Discussion Paper

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The Impact of the Provision of Public Infrastructures on Regional Economic Development in Germany

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Abstract

The present paper presents an analysis of the impact of public infrastructure capital on regional economic developments in Germany. After presenting some descriptive statistical data on the economies of the 11 regions in (West) Germany a simple theoretical model of a cost-minimizing firm is presented in which the stock of public capital is included as a proxy for public services provided to firms as a fixed unpaid factor of production. Duality theory is used to recover the productivity effects of public infrastructures by calculating the cost-saving effects that are associated with public services. It is shown that these cost-saving effects work their way through adjustments in the demand for private inputs. Using a translog cost function we present panel estimates for the 11 federal states of (West) Germany with labour, structures and equipment as private factors of production. The results strongly indicate that public capital formation encourages private investment. In addition, it is demonstrated empirically that with respect to private capital a distinction between structures and equipment is of crucial importance because the effects on the former are of far greater importance than the effects on the latter.

JEL Classification: E6, H3, H4.

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I. Introduction: The Rise of Regional Economics

Recently, economists devote increasing research efforts to the investigation of regional economic developments. One reason for this is undoubtly the formation of the Common Market: Economic barriers will be removed which in the past have hampered the free flow of goods, capital and labour; the prospect of a common currency for all member countries is expected to create a further push toward economic integration. However, there are still plenty of unresolved problems associated with the regionalization of blocks of former independent national economies. As a consequence, the instruments used by economists in the past to analyze relations between the European countries, that is International Trade Theory, will have to be replaced by analytical instruments that have been in use in the past within the area of Regional and Urban Science. In a recently published book entitled 'Geography and Trade', Paul Krugman (1991) showed in a comprehensive way how to connect International Trade Theory and Regional and Urban Economics to analyze the new economic order that will be created by the formation of economic integrated nations.

The central focus of the current research in the area of regional economics is the question, whether regional economies exhibit convergent or divergent behavior. The former view is supported by the neoclassical growth model as pioneered by Solow (1956). Barro and Sala-i-Martin (1992) applied an extended version of this model to the US states using data that cover a period of more than a century and provide evidence in favour of convergence. However, these findings are challenged by proponents of the theory of endogenous growth, which predicts permanent differences between regional economies, see for example Romer (1986, 1987). Concerning the mechanisms that bring about convergent of divergent behavior two approaches have recently been advanced, namely the migration of jobs and workers, and the provision of public services. Blanchard and Katz (1992) examined the question whether jobs or workers migrate in response to regional development differentials showing that labour migration is of far greater importance than job migration. The contribution of the provision of public capital, notably infrastructures, to regional economic development has been examined by Costa, Elson and Martin (1987), Merriman (1990), Holtz-Eakin (1991), Duffy-Deno and Eberts (1991), Morrison and Schwarz (1992), and Garcia-Milá and McGuire (1992) to mention just a few. The key argument in this approach is the 'public capital hypothesis', see Conrad and Seitz (1992), which posits that public capital enhances private productivity and that private and public capital are complementary, that is, the provision of public capital encourages private investment and can therefore be considered to be an engine for economic growth.

The present paper examines the latter aspect, that is the impact of public infrastructures on regional economic activities. Many applied infrastructure studies in the past used aggregate national data on the private sectors of the economy and the aggregate national stock of public infrastructure investment, such as Nadiri and Mamuenas (1991), Berndt and Hansson (1991), Conrad and Seitz (1992), and Seitz (1992a,b). However one has to be aware that infrastructures do have a strong spatial dimension because of their limited accessibility and limited spatial spillover-effects. Therefore even the regional approach taken in the present study might still be too highly spatially aggregated, if we take into account that most infrastructure capital has a pronounced urban character. As a background for our study, in Section II we present some selected descriptive regional data for the manufacturing industry in West Germany for the period 1970 - 1988; for lack of data the "Neue Bundesländer" can be given only a very cursory glance. In addition, we provide a limited international comparison of infrastructure investment within OECD countries. The theoretical part in Section III briefly outlines a model of a cost-minimizing firm incorporating the stock of public capital as a fixed unpaid factor of production. Section IV presents theestimation results obtained from applying the theoretical model to the manufacturing industry of the 11 states of the Federal Republic of Germany for the period 1970 - 1988. It is shown, that the provision of public capital encourages private investment, especially investment in structures and to a lesser extend investment in equipment capital. However, due to the substitutability of private capital and labour our results suggest a labour saving effect of public investment. Finally, Section V summarizes our findings, comments on the shortcomings of our approach and provides some conclusions for further research.

