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Regional Infrastructure Policy and Its Impact on Productivity: A Comparison of Germany and France

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Keywords: Infrastructure Policy, Productivity, Germany, France
JEL Classification: C33, H54, O57

ZUSAMMENFASSUNG

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Die Arbeit beschreibt die unterschiedlichen institutionellen Rahmenbedingungen, unter welchen Planung und Finanzierung von Infrastruktur in Deutschland und Frankreich realisiert werden. Weiterhin werden die wirtschaftlichen Effekte von Infrastruktur ökonometrisch für deutsche und französische Regionen geschätzt. Es wird Evidenz dafür gefunden, dass regionale Straßeninfrastruktur einen signifikanten Einfluss auf den regionalen Output hat. Wir finden auch empirische Evidenz dafür, dass in Deutschland die Priorität für die Angleichung der Lebensverhältnisse in den Regionen eine wichtige Determinante für regionale Infrastrukturpolitik ist.

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1 Introduction

At the end of the 1960's, economic research began to deal increasingly with the importance of infrastructure for economic development. Early studies e.g. Frey (1970), Jochimsen (1966), Jochimsen and Simonis (1970) or Simonis (1977) dealt especially with the theoretical aspects of infrastructure provision and infrastructure's conceptual basis.

Since the end of the 1980's, there has been greater interest also in empirical infrastructure research. By using production function approaches, the direct and indirect effect of improvements in infrastructure on private productivity have been estimated. The studies by Aschauer (1988; 1989a; 1989b) have not only raised the attention of scientists but have also had an effect on economic policy. As a result, spending on public infrastructure in the US increased considerably during President Clinton's first term of office (Gramlich, 1994).

For the period 1949-1985, Aschauer (1989a) reports a significant elasticity of output with respect to public non-military capital between 0.38 and 0.56 for the US using aggregated time series data. Thus the estimated marginal productivity of public capital in this study considerably exceeded that of private capital. This finding implies that returns resulting from public investment were higher than those arising from private investment projects.

Turning to the hypothetical effects of infrastructure, Aschauer (1995), for example, postulates that public capital can have both a direct and indirect effect on private output. The direct effect arises because changes in public capital stock alter the level of output by making private labour and capital inputs more or less productive. The indirect effect arises because an increase in public capital stock will affect the marginal products of labour and private capital, which in turn influence the chosen quantities of private inputs.

Furthermore, Aschauer advances the theory that the up to 60 percent of the decrease of productivity growth in the USA during the 1970's and 1980's can be attributed to the cut-back in public infrastructure investment during this period.

However, some economists have voiced doubts about the plausibility of the results of Aschauer's studies (Aaron, 1990; Gramlich, 1994; Hulten and Schwab, 1991; Jorgenson, 1991; Tatom, 1991a). One criticism is the high degree of aggregation of the data used by Aschauer. Therefore, more recent research works have examined the effects of infrastructure on regionally more disaggregated levels.

Yet the results of these studies are not unequivocal. Whereas for instance Munnell (1990; 1992; 1993) confirm the hypothesis formulated by Aschauer, the studies by Baltagi (1995*a*), Garcia-Milà, McGuire and Porter (1996), Holtz-Eakin (1994), or Holtz-Eakin and Schwartz (1995) find no evidence of a significant influence of infrastructure on productivity for the US.

Authors such as Baltagi (1995*a*) or Holtz-Eakin (1994) point out that regional effects should be taken into consideration in econometric examinations on a disaggregated level. Differences between the regions regarding the geographical location (centre versus periphery), climate or factor endowments can be captured by econometric techniques using fixed or random cross-sectional effects. Our study takes this criticism into account in that the econometric methods applied here are able to estimate such regional-specific influences.

In the literature, when referring to the differentiation of individual areas of infrastructure,[1] a distinction is made between household-related infrastructure and business / or business-related infrastructure. Household infrastructure covers healthcare and educational, leisure and cultural institutions. Road infrastructure can be placed under the heading of business related infrastructure. Not only transport belongs under this heading, also energy and water provision and telecommunications infrastructure are business-related (Frey, 1978). This study focuses on road infrastructure because comparable data for both the French and German regions for this section of infrastructure are available.

The purpose of this essay is threefold. First, we survey the institutional framework of infrastructure policy as an instrument of regional policy in Germany and France. Second, we study the effects of infrastructure on private productivity. Third, we investigate the determinants of regional infrastructure investment al-

[1] Throughout the essay we use the terms 'infrastructure' and 'public capital' interchangeable. Note, however, that in a more rigorous fashion public capital refers to infrastructure services that are solely publicly financed, whereas the more general term 'infrastructure' applies also to privately financed services.

location.

One contribution of our study to the existing empirical infrastructure literature is that it simultaneously refers to both French and German regions. The main advantage of pooling the data for Germany and France is that the database is expanded and therefore we are able to obtain more reliable estimates of the parameters of the model. A further contribution is that our study implements some methodological improvements in comparison with previous investigations in that the estimations of the effects of infrastructure on French regions are carried out by taking regional-specific effects into account. Another important aspect of our study, which has seldom been dealt with in the existing literature, is that it highlights the different institutional frameworks under which infrastructure policy is carried out in Germany and France. Finally, our study discusses and implements a new framework for studying empirically the determinants of regional infrastructure investment allocation.

The further development of this essay is as follows: In the next subsection, we provide an overview on related studies. In the second section we compare regional policies in Germany and France. In addition, some theoretical aspects of the rationale of regional policies are collated and discussed. In the third section we present the results of the empirical analysis of the effects of infrastructure on productivity. Furthermore, an investigation on the empirical determinants of the allocation of road infrastructure is carried out. In the fourth and final section, the results of the study are summarised and discussed.

1.1 Related literature

A number of investigations into the effects of infrastructure on private production in Germany have already been carried out (Conrad and Seitz, 1992; Conrad and Seitz, 1994; Erber, 1995; Hofmann, 1996; Licht and Seitz, 1994; Schlag, 1997; Seitz, 1993; Seitz, 1994; Seitz, 1995; Stephan, 1997). However, as far as we know only two studies have been undertaken with regard to the impact of infrastructure on regional development in France (Fritsch, 1995; Prud'Homme, 1996).

The majority of the previous studies with regards to Germany apply a cost function approach, only a few studies are based on a production function approach. The regional and sectoral levels of reference of the respective studies are sometimes very different, making a comparison of results very difficult. Furthermore, also different measures and definitions of infrastructure and public capital respectively are used in these studies.

For example Licht and Seitz (1994) examine the economic importance of infrastructure at the level of the 11 West German federal states. The method of investigation is based on a cost function approach. The estimated cost elasticity for public capital is significant and ranges from -0.01 to -0.36. Also, the studies by Conrad and Seitz (1992), Seitz (1993), and Conrad and Seitz (1994) confirm the evidence of cost effects arising from infrastructure at the aggregated level of West Germany. Erber's study (1995), which performs the analysis for both Germany and the US finds only for 4 of 26 branches an influence of the public capital stock on costs.

In Seitz (1995), 85 self-administrated cities in Germany serve as the regional level of reference. Significant effects on the cost of private production are found in this infrastructure study. Hofmann (1996) analyses the effects of public infrastructure on productivity applying various econometric methods for Hamburg. However, no plausible results are obtained so that it is not possible to make conclusions about the importance of public infrastructure for Hamburg.

