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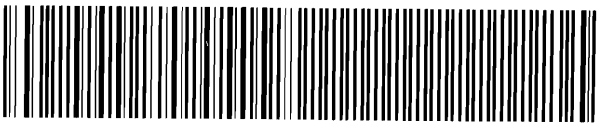

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Regional Productivity Growth and Investments in Public Infrastructure: The Case of Germany

by

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Abstract

This paper examines whether the productivity growth in the West-German states is influenced by the provision of public infrastructure. Medium-term labour productivity growth and output growth varies a lot between German states. This differences are more pronounced during the eighties. The traditional total factor productivity shows a smaller difference than labour productivity. The regional differences in the productivity growth rates can only partly be attributed to the differences in factor input growth.

We estimate a translog-cost-function for the period 1970-1988 for 11 German states using a three-equation fixed-effects panel data model. We show that there are important cost-saving effects that are associated with public services. Likewise, the demand for labour, and the private investment demand for structures and equipment is effected by public capital goods. Our estimates indicate that public capital formation encourages private investment. This effect is especially strong with respect to the private demand for structures. These results confirm that regional or urban economic growth can be forstered by the government by public investment.

JEL Classification: E6, H3, H4.

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1. Introduction

Recently, economists devote an increasing attention to the regional dimension in the economic development of nations. There are several reasons for this redirection of economic research: To begin with, the formation of the Common Market will initiate and enforce the regionalization of Europe. Countries that in the past have been considered to be economically independent units linked through foreign trade relations are loosing their national character and taking on the role of regions in the future European economy. For economists this means that the instruments developed within the International Trade Theory will have to be replaced by instruments that in the past have been applied within the area of Regional Economics (see Krugman 1991). Some economists, such as Blanchard and Katz (1992) and Barro and Sala-i-Martin (1992) tried to make inferences about the future of European integration by studying regional economic developments in the U.S. With respect to the current situation in Germany, the dramatic differences between the West German Economy and the economies in the Neue Bundesländer create a tremendous demand for regional research directed toward the mechanisms that bring about regional economic divergent or convergent behavior.

A central topic is to explain why some regions resp. countries show - at least over a medium range of time - a more favourable performance than others (see. Dowrick 1992 for further references). Several hypotheses have been raised to explain these patterns in income or production per capita in the current research. First, growth differentials are inherently transient. Therefore growth rates of regions should show convergence. This view is supported by Solow-type neoclassical growth models. Using an extended version of the traditional growth models, Barro and Sala-i-Martin (1992) found some empirical support using data for US-states covering a period of more than a century. A second line of research explains long lasting growth advantages by a superior fit of organisational design and the technological state-of-the-art. Freeman (1987) as well as Womack, Jones and Roos (1991) - to mention just two well known monographs - explained the Japanese takeover of world technological leadership with this argument. A third view stresses the importance of networks of individuals and organisations in generating long-run productivity growth differentials (see Nelson and Wright 1992). If nationality becomes a less important element in these networks convergence will result. Fourth, the theory of endogenous growth predicts permanent differences between regional economies caused by scale economies (see e.g. Romer 1986, 1987). Finally, some authors argue that the decline in public investment in infrastructures in the last twenty years contributes to the recent productivity slowdown (e.g. Aschauer 1989). If regions or countries differ with respect to the provision of public capital, productivity and growth differentials will also result.

If the latter hypothesis is true, regional and national governments can foster productivity and growth by providing infrastructure services to private enterprises. Therefore, public investment policy can substitute economic effects of borders which in the past has hampered the flow of services and capital and will be especially important for economies with high private average costs. Within the newly formed economic blocks infrastructure will become an important tool in the interregional and international competition for jobs, taxes, etc. Having this in mind one

can easily understand why the search for infrastructure effects has now become a central item in regional economics research.

A first generation of research applies a production function framework and uses aggregate time series data to explore the productivity effects of public infrastructure expenditures (see the survey by Munnel 1992 for further references). More recently, several papers have tested the public capital hypothesis using regional data for the US (e.g. Holtz-Eakin 1991, Morrison and Schwarz 1992, and Garcia-Milá and McGuire 1992). The present paper follows this line of research using data of German states for the period 1970-1988. We extend the empirical evidence in favour of the public capital hypothesis already given for Germany by Conrad and Seitz (1992), and Seitz (1992a,b) using aggregated resp. industry data. Because of the fact that infrastructures do have a strong spatial dimension which is caused by the limited spatial accessibility and spillover-effects, we provide a missing link in the existing empirical evidence for Germany .