II. Regional Developments in Germany 1970 - 1988

Before unification, West Germany was organized in 11 states, see **Figure 1**, three of which are in fact large cities, namely West-Berlin, Bremen and Hamburg. After unification on October the 3rd in 1990, five additional states have been created: Mecklenburg-Vorpommern, Brandenburg, Sachsen-Anhalt,

Germany after unification

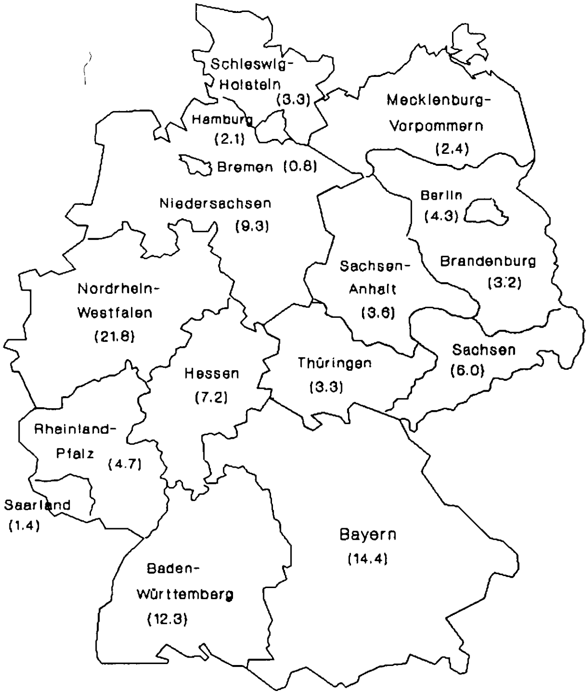

Figure 1 %-share of population in 1991 in parenthesis.

Sachsen and Thüringen; in addition, West-Berlin and East-Berlin have been joint to form the new city state Berlin.

We start our short descriptive analysis of regional economic developments in (West) Germany by looking at the deindustrialization process, measured in terms of employment, see **Figure 2** and **Figure 3**. On average, the share of employment in manufacturing decreased by about 6% in the period 1970 - 1988 for the FRG as a whole. However, there are marked differences between the regions: The most dramatic decline of the importance of manufacturing

Share of Employment in Manufacturing

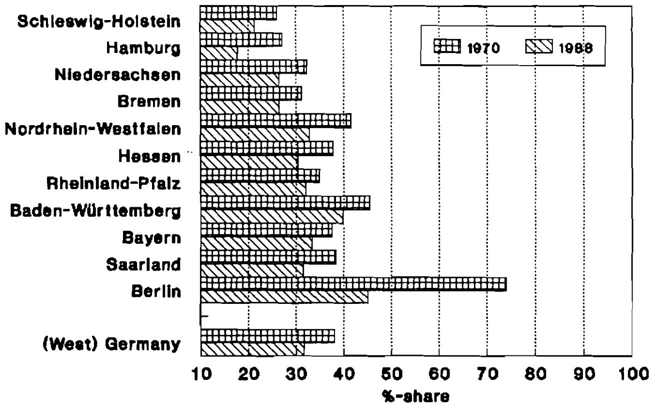

Figure 2

Source: VGR der Bundesländer

Change in Employment 1970 - 1988

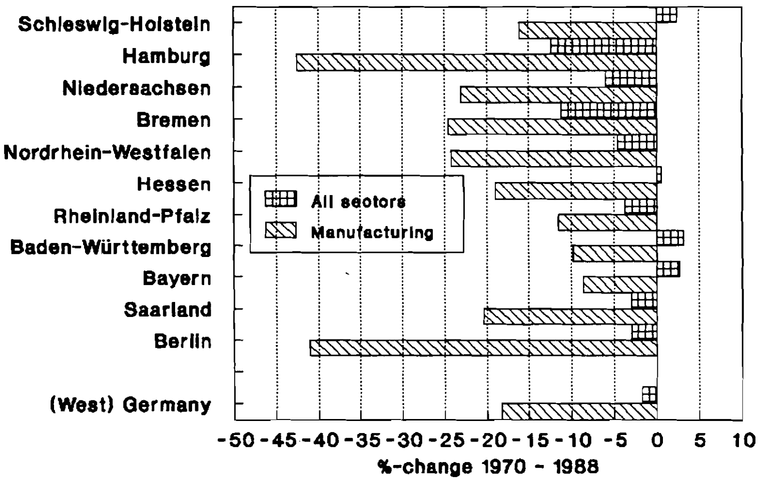

Figure 3

Source: VGR der Bundesländer

employment has been experienced by the city states Berlin and Hamburg, both of which lost more than 40% of their manufacturing employment, whereas Bayern, Baden-Württemberg and Rheinland-Pfalz experienced the lowest employment losses. If we look at total employment, only in Baden-Württemberg, Bayern, Schleswig-Holstein and Hessen the losses in manufacturing employment have been overcompensated by increases in employment in other sectors, especially in the service industry. On the average, employment in manufacturing decreased by about 18% whereas total employment decreased by only about 2%.

Looking at other European countries, see **Figure 4**, reveals that the German deindustrialization process is not unique: France, Italy and Germany lost about 6% of their manufacturing employment share in the last 20 years;