In Stephan (1997), the influence of road infrastructure on production in the manufacturing industry in the 11 West German federal states for the period 1970-1995 is examined based on a production approach. Using this method, significant effects of infrastructure are found for almost all specifications.

Schlag (1997) studies the causality link between the public infrastructure capital and the output of the total business sector in Germany at an aggregate level. Cointegration analysis is applied and error correction models for time series and panel data results from Granger causality tests are presented. The results indicate bi-directional causality (feedback) between the public infrastructure capital and the output.

Fritsch (1995) estimates a significant effect of infrastructure on productivity in 21 French regions. Also Prud'Homme (1996), whose study is likewise based on the 21 French regions, provides evidence of a significant effect. However, regional specific effects are not specified in the econometric estimations in both of these studies.

In sum, so far no clear-cut evidence of the effects of infrastructure on private productivity emerges from empirical studies carried out for Germany or France. Whereas a number of studies find significant effects of infrastructure others do not. However, it is worth pointing out that the results of the different approaches for testing the significance of infrastructure are hardly comparable due to the different levels of regional or sectoral reference as well as due to the different definitions of infrastructure capital used in the studies. In the following section, we highlight and discuss the differences between infrastructure policies in Germany and France. Before that, we provide evidence on the development of regional income disparities in Germany and France.

2 A comparison of infrastructure policies in Germany and France

Infrastructure is often used as an instrument for regional economic policies in order to reduce regional disparities in income. Proponents of active regional economic policies maintain that without these state support, disparities in income will increase between the regions.

Figure 1 shows the development of the regional differences in productivity in Germany and in France. Regional productivity is measured as gross value added per worker. For each year, we have calculated the coefficient of variation for this variable. Note that the coefficient of variation is a unitless measure of relative variability. It is defined as the ratio of the standard deviation to the mean expressed as a percentage. If a convergence of regional productivities occurs, the coefficient of variation will decrease over the course of time.

Figure 1 reveals that although regional differences in productivity decreased during the period 1970-81, they increased slightly from 1982-86, and following a further fall during the period 1987-88, have increased again since 1989. There-

Fig. 1: Regional Productivity Differences for 11 West German Bundesländer 1970-95, 21 French regions 1978-92

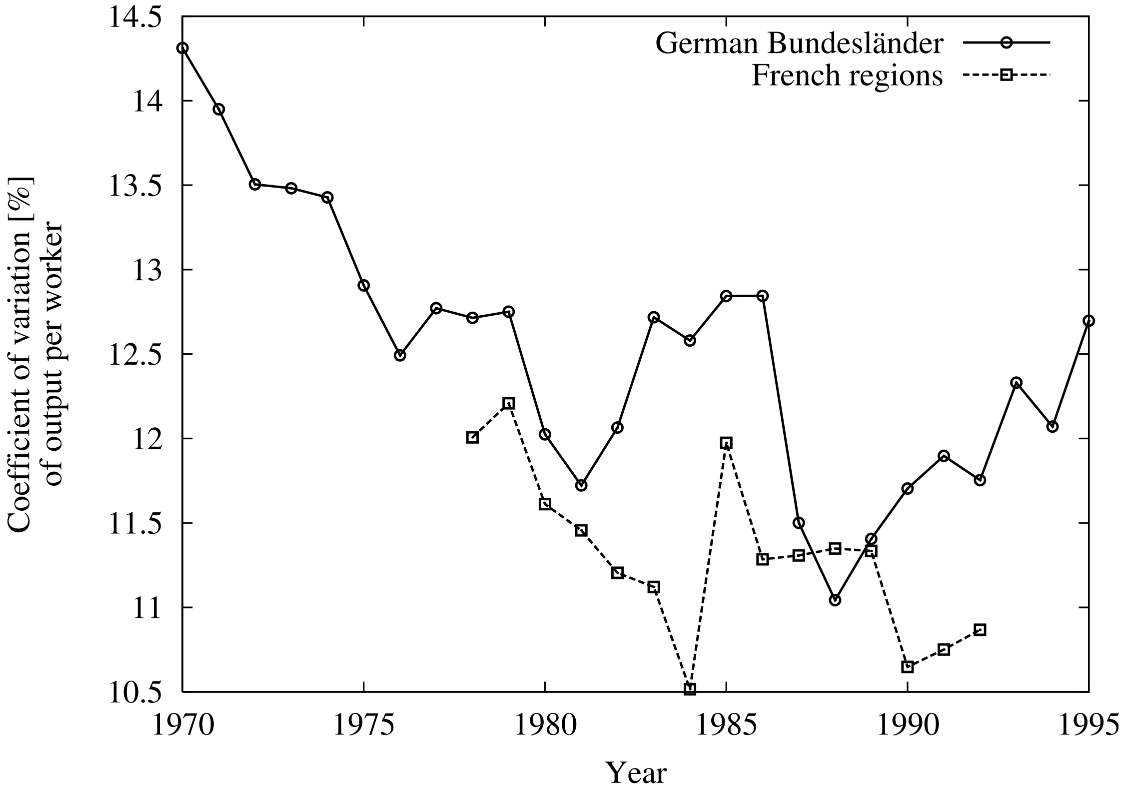
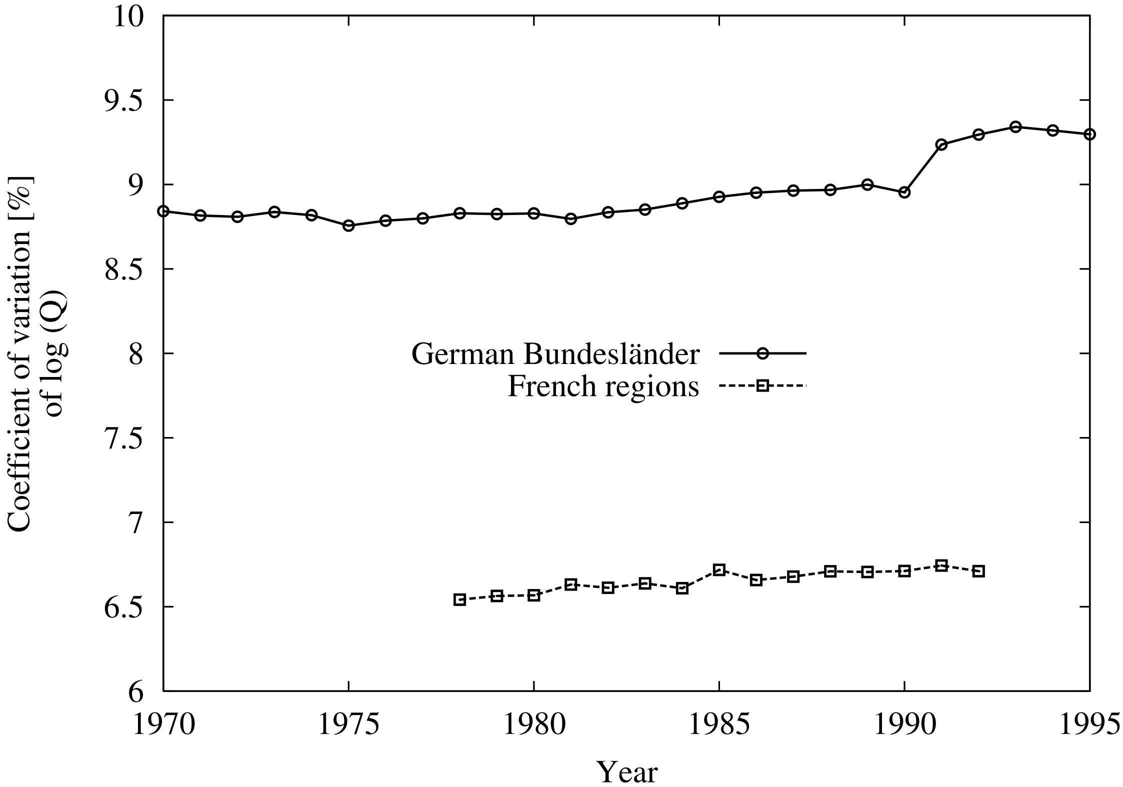