The paper is organised as follows: In Section 2 we present a descriptive analysis of regional factor inputs and productivity using a growth accounting framework. Section 3 presents the estimation results obtained from applying the cost-function approach 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 reduces private production costs and therefore enhances productivity. Moreover, we emphasize that private demand for investment in structures is more sensitive to public capital than the demand for equipment. Due to the substitutionability of private capital and labour our results suggest a labour saving effect of public investment. Finally, Section 4 summarizes our findings, comments on the shortcomings of our approach and provides some conclusions for further research.

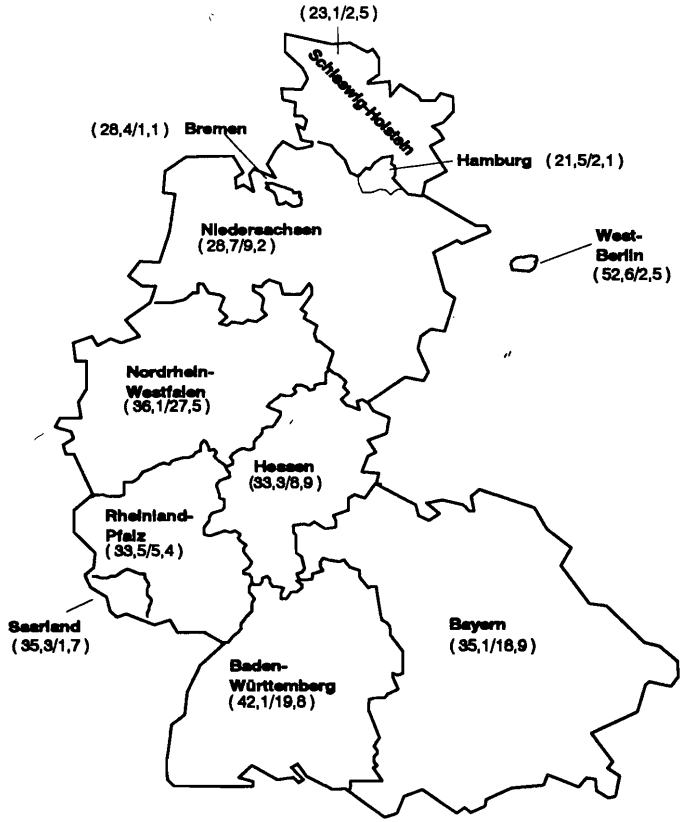
2. Factor Input and Productivity Growth in German Regions

Prior to unification, West Germany was organized in 11 states, three of which are in fact large cities, namely West-Berlin, Bremen and Hamburg. After unification in October 1990, five additional states have been created: Mecklenburg-Vorpommern, Brandenburg, Sachsen-Anhalt, Sachsen and Thüringen; in addition West-Berlin and East-Berlin have been joined to form the new city state Berlin. Due to lack of data our analysis is restricted to the manufacturing sector of West-German states before unification.

Let us begin with some comments on regionalization of German industry. As can been seen from **Figure 1** our analysis deals with very uneven regions as far as the importance of the manufactur-ing sector for total employment in each state as well as for total manufacturing employment in Germany as a whole is concerned.[1]

[1] A description of our data base can be found in the Appendix 1. We thank Dr. Berthold Fischer from the statistical office of Baden-Württemberg for providing us with the data and for some helpful comments on the coverage of the data.

Figure 1. German Federal States Before Unification



Note:
The first number in parenthesis gives the percentage share of manufacturing employment relative to total employment in each state. The second number is the percentage share of manufacturing employment in each state relative to total manufacturing employment in Germany as a whole. Both numbers are averaged over the period 1971-1988.

Surprisingly, the relative size of the manufacturing sector is largest in the city state of Berlin. This cannot exclusively be attributed to the high subsidies to enterprises given for political reasons because manufacturing sector employment has sharply declined in the last twenty years in absolute as well as in relative terms in this city. The deindustrialization process is also very significant for Hamburg, which has the smallest manufacturing sector of all states and also shows the largest decline in manufacturing employment since 1970. This strong decline in Hamburg is caused by relocations of plants from the city of Hamburg to Schleswig-Holstein, which in turn is the only northern state whose absolute number of employees has raised in the last twenty years. Even in the southern states, namely in Bayern, Baden-Württemberg and Rheinland-Pfalz, which show a growing number of employees, the relative employment share of manufacturing has declined. Manufacturing employment is concentrated in the three states Nordrhein-Westfalen, Baden-Württemberg und Bayern, which together account for about 60 per cent of total manufacturing employment.

