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Output Effects of Infrastructures in East and West German States

With respect to the recently ratified economic stimulus package in Germany, it is fundamentally important to observe whether the expansion of physical infrastructure will further contribute to economic growth. This paper presents a way to address the problem of endogeneity using panel data on 16 federal states in Germany and by estimating a panel vector autoregression model for the period from 1993 to 2006. The analysis offers practical benefits for economic policy, indicating that both human capital and transport infrastructures cause heterogeneous output effects in East and West Germany.

In response to the current economic crisis, the German federal government established a 50 billion euro economic stimulus package which is meant to stimulate economic growth by means of investments in schools, streets and communication infrastructures. Political decision-makers expect a positive impact from infrastructural investments. These infrastructures are not only of a physical nature, such as transport infrastructures, but are also in the form of social overhead capital (i.e. intellectual, entrepreneurial and technical abilities) which can be classified as personnel infrastructure.[1] The effectiveness of the economic stimulus package depends on the particular measures and their impact on output. Varying forms of infrastructure investment differ with regard to their contribution to output, and the region in which the investment occurs is also an important variable. For this reason, this study deals with the output effects of investment in different types of infrastructure at the federal state level in Germany.

For the purpose of an optimal allocation of resources, economic policymakers must principally be aware of:

- which type of infrastructure will produce the largest output effects
- whether personnel infrastructures (i.e. human capital) contribute more to economic growth than physical infrastructures
- whether the infrastructure endowment of East Germany causes larger output effects than in West Germany.

The results of the analysis indicate that overall investment in transport infrastructure (throughout all states) causes negative output effects, implying an overinvestment. However, transport infrastructures in East Germany have a positive impact. Contrarily, human capital causes larger output effects in West German than in East German states. An area-wide fostering of infrastructure projects would be futile, because the expansion of infrastructure reveals different output effects depending on the different regions and the forms of infrastructure.

Infrastructure and Economic Output: A Theoretical and Empirical Overview

In the relevant theoretical literature, we find that output is produced combining the input factors labour, human capital, private capital and public (infrastructure) capital. Input factors and total factor productivity are combined to produce the total level of domestic production. Output effects can be caused directly or indirectly. An enlargement of the infrastructure capital stock (also personnel infrastructures) directly increases the productivity of the other factors. The capital stock is used in private production as an unpaid input which raises productivity and reduces production costs. Furthermore, infrastructure investments directly raise employment and production levels in infrastructure-related industries. Firms which sell materials and supplies benefit indirectly from the increasing output. The sum of initiated demand effects can unfold positive output effects for the whole economy. Moreover, transport infrastructures help to interconnect economically weak regions with fast growing agglomeration areas and therefore enable perfect factor allocation and knowledge spillovers which induce positive effects for the peripheral regions.[2]

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1 R. Jochimsen: Theorie der Infrastruktur: Grundlagen der marktwirtschaftlichen Entwicklung, Tübingen 1996.

2 R.E. Baldwin, R. Forslid, P. Martin, P.G.I. Ottaviano, F. Robert-Nicoud: Economic Geography and Public Policy, Oxford 2003.

Personnel infrastructure is just another expression for the human capital of an economy. In societies like Germany which are based on the division of labour, human capital is of great importance. Skilled workers and research and development are required more than ever in Germany. Endogenous growth theory reveals human capital to be one of the essential components of technological progress, which itself fosters economic growth.[3] The allocation of human capital leads to the diffusion of innovative ideas and production techniques among economic sectors. The relationship between personnel and physical infrastructures is predominantly limitational, which means that shortages in the endowment of one type of infrastructure cannot be compensated for by the other type.[4] Furthermore, over-investments in infrastructure capital are also not useful, due to the fact that scarce resources are tied up and cannot be used in more efficient production possibilities. An optimal disposition of infrastructure capital takes place if private sector profits, created by infrastructure supply, equal the costs of this infrastructure supply.[5]

As a basis for this analysis, decreasing rates of return of infrastructure endowment are assumed, i.e. high infrastructure endowment levels would lead to relatively smaller output effects than low infrastructure endowment levels. The effect can even become negative if there is an over-endowment, meaning that resources are wasted in futile dispositions because further expansions of the endowment level will necessarily detract scarce resources from beneficial applications. Bearing this in mind, it is expected that:

- the output effects of Germany's infrastructure are low because the infrastructure capacity is relatively large, as compared to other countries;
- the effects are larger in East German states due to the present infrastructure gap;
- education infrastructure investment will exert lower effects in East German states because of the higher endowment levels in these states;
- the total output effect of human capital should be positive over all states because qualified workers are in high demand;
- the positive output effect should be larger for East German states as a result of the lower endowment.