Fig. 2: Regional Differences of Value Added for 11 West German Bundesländer 1970-95, 21 French regions 1978-92



fore, at least for the period 1976-95, it is not possible to determine a convergence of regional productivity in Germany. Note, that this result for the 11 West German states, which emerges from a rather descriptive analysis, is in line with the findings of studies using more sophisticated analytical tools e.g. unit root tests for panel data (Bohl, 1998; Funke and Strulik, 1999).

A similar picture is found for France. Although regional differences decreased during the period 1979-84 and 1986-90, increases can be seen in the years 1984-85 as well as since 1991. This result that regional convergence can neither be found for France nor for Germany is also confirmed by Figure 2. Here the coefficients of variation are calculated based on the logarithms of regional value added. By taking logarithms of the levels of output the regional absolut differences are transformed into relative percentage differences. Again, we expect a decrease in the coefficient of variation if a convergence in regional outputs occurs.

In contrast to Figure 1, where in the coefficient of variation the effects of the development of regional labour force are also included, only the development of the relative regional output differences is captured in Figure 2 independent of the development in the labour force (for instance due to labour migration between regions). Apparently, in the period under investigation neither in France nor in Germany convergence of regional income is observed.

As a result of this section we state that a decrease in regional disparity in income can neither be observed in Germany nor in France during the period 1970-1995 and 1978-1991 for France respectively. However, when no regional convergence can be found in the two countries the question arises whether regional policies were efficient or whether the disparities would have been even more marked without active regional policies. The following section describes some important institutional differences in infrastructure and regional policy in Germany and France.

2.1 The different frameworks of infrastructure policy in Germany and France

The geographical differences (density of population 104 inhabitants per square km in France and 223 inhabitants per square km in Germany) highlight the differing conditions for the forming of infrastructure policy in Germany and in France. In Germany in 1992 there were a total of 11,000 km of motorway ('Bundesautobahnen'), 42,000 km A roads ('Bundesfernstraßen'), 170,140 km B roads (85,200 km 'Landesstraßen' and '84,940 Kreisstraßen') and 413,000 km smaller roads and streets ('Gemeindestaßen') (Source: Bundesministerium Für Verkehr, 1995).

In France there are similarly 5 categories of road: 'autoroutes' (motorways), 'routes nationales' (A roads), 'routes départementales' and 'voies communales' (B roads) and 'chemins ruraux' (smaller roads and streets).

In 1992 the length of the French motorway network was 9,081 km and is therefore comparable with the extent of the German system. The length of the 'routes nationales' consisting of 27,500 km is around half the length of the German A roads. On the other hand, there are 365,600 km of B roads and in addition a network of smaller roads and streets ('voies communales') which, with its 579,000 km is clearly longer than in Germany. This can be attributed to the larger geographical area of France (Centre National de Documentation Pédagogique, 1998).

However, not only the geographical differences but also history and politics have contributed to forming differing infrastructure policies. French infrastructure policy is on the one hand marked by strong regional policy considerations and on the other by the emphasis given to individual large infrastructure projects (Kistenmacher, Marcou and Clev, 1994).

Due to its tradition of political centralism in the first years of the post second world war, a markedly interventionist regional policy was approved. For a long time Paris and the greater Paris area (Ile-de-France) stood in the foreground of regional development. However, in the following years a policy of de-concentration and the development of industrial centres outside of the area around Paris was increasingly pursued. The central regional planing institution DATAR (=Délégation à l'aménagement du territoire et à l'action régionale), set up in 1963 for this purpose, has wide-reaching decision making powers. In order to improve the carrying out of proactive centrally controlled regional policy DATAR was put directly under the control of the Prime Minister.

Since the beginning of the 1980's it has also been possible to observe an increasing tendency towards the decentralisation of planning in France. The hierarchical control of the 1960's and 1970's has been superseded in the form of a contractual agreement between the central state and the regions (Neumann and Uterwedde, 1994).

Furthermore, the private building and management of motorways plays an important role. Private or non-profit making firms manage the majority of the motorway network (6,490 km of a total of 9,081 km) and charge the road users tolls. Through concessions, the public authorities grant the private firms specific rights. Not only the maintenance and management of the motorways are financed by tolls, but the building of further motorways is also financed this way (Ministère de L'Equipement, des Transports et du Logement, 1998).

The 'Direction des Routes' is responsible for the financing and planning of the 'routes nationales' and the state motorways. This is subordinate to the ministry responsible (Ministère de l'Equipement, des Transports et du Logement). On the one hand, the 'Direction des Routes' sets the targets for road and motorway construction according to a certain scheme (Schéma directeur routier national). On the other hand the 'Direction des Routes' enacts laws which determine building, maintenance and management. Additionally, the determination of the necessary means for finance is undertaken by the 'Direction des Routes'. The 22 regions are therefore represented by the 'Ministère de l'Equipement, des Transports et du Logement' (DRE) and are subordinate to the 'Direction des Routes'.

In Germany, in contrast to France, several regional metropolitan areas of equal rank have developed over the years (polycentric development). The principle of federalism played an important role in the forming of regional policy in Germany during the post-war period. The constitutional law promoting the convergence of living conditions throughout the regions above all represents an important target of regional policy.

As a result of the federal structure, the states have legislative competence for B roads and smaller roads and streets. On the other hand the federal government is the owner of and responsible for motorways and A roads; these are built and administered upon commission from the federal government by the federal states (Bundesministerium Für Verkehr, 1995).

In the immediate post-war period, the intention was that the federal government would only play a role in setting out the conditions in the planning of regional policies. With the passing of the regional planning law ('Raumordnungsgesetz') in 1965, the importance of the federal government within the federal system was strengthened. Through the federal transport infrastructure plan ('Bundesverkehrswegeplanung'), a transport policy program was introduced which was supposed to co-ordinate all federal transport (federal roads, federal rail and federal waterways). Federal transport infrastructure plans were drawn up by the Federal Cabinet and regularly reformulated. Similar long term transport planning did not exist in France at the time.

To sum up, we can determine that infrastructure and regional policy in Germany was accompanied by the aim of having similar living standards throughout the regions, whereas in France during the last few decades, importance was placed, above all, on decentralisation and the relief of the concentrated area around Paris. The differences which still exist between infrastructure policy in Germany and France will, in the future, become less prominent due to the European integration (Kistenmacher, Marcou and Clev, 1996). In the next section some theoretical considerations regarding the efficiency of regional infrastructure policies are collated and discussed.