Let us now turn to productivity issues. Table 1 and Table 2 show average growth rates of labour and capital.productivity for the eleven states in the seventies and the eighties and in boom and recession years respectively. The labour productivity is calculated as log-differentials between real value added divided by labour input. The differences between labor productivity measured in terms of working hours and in terms of the number of employes is mainly caused by shorting of the working week as well as increasing the number of paid holidays. Capital productivity is real value added divided by net total private capital stock.

The average growth rates of labour productivity - measured in terms of working hours - in the German manufacturing industry declined on the average from 4.7% in the 70ties to 2.6% in the 80ties. This productivity decline is also reported for numerous other countries and regions. However, as can be seen, the productivity decline is not distributed uniformly across the German regions: Bayern, for example, experienced a much more less severe productivity decline as the city states Hamburg and Bremen. Because some researchers, e.g. Flaig and Steiner 1993, argue that the productivity slowdown can be attributed at least partly to the underutilization of the factors of production, Table 2 presents productivity data for 'boom' and 'recession' periods.[2]

[2] Boom periods are defined as those years in which the growth rate of real value added exceeds 1%; recession periods are defined correspondingly.

Table 1. Productivity and Capital Stock Growth of German States 1971-79 vs. 1980-88

	Productivity Growth			Capital Stock Growth		Period
	Labour (per hour)	Labour (per head)	Capital	Public Capital	Private Capital	
Schleswig-	5.36	4.34	0.49	3.84	2.78	71 - 79
Holstein	2.00	0.80	-0.25	2.32	0.18	80 - 88
Hamburg	5.88	4.84	-3.18	3.29	4.35	71 - 79
	1.96	0.70	-0.02	1.36	-1.77	80 - 88
Niedersachsen	5.32	4.40	0.22	4.21	2.36	71 - 79
	2.82	1.61	-0.26	1.78	0.79	80 - 88
Bremen	4.46	3.39	-0.36	4.74	2.52	71 - 79
	3.05	1.93	-1.99	0.83	2.02	80 - 88
Nordrhein-	4.33	3.37	0.22	4.58	1.50	71 - 79
Westfalen	2.43	1.29	0.26	1.78	-0.41	80 - 88
Hessen	5.06	4.09	1.40	4.37	1.26	71 - 79
	2.32	1.17	-0.65	1.92	0.91	80 - 88
Rheinland-	4.66	3.55	0.26	4.34	2.83	71 - 79
Pfalz	2.64	1.63	0.26	2.11	0.47	80 - 88
Baden-	4.45	3.49	-0.09	4.25	2.70	71 - 79
Württemberg	2.73	1.42	-0.98	2.39	2.13	80 - 88
Bayern	4.79	3.82	1.18	4.60	1.91	71 - 79
	3.01	1.94	-0.59	2.64	2.25	80 - 88
Saarland	6.37	5.25	3.00	2.91	1.28	71 - 79
	3.51	2.39	0.54	1.55	0.30	80 - 88
Berlin	5.54	4.66	-1.22	5.73	1.55	71 - 79
	4.20	3.04	-0.37	3.25	1.88	80 - 88
Total: West	4.71	3.72	0.34	4.39	2.02	71 - 79
Germany	2.63	1.49	-0.30	2.12	0.90	80 - 88

Labour productivity growth is smaller in recessions because of labour hoarding. As the fixed costs of hiring and firing workers have increased, labour hoarding has also increased which can explain to some extent the bad labour productivity performance of the eigthies. Due to the use of flexible working time arrangements, labour productivity growth per hour is larger in booms and recessions than productivity growth per head. Moreover, one can see from table 1 that the productivity growth performance in the eighties show a north-south differential, which has not been that marked a decade ago. However, this geographical differential is less pronounced in the productivity series than in other regional economic time series, e.g. unemployment rate.

Table 2. Productivity and Capital Stock Growth of German States
Boom vs. recession periods