During the 1990s, a variety of studies were related to the estimation of marginal output and cost elasticities of public infrastructures in Germany using different estimation techniques. Building on Aschauer's approach[6], the growth effects of infrastructure capital were actively debated, at first in the USA[7] and later also in Germany.[8] Initial studies overestimated marginal output and growth effects of non-military capital due to the fact that the problem of reverse causality was not addressed. More sophisticated estimation techniques indicate smaller or even insignificant output effects. Pfähler, Hofmann and Bönte[9] give an overview of the estimated output elasticities of public capital for specific kinds of physical infrastructure. The productivity effects of investment in university education and science are given by Pfähler, Clermont and Hofmann.[10]

There seems to be no agreement in the most recent works about the actual size of the output effects of transport or education infrastructures. Furthermore, it is still ambiguous whether there is an effective transfer from infrastructure endowment to economic output or if reverse causal-

3 R.E. Lucas: On the Mechanics of Economic Development, in: Journal of Monetary Economics, Vol. 22, 1988, pp. 3-42.

4 R. Jochimsen, op. cit.

5 B. Felderer, U. Schuh: Wachstum und Beschäftigung durch Infrastrukturinvestitionen. Studie im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie (Austria), http://www.bmvit.gv.at, 2005. See also A.B. Reis, T.N. Sequeira: Human capital and over-investment in R&D, in: The Scandinavian Journal of Economics, Vol. 109, No. 3, 2007, pp. 573-591. The authors find evidence for negative output effects of infrastructure concerning over-investments in the R&D sector.

6 D.A. Aschauer: Is public expenditure productive?, in: Journal of Monetary Economics, Vol. 23, No. 2, 1989, pp. 177-200.

7 See for example: C.R. Hulton, R.M. Schwab: Is there too little Public Capital? Infrastructure and Economic Growth. Presented at the American Enterprise Institute Conference on Infrastructure Needs and Policy Options for the 1990s in Washington, 1991; A.H. Munnell: How does Public Infrastructure Affect Regional Economic Performance, in: New England Economic Review, Vol. Sept./Oct., 1990, pp. 11-32; J.A. Tatom: Public capital and private sector performance, in: Review, Vol. 73, No. 3, 1991, pp. 3-15; as well as M.I. Nadiri, T.P. Mamuneas: Public R&D Policies and Cost Behavior of the U.S. Manufacturing Industries, in: Journal of Public Economics, Vol. 63, No. 1, 1994, pp. 57-81.

8 See K. Conrad, H. Seitz: The Economic Benefits of Public Infrastructure, in: Applied Economics, Vol. 26, No. 4, 1994, pp. 303-311; H. Seitz, G. Licht: The Impact of Public Infrastructure Capital on Regional Manufacturing Production Cost, in: Regional Studies, Vol. 29, No. 3, 1994, pp. 231-240; U. Hofmann: Produktivitätseffekte der öffentlichen Infrastruktur. Meßkonzepte und empirische Befunde für Hamburg, in: Europäische Hochschulschriften, Vol. V, No. 1945, Frankfurt u.a 1996, Lang; as well as A. Stephan: The Impact of Road Infrastructure on Productivity and Growth: some preliminary Results for the German Manufacturing Sector, in: Wissenschaftszentrum Berlin für Sozialforschung (WZB) (ed.): CIG Working Papers, No. FS IV 97-47, Berlin 1997.

9 W. Pfähler, U. Hofmann, W. Bönte: Does Extra Public Infrastructure Matter? An Appraisal of the Empirical Literature, in: Finanzarchiv, Vol. 53, No. 1, 1996, pp. 68-112.