2.2 Can regional policies work in principle? Some preliminary considerations

The following reflections should serve as a compilation of several arguments based on economic theory for or against an active role of regional policy. Regional disparities in income often prompt governments to make efforts in order to achieve a more evenly balanced regional economic development. Traditionally, public infrastructure policy has been an instrument for regional economic support. The intention of this policy is to minimise competitive disadvantages in the regions, and promote private investment through the improvement of regional infrastructure.

According to standard neoclassical growth theory built on the assumption of decreasing returns to reproducible factors on the other hand, income disparities arising from differences in regional capital/labour ratios will diminish over time: both trade and factor flows tend to equalise factor prices. A convergence of income in the regions would therefore also take place without active regional policy. Similarly, also the so-called 'rule of thumb' of a 2 percent convergence rate according to empirical studies based on neoclassical growth theory leaves no scope for an active role of regional policy (for an overview, see Barro and Sala-I-Martin, 1995).

Apparently, the presence of externalities (spill-over effects) can give objective reasons for regional economic support. For instance, if negative 'crowding' externalities exist in economically better developed regions, these can be mitigated by regional policies which provide infrastructure to economically less developed regions, so that labour migration from the less to the better developed regions is prevented and externalities thus reduced.

However, according to Homburg (1993) even in the absence of externalities active regional distribution policies can be justified. To analyse the consequences of regional distribution policies, Homburg's model assumes a neoclassical production function $Q_i = f(G_i, K_i, \overline{L}_i)$, $i = 1 \ldots N$, linear homogenous of degree one, where Q_i is region i's output, G_i is the *stock* of public capital in region i, K_i is the *stock* of private capital in region i, and $\overline{L}_i$ is an immobile factor of production in region i, e.g. land endowment, geographical characteristics etc.

The steady state of the model is described by the two conditions: (i) $\tau Q_i = \delta G_i$, where τ denotes the tax rate, δ denotes the depreciation rate of public capital, and (ii) $(1-\tau)F_K^i = r + \delta$, where F_K^i denotes the marginal productivity of private capital for region i and r the exogenous rate of interest. Condition (i) states that in steady state taxes are only used to finance replacement of G_i, and condition (ii) states that the marginal after-tax productivity of private capital equals the rental price of private capital $r + \delta$.

Homburg (1993) shows that a *spatial efficient* allocation of infrastructure can be regarded as a maximisation of the joint total output $\sum Q_i$ given the sum of stocks of private capital $\sum K_i$ and given the sum of endowments with infrastructure $\sum G_i$. The spatial efficient allocation of infrastructure solves the following maximisation problem

$$\max! \sum Q_i, \text{ given } \sum K_i = \overline{K} \text{ and } \sum G_i = \overline{G}. \tag{1}$$

It can be shown that the condition for the spatial efficient allocation applies exactly when the marginal productivities of infrastructure F_G^i and private capital F_K^i in all regions are given as

$$F_G^i = \mu \text{ and } F_K^i = \theta \text{ for all } i.$$

This means that the marginal productivities of private and public capital are equal for all regions. If public and private capital is also homogeneous in a neoclassical sense, then furthermore $\mu = \theta$ should also apply. From this result we can state that under neoclassical assumptions it would be optimal to allocate infrastructure investment in such a way across regions that the marginal productivity of infrastructure is equal in all regions.

An important result of this model is that the spatial efficiency criterion is valid whether the total endowment with infrastructure is optimal or sub-optimal. If the assumptions of the model apply, then an efficient spatial allocation of infrastructure is observed in the steady-state equilibrium even without governmental subsidies. However, as Homburg shows in his further analysis, the adjustment processes to this efficient steady state equilibrium is characterised by an inefficient spatial allocation. This implies that the adjustment path can be improved upon by means of using intergovernmental grants.

As the main result therefore we can state that if the initial allocation of infrastructure stocks of infrastructure across the regions is unbalanced, the joint national product can be increased by a regional infrastructure policy. The target of such a policy should be to balance the ratio of output Q_i to infrastructure stock G_i in all regions, i.e. to equalise the marginal productivities of infrastructure across regions.

However, it should be noted that studies such as Martin (1998; 1999) or Ottaviano and Thisse (1999) arrive at different results regarding the possible effects of regional infrastructure policy. These models of the 'New Economic Geography' predict that the consequences of a policy which targets at the achievement of a balanced spatial allocation of economic activity can result even in greater regional disparities. The mechanism behind this result is that the reduction of transport costs, for example by means of improved transport infrastructure, can have negative effects on the economic development of poorer regions. This will happen if companies from the poorer regions move to take advantage of the agglomeration and scale economics in centrally located regions while at the same time, however, they can maintain their sales outlets in the poorer regions due to the reduced transport costs.

In the next section we analyse empirically whether investment in road infrastructure has a positive effect on economic development. For this purpose, an econometric analysis is carried out based on a production function with panel data for the French regions and the German federal states.

3 Empirical analysis

The first part of the empirical analysis deals with the productivity effects of infrastructure. In the second part, we investigate the determinants of the regional allocation of infrastructure investment.

3.1 Productivity effects of regional road infrastructure in Germany and France

The central hypothesis to be examined empirically is that infrastructure increases private output or reduces respectively the costs for a given unit of output. From a theoretical point of view, this can be the case when infrastructure either directly exerts a positive effect on private factor productivities or indirectly exerts a positive influence on private factor productivities which in turn increases the demand for private factor inputs (Aschauer, 1995).

In the following section, the effects of road infrastructure on productivity are examined using two different approaches

1. Cobb-Douglas production function
2. Transcendental logarithmic (translog) production function according to Christensen, Jorgenson and Lau (1971; 1973).

For the estimations, we employ econometric methods from panel data analysis by specifying fixed cross-sectional effects (Baltagi, 1995*b*; Hsiao, 1986). For the first approach, our empirical model is based on the production function for region i, $i = 1 \ldots N$, in year t, $t = 1 \ldots T$,

$$Q_{it} = A_{it}(t)F(t, X_{1it}, \ldots, X_{Mit}), \tag{2}$$

where Q_{it} describes output, $A_{it}(t)$ technical efficiency (or the Hicks-neutral technical progress) and $X_{1it}, \ldots, X_{Mit}$ describe the M factors of production. Assuming a Cobb-Douglas production technology and with factor inputs labour L_{it}, private capital K_{it} and road infrastructure G_{it} and after taking logarithms and dividing by L_{it}, we obtain the following empirical model is obtained which forms the basis of our empirical assessment

$$\begin{aligned} \ln q_{it} &= \ln A_{0i} + \alpha_t t + \alpha_k \ln k_{it} + \alpha_g \ln g_{it} + \widetilde{\alpha}_L \ln L_{it} + u_{it}, \\ u_{it} &= \rho u_{i,t-1} + \epsilon_{it} - \gamma \epsilon_{it-1}, \\ \text{and } \widetilde{\alpha}_L &= \alpha_k + \alpha_g + \alpha_L - 1, \end{aligned} \tag{3}$$

where u_{it} follows an autoregressive moving average process ARMA(1,1) and ϵ_{it} denotes normal i.i.d. distributed random innovations. In addition, we assume that $A_{it}(t) = A_{0i}exp(\alpha_t t)$. Note that variables in lower-case letters in (3) are defined as $x = X/L$. The parameters α_k, α_g, α_L describe the elasticity of the output Q_{it} with respect to inputs K_{it}, G_{it} and L_{it}.

