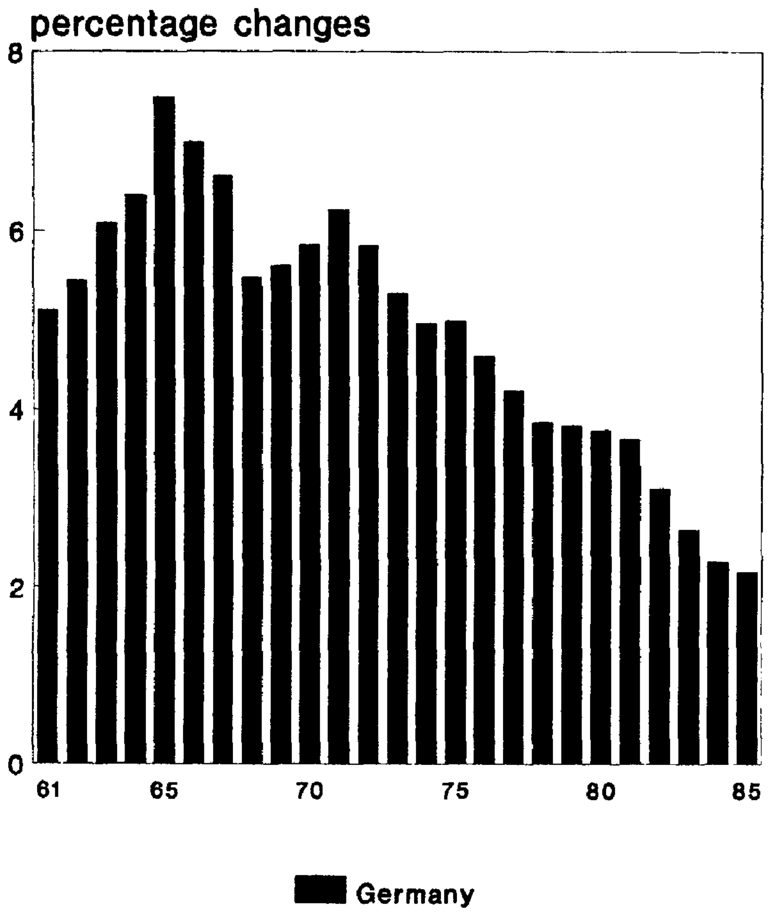
In calculating the German database, two industries caused difficulties in obtaining reasonable estimates of the wages and salaries to be attributed to the self-employed and helping family members. The first one was agriculture and the second one furniture. These two industries were therefore excluded from this study. We hope that, with suitable proper adjustments, it will be possible to include them in future studies.

Differences in Public Infrastructure Capital between the United States and Germany

Looking at the data for the public infrastructure capital stocks it can be ascertained that it increased in Germany more rapidly than in the U.S. From about 226 billion Dollars in 1960 it tripled to 744 bill. in 1985. In the United States its accumulation started from 1285 bill. in 1960 and doubled to 2625 bill. in 1985. The faster accumulation in Germany reduced the relative gap in public infrastructure between the United States and Germany from 15.6% in 1960 to 28.3% in 1985.