10 W. Pfähler, C. Clermont, U. Hofmann: Sektorale Produktivitätseffekte der Hochschulbildungs- und Wissenschaftsausgaben in Hamburg, in: R. von Weizsäcker (ed.): Bildung und Wirtschaftswachstum, Berlin 1998, Dunker & Humblot, pp. 77-104.

ity is present, i.e. that a higher per capita output leads to a greater infrastructural endowment.

Many authors focus on the effect of total public capital without distinguishing between different types of infrastructures.[11] Another unresolved question is whether output effects differ between East and West German states. To the best of our knowledge, there is no study on infrastructure output effects at the federal state level thus far.

Database and Infrastructure Endowment in East and West German States

As described above, the output effects of infrastructures strongly depend on the economy's endowment level. The quality and quantity of infrastructure capital stocks in the transport, education, energy, communication as well as water and waste management sectors should be employed to portray the total amount of physical infrastructures. The personnel infrastructure or human capital consists of the population's mental, entrepreneurial and professional skills and can be depicted by a number of qualitative indicators such as the number of patent applications or high school graduates.

The selected variables of the estimated model were in part subject to constraints in the availability of data. First, the exactness of data from the years 1991-1993 must be regarded with caution, because much of the East German economic data had to be newly estimated shortly after German reunification due to the fact that data sources in the former GDR were unreliable. Second, many preferable variables are not reported at the state level (e.g. monetary infrastructure capital stocks covering power generation, communication networks and water and waste management infrastructures). Unfortunately, personal calculations of the infrastructure capital stock at the state level were unworkable due to the uncertainty or unavailability of data.

Physical infrastructures were captured approximately by using data from transport areas (roads, freeways, navigable rivers and canals) and education infrastructures (school classes).[12] The transport infrastructure level was measured by the log of transport areas in kilometres per 1000 square km of state territory. Transport infrastructures represent a large share of the total stock of physical infrastructures in the German economy. According to the German Federal Ministry of Transport, Building and Urban Affairs, the share of gross fixed assets in the transport sector (€905 billion) accounted for 15.5% of all economic sectors' assets.[13]

Likewise, education infrastructures cover a substantial proportion of the entire infrastructure capital stock of the German economy. In 2008 gross fixed capital formation to the amount of €8.3 billion was allocated to the educational sector, which represents 22% of total investment (€38 billion).

Education infrastructure data should not comprise qualitative elements when addressing the pure effect of physical infrastructures. For this reason, the number of school classes per 1000 pupils at general educational schools was chosen as the indicator for education infrastructure.

In this analysis, two variables – patent applications per 100,000 inhabitants[14] and share of high school graduates in the coeval resident population – were applied to map the stock of human capital. The variables' values vary immensely between the East and West German states.

To control for other factors affecting the output, further variables were employed, namely the capital stock of the manufacturing sector in euros, the unemployment rate, public consumption per inhabitant, as well as dummies for time periods and a regional dummy for the entirety of the East German states.

The capital stock comprises the annual average of gross fixed assets (base year: 2000). The capital stock was weighted by the modernity rate to depict the real productive capacity. The modernity rate describes the share of the capital stock that is not depreciated yet by putting net fixed assets in relation to gross fixed assets.

Labour, as a further factor of production, is integrated within the model and represented by the rate of unemployment. A negative effect on output is expected because the rate of unemployment will rise in times of economic contraction, leading to decreasing per capita outputs. Furthermore, structural problems such as a mismatch between the supplied and required qualifications