	Productivity Growth			Capital Stock Growth		Period
	Labour (per hour)	Labour (per head)	Capital	Public Capital	Private Capital	
Schleswig-Holstein	5.36	3.61	1.54	3.30	1.00	Boom
	2.00	1.53	-1.30	2.86	1.96	Recession
Hamburg	8.22	6.34	-0.25	2.43	2.92	Boom
	-0.39	-0.80	-2.95	2.22	-0.34	Recession
Niedersachsen	5.68	4.55	1.30	3.03	1.95	Boom
	2.46	1.47	-1.34	2.95	1.20	Recession
Bremen	5.90	4.04	-1.46	2.60	3.64	Boom
	1.61	1.27	-0.89	2.97	0.90	Recession
Nordrhein-Westfalen	5.75	4.26	1.70	3.33	1.19	Boom
	1.02	0.39	-1.23	3.03	-0.10	Recession
Hessen	5.89	4.52	2.55	3.35	1.56	Boom
	1.49	0.75	-1.79	2.95	0.60	Recession
Rheinland-Pfalz	6.48	4.76	2.28	3.45	1.98	Boom
	0.82	0.41	-1.76	3.00	1.32	Recession
Baden-Württemberg	5.85	4.40	1.13	3.45	2.96	Boom
	1.33	0.50	-2.20	3.19	1.88	Recession
Bayern	6.07	4.90	2.49	3.83	2.00	Boom
	1.73	0.86	-1.90	3.41	2.15	Recession
Saarland	6.51	5.01	2.87	2.48	1.59	Boom
	3.37	2.63	0.67	1.98	-0.01	Recession
Berlin	6.99	5.39	0.59	4.60	2.28	Boom
	2.75	2.31	-2.18	4.38	1.15	Recession
Total: West Germany	5.87	4.50	1.68	3.40	1.91	Boom
	1.48	0.70	-1.63	3.10	1.01	Recession

Turning to the last two columns of Table 1 one can see that investment in public capital[3] as well as in private capital was on average much larger in the seventies than in the eighties. As far as private investment in capital good is concerned there are large disparities between the German states. In the northern regions investment in privat capital was very low during the eighties. It was even negativ for Hamburg and Nordrhein-Westfalen. In the case of Hamburg this again reflects the outmovement of many plants to the surrounding state of Schleswig-Holstein. In the case of Nordrhein-Westfalen this decrease in the stock of privat capital is rooted in the structural crises in the iron and steel industries. Only in Bayern and Berlin private investment has accelerated in the eighties, whereas in Baden-Württemberg and Bremen it stayed on the same level.

[3] Public capital is defined as the net public capital stock owned by state and local governments evaluated at 1980 prices.

The differences in privat investment between the states are not reflected in public investment. The overall decrease is much more uniform. Again Bayern and Berlin exhibit a larger average growth than the rest of Germany. With the exception of Bremen in the eighties and Hamburg in the seventies, the investment in public capital increased with a larger rate than privat capital investment in both decades.

Let us now turn to the productivity issue again. **Table 3** and **Table 4** show average values of total factor productivity growth in German states for the two last decades and for boom and recession years. The total factor productivity growth (TFP) is calculated as:

$$(1)\quad f_{it} = x_{it} - 0.5\,(s_{Lit} + s_{Li,t-1})\,l_{it} - 0.5\,(s_{Ait} + s_{Ai,t-1})\,a_{it} - 0.5\,(s_{Bit} + s_{Bi,t-1})\,b_{it},$$

where f_{it} denotes the total factor productivity, x_{it} denotes the growth rate of real value added, s_{Lit}, s_{Ai}, s_{Bit} denote the cost shares of labour, capital invested in equipment and structures, l_{it}, a_{it}, b_{it},denote the growth rates of hours worked, stock of equipment capital and structures capital, respectively. Calculated in this way TFP represents the part of output growth that cannot be explained by the growth of the inputs of production. Note that the simple TFP measure (1) is derived under the (restrictive) assumptions i) of constant returns to scale in private inputs, ii) perfect competition in factor markets and iii) product markets, and the neglect of public inputs, such as infrastructure services. Table 3 and Table 4 also report the growth rate of output and the cost share weighted input growth rates.

Table 3. Sources of Growth in German States 1971-79 vs. 1980-88

	Real Value Added	Labour	Investment		Total Factor Productivity	Period
			Structures	Equipment		
Schleswig-	3.27	-1.59	0.16	0.56	4.14	71 - 79
Holstein	-0.07	-1.53	-0.09	0.23	1.32	80 - 88
Hamburg	1.17	-3.72	0.11	0.88	3.90	71 - 79
	-1.79	-2.98	-0.13	-0.21	1.53	80 - 88
Niedersachsen	2.57	-2.09	0.11	0.49	4.06	71 - 79
	0.54	-1.72	-0.02	0.25	2.02	80 - 88
Bremen	2.16	-1.91	0.06	0.49	3.51	71 - 79
	0.03	-2.48	0.13	0.30	2.08	80 - 88
Nordrhein-	1.72	-1.97	0.08	0.30	3.30	71 - 79
Westfalen	-0.15	-1.97	-0.07	0.02	1.88	80 - 88
Hessen	2.66	-1.84	0.10	0.18	4.23	71 - 79
	0.26	-1.61	-0.07	0.33	1.61	80 - 88
Rheinland-	3.08	-1.12	0.15	0.70	3.36	71 - 79
Pfalz	0.74	-1.39	-0.02	0.19	1.96	80 - 88
Baden-	2.62	-1.43	0.15	0.44	3.46	71 - 79
Württemberg	1.15	-1.24	0.05	0.43	1.91	80 - 88
Bayern	3.09	-1.29	0.09	0.39	3.90	71 - 79
	1.65	-1.05	0.01	0.54	2.15	80 - 88
Saarland	4.28	-1.51	0.05	0.35	5.39	71 - 79
	0.83	-2.01	-0.04	0.16	2.73	80 - 88
Berlin	0.33	-3.93	0.08	0.33	3.85	71 - 79
	1.51	-1.95	-0.03	0.66	2.83	80 - 88
Total: West	2.37	-1.79	0.11	0.40	3.65	71 - 79
Germany	0.60	-1.56	-0.02	0.28	1.91	80 - 88