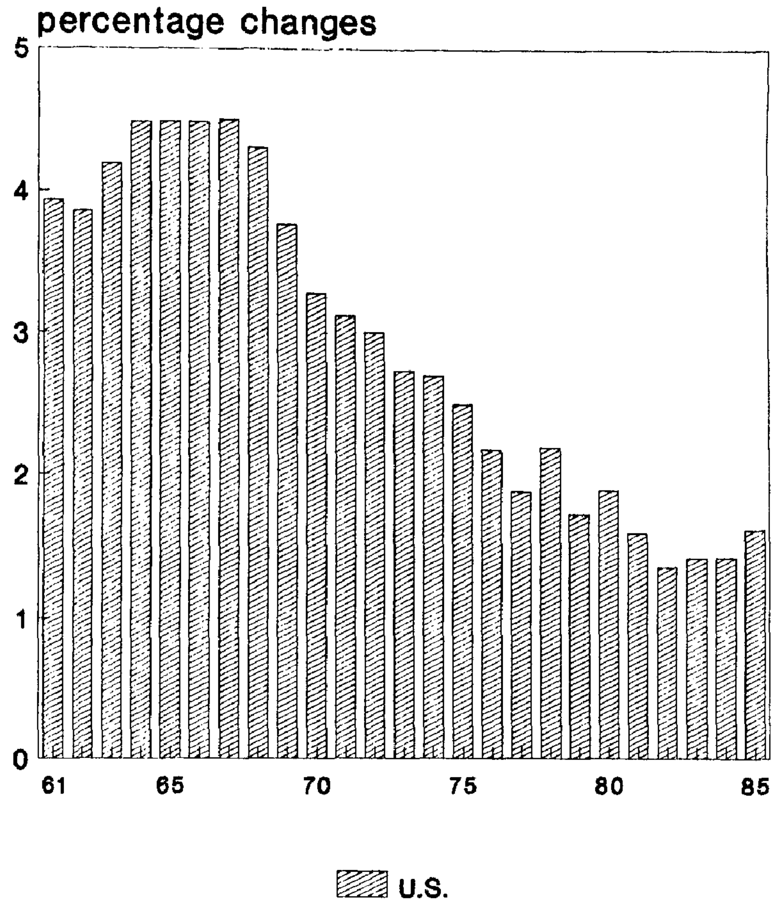
The development of public infrastructure capital stocks, however, show also similar patterns in both countries if we compare their annual growth rates over this period. In both countries we can observe a substantial and fairly steady decline since the mid-1960s. Public infrastructure capital growth accelerated in both countries between 1960 to 1965. In Germany it started at about 5% in 1960 reaching its peak of more than 7% in 1965. In the U.S. growth rates were already lower at about 4% in 1960 followed by a moderate increase to 4.5% in the period from 1964 to 1968. Since then the growth of public infrastructure accumulation slowed down in 1985 to about 2.1% for Germany and 1.7% for the United States (see fig 1). Considering these very similar developments in the speed of public infrastructure accumulation, it is not surprising that these developments seemed to go a considerable way towards explaining a similar slowdown in productivity which occurred in

Real Public Infrastructure Capital Stock
in Germany
excluding military facilities



DIW 94

Real Public Infrastructure Capital Stock
in the United States
excluding military facilities



DIW 94

both countries at the aggregate level after 1973. Therefore, we want to use these data to test whether this pattern in public infrastructure is sufficient to explain a significant part played by productivity development at the industry level of both countries.

Econometric Estimation and Testing for Impacts of Public Infrastructure

The two data sets were pooled to form a two country panel data set of 50 observations (25 for each country). The necessary data for the growth rate of cost diminuition (the negative value of the growth rate of total factor productivity) and the differences in cost efficiency levels were obtained by using the standard Törnqvist index formulas.

The homogeneity condition was utilized to transform the model in the estimation process, so relative price variables, with the hourly wage price index as numéraire, were used. This transformation reduces the multicollinearity between the price variables as well as between the time trend and output variable. Therefore the parameter estimates are less sensitive to biases caused by multicollinearity. The time trend variable was normalized to equal zero in the base year 1980.[9]

Note that the pooling of the data for the two countries to estimate non-constant returns to scale seems to be especially useful here because it increases the variance of the output variable substantially given the different absolute sizes of the industries in the two economies. This helps substantially in identifying economies of scale, especially if they are close to unity.

The model was estimated for 24 industries using a FIML estimation which imposed all necessary parameter restrictions to assure adding-up, homogeneity and symmetry (TSP 4.2B was the econometric programme package applied). Note that the model is still linear in the parameters. Convergence of the estimation process occured after 7 to 15 iterations.

We refrained from using an instrumental variable estimation for the output variable. On the one hand, from an econometricians point of view, it should account for the potential endogeneity of the output variable (see for the arguments and a way to select instrumental variables Flaig; Steiner, 1993; Nakamura, 1992), on the other hand it seems quite likely that if the instruments are not properly chosen so that they are not sufficiently exogenous, they will bias the parameter estimates (cf. Hall, 1988, p. 932 or Basu; Fernald, 1992 p. 17 ff.). The instruments chosen by the two abovementioned studies however reduce the variance of the output variable by making it smoother without removing the trend, and as a consequence lead to a higher degree of collinearity between output and

[9] This procedure is especially useful under the condition of constant returns to scale, since it gives an inuitive interpretation of the constant terms of the equations. It is less so under the condition of nonconstant returns to scale because the output variable is not normalized meaning that you have to sum up the constant term with the output term to obtain an estimate for the average cost share, rate of cost diminuition, etc.

the time trend variable. Since the parameter estimates for the time and output variable seem to be quite sensitive to the collinearity between the two variables we refrained from introducing an instrument variable for output which might have increased collinearity between those two variables even further.[10]

For testing the hypothesis we used the Wald test for all combined hypotheses concerning two or more parameters or parameter combinations simultaneously. Testing hypotheses affecting only a single parameter a t-statistic was used. As a significance level to reject a hypotheses we always used 5%.