The advantage of this specification for the production function is that by dividing (2) by L_{it} the problem of heteroscedasticity for the empirical estimation is reduced. Notice also that no 'a priori' restrictions are placed on (3) regarding returns to scale. If the parameter $\widetilde{\alpha}_L$ is significantly different from zero, then the null hypothesis of constant returns to scale is rejected.

Table 1 contains the results for the Cobb-Douglas production function which has been estimated by using the procedure PROC MIXED in SAS V8. A detailed description of the data used in this analysis can be found in the Appendix.

Maximum likelihood estimation (MLE) is applied to all specifications based on a total of 596 observations (281 for Germany and 315 for France). The main benefit of pooling the data for France and Germany is that the analysis can be based on a larger data set and therefore more reliable estimates of the parameters of the model are obtained.

In column (1), the model is estimated assuming heterogenous parameters for German and French regions. Note, that in contrast to Ordinary Least Squares (OLS) estimation the parameters in column (1) are different due to the specified covariance structure from parameters that would be obtained by running two separate regressions for German and French regions.

In column (2), we assume parameter homogeneity for German and French regions except for the covariance parameters ρ and γ. That means that the specification in column (2) can be deduced from column (1) by imposing restrictions with respect to parameter homogeneity on the specification of column (1). Furthermore, in column (3), except for labour and the covariance parameters ρ and γ, parameter homogeneity across German and French regions is assumed.

Note, that fixed cross-section effects are added to all specifications (1)-(3) of Table 1. The results of likelihood ratio (LR) tests not reported here imply that these fixed cross-section effects are significantly different from zero. Also, because a linear time trend t is included in eq. (3), it is not possible to estimate additional time effects due to the resulting singularity.

The ARMA(1,1) parameters ρ and γ for both Germany and France are significantly different from zero for all specifications. The model selection criteria AIC and SBC, which we describe below indicate that these specifications are preferred compared with AR(1) alternatives not reported here. The displayed 'null model

Tab. 1: Regression Results for the Productivity Effects of Road Infrastructure

	Maximum-Likelihood Estimations (MLE)					
	(1)		**(2)**		**(3)**	
Intercept	*fixed effects******		*fixed effects******		*fixed effects******	
t	0.0114[1] 0.0141[2]	(6.88)*** (7.74)***	0.0151	(12.93)***	0.0133	(10.67)***
$\ln k$	0.2310[1] 0.1254[2]	(3.03)*** (3.36)***	0.1162	(3.55)***	0.1457	(4.28)***
$\ln g$	0.0828[1] 0.1282[2]	(1.32) (2.13)**	0.0837	(2.12)**	0.1120	(2.79)***
$\ln L$	0.3455[1] -0.2932[2]	(3.56)*** (-3.39)***	-0.0588	(-0.94)	0.2784[1] -0.3337[2]	(3.18)*** (-4.14)***
AR(1) ρ	0.7857[1] 0.5888[2]	(16.79)*** (7.08)***	0.8370[1] 0.5257[2]	(20.96)*** (6.15)***	0.8172[1] 0.6303[2]	(18.99)*** (8.29)***
MA(1) γ	0.8477[1] 0.6431[2]	(29.35)*** (12.89)***	0.8823[1] 0.5977[2]	(34.55)*** (12.08)***	0.8678[1] 0.6686[2]	(31.59)*** (13.69)***
Null Model LR Test χ^2	447.9***		504.1***		506.4***	
Log-Likelihood	1531.2		1514.8		1528.7	
AIC	1485.2		1472.8		1485.7	
SBC	1451.5		1442.0		1454.2	
Observ.	281[1] 315[2]		281[1] 315[2]		281[1] 315[2]	

Parameters for [1]German regions, [2]French regions, otherwise for both regions (homogenous).
Approx. t-statistics are given in parentheses. Significance levels: *10 %, **5 %, ***1 %.
Dependent variable is the natural logarithm of (regional value added / labour).

likelihood ratio test' checks the model without covariance parameters against the alternative of the specified ARMA(1,1) covariance structure. Thus, the 'null model' without covariance structure parameters is rejected for each of the three specifications (1)-(3).

In column (1) of Table 1, the estimates of the parameters of the input factors k, g and L are statistically significant for the French regions. For the German 'Bundesländer' (federal states), estimates of the parameters of input factors k and L are statistically significant, however not for g. Note, that constant returns to scale are rejected both for German as well as for French regions.

In column (2), a decrease in the value of the log likelihood from 1531.2 in column (1) to 1514.8 in (2) can be observed. Indeed, the LR test for the restriction of parameter homogeneity, $-2[1514.8 - 1531.2] = 32.8 \backsim \chi^2(4)$, is highly significant, thus the null hypothesis of parameter homogeneity across German and French regions is rejected. This is also reflected in the decrease of the Akaike Information Criterion (AIC) (Akaike, 1974), which has been computed as AIC$= l(\widehat{\theta}) - d$, where $l(\widehat{\theta})$ is the maximised log likelihood and d is the effective number of parameters (fixed effects and covariance parameters). It can be used to compare different models; the model with the largest AIC is deemed best. Similarly, Schwarz's Bayesian Criterion (SBC) (Schwarz, 1978) has been computed as SBC$= l(\widehat{\theta}) - \frac{1}{2}d \log N$, where N equals the number of valid observations for maximum likelihood estimation. Again, models with larger SBC are preferred, but note also that SBC penalises models with a greater number of parameters more than AIC does, that means it will lean toward a simpler model. Therefore, the specification of column (1) is preferred compared to (2) by both criteria.

However, the rejection of specification (2) is mainly driven by the heterogeneity of the parameter for labour between German and French regions. Therefore, in column (3) we allow for this heterogeneity, whereas the other parameters (except the covariance parameters) are restricted to be equal across German and French regions. In contrast to column (2), this specification is not rejected by the LR test, $-2[1528.7 - 1531.2] = 5 \backsim \chi^2(3)$. Furthermore, also the AIC and SBC criteria are higher than for column (1). Thus, we conclude that column (3) contains the results of the preferred specification of the empirical model. We find that the time trend t with a value of 0.0133 is significant, and private and public capital is significant with values of 0.1457 and 0.1120 respectively. In sum, the main finding of the performed analysis is that road infrastructure is significant for private production at the regional level.