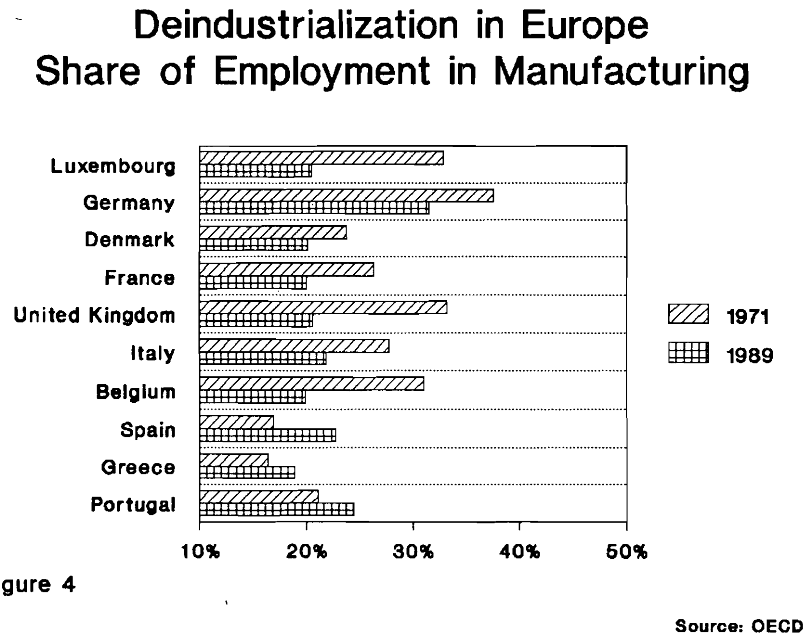

Figure 4

Great Britain even more than 12%. It is interesting to note that the southern European countries, Spain, Portugal and Greece still seem to be in an industrialization process, that is, the share of employment in the manufacturing industry in these countries is still growing.

The marked regional differences depicted in Figure 2 and 3 are also reflected in rather strong interregional differences in the unemployment rate, see **Figure 5**. In 1988 the average unemployment rate was about 8%; it was less than 5% in Baden-Württemberg and more than 12% in the city state Bremen. In general, most indicators of regional economic activities in Germany indicate rather strong North-South differences and the data available to us suggest divergent more than convergent regional economic developments in the last 2 decades within (West) Germany; for a more detailed discussion of regional economic developments in Germany see Bade and Kunzmann (1991).

Figure 5

Source: Statistisches Bundesamt

Before we turn to the infrastructure issue we briefly look at some of the latest available data on the economic conditions in the Neue Bundesländer. **Figure 6** shows the dramatic loss of employment in the manufacturing industry in the East of Germany. The data in figure 6 refer to a period of 12 month, that is July 1991 to July 1992. As can be seen, East Germany lost more employment within one year than West Germany within 20 years - measured in terms of %-growth rates. At the current time the offical unemployment rate in the East is about 15%. However, if we take into account that lots of people retired already at the age of 55 and even 50, and that there are large-scale limited-time-employment-programs, the 'true' unemployment rate might currently be close to 30%, see Licht and Steiner (1992) for a more detailed picture of the East Germany economy. **Figure 7** depicts the dramatic increases in wages that have been negotiated for workers in the Neue Bundesländer. Between July 1991 and July 1992 wages in East Germany increased by about 40% - 50%, which is

Economic Developments in the "Neue Bundesländer" Employment in Manufacturing

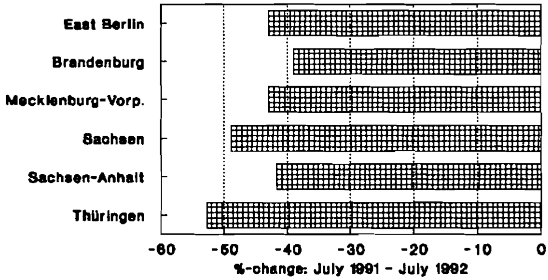

Figure 6

Source: Statistisches Bundesamt

Economic Developments in the "Neue Bundesländer" Average monthly income in manufacturing

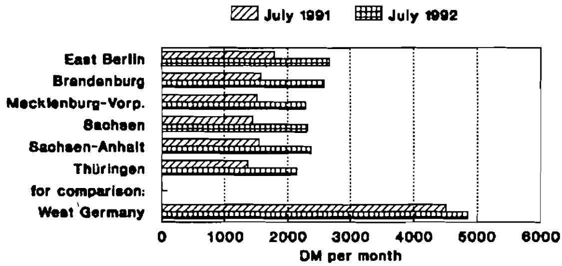

Figure 7

Source: Statistisches Bundesamt

generally believed to be one of the main factors that explain the dramatic downturn of the East German economy.

After this cursory look at some regional economic data we turn to the central focus of the paper, that is the impact of the provision of public infrastructure capital on regional economic acitivities. Public capital comprises the stock of non-military capital owned by federal, states and local governments.

Investment in Public Infrastructures*)

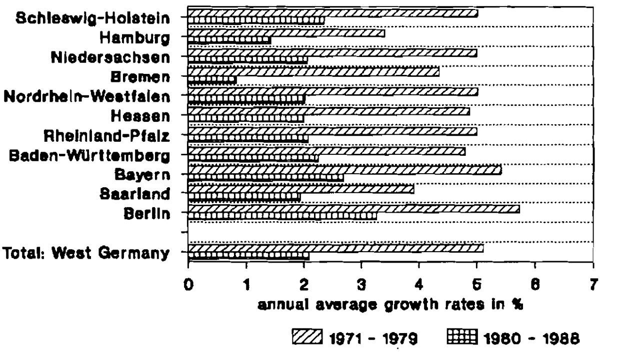

Figure 9

*) real net public capital stock

Source: OECD

Investment in Public Infrastructures*)