Table 3 also confirms the impression of a significant productivity slowdown as all regions show a pronounced deceleration of TFP growth in the seconc subperiod. And again there are some differences between the north and the south of Germany. In general, the southern states perform slightly better than the northern states. This north-south differential is more pronounced in the growth rate of real value added. Whereas in the first decade a relative even output growth takes place in all regions this is no longer true for the second decade. Some regions experienced even a decline in manufacturing value added. Only Berlin was able to increase the rate of value added growth in the eighties. Because we use value add net of indirect taxes and subsidies this cannot be attributed to a direct effect of special tax and subsidy laws in favour of Berlin. But probably Berlin was able to attract some new plants (e.g. in the tobacco industry) due to this laws which in turn make Berlin an outlier from the north-south rule.

Table 4. Sources of Growth in German States
Boom vs. Recession Periods

	Real Value Added	Labour	Investment		Total Factors Productivity	Period
			Structures	Equipment		
Schleswig-	2.53	-2.14	-0.01	0.31	4.37	Boom
Holstein	0.66	-0.99	0.08	0.48	1.09	Recession
Hamburg	2.67	-4.43	-0.01	0.68	6.42	Boom
	-3.29	-2.28	-0.02	-0.01	-0.99	Recession
Niedersachsen	3.25	-1.86	0.07	0.41	4.62	Boom
	-0.14	-1.95	0.02	0.32	1.46	Recession
Bremen	2.18	-3.05	0.12	0.68	4.43	Boom
	0.01	-1.34	0.07	0.11	1.16	Recession
Nordrhein-	2.90	-2.17	0.04	0.30	4.73	Boom
Westfalen	-1.33	-1.77	-0.03	0.02	0.45	Recession
Hessen	4.11	-1.38	0.05	0.34	5.11	Boom
	-1.19	-2.07	-0.02	0.18	0.72	Recession
Rheinland-	4.26	-1.62	0.09	0.50	5.28	Boom
Pfalz	-0.44	-0.90	0.03	0.39	0.04	Recession
Baden-	4.08	-1.39	0.13	0.53	4.82	Boom
Württemberg	-0.32	-1.28	0.07	0.34	0.55	Recession
Bayern	4.49	-1.22	0.06	0.43	5.22	Boom
	0.26	-1.12	0.04	0.50	0.84	Recession
Saarland	4.45	-1.53	0.02	0.51	5.44	Boom
	0.66	-2.00	-0.01	0.00	2.67	Recession
Berlin	2.87	-3.09	0.05	0.62	5.29	Boom
	-1.03	-2.80	0.01	0.36	1.39	Recession
Total: West	3.59	-1.76	0.07	0.42	4.86	Boom
Germany	-0.62	-1.59	0.02	0.25	0.71	Recession

As can be seen from the second column, the trend of the labour saving technical progress continues in the eighties. Investments in structures did not play an important role in the growth process. A larger part of output growth can be explained by additional investment in equipments.

The different developments between the northern and the southern region is even more pronounced in table 4, where we have averaged TFP-growth and it`s components over boom and recession years. Especially in boom years the south shows a larger value added growth, whereas in recession years both parts of Germany grew more uniformly. Given that in the south, namely in Baden-Württemberg, the more cyclical investment good industries are concentrated, this pattern can hardly be attributed to the industry structure. As it is already stated productivity growth is highly sensitiv to business conditions. TFP grew at a rate of about 5 % in booms and about 1 % in slack years.

To sum up: On the average, labour productivity growth and output growth varies a lot between German states. This difference is more pronounced during the eighties. Compared to the differences in output growth or some other economic indicators, as it is documented in Seitz and Licht (1993), there is only a small North-South divide also with respect to total factor productivity measure in the second decade. Given the differences in the weighted input growth rates we cannot attribut TFP-growth differentials to the differences in factor input growth, solely. Unlike the evidence presented for the US manufacturing by Moomaw and Williams (1991) or Hulten and Schwab (1984) we conclude that interregional differences are not the result of differences in the growth of private capital and labour inputs. Our data show, however, that rapid TFP growth is associated with rapid output growth.