However, the Cobb-Douglas production function approach restricts the elasticities of input substitution to equal one. In order to overcome this limitation, our second approach is based on a translog production function

$$\begin{aligned}\ln Q_{it} &= \ln A_{0it} + \alpha_t t + \alpha_k \ln K_{it} + \alpha_g \ln G_{it} + \alpha_L \ln L_{it} \\ &+\alpha_{kg} \ln K_{it} \ln G_{it} + \alpha_{kl} \ln K_{it} \ln L_{it} + \alpha_{gl} \ln G_{it} \ln L_{it} \\ &0.5 \left[\alpha_{kk} \ln^2 K_{it} + \alpha_{gg} \ln^2 G_{it} + \alpha_{ll} \ln^2 L_{it}\right] + \epsilon_{it}, \\ u_{it} &= \rho u_{i,t-1} + \epsilon_{it} - \gamma \epsilon_{it-1}.\end{aligned} \tag{4}$$

Again, we assume that u_{it} follows an autoregressive moving average process ARMA(1,1). The effect from public input G on private factor productivities, i.e. $\partial^2 Q/\partial K \partial G$ and $\partial^2 Q/\partial L \partial G$, can be derived from the estimates of equation (4) as

$$\widehat{\alpha}_{kg} = \frac{\partial^2 \ln Q}{\partial \ln Q \partial \ln K}, \qquad \text{and} \qquad \widehat{\alpha}_{gl} = \frac{\partial^2 \ln Q}{\partial \ln G \partial \ln L}, \tag{5}$$

from which $\partial^2 Q/\partial K \partial G$ and $\partial^2 Q/\partial L \partial G$ can be computed as

$$\frac{\partial^2 Q}{\partial K \partial G} = \widehat{\alpha}_{kg} \frac{Q}{KG}, \qquad \text{and} \qquad \frac{\partial^2 Q}{\partial G\, L} = \widehat{\alpha}_{gl} \frac{Q}{G\, L}. \tag{6}$$

Since the ratios Q/KG and Q/GL are positive, we can infer from the signs of $\widehat{\alpha}_{kg}$ and $\widehat{\alpha}_{gl}$ whether the effect of G on private factor productivities is positive or negative respectively.

Furthermore, several restrictions on the production technology can be tested within a translog function framework. If technology is homogeneous, then the sum of the coefficients of the squared terms and the cross-effects will be zero

$$\sum_p^m \sum_l^m \widehat{\alpha}_{pl} = 0, \tag{7}$$

where $p, l \in \{K, G, L\}$, $m = 3$. In addition, linear homogeneity requires the above condition plus that the sum of the linear terms equals one (Chambers, 1988)

$$\sum_{p}^{m} \widehat{\alpha}_p = 1. \tag{8}$$

We obtain the following results for the translog production function approach

$\widehat{\ln Q_{it}}$ = fixed effects***

$+0.014\, t$	$-0.445 \ln K_{it}$	$+0.740 \ln G_{it}$	$-0.659 \ln L_{it}$
$(11.70)^{\star\star\star}$	(-1.16)	$(2.20)^{\star\star\star}$	(-1.53)
$-0.106 \ln K_{it} \ln G_{it}$	$-0.362 \ln K_{it} \ln L_{it}$	$-0.143 \ln G_{it} \ln L_{it}$	
(-1.19)	$(5.29)^{\star\star\star}$	$(-2.31)^{\star\star\star}$	
$+0.096 \ln^2 K_{it}$	$+0.176 \ln^2 G_{it}$	$-0.198 \ln^2 L_{it}$	
(-0.83)	$(2.00)^{\star\star\star}$	$(-2.16)^{\star\star\star}$	

N : 596 Log-Likelihood: 1536.9 AIC: 1488.9 SBC: 1453.8

The value of the LR statistic, $-2[1514.8 - 1536.9] = 44.2 \backsim \chi^2(6)$, which is highly significant, shows that due to the addition of cross and quadratic terms the translog model is preferred compared with the Cobb-Douglas specification in column (2) of table 1 (however, it is not preferred according to the SBC criterion). Again, we find that infrastructure G_{it} is significant. Moreover, with respect to marginal productivities inputs G_{it} and L_{it} are substitutes ($\alpha_{gl} = -0.143$), whereas G_{it} and K_{it} appear not to affect each other (α_{kg} is insignificant).

However, it should be mentioned that the results of the translog specification should be interpreted with some caution due to the high correlation of the single with the quadratic and the cross terms. The correlations not reported here between the single and the cross and quadratic terms are greater than 0.8 for most of the cross and quadratic terms. Due to this high degree of multicollinearity between the explanatory variables, imprecise or even estimates with implausible signs can result (Judge, Griffiths, Hill, Lee and Lütkepohl, 1985, chap. 22). Finally, note that by applying LR tests, linear homogeneity is rejected for the estimated translog production function.

It can be summarised that our empirical analysis finds evidence that regional road infrastructure has a significant impact on regional output. The specification with heterogenous parameters between German and French regions appears to indicate that the effect of road infrastructure on productivity is significant only for France. However, by pooling the data for Germany and France we obtain more efficient and reliable parameter estimates. Thus, the model with heterogenous parameters is rejected and the specification where only for labour heterogeneity of parameters is assumed is deemed best. In the following section, the determinants of the regional allocation of road infrastructure in Germany and France are analysed.

3.2 Empirical determinants of the regional allocation of road infrastructure investment

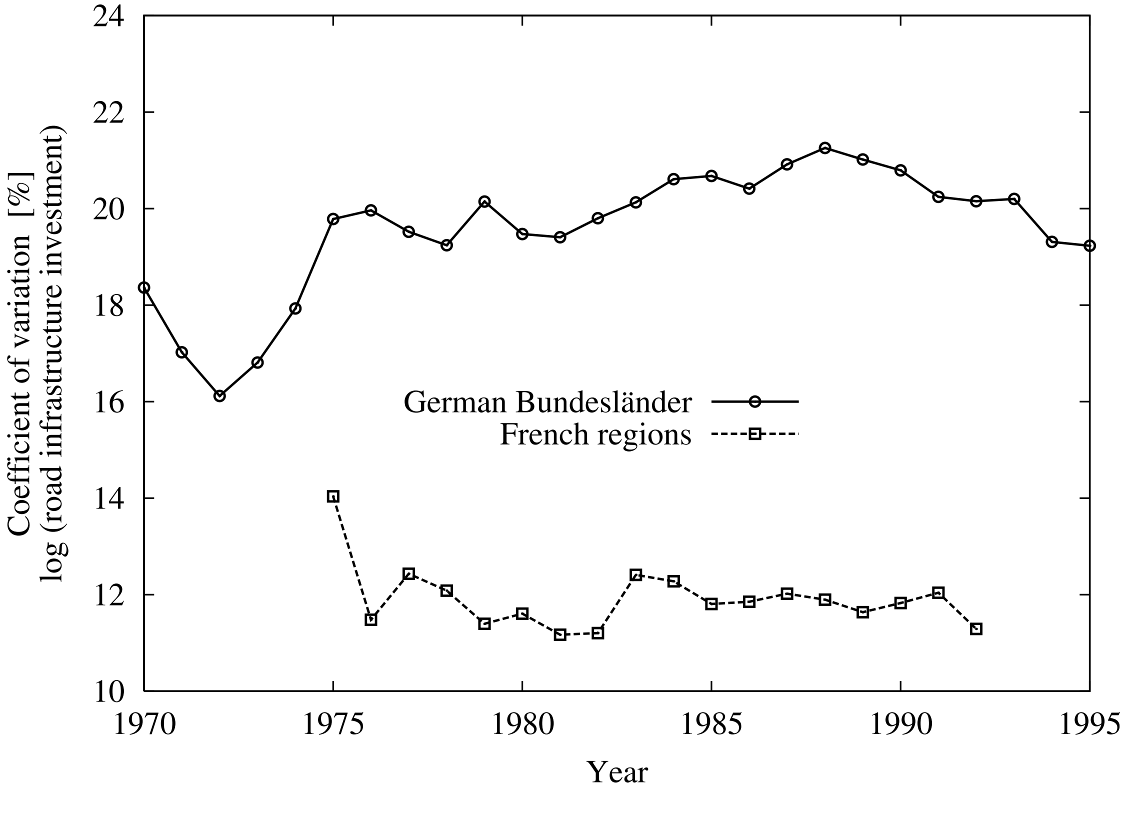
Figure 3 shows the variation in the allocation of regional road infrastructure investment in Germany and in France. Again, the development of the variation is expressed in terms of the coefficient of variation calculated for each year. For Germany, the variation increased relatively constant in the period 1972-89, but decreased after 1990. This is probably a result of the German reunification after which priority was given to improvements of infrastructure in East German regions, whereas differences of infrastructure investment in the West German regions are levelled out due to budget constraints.