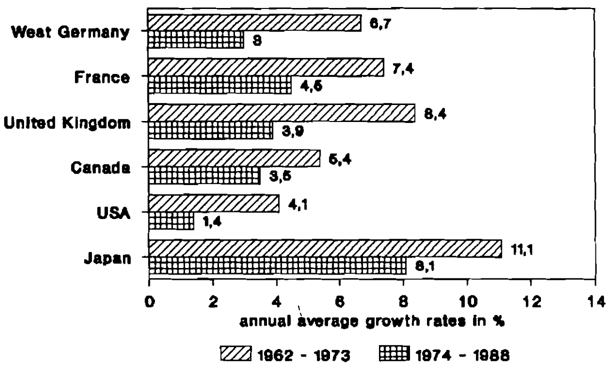

Figure 8

*) real net public capital stock

Source: Ford/Poret (1991)

Following Diewert (1986) there are four broad categories of public capital that are generally thought to be relevant for private business:

- *utilities* (sewage disposal, water supply, etc.),
- *communication* (telephone, postal services, etc.),
- *transport* (railways, roads, etc.), and
- *land development* (land preparation projects, etc.).

The degree of private and public provision of these kinds of capital varies accross countries, however, even if the provision is private, firms engaged in these kinds of activities are usually highly regulated and therefore there are either no direct user charges or user charges are not based on market prices.

In order to grasp the importance of public infrastructure provision, **Figure 8** provides some international comparative data. In the period 1962 - 1973 the public capital stock in Germany increased on the average by about 6.7% per year. Higher growth rates are reported for France, the UK and especially Japan. However, public investment decreased dramatically after 1973 to annual average growth rates of about 3% in Germany, 4.5% in France and 1.4% in the US. The data provided in **Figure 9** for the West German regions indicate that there have not been that much regional differences in the period 1970 - 1980. However, since 1980 regional disperities are becoming evident. The city states Hamburg and Bremen increased their stock of public capital far below the national average growth rate whereas West-Berlin, Schleswig-Holstein and the Southern states invest more than the national average.

III. A theoretical framework

As a starting point we consider the cost function (1) of an industry in region i:

$$(1)\ C_i = C_i(w_i, P_{Ai}, P_{Bi}, t, X_i, KI_i)$$

with w_i denoting the wage, P_{Ai} the rental cost of equipment investment, P_{Bi} the rental cost of structures, X_i the output and KI_i the flow of services rendered by the stock of public capital provided in region i which we proxy by the stock of public capital. The time counter t is included as a proxy for technical change. The cost function (1) can be derived by minimizing the private production cost:

$$(2)\ C_i = w_i \cdot L_i + P_{Ai} \cdot A_i + P_{Bi} \cdot B_i$$

subject to the production function:

(3) $X_i = f_i(L_i,A_i,B_i,t,KI_i)$

where L_i, B_i and A_i denote labour input, structures, and equipment respectively. For ease of notation the variables in equations (1) through (3) do not carry indices for the period of time and the industries and we will stick to this practice in the remainder of the text.

Despite the fact the the provision of KI_i is not taken into account by private firms in the cost minimization process, KI_i appears as an argument in the private cost function as a fixed unpaid factor of production because public services enter the private production function. One should expect that an increase in the provision of KI_i enhances private productivity, that is $\partial X_i/\partial KI_i \geq 0$. This productivity impact of public services can also be cast in terms of the cost function by differentiating (1) with respect to KI_i which yields:

$$(4) \qquad s_i = - \frac{\partial C_i(w_i,P_{Ai},P_{Bi},t,X_i,KI_i)}{\partial KI_i}$$

s_i denotes the change in private production cost in the industry in region i if the public capital stock increases by one unit. Because of the free disposal assumption with respect to public infrastructure one should expect that $s_i \geq 0$, that is, the provision of infrastructures saves private production cost. s_i is called the shadow price of public capital or the willingness-to-pay for public services. Application of the envelope theorem provides a simple relation between the monetary measure s_i and the physical marginal product of public capital:

$$(5) \qquad f_{i,KI_i} = \frac{s_i}{C_{X_i}}$$

with $f_{i,KI}$ denoting the marginal product of KI_i and $C_X = \partial C_i/\partial X_i$ marginal cost. This relation provides a link between the primal (that is, via the production function) and the dual (that is, via the cost function) measurement of the productivity impact of public services.

Thus, if public capital renders significant productive services to private firms one should expect that firms located in regions with more or better infrastructures should have a cost advantage as compared to firms located in regions with a smaller or lower quality stock of public capital. Consequently, regional govern-ments can increase the competitiveness of firms located within their area by providing a more favourable infrastructure environment. This suggests that the variable KI_i can be viewed as a strategic weapon for interregional competition, a point which cannot be further pursued here, see for example Wilson (1986).