To ascertain the impacts of public infrastructure capital stocks as determining factors for the cost structure and rate of productivity growth, as well as differences in cost efficiency levels, we tested for the significance of the group of parameters given by equation (10). If all parameters in equation (10) turned out to be together statistically not far off zero we conclude that the hypothesis of an impact of public infrastructure capital is rejected. Since the cost structure is only affected by two parameters related to public infrastructure, in the cost share equations we divided the group of seven parameters measuring different impacts of public infrastructure capital into two subgroups. The first subgroup was formed by the two parameters determining the effects of public infrastructure capital on the cost structure, while the remaining five parameters of equation (10) formed the second subgroup determining the remaining impacts of public infrastructure on productivity growth and differences in cost efficiency levels given by equations (15) and (16). The latter test of statistical significance of all parameters in the second subgroup to be not equal to zero is labeled as a test on the impacts on productivity growth. The results of the three different tests for all 24 industries are summerized in table 1.

It is clear from the results of the tests that a significant impact of public infrastructure capital is found only in very few industries. For the majority of the industries any impact on cost structures or productivity growth is rejected. For just four industries, i.e. stone, machinery, motor verhicles, and finance, we accepted the hypothesis that public infrastructure has influences on the cost structure or productivity growth. Only for motor vehicles are both impacts significant whereas for stone and finance only an impact on productivity growth is noticeable. For transport equipment the impact on the cost structure is to be seen but when all parameter estimates of the whole group are taken into account, this leads to a rejection. The results obtained from our tests of the public infrastructure hypothesis on the level of single industries lends little support to the theory that public infrastructure is an important source of productivity growth. The impacts on cost structure are even less significant.

[10] A sensitivity analysis of this collinearity problem would help. We hopefully will carry out this exercise in the future.

Table 1

Testing Impacts of Public Infrastructure for the Bilateral Factor Demand System of the US and Germany by Industry

(1960-1985)

	Industry	Impacts on Cost Structure	Impacts on Productivity Growth	Overall Impacts
1	Agriculture			
2	Mining	rejected	rejected	rejected
3	Construction	rejected	rejected	rejected
4	Foods	rejected	rejected	rejected
5	Textiles	rejected	rejected	rejected
6	Apparel	rejected	rejected	rejected
7	Lumber	rejected	rejected	rejected
8	Furniture			
9	Paper	rejected	rejected	rejected
10	Printing	rejected	rejected	rejected
11	Chemicals	rejected	rejected	rejected
12	Petroleum	rejected	rejected	rejected
13	Rubber	rejected	rejected	rejected
14	Leather	rejected	rejected	rejected
15	Stone	rejected	accepted	accepted
16	Primary Metal	rejected	rejected	rejected
17	Fabricated Metal	rejected	rejected	rejected
18	Machinery	rejected	rejected	accepted
19	Electrical Machinery	rejected	rejected	rejected
20	Motor Vehicles	accepted	accepted	accepted
21	Transport Equipment	accepted	rejected	rejected
22	Precision Instruments	rejected	rejected	rejected
23	Miscellaneous Manufacturing	rejected	rejected	rejected
24	Utilities	rejected	rejected	rejected
25	Finance	rejected	accepted	accepted
26	Remaining Services incl. Government	rejected	rejected	rejected

Source: own computations.

For the motor vehicle industry the cost share elasticity of intermediate inputs with respect to public infrastructure capital has a value of -0.1 which is balanced by that for labor inputs of 0.1 . An increase of public infrastructure capital reduces the intermediate cost share by 0.1% and increases that of the labor costs by the same amount. One reason for this might be that the public infrastructure available reduces transportation costs which are a component of intermediate costs. If this explanation is valid then it is surprising that transportation costs only have an impact in the motor vehicle industry. To see how important transportation costs are for the different industries one would however have to seperate them explicitly by using input-output tables. On average it is expected that transportation costs do not represent a very large share in overall private costs. Just like with energy costs which are a crucial cost component in total costs only in very few industries such as for example in the aluminum industry, even a substantial saving in transportation costs might prove insignificant when total costs are considered. Since a substantial part of public infrastructure consists in the public supply of roads, waterways and airports, the impacts on industries related to the production of transportation equipment such as motor vehicles and other transport equipment might benefit most from the supply of this type of public infrastructure. For the motor vehicle industry it also increases the rate of technological progress and the static returns to scale. The impacts observed for public infrastructure in the motor vehicle industry indicate also that there are no significant national differences in this respect between both countries.