3. Infrastructure Investment and Productivity Growth

One major shortcoming of the traditional analysis above is the assumed constant returns to scale production technology and the neglect of the provision of public infrastructure services, e. g. roads, as a further input into the private production process. The role of public infrastructure provision for private economic acitivity has recently attracted much attention by economists. Thus, for the U. S. it is argued that the neglect of public investment is one major source of the productivity slowdown and the falling behind of the U. S. economy. With respect to the economic situation in the East of Germany, several scholars argue that the slow take-off in the Neue Bundesländer is due do the small and outdated stock of public infrastructures inherited by the former GDR. Therefore, it seems worthwile to examine the quantitative importance of infrastructures empirically.

To uncover the productivity enhancing effects of the provision of public infrastructure we introduce the stock of public capital as an additonal unpaid factor into the production function. As it is recently discussed in the literature (see Munnell 1992) there are clearly some advantages adopting the cost function approach instead of a production function. The cost function approach enables us to take into acount the effects of factor prices and to use also some less restrictive assumptions concerning firm` technology and behavior.

Although we omit here a detailed description of our empirical model, we give a rough outline of our approach.[4] As a starting point we assume that the technology of the manufacturing sector of region can be caught in a cost function

$$(2) \quad C_i = C_i(w_i, P_{Ai}, P_{Bi}, t, X_i, KI_i)$$

where w_i denotes 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 proxied by the stock of public capital. The time counter t is included as a proxy for technical change. For notational convienence we suppress the time index on all variables in equation (2) as well as in the following equations. The productivity impact of public services can easily be derived by differentiating (2) with respect to KI_i which yields:

[4] A detailed description of the model used can be found in Seitz and Licht 1993.

$$(3) \quad s_i = -\frac{\partial C_i(W_i, P_{Ai}, P_{Bi}, t, X_i, KI_i)}{\partial KI_i}$$

where s_i denotes the change in private production cost in the industry in region i if the public capital stock increases by one unit. Public capital enhances productivity if it decreases private cost which implies $s_i > 0$. s_i is called the shadow price of public capital. If we have an estimate of s_i we can derive an estimate of the implicit cost share of public services as:

$$(4) \quad s_{KIi} = s_i.(KI_i/C_i)$$

Using the implicit cost share we can adjust the TFP measure as derived in equation (1) to take into account the productivity impact of KI:

$$(5) \quad f_{it,KI} = f_{it} + 0.5\,(s_{KIi,t} + s_{KIi,t-1}).dKI_{it}/dt.$$

The public capital adjusted TFP measure $f_{it,KI}$ is always smaller than f_{it} as long as public capital enhances private productivity. Thus, the provision of public intermediate inputs provides one factor in explaining the 'unexplained' Solow residual. In addition, equation (5) reveals that low investment in public infrastructures can provide one reason for the generally observed productivity slowdown.

Using the cost function approach it also possible to examine the impact public capital has on the demand for private inputs by evaluating the derivative of the conditional demand for private inputs with respect to public capital, which in the case of the demand for labor is given by:

$$(6) \quad \frac{\partial A_i^*}{\partial KI_i} = \frac{\partial^2 C_i(w_i, P_{Ai}, P_{Bi}, t, X_i, KI_i)}{\partial P_{Ai} \partial KI_i}.$$

Space limitations prevent us from going in more details on the estimation of the cost and associated factor demand functions; the complete model and the estimation results are reported in Seitz and Licht (1993). We estimated a generalized translog cost function with labor (measured in working hours), structures and equipment capital as well as the stock of public capital. The cost function together with the two independent factor share equations for labour and equipment have been estimated using annual data for the 11 states for the period 1970-1988. Regional specific effects have been accounted for by introducing region specific dummies in all equations and applying a panel estimation technique to the model.

We used likelihood-ratio test statistics to test for the presence of region specific effects, for constant returns to scale in the underlying production technology, and the overall significance of the infrastructure variable. These tests revealed that regional specific effects are significant, that the data is incompatible with the assumption of constant returns to scale, and that the infrastructure variable enters our model significantly.

Summarising the economic implication, our estimates suggest 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. The estimated shadow prices for public capital are positive in virtually all periods and regions. The only exception is the city state Bremen for which we estimate a negative willingness-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. This probably indicates that in the case of Bremen the industrial structure which emerges in the eighties does not fit to the existing infrastructure or turning the other way round the infrastructure investment in eighties doesnot fit the existing industrial composition of that state.