In order to study the way in which public infrastructure services affect the private economy, estimates of the willingness-to-pay, s_i, do not provide that much insight into the mechanisms that bring about private cost savings. The only way these cost saving effects can result is by adjustments in the demand for private factors of production. Therefore, we apply Shephard's Lemma to the cost function (1) which gives us the cost-minimizing factor demand equations for labour, equipment and structures:

$$(6)\quad L_i^* = \frac{\partial C_i}{\partial w_i} \;;\; A_i^* = \frac{\partial C_i}{\partial P_{Ai}} \;;\; B_i^* = \frac{\partial C_i}{\partial P_{Bi}}.$$

These cost-minimizing conditional factor demand equations depend on the same variables as the cost function, that is on w_i, P_{Ai}, P_{Bi}, X_i, t and also KI_i. By differentiating the factor demand equations with respect to KI_i we can infer in which way the demand for private factors of production depend upon public infrastructures. Thus, in the case of the demand for private equipment we evaluate:

$$(7)\quad \frac{\partial A_i^*}{\partial KI_i} = \frac{\partial^2 C_i(w_i,P_{Ai},P_{Bi},t,X_i,KI_i)}{\partial P_{Ai}\partial KI_i} = \epsilon_{A,i}$$

ϵ_{Ai} indicates the (physical) amount of private equipment capital that is saved - if $\epsilon_{Ai} < 0$ - or additionally demanded - if $\epsilon_{Ai} > 0$ - if the public capital stock in region i is expanded by one unit. $\epsilon_{Ai} > 0$ (<0) indicates that public capital and private equipment are compelementary (substitutive), whereas a neutral relationship emerges for $\epsilon_{Ai} = 0$. In a similar way we can evaluate the impact KI_i has on private structures and labour by evaluating the corresponding effects ϵ_{Bi} and ϵ_{Li}. Using the cost minimizing factor demand equations we can rewrite the cost function (1) as:

$$(1')\quad C_i = w_i \cdot L_i^* + P_{Ai} \cdot A_i^* + P_{Bi} \cdot B_i^*$$

and differentiate (1') with respect to KI_i which yields:

$$(8)\quad \frac{\partial C_i}{\partial KI_i} = -w_i \cdot \frac{\partial L_i^*}{\partial KI_i} - P_{Ai} \cdot \frac{\partial A_i^*}{\partial KI_i} - P_{Bi} \cdot \frac{\partial B_i^*}{\partial KI_i}$$

$$= -w_i \cdot \epsilon_{Li} - P_{AI} \cdot \epsilon_{Ai} - P_{Bi} \cdot \epsilon_{Bi} = s_{Li} + s_{Ai} + s_{Bi}.$$

Equation (8) decomposes the productivity or cost saving effects of public infrastructures into adjustment effects of the demand for labour, equipment and structures. s_{Ai} indicates the amount of money private firms spent on additional equipment investment if KI_i and A_i are complementary, or the amount of money firms decrease their monetary stock of equipment capital if both inputs are substitutive. Cost saving effects thus arise out of adjustments in the demand for private factors of production.

IV. Estimation Results

In order to examine the model outlined above empirically, we use a translog cost function of the following form:

$$\begin{aligned}
\ln C = {} & \sum_{i=1}^{n} \alpha_{0,i} \cdot D_i + \sum_{i=1}^{n} \alpha_{L,i} \left(\frac{w}{p_B} \right) \cdot D_i + \sum_{i=1}^{n} \alpha_{A,i} \left(\frac{p_A}{p_B} \right) \cdot D_i + \ln p_B \\
& + \alpha_X \ln X + \alpha_{KI} \ln KI + \alpha_T \cdot t + 0.5(\beta_{L,L} \ln^2 \frac{w}{p_B} \\
& + \beta_{A,A} \ln^2 \frac{p_A}{p_B} + \beta_{X,X} \ln^2 X + \beta_{KI,KI} \ln^2 KI + \beta_{T,T} \cdot t^2) \\
(9) \qquad & + \beta_{L,A} \ln \frac{w}{p_B} \ln \frac{p_A}{p_B} + \beta_{L,X} \ln \frac{w}{p_B} \ln X + \beta_{L,KI} \ln \frac{w}{p_B} \ln KI \\
& + \beta_{L,T} \ln \frac{w}{p_B} \cdot t + \beta_{A,X} \ln \frac{p_A}{p_B} \ln X + \beta_{A,KI} \ln \frac{p_A}{p_B} \ln KI \\
& + \beta_{A,T} \ln \frac{p_A}{p_B} \cdot t + \beta_{X,KI} \ln X \ \ln KI + \beta_{X,T} \ln X \cdot t \\
& + \beta_{KI,T} \ln KI \cdot t + \beta_{L,WT} \ln \frac{w}{p_B} \cdot WT + \beta_{A,WT} \ln \frac{p_A}{p_B} \cdot WT + U_C
\end{aligned}$$

For convience sake the exogenous variables do not carry neither an index for the region i nor for the period of time, however, as a matter of course, all data on wages, the user cost of equipment and structures, the stock of public capital, and output are measured region and time specific. Note, that the way in which the cost function (9) is written implicitly assumes that the production cost of the industry is identical accross all regions except the region specific effects $\alpha_{0,i}$ $\alpha_{L,i}$ and $\alpha_{A,i}$, see Luger and Evans (1988) and Carlino and Voith (1992) for an examination of this assumption for the US. The variable D_i indicates a dummy variable that takes on the value 1 for region i and zero otherwise. For estimation, the cost function (9) has been appended by an error term U_C. Applying Shephards Lemma to (9) by differentiating with respect $\ln(w_i)$ and $\ln(P_A)$ yields the cost minimizing labour cost and equipment cost shares, γ_{Li} and γ_{Ai}:

$$(10)\quad \gamma_{Li} = \frac{w_i \cdot L_i^*}{C_i} = \sum_{i=1}^{n} \alpha_{L,i} \cdot D_i + \beta_{L,L} \ln \frac{w}{p_B} + \beta_{L,A} \ln \frac{p_A}{p_B} + \beta_{L,X} \ln X + \beta_{L,KI} \ln KI + \beta_{L,T}\, t + \beta_{L,WT}\, WT + U_L$$

$$(11)\quad \gamma_{Ai} = \frac{p_A \cdot A_i^*}{C_i} = \sum_{i=1}^{n} \alpha_{A,i} \cdot D_i + \beta_{A,A} \ln \frac{p_A}{p_B} + \beta_{L,A} \ln \frac{w}{p_B} + \beta_{A,X} \ln X + \beta_{A,KI} \ln KI + \beta_{A,T}\, t + \beta_{Bi}\, WT + U_A$$