With regards to France, neither a constant increase nor decrease can be observed. This means that the variation of the investment allocation remains relatively constant with the course of time. Considered on the whole, no decrease in the variation of the allocation can be identified for both countries.

According to expectations from neoclassical theory this finding is surprising since in the long-run infrastructure endowments across regions should become more balanced and therefore the variation in the regional allocation of infrastructure should decrease in the course of time. However, this only applies if the government actually aims at equalising the marginal productivities of infrastructure across regions. Therefore, in the following we examine the empirical determinants of the allocation of infrastructure investment across regions.

De La Fuente and Vives (1995) identify three criteria which could be of relevance for the regional allocation of public investment in road infrastructure. If the

Fig. 3: Regional Differences of Road Infrastructure Investment in Germany and France



government strives for equal living standards in all regions, then according to the first criterion, labelled *equality*, investment in infrastructure should be directed to where the regional per capita income or productivity respectively is below average. The aim of such a policy would be to reduce competitive disadvantage in a region by improving the public infrastructure and thereby to attracting private investment. In order to operationalise the *equality* criterion empirically, we use the labour productivity Q_i/L_i as a measure for regional income differences.

According to the second criterion, which is labelled as *efficiency* criterion, infrastructure investment should flow where the marginal productivity of investment is highest. Thus the objective of this criterion would be to maximise the sum of regional incomes. In order to obtain an empirical measure for this criterion, by assuming a linear homogenous production function F of degree one the marginal productivity $\partial F/\partial G_i$ of the infrastructure capital stock in region i is proportional to the ratio of the output Q_i to the infrastructure stock G_i, i.e.

$$\frac{\partial F}{\partial G_i} \sim \frac{Q_i}{G_i}.$$

Thus, we use the ratio Q_i/G_i as an operational measure for a regional infrastructure policy criterion according to the *efficiency* criterion.

A third criterion for the allocation of investment in infrastructure can be labelled as *neutrality*. The rationale for this criterion is that the state should ensure that differences in public capital stocks do not give an unfair advantage or disadvantage to any region. The goal of this policy would be to equalise the infrastructure endowments across regions. In practice, this criterion would be met when for example G_i/L_i, i.e. the capital intensity of infrastructure (or any other regionally comparable measure for infrastructure endowment), is equal in all regions.

If a government intends to apply these criteria to the decision process of regional investment allocation, in most cases these three criteria cannot be fulfilled simultaneously. On the contrary, they will quite often lead to conflicting priorities regarding the ranking of infrastructure investment projects. For the Spanish regions, for example, De La Fuente and Vives (1995) find a conflict between the *efficiency* criterion on the one hand, and the *neutrality* criterion and *equality* criterion on the other hand.

Table 2 shows the results of a regression of I_{it}/L_{it}, i.e. investment per labour as a measure for the regional allocation of infrastructure investment, on the measures for the three criteria *equality*, *efficiency* and *neutrality* described above. Furthermore, we have also added a measure for private capital intensity, i.e. K_{it}/L_{it}, which is another potential determinant of regional infrastructure investment.

Note, that infrastructure investment is measured in *net* figures in order to reduce the size effect in the allocation of investment, due to the fact that higher stocks also require higher maintenance investment which is reflected in higher *gross* investment figures.

One important issue for the implementation is that at least for Germany, investment of different levels of governments, i.e. the Federal government, the governments of the federal states and the local governments of the counties, are included. One could argue that the autonomous investment decisions at lower governmental levels are unlikely to reflect especially the *equality* and *neutrality* criteria, whereas the *efficiency* criterion should be also relevant for investment undertaken by lower levels of government. However, investment by the federal government is not only the main part of total infrastructure investment, but the federal government can also influence investment decisions at lower government levels via its investment grant policy. Thus, we argue that this investment figures including all levels of government are appropriate for the problem of regional investment allocation we study here.

In case the government pursues a regional infrastructure policy according to the *neutrality* criterion, we expect a negative correlation between the investment per person in work (I_{it}/L_{it}) and the infrastructure intensity (G_{it}/L_{it}). A negative correlation between (I_{it}/L_{it}) and (Q_{it}/L_{it}) is expected if the government allocates investment according to the criterion of *equality*. Hence, regions with lower income will receive more investment. Finally, if the government pursues a regional infrastructure policy according to the criterion of *efficiency*, then we expect the correlation between (I_{it}/L_{it}) and (Q_{it}/G_{it}) to be positive. Thus, regions where the expected returns of infrastructure investments are higher would obtain more investment.

Tab. 2: Determinants of Regional Infrastructure Investment Allocation in Germany and France

Results of the regression analysis:

Dependent variable: I/L

	(1) Germany	**(2) France**
Independent variables:		
Equity Y/L	(0)	(0)
Efficiency Q/G	(0)	(0)
Neutrality G/L	$(-)^{***}$	$(+)^{**}$
Private Capital K/L	(0)	(0)

Significance levels: $^{***}1\%, ^{**}5\%, ^{*}10\%$

(0) not significant, (+) with positive sign, (-) with negative sign

The estimation of the regression in Table 2 has been carried out separately for the German and the French regions by again using MLE with an ARMA(1,1) specification for the covariance structure. Also, fixed cross-section and time-effects were added to the specification, which turned out to be highly significant.

From the results reported in Table 2, we find that only the criterion of *neutrality* can explain differences in the amount of infrastructure investment the regions receive, but only for Germany it has the expected sign. This finding fits well into the institutional framework of infrastructure policy in Germany we have described in section 2.1 where priority is given to the convergence of living conditions throughout all regions in Germany. For France, a potential explanation for the positive sign of the criterion of *neutrality* is that in the process of deconcentration of the Paris region, political priorities are given to the development of certain regions, but not to the development of *all* regions with equal priority.

On the other hand, surprisingly neither the criterion of *efficiency* nor the private capital intensity are significant for Germany or France. Thus, governments do not seem to anticipate the expected returns of infrastructure investments in the decision process. Moreover, the *equity* criterion is not significant. As a by-product of this result we can also infer that—contrary to what is often presumed in the literature—simultaneity between infrastructure investment and output is negligible, i.e. Q_{it}/L_{it} does not determine I_{it}/L_{it}. It is worth noting that if simultaneity matters we expect a positive sign for Q_{it}/L_{it}, because prosperous states are financially more capable of infrastructure spending than poorer ones.