All in all, one should however bear in mind that this fairly reasonable conclusions of significant impacts shows up in only a single industry. Taking the results of our analysis as a criterion we have to conclude that macroeconomic benefits of public infrastructure capital for all producers in a country are more or less non-existent.

Conclusions

The outcome of our attempt to measure the benefits to producers of supplying public infrastructure capital reject those obtained by Aschauer (1989a, 1989b). Since only very few industries show at least some impacts of public infrastructure, which seem to be related to the supply of public transportation networks, it might be reasonable to exclude other components of the public infrastructure capital stock to obtain a core public infrastructure capital. One could use this narrow definition of public infrastructure capital instead of the broad definition applied in our study. Seitz (1992a) made an attempt in this direction and found that the estimates of the impacts of road networks were significantly higher than those of the broader definition of public infrastructure capital.

Another reason why our analysis of impacts of public infrastructure gave no indication that spending on public infrastructure should be increased might be the fact that Germany and the U.S.

have always been much better equipped with public infrastructure than other countries (see e.g. results for other countries which are less well equipped in the study of Ford and Poret (1991). If public infrastructure available in the United States and Germany already gave them a comparative advantage over other international competitors it could not constitute a significant bottleneck for choosing them as an industrial location. A further expansion of public infrastructure would not have given them further scope for competitiveness.

The decline observed in annual growth rates of the public infrastructure capital stocks which also occurred in other industrialized countries would only serve to demonstrate that a certain level of saturation has been reached for both economies as far as supplying additional public infrastructure is concerned.

The emergence of new technologies in the area of communications and information networks which rest to some extent on the supply of additional public infrastructure in areas to support the development for example of high-speed rail networks or electronic superhighways for multimedia services might again stimulate investment in public infrastructure in both countries. However, one should bear in mind that this might be possible by a reallocation of resources as well as an increase in public infrastructure. The reallocation of total spending on public infrastructure for different purposes lead to structural changes in the composition of the public infrastructure capital stock which has to be taken into account. To test a hypotheses based not only on the level of total public infrastructure but also its compositional changes we would have to introduce structural change indicators for the public infrastructure capital stock.

Another direction for extending the present study would be to separate transportation costs or even communication or information costs from other cost components. Measuring the impacts of public infrastructure on the cost shares of these services might result in higher elasticities for them because they would be more closely linked to the particular services of public infrastructure.

All in all, with the exception of East Germany after unification with the West, additional public infrastructure investment, if it is not directed in new emerging fields of rapidly growing demand, seems to be incapable of creating substantial benefits for producers in the United States and Germany in the past decades. This finding is consistent with Gramlich's (1994) who ends his review essay with the conclusion that results of most studies are fairly mixed and fragile to lend support to the Aschauer hypotheses that a shortage of public investment in infrastructure might has caused the productivity slowdown in the industrialized countries.

References

D. A. Aschauer (1989a): Is Public Expenditure Productive?, Journal of Monetary Economics, Vol. 23, pp. 177-200.

D. A. Aschauer (1989b): Public Investment and Productivity Growth in the Group of Seven, Economic Perspectives, Federal Reserve Bank of Chicago, September/October, pp. 17-25.

D. A. Aschauer (1991): Why Is Infrastructure Important? in: Proceedings of a Conference in June 1990, ed. A. H. Munnell, Conference Series No. 34, Federal Reserve Bank of Boston, pp. 21-50, Boston, 1991.

S. Basu; J. G. Fernald (1992): Productive Externalitites in U.S: Manufacturing: Do They Exist, and Are They Important ?, manuscript, Harvard University.

E. R. Berndt; B. Hansson (1991): Measuring the Contribution of Public Infrastructure Capital in Sweden, NBER Working paper, No. 3842.

L. R. Christensen; D. W. Jorgenson; L. J. Lau (1971): Conjugate duality and the transcendental logarithmis function, Econometrica, Vol. 39, pp. 255-256.