Because cost shares add to 1 the cost share equation of structures cannot be taken into account during the estimation process. Note, that the region specific parameters $\alpha_{L,i}$ and $\alpha_{A,i}$ on the variables (w/P_{Bi}) and (P_{Ai}/P_{Bi}) reappear in the two factor cost share equations as region specific fixed effects. Equations (10) and (11) have also been appended by error terms U_L and U_A.

In the cost function and in the two factor cost share equations a new variable, WT, has been introduced that did not appear in our theoretical model. WT is a index variable ($WT_{1970} = 1$) of the negotiated weekly working hours. On the average, the negotiated weekly working hours have been reduced from about 44 hours/week in 1970 to about 40.1 hours/week in 1988. WT is included to capture labour demand adjustment effects that have been 'enforced' upon firms by contractual aggreements between the trade unions and the employers.

For empirical implementation, labour input L_i is measured in terms of total working hours in the manufacturing industry in region i. Total working hours are calculated by multiplying the number of employees with the number of average yearly working hours per employee under the assumption that white and blue collar workers have the same number of working hours.[1] The factor prices for capital inputs have been calculated by refering to the concept of the user cost of capital as developed by Jorgenson (1963):

$$(12)\quad P_{Ai} = PI_{Ai}(R_{Gs} + \delta_{Ai} - \frac{dPI_{Ai}}{dt}) \text{ and: } P_{Bi} = PI_{Bi}(R_{Gl} + \delta_{Bi} - \frac{dPI_{Bi}}{dt})$$

where δ is the depreciation rate (δ_{Ai} = 0.1771; δ_{Bi} = 0.0548)[2]. PI_{Ai} and PI_{Bi} are the price indices for equipment and structures, R_{Gl} and R_{Gs} are the interest rate on long term government bonds and long bills, respectively. The stocks of private equipment and structure capital are measured by the total net capital stocks of the manufacturing industry in region i, evaluated at 1980 prices. All regional data have been supplied by the 'Arbeitskreis Volkswirtschaftliche Gesamtrechnung der Länder'[3]. This institution also provides data on the stock of public capital - net, evaluated at constant prices - in the various federal states. However, the public capital stock provided by this source excludes the stock of capital invested in the road network.[4] However, aggregate data at the national level of the real net stock of public roads are available by the Ministry of Traffic and Transport, see Seitz (1992a) for a more detailed description of these data and a detailed study of the effects of infrastructure investment into the public road network. Therefore, we used these national figures and assigned every federal state a stock of road network capital proportional to its share of i) the length of the total public road network and ii) the length of the total

[1] Offical statistics provid working hours only for blue collar workers but not for white collar workers.

[2] Both depreciation rates have been calculated using data supplied by official statistical authorities, see below in the text and the list of references for data source.

[3] Special thanks we owe to Mr. Dr. Fischer and Mrs. Dr. Walter from the "Statistisches Landesamt Baden-Württemberg" who provided us with unpublished regional data.

[4] Official statistical authorities assume that there is no depreciation for public roads because constant repair activities maintain the 'usability' of this type of public capital.

motorway network. Results from these two different procedures turned out to be almost identical and therefore in the following we present only those results we got from using the region-specific share in the lenght of the motorway network. The public capital stock variable KI_i enters our empirical model with a one period lag. As a matter of course, all data - except R_{Gs}, R_{Gl}, and the depreciation rates - have been calculated region-specific.

For estimation the 3 equations (9) - (11) have been estimated by pooling annual data on the manufacturing industry in the 11 federal states of (West) Germany for the period 1970 - 1988 using iterative seemingly unrelated regression. In order to handle a potential simulaneity bias we instrumented output and the three factor prices on the exogenous variables.[5] **Table 1** presents the estimation results. All parameters - except the parameter $ß_{A,X}$ are estimated to be significantly different from zero and the goodness-of-fit statistics are highly satisfactory if we take into account that the model has been applied to a panel data set. Table 1 also indicates some likelihood-ratio tests of the estimated specification against alternative specification: LR_D tests our model against a corresponding model in which no regional fixed effects are present, and LR_H tests against the assumption of constant returns to scale, which is very often assumed in applied infrastructure studies, see for example Nadiri and Mamuenas (1991). Both tests indicate a rather strong rejection of the alternative models. In addition, we calculated the test statistic LR_{KI} which tests the overall significance of the KI_i variable. All individual t-ratios of theparameters of the variables that involve KI_i as well as the likelihood-ratio test LR_{KI} indicate that the public infrastructure variable significantly enters the cost function and the two cost share equations.