Table 5. Effects of Public Capital on Private Cost and Input Demand

	(1) $\eta_{C,KI}$	(2) $\eta_{A,KI}$	(3) $\eta_{B,KI}$	(4) $\eta_{L,KI}$
Schleswig-Holstein	- 0.194	0.148	0.161	- 0.297
Hamburg	- 0.104	0.350	0.402	- 0.203
Niedersachsen	- 0.306	0.014	0.121	- 0.408
Bremen	- 0.018	0.415	0.364	- 0.114
Nordrhein-Westfalen	- 0.357	- 0.041	0.095	- 0.409
Hessen	- 0.281	0.047	0.267	- 0.381
Rheinland-Pfalz	- 0.254	0.031	0.144	- 0.359
Baden-Württemberg	- 0.325	0.037	0.169	- 0.402
Bayern	- 0.342	0.017	0.097	- 0.402
Saarland	- 0.097	0.190	0.344	- 0.201
Berlin	- 0.099	0.206	0.244	- 0.204
Average:	- 0.216	0.129	0.219	- 0.317

Notes:

(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) Public capital elasticity of the private labour demand.

Table 5 presents in column (1) the estimated elasticities of the private production cost with respect to public capital which indicates the %-decrease in private production cost if the stock of public capital is expanded by one %. On the average, the cost elasticity of public capital is about 0.2. These cost reducing effects are largest in those states which have large areas, such as Nordrhein-Westfalen, Bayern, and Baden-Württemberg whereas this effect is quite small in those states which are in fact cities like Berlin, Hamburg, and Bremen. This might reflects that for large-area states a well-developed road system is very important, given that nearly 50% of the public capital stock consists of traffic infrastructures.

In column (2) and (3) the elasticities of the private demand for equipment capital and the private demand for structures with respect to public capital are reported. There are large differences between these two elasticities. Therefore, it is necessary to split up the private capital stock into structures and equipment. On

the average, the impact on structure is about 100 % larger than the impact on equipment demand. Again, our results point to differences between small-area and large-area states. In small area-states, public capital effects private demand for structures resp. equipment by the same amount. In large-area states public infrastructure investment has only a small effect on private demand for equipment but a large effect on structures. Moreover, both elasticities are larger in small states than in large state. The overwhelming importance of public capital provision for private structures investment seems to be obvious. Cities and communities make investments into land-development programs. These types of infrastructure investment favour the location and/or relocation of firms which makes private investment into structures more profitable and/or necessary and therefore is directly linked to private demand.for capital. Taking into account that regions use public infrastructure investment to attract private firms the results are quite compatible with our everyday-life experience. Two states do not fit into these patterns. For Bremen the estimated effect on equipment dominates the effect on structures. For Nordrhein-Westfalen our estimates indicate rather small effects of public investment on private investment demand and we even get a substitutive relationship between private structure investment and public investment.

Finally, column (4) reports the elasticity of the demand for private labour with respect to public capital. On the average a one percent increase of the stock of public infrastructure reduces the private demand for labour by 0.3 percent. This labour saving effect is more important for the large-area states. In interpreting the effect one has to keep in mind that our estimates assume that output is given. Because of the cost reducing effect of the provision of public infrastructure which c.p. induces lower prices and therefore increases output, the total effect on labour demand could still be positive.

Let us now go back to the productivity issue. As shown in equations (4) and (5) the cost reducing effect of public infrastructure can be translated into a productivity enhancing effect.[5] **Table 6** reports the total factor productivity taken from table 3, the shadow cost weighted growth rate of of public infrastructure as an additional source of growth and the TFP-measure adjusted for the influence of public capital.

[5] This implies a small error in our calculations due to the implicit assumption of constant returns to scale but does not affect the main argument.

Table 6. Total Factor Productivity Growth and Infrastructure Investment

	Total Factor Productivity	Infrastructure effect	TFP adjusted for infrastructure	Period
Schleswig-Holstein	4.14	0.99.	3.15	71 - 79
	1.32	0.44.	0.88	80 - 88
Hamburg	3.90	0.38	3.52	71 - 79
	1.53	0.13	1.40	80 - 88
Niedersachsen	4.06	1.55	2.51	71 - 79
	2.02	0.62	1.40	80 - 88
Bremen	3.51	0.11	3.40	71 - 79
	2.08	0.01	2.07	80 - 88
Nordrhein-Westfalen	3.30	1.81	1.49	71 - 79
	1.88	0.71	1.17	80 - 88
Hessen	4.23	1.39	2.84	71 - 79
	1.61	0.56	1.05	80 - 88
Rheinland-Pfalz	3.36	1.28	2.08	71 - 79
	1.96	0.52	1.42	80 - 88
Baden-Württemberg	3.46	1.57	1.87	71 - 79
	1.91	0.72	1.19	80 - 88
Bayern	3.90	1.86	2.04	71 - 79
	2.15	0.91	1.24	80 - 88
Saarland	5.39	0.41	4.98	71 - 79
	2.73	0.17	2.56	80 - 88
Berlin	3.85	0.56	3.29	71 - 79
	2.83	0.32	2.51	80 - 88
Total: West Germany	3.65	1.08	2.56	71 - 79
	1.91	0.46	1.45	80 - 88