K. Conrad (1985): Produktivitätslücken nach Wirtschaftszweigen im internationalen Vergleich, Beschreibung und ökonometrische Ursachen Analyse für die U.S.A., Japan und die Bundesrepublik Deutschland, 1960-1979, Studies in Contemporary Economics, Vol. 17, Springer-Verlag, Berlin-Heidelberg-New York-Tokyo, 1985.

K. Conrad; D. W. Jorgenson (1985): Sectoral Productivity Gaps between the United States, Japan and Germany, 1960-1979, Schriften des Vereins für Socialpolitik, Probleme und Perspektiven der wirtschaftlichen Entwicklung, Duncker und Humblot, Berlin, pp. 335-347.

K. Conrad (1988): Theory and Measurement of Productivity and Cost Gaps: A Comparison for the Manufacturing Industry in U.S., Japan and Germany, 1960-1979, in: Measurement in Economics, ed. by W. Eichhorn, Physica-Verlag, Heidelberg, pp. 749-751.

K. Conrad (1989): Productivity and Cost Gaps in Manufacturing Industries in U.S:, Japan and Germany, in: European Economic Review, Vol. 33, pp. 1135-1159.

K. Conrad; H. Seitz (1992): The Public Capital Hypothesis: The Case of Germany, Recherches Economiques de Louvain, Vol. 58, pp. 309-327.

K. Conrad; H. Seitz (1994): Strategic Competition with Infrastructure Services, Discussion paper, University of Mannheim, January 1994.

W. E. Diewert (1976): Exact and superlative index numbers, Journal of Econometrics, Vol. 4, pp. 115-145.

W. E. Diewert (1986): The Measurement of the Economic Benefits of Infrastructure Services, Springer Verlag, Heidelberg-New York, 1986.

G. Erber (1993): Catching-Up or Falling Behind, Relative Differences in Productivity and Price Competitiveness between U.S. and German Industries, 1960-1985. Research Report, DIW, Berlin, August 1993.

G. Erber (1994): Technical Change, Economies of Scale, and Factor Augmentation, Impacts on Relative Differences in Productivity and Price Competitiveness between U.S. and German Industries, DIW Discussion Paper No. 93, Berlin.

EU (1993): Growth, Competitivesness, Employment, The Challenges and Ways Forward into the 21st Century, White Paper, Commission of the European Communities, COM(93) 700 final, Brussels, 5th December 1993.

G. Flaig; V. Steiner (1993): Searching for the "Productivity Slowdown": Some Surprising Findings from West German Manufacturing, The Review of Economics and Statistics, p. 57-65.

R. Ford; P. Poret (1991): Infrastructure and Private-Sector Productivity, OECD Economic Studies No. 17, pp. 63-89, Autumn 1991.

F. M. Gollop (1974): Modeling Technical Change and Market Imperfections: An Econometric Analysis of U.S. Manufacturing, 1947-1971, unpublished Ph. D. dissertation, Harvard University, Cambridge, Massachusetts.

F. M. Gollop; M. J. Roberts (1981): The Sources of Economic Growth in the U.S. Electric Power Industry, in: Productivity Measurement in Regulated Industries, Eds. Th. G. Cowing; R. E. Stevenson, Academic Press, 1981, pp. 107-143.

E. M. Gramlich (1994): Infrastructure Investment: A Review Essay, in: Journal of Economic Literature, Vol. 32, pp. 1176-1196.

R. Hall (1988): The Relation between Price and Marginal Cost in U.S. Industry, Journal of Political Economy, October 1988.

Ch. Hulten; R. Schwab (1991): In There Too Little Public Capital?, AEI Conference on Infrastructure Needs, February 1991.

D. W. Jorgenson; M. Nishimizu (1978): U.S. and Japanese Economic Growth, 1952-1974: An International Comparison, Economic Journal, Vol. 88, No. 352, Dec. 1978, pp. 707-726.

D. W. Jorgenson; F. Gollop; B. Fraumeni (1987): Productivity and U.S. Economic Growth, Contributions to Economic Analysis, Vol. 169, North-Holland, Amsterdam, 1987.

D. W. Jorgenson; M. Kuroda; M. Nishimizu (1987): Japan - U.S. Industry-Level Productivity Comparisons, 1960-1979, Journal of Japanese and International Economics, Vol. 1, No. 1, March 1987, pp. 1-30.

D. W. Jorgenson; H. Sakuramoto; K. Yoshioka; M. Kuroda (1990): Bilateral Models of Production for Japanese and U.S: Industries, in: Productivity Growth in Japan and the United States, ed. Ch. Hulten, pp. 29-67.