With respect to the economic implication of our estimates we calculate that labour is substitutive to both equipment and structures and that structures and equipment are complementary. Public capital is complementary to both types of private capital but substitutive to private labour input. Using our estimated cost function we can derive an estimate of the willingness-to-pay for public infrastructure services in the manufacturing industry in the 11 regions. These estimates are positive in virtually all periods and regions. The only exception is the city state Bremen for which we estimate a negative willingness-

[5] The following variables have been used as instruments: KI_i, t, R_{Gs}, R_{Gl}, population, the lagged value of the left hand side variable, and dummies for each region.

Table 1: Results of the panel-estimation for the 11 regions of the FRG 1971 - 1988[1)]

α_L	3.9382 (7.4)[2)]	α_A	- 1.7190 (3.2)[2)]
β_t	- 0.0294 (2.2)	β_{KI}	1.1830 (3.2)
β_X	- 1.3839 (4.3)	$\beta_{L,L}$	0.1254 (15.2)
$\beta_{A,A}$	0.1108 (12.8)	$\beta_{t,t}$	- 0.0013 (3.2)
$\beta_{KI,KI}$	- 0.1037 (2.8)	$\beta_{X,X}$	0.1519 (4.3)
$\beta_{L,A}$	- 0.0852 (11.9)	$\beta_{L,t}$	- 0.0027 (3.2)
$\beta_{L,KI}$	- 0.0791 (3.7)	$\beta_{L,X}$	0.0263 (2.3)
$\beta_{A,t}$	0.0024 (3.3)	$\beta_{A,KI}$	0.0499 (2.7)
$\beta_{A,X}$	- 0.0089 (0.9)	$\beta_{KI,t}$	0.0078 (4.1)
$\beta_{X,t}$	- 0.0039 (2.4)	$\beta_{L,WT}$	- 0.7088 (6.1)
$\beta_{A,WT}$	0.4261 (4.1)		

Cost Equation: $R^2 = 0.990$
Labour Demand Equation: $R^2 = 0.651$
Capital Demand Equation: $R^2 = 0.433$

Specification tests:[3)]
LR_D (FG = 33) = 1151.94
LR_{KI} (FG = 5) = 28.68
LR_H (FG = 5) = 77.94

1) t-ratios in parenthesis.
The total number of observations are t[=18]·n[=11] = 198.
2) The reported parameters as well as the associated t-values are average values for the 11 regions because these parameters are estimated region-specific.
3) LR indicates Likelihood-Ratio test-statistics, which follow a chi-square with degress of freedom as indicated in parentthesis.
LR_D: Tests the model with fixed-effects against the model without region-specific dummies.
LR_{KI}: Tests the model inclusive the variable KI against the model exclusive of KI, with region-specific dummies specified in each model. This statistic tests for the overall significance of the variable KI.
LR_H: Tests the assumption of constant resturns to scale in the cost function. The associated probability values for all tests are 0.0000.

to-pay in the period after 1980; however, both before and after 1980 the estimated values of s_i are rather small in the case of Bremen suggesting that private production cost in this region are rather insensitive to the provision of public infrastructures.

Table 2 presents in column (1) the estimated elasticities of the private production cost with respect to public capital [$\eta_{C,KI} = (\partial C_i/\partial KI_i)\cdot(KI_i/C_i) = -s_i\cdot(KI_i/C_i)$] which indicates the %-decrease in private production cost if the stock of public capital is expanded by one %. In interpreting the figures in column (1) one has to keep in mind that these elasticities are calculated c. p., that is, all factor prices and especially output is kept constant[6], see Seitz (1992b) for a more general analysis of the cost reducing effects of the provision of public inputs. On the average, the cost elasticity of public capital is about - 0.2%. These cost reducing effects are largest in those regions that have the largest areas, such as Nordrhein-Westfalen, Bayern and Baden-Württemberg. This might be due to the fact that almost 50% of the public capital stock consists of traffic infrastructures and that for these large-area regions a well-developed road system is of the utmost importance.The most interesting results of our analysis can be taken from column (2) and (3) which show the elasticity of the demand for equipment capital [$\eta_{A,KI} = (\partial A_i/\partial KI_i)\cdot(KI_i/A_i) = \epsilon_{Ai}\cdot(KI_i/A_i)$] and structures [$\eta_{B,KI} = (\partial B_i/\partial KI_i)\cdot(KI_i/B_i) = \epsilon_{Bi}\cdot(KI_i/B_i)$] with respect to public capital. Contrary to all empirical studies we are aware of[7], we have been able to split the stock of private capital into equipment and structures.[8] As column (2) and (3) indicate, the decomposition of the stock of private capital into these two components is of crucial importance. On average, the impact of public capital on investment into structures is almost twice as large as the impact of KI_i on equipment. There are only two regions, the city states Hamburg and Bremen, for which we estimate that the effect on equipment relative to the effect on structures is rather large and in the case of Bremen the former even

[6] This c. p. interpretation also applies to the figures presented in the remaining columns (2) - (4) of table 2.

[7] Garcia-Mila and McGuire (1992) separate structures and equipment in a study of the contribution of publicly provided inputs to the US states economies. However, that study examines only a (Cobb-Douglas) production function.

[8] For the sake of informaton, column (5) of table 2 presents the share of private capital invested in structures to the total private capital stock.