As shown in Table 6 the productivity slowdown of the eighties can partly be explained by the reduction in the rate of infrastructure investment. On average, the growth rate of infrastructure reduces our original TFP-growth by about 30% in the first decade and about 25% in the second decade. This reduction is very unevenly distributed over the states. As a rule, the provision of infrastructure seem far more important as a source of economic growth in the large-area states than in the city states which mirrors the uneven cost reduction effects we discussed above. Adjusting for the infrastructure component the coefficient of variation of TFP-growth rates gets smaller. This again points to the importance of the public capital stock in explaining productivity development.

4. Summary and Conclusions

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. Our estimates show that private capital has quantitatively very different effects on the private demand for structures and equipment and therefore it is of crucial importance to make a distinction between the two components of private capital. Moreover, the provision of public capital induces a change in the composition of private factor inputs demand favouring private capital formation.

Investments in public capital have a large cost reducing effect on private production. We translated this effect into a productivity enhancing effect and showed that the reduction in the growth rate of the public capital stock can partly explain the productivity-slowdown of the eighties. Moreover, adjusting TFP-growth for the infrastructure effect the North-South productivity differential in Germany, which seems to be evident using labour productivity and unadjusted TFP measures, virtually disappears. Therefore we conclude that we have untangled one major effect for differences in regional productivity development as well as for the explanation of the 'Solow'-residual.

Finally, we comment on some shortcomings and possible extentions of our approach. First of all, because we did not consider the fact that firms directly and indirectly pay for public infrastructure services by taxes. Secondly, our approach did not take into account output adjustments of firms as a consequence of the provision of public infrastructure. Thirdly, the lack of adequate data forces us to use several restrictive assumptions concerning different levels of aggregations of our data. We have been unable to conduct our analysis on a more disaggregated level of the manufacturing sector. As the sector composition of the manufacturing industry varies considerably across the 11 federal states this might affect our estimation results. Measuring the influence of the provision of public infrastructure services by an highly aggregate public capital stock variable can also bias our estimates. Therefore, further research should be dedicated to a more sophisticated measurement of public services in which different kinds of public infrastructures as well as other characteristics, such as quality of the capital stock, are considered.

Appendix: Data Description

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.[6] 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):

$$P_{Ai} = PI_{Ai}\left(R_{Gs} + \delta_{Ai} - \frac{dPI_{AI}}{dt}\right) \text{ and } P_{Bi} = PI_{Bi}\left(R_{Gi} + \delta_{Bi} - \frac{dPI_{BI}}{dt}\right)$$

where δ is the depreciation rate ($\delta_{Ai} = 0.1771$; $\delta_{Bi} = 0.0548$)[7]. PI_{Ai} and PI_{Bi} are the[8] price indices for equipment and structures, R_{Gl} and R_{Gs} are the interest rate on long (10 years) term and short (5 years) term government bonds. 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.

For the years 1970-85 the regional data have been published in 'Volkswirtschaftliche Gesamtrechnung der Länder: Entstehung, Verteilung und Verwendung des Sozialproduktes in der Ländern der Bundesrepublik Deutschland, revidierte Ergebnisse 1970-1985, Heft 15' and 'Volkswirtschaftliche Gesamtrechnung der Länder: Anlagevermögen, Anlageinvestitionen und Abschreibungen der Länder der Bundesrepublik Deutschland 1970-1985, Heft 17'. Regional data 1986-1988 have been supplied by the 'Arbeitskreis Volkswirtschaftliche Gesamtrechnung der Länder'. This institution also provides data on the stock of public capital - net, evaluated at constant prices - available in the various federal states. However, the public capital stock provided by this source excludes the stock of capital invested in the road network.[8] 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). We used these national figures and assigned every federal state a stock of road network capital proportional to its share of the length of the total public road 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_G and the depreciation rates - have been calculated region-specific.

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6 Official statistics provide working hours for blue collar works only.

7 Both depreciation rates have been calculated using data supplied by official statistical authorities.

8 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.

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