D. W. Jorgenson (1991): Fragile Statistical Foundation, The Macroeconomics of Public Infrastructure Investment, Harvard University, mimeographed.

G. Licht; H. Seitz (1993): Regional Productivity Growth and Investments in Public Infrastructure: The Case of Germany, Discussion Paper No. 10 of Zentrum für Europäische Wirtschaftsforschung, Industrial Economics and International Management Series, Mannheim, 1993.

M. W. Luke Chan; D. C. Mountain (1983): Economies of Scale and the Törnqvist Discrete Measure of Productivity Growth, Review of Economics and Statistics, Vol. 65, pp. 663-667.

J. Mairesse; B. H. Hall (1993): Comparing the Productivity of Research and Development in French and United States Manufacturing Firms, paper presented at the conference on International Productivity Differences and their Explanations, Science Center Berlin, November 1993, mimeographed.

A. H. Munnell (1990): Why Has Productivity Growth Declined? Productivity and Public Investment, New England Economic Review, Federal Reserve Bank of Bostonn, January/February. pp. 3-22.

A. H. Munnell (1991a): Is There a Shortfall in Public Capital Investment, An Overview, in: Proceedings of a Conference in June 1990, ed. A. H. Munnell, Conference Series No. 34, Federal Reserve Bank of Boston, pp. 4-20, Boston, 1991.

A. H. Munnell (1991b): How Does Public Infrastructure Affect Regional Economic Performance? with the assistance of L. M. Cook, in: Proceedings of a Conference in June 1990, ed. A. H. Munnell, Conference Series No. 34, Federal Reserve Bank of Boston, pp. 69-103, Boston, 1991.

I. Nadiri; Th. Mamuneas (1991): The Effect of Public Infrastructure and R&D Capital on the Cost Structure and Performance of U.S. Manufacturing Industries, NBER Working Paper 3887.

S. Nakamura (1992): Explaining Japan and U.S. TFP Difference, The Economic Studies Quarterly, Vol. 43, No. 4, Dec. 1992, pp. 326-336.

H. Pack (1994): Endogenous Growth Theory: Intellectual Appeal and Empirical Shortcomings, Journal of Economic Perspectives, Vol. 8, No. 1, pp. 55-72.

G. E. Peterson (1991): Is Public Infrastructure Undersupplied?, in: Proceedings of a Conference in June 1990, ed. A. H. Munnell, Conference Series No. 34, Federal Reserve Bank of Boston, pp. 113-135, Boston, 1991.

H. Seitz (1992a): The Economic Benefits of the Public Road Network: A Dual Approach to the Analysis of Public Infrastructure, Diskussion paper, University of Mannheim, March 1992.

H. Seitz (1992b): Public capital and the demand for private inputs, Diskussion paper, University of Mannheim, March 1992.

H. Seitz (1993): The Effects of the Provision of Urban Infrastructures on the Manufacturing Industry in Cities: A theoreticla and empirical investigation, Discussion per of University of Mannheim, mimeograhed, August 1993.

H. Seitz (1994): Public Infrastructure Capital, Employment and Private Capital Formation, paper presented at the OECD Conference on Capital Formation and Employment, January 27-28, 1994.

H. Seitz; G. Licht (1993): The Impact of the Provision of Public Infrastructures on Regioal Economic Development in Germany, Discussion Paper No. 13 of Zentrum für Europäische Wirtschaftsforschung, Industrial Economics and International Management Series, Mannheim, 1993.

F. Stille (1981): Investitionen und Anlagevermögen in den staatlichen Aufgabenbereichen, Wochenbericht des DIW, Nr.38/1981, pp.435-440.

R. M. Solow (1956): A Contribution to the Theory of Economic Growth, Quarterly Journal of Economics, Vol. 70, pp. 65-94.

J. A. Tatom (1991a): Should Government Spending on Capital Goods Be Raised?, Review of the Federal Reserve Bank of St. Louis, Vol. 73, pp. 3-15, March/April 1991.

J. A. Tatom (1991b): Public Capital and Private Sector Performance, Review of the Federal Reserve Bank of St. Louis, Vol. 73, pp. 3-15, May/June 1991.

U.S. Department of Commerce, Bureau of Economic Analysis (1987): Fixed Reproducible Tangible Wealth in the United States, 1925-1985, Government Printing Office, Washington D.C., June 1987.

World Bank (1994): World Development Report 1994, Infrastructure for Development, Oxford University Press, Washington D.C., 1994.