As a result of this section we can determine on balance that, contrary to France, the criterion of *neutrality* does appear to play a role in the allocation of public infrastructure investment in Germany. Public investment in Germany has flowed above all into regions with a below average initial endowment of road infrastructure, thus in Germany infrastructure policy is used as an instrument of regional policy to minimise the competitive disadvantages of economically underdeveloped regions.

4 Summary and conclusions

In the first part of this study, we described the differences in infrastructure and regional planning policies between Germany and France. In France, for example, a dominance of Paris and the surrounding region compared to the other French regions can be observed. A further basic difference is that regional planning in Germany is divided hierarchically between the regional authorities and is conceived in the medium to long-term. In contrast to this, regional planning in France is based on so called 'planning contracts' between the state and the regions, in which the individual regional authorities have equal rights and planning is conceived rather in the medium to short-term.

Following the description of the institutional concepts of regional infrastructure policy in Germany and France, the effects of road infrastructure on productivity were examined for the German and French regions in the second part of this study. For that purpose, production functions were estimated using the data of an 'unbalanced panel' consisting of the 21 French regions for the period 1978-92 and the 11 West German federal states for the period 1970-95.

On the whole it can be concluded that regional road infrastructure has a significant impact on regional output. In addition, we find evidence that the direct effect arising from infrastructure, i.e. increasing the marginal productivities of private factors, is more important than the indirect effects, i.e. the positive effects on the demand for private factor inputs. As a caveat, however, the results regarding the indirect effects of infrastructure should be interpreted with some caution due to the strong correlation between the explanatory variables in the translog model.

In addition, we cannot observe a decrease in income disparities in the period of investigation either in Germany or France. This finding is at odds with the predictions of neoclassical economic theories. On the contrary, economic counter-effects could have emanated that worked against regional convergence as assumed by models of the 'New Economic Geography' due to the removal of transport barriers. The explanation of this puzzling evidence is a challenging issue for future research.

Finally, the determinants of the allocation of infrastructure investment in Germany and France were examined empirically by applying a new approach. Surprisingly, neither in France or Germany do efficiency considerations matter for the allocation of infrastructure investment across regions. However, it could be shown that in Germany, in contrast with France, the criterion of *neutrality* plays a role in the allocation of public investment in infrastructure, which means that public investment flows above all to those regions which have a below average endowment with public capital. Despite the principal difficulty to link the institutional differences in infrastructure policies in Germany and France with this evidence of the determinants of infrastructure investment allocation, we interpret this finding as a reflection of the priority of promoting the regional convergence of living conditions for infrastructure policy in Germany.

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Appendix

A Data

The German-French regional data include 21 of the 22 French regions (Corsica was not included due to incomplete statistical information) for the period 1978-

1992 and 11 West German federal states for the period 1970-1995 although in the case of West Berlin data is only available for the period 1970-1990.[2] All values have been converted into ECU at constant 1991 prices. For investment in transport infrastructure, we are able to differentiate in France between roads, rail and inland waterways. The infrastructure data for France are also described in Fritsch (1995) and Cadot, Röller and Stephan (1999). Note, that road infrastructure investment in France includes both public investment for all road categories and private investment for licensed motorways.

In the case of Germany, with respect to transport infrastructure only investment data for *road* infrastructure are available at the regional level of the Bundesländer. Therefore, in order to allow a comparison of the infrastructure data between Germany and France, the empirical analysis focuses on road infrastructure.

For Germany we are able to differentiate investment between categories of road (A roads, B roads and smaller roads and streets). An internal report of the German Ministry of Transport, Building and Housing was used as a source for the investment made by the Federal Government and the Federal States ('Straßenbaubericht 1996'). Thus, this report gives the allocation of Federal investment for motorways and A roads across the Bundesländer in the period 1970-1995.

The information regarding investment made by the State and local governments in B and smaller roads was taken from a publication published by the Federal Statistical Office Wiesbaden *'Rechnungsergebnisse des öffentlichen Gesamthaushalts'*, series 14, Reihe 3.1. It contains the road investment of the different bodies at the regional level of the Bundesländer.

The regional capital stocks of road infrastructure in Germany and France were determined from the regional investment series (French regions 1975-1992, German Bundesländer) using the 'Perpetual Inventory method' (PIM). Different procedures were used for both Germany and France. The problem in the case of France was to determine the initial capital stock for 1975 for each region. Thus the aggregated transport infrastructure stocks in France as given by the Feder-

[2] The data used in this analysis are available from the authors upon request.

ation Nationale des Travaux Publics (FNTP) have been allocated proportionally to the individual regions in accordance with the investment proportion of the individual regions. The calculated value was then used as the initial stock for the Perpetual Inventory Method (PIM). For the linear depreciation rate we assumed a value of 2.5 percent. As a control for the capital stocks of road infrastructure arrived at by using this method, the sum over the individual regions was computed and compared with the aggregated value reported by FNTP. It became apparent that the deviation between the sums of the regional and the aggregated stock was only between 1 and 2 percent.

In contrast to this method applied for France, in the case of Germany it is possible to use a study carried out by the German Institute for Economic Research (DIW), in which the regional capital stock of road infrastructure was estimated for the West German federal states for the year 1970 (Bartholmai, 1973). In order to update the initial stocks for 1970 over the period 1971-1995 the Perpetual Inventory Method was used. The publication series 'Verkehr in Zahlen' (Transport in figures) of the DIW also gives the aggregated stock of road infrastructure for the period 1970-1995. Therefore it was possible to apply a restriction for the calculation of the regional stock. Contained within this restriction was the assumption that the sum of the stocks in the regions equals the aggregated value for Germany given by DIW.

Furthermore, the majority of regionally specific measures were obtained from official statistics such as value added as a measure for output we use in the analysis. In the case of Germany, the majority of this data originates from the series of 'National Accounts for the Bundesländer' which is published by the Statistical Office of Baden-Württemberg ('Statistisches Landesamt Baden-Württemberg').

Gross value added (for all areas at market prices) is taken from the publication 'Entstehung des Bruttoinlandsprodukts in den Ländern der Bundesrepublik Deutschland 1979-1996' ('The Origin of Gross National Product in the Federal States of the Federal Republic of Germany, 1970-1996'), vol. 30, and is used as a measure for the output Q of the federal states for the period 1979-1995.

For France, the measure for labour has been taken from the EUROSTAT data base 'New Cronos', June edition 1999. The regional value added data at market prices for the years 1980-1992 were drawn from the EUROSTAT publications 'Regional and Statistical Yearbook, Series 1A, 1993, 1995.' The values for 1979 and 1978 were extrapolated using the information of the development of gross domestic product (GDP) for the years 1978 and 1979.

The data relating to the regional stock of private capital in France for the period 1978-1991 were provided to us by Professor Remy Prud'Homme of the University of Paris. A description of these data can be found in Prud'Homme (1996). The stocks for the year 1992 were computed by applying the Perpetual Inventory Method from the stocks in 1991 by adding regional gross investment in 1992 for all industries taken from the 'New Cronos' data base and assuming a linear depreciation rate of 10 percent.

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