Table 2: Effects of Public Capital on Private Cost and Private Input Demand:

	(1) $\eta_{C,KI}$	(2) $\eta_{A,KI}$	(3) $\eta_{B,KI}$	(4) $\eta_{L,KI}$	(5) α_B
Schleswig-Holstein	- 0.194	0.148	0.161	- 0.297	0.497
Hamburg	- 0.104	0.250	0.402	- 0.203	0.416
Niedersachsen	- 0.306	0.014	0.121	- 0.408	0.433
Bremen	- 0.018	0.515	0.364	- 0.114	0.584
Nordrhein-Westfalen	- 0.357	- 0.041	0.095	- 0.459	0.415
Hessen	- 0.281	0.047	0.267	- 0.381	0.382
Rheinland-Pfalz	- 0.254	0.031	0.144	- 0.359	0.422
Baden-Württemberg	- 0.325	0.037	0.169	- 0.423	0.429
Bayern	- 0.342	0.017	0.097	- 0.442	0.457
Saarland	- 0.097	0.190	0.344	- 0.201	0.398
Berlin	- 0.099	0.206	0.244	- 0.204	0.465
Average:	- 0.216	0.129	0.219	- 0.317	0.445

(1) Elasticity of private cost with respect to public capital.
(2) Public capital elasticity of the demand for equipment.
(3) Public capital elasticity of the demand for structures.
(4) Share of the the demand for labour with respect to public capital.
(5) α_B = (stock of capital in structures/total stock of capital).

dominates the latter. The economies of these two regions are dominated by the presence of the only two large seaports of Germany. This suggests, that private investment into containers and container terminal equipment responds rather sensitive to public investment in seaport infrastructures.

The dominant effect of infrastructures on private structures seems to be quite plausible if we take into account that traffic infrastructure investment accounts for the largest part of the public capital stock. In addition, cities and communities make investments into land-development programs. These types of infrastructure investment favor the location and relocation of firms which makes private investment into structures more profitable and/or necessary. In addition, if we take into account that regions use public infrastructure investment as an inducement to attract private firms, our estimation results are quite compatible with everyday-life experience.

For one region, Nordrhein-Westfalen, our estimates indicate rather small effects of public investment on private investment demand and we even get a substitutive relationship between private investment in structures and public investment. The former industrial heartland of (West) Germany, the Ruhr Area, is completely located in the federal state Nordrhein-Westfalen. With the severe problems that emerged in the steel industry in Europe and in Germany since about 1975, the economy of this region has experienced a rapid economic downturn. Nordrhein-Westfalen is currently in a process of reconstructing its old industry structure, however, this process just started in the middle of the eighties and still many of the old heavy industry firms directly or indirectly depend upon financial aid from the federal and state government. These economic conditions and the low level investment into public infrastructures, see Figure 9 above, might explain the atypical result for Nordrhein-Westfalen.

Finally, column (5) reports the substitutive relationship between public capital and the demand for private labour by showing the elasticity of the demand for private labour with respect to public capital [$\eta_{L,KI} = (\partial L_i/\partial KI_i)\cdot(KI_i/L_i) = \epsilon_{Li}\cdot(KI_i/L_i)$]. This substitutive effect can be considered to be of an indirect nature: Because public capital and private investment are complementary and private investment and private labour input are substitutive, an increase in public investment increases private capital formation which in turn substitutes private labour.

V. Summary and Conclusions

The present paper presented a simple theoretical model of cost-minimizing firms with the stock of public capital included as a proxy for public services provided to firms as a fixed unpaid factor of production. We used duality theory to recover the productivity effects of public infrastructures by calculating the cost-saving effects that are associated with public services. It has been shown that these cost-saving effects work their way through adjustments in the demand for private inputs. Using a translog cost function we presented panel estimates for the 11 federal states of (West) Germany with labour, structures and equipment as private factors of production. The results strongly indicate that public capital formation encourages private investment. It has been demonstrated empirically that with respect to private capital a distinction between structures and equipment is of crucial importance because the effects on the former are of far greater importance than the effects on the latter. However, the results also indicate that there is a technologically induced labour saving effect through higher private investment. With regard to regional development policy, investing in public infrastructures can be considered to be an instrument to improve the competitiveness of cities, regions and nations. Regional governments can increase the attractiveness of their region by providing more and a better quality stock of cost-reducing public infrastructures.

At last, some critical notes on our approach should be mentioned and taken as avenues for further research. To beginn with, we did not take into account that firms indirectly pay for public infrastructure services by taxes. In addition, our theoretical model did not take into account supply side reactions of the firms, see for example Conrad and Seitz (1992) where responses with supply prices are explicitly considered. With respect to our empirical analysis, due to the lack of data, we have been unable to disaggregate the manufacturing industry to the 2-digit level. Because the sectorial structure of the manufacturing industry varies considerably accross the 11 federal states one should expect that this might affect our estimation results. Empirically it is also rather dissatifactory to measure the influence of the provision of public infrastructure services by an aggregate public capital stock variable. Therefore, further research should be dedicated to a more sophisticated measurement of public services, using perhaps some hedonic measurement concept, in which not only different kinds of public infrastructures could be taken into account but also different characteristics, such as quality indicators, indicators of congestion etc.

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