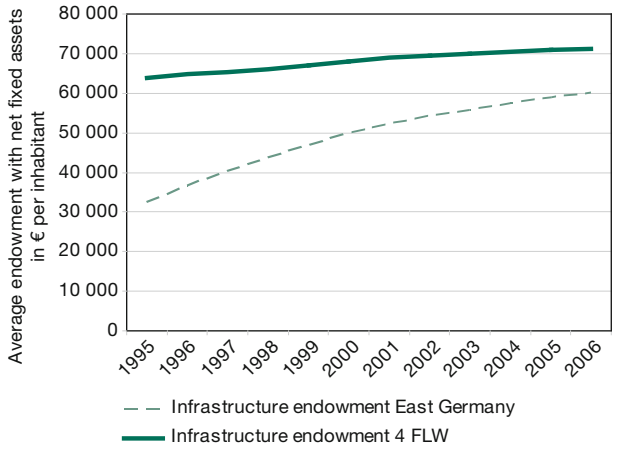
11 As in R. Jong-A-Pin, J. de Haan: Time-varying impact of public capital on output: New evidence based on VARs for OECD countries, in: EIB Papers, Vol. 13, No. 1, 2008, pp. 56-80; and C. Kamps: The Dynamic Effects of Public Capital: VAR Evidence for 22 OECD Countries in: International Tax and Public Finance, Vol. 12, No. 4, 2005, pp. 533-558.

12 Descriptive statistics of all employed variables are available upon request.

13 Bundesministerium für Verkehr, Bau und Stadtentwicklung (BMVBS): Verkehr in Zahlen, Hamburg 2008.

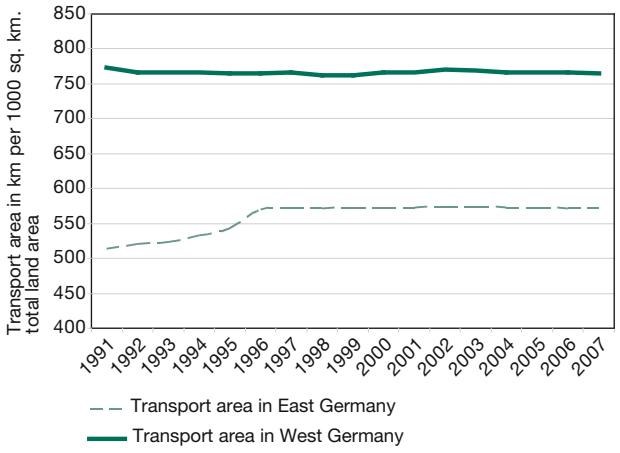
14 As in W. Eggert, M. von Ehrlich, R. Fenge, G. König: Konvergenz- und Wachstumseffekte der europäischen Regionalpolitik in Deutschland, in: Perspektiven der Wirtschaftspolitik, Vol. 8, No. 2, 2007, pp. 130-146.

Figure 1
Infrastructure Endowment and Catching-up Process of East German States



Source: Federal Statistical Office.

Figure 2
Transport Infrastructure Endowment



Source: Federal Statistical Office.

of workers can lead to the production potential not being fully exhausted.

Final public consumption expenditure per capita was included in the model to control for the output effects of the public sector. Ganelli and Tervala find evidence for positive welfare effects if expenditure on the infrastructure capital stock is raised to the detriment of expenditure on public consumption.[15]

Year dummies were added to control for time effects such as economic cycles or election years. The regional dummy equals one in the case of East German states and helps to eliminate structural differences between East and West German states if those effects are not covered by the explaining variables. Structural differences can be traced back to the consequences of the transformation process or to cultural diversity, for example.

The German states show varying levels of infrastructure endowment per inhabitant. To calculate the measure of the infrastructure gap, net average fixed assets per capita in the four financially weak states of West Germany (Lower Saxony, Rhineland-Palatinate, Saarland and Schleswig-Holstein) were compared to the assets of the East German states.[16] Here, the infrastructure gap does not refer solely to personnel and productive physical infrastructures but also to other infrastructures, such as residential buildings. However, Figure 1 shows that the East German states have caught up with the four financially weak West German states. The gap in net fixed assets decreased from 50% to 15% over time.

Differences in the endowment of transport areas and education infrastructures are presented in Figures 2 and 3. The newly formed German states (excluding Berlin) showed a rising level of transport areas until 1996 and thereafter a constant level of 570 km per 1000 sq. km of total land area. Similarly, the amount of transport areas in the West German states has also barely changed. However, the number there (around 770 km) is considerably higher than in the newly formed states. Roads and highways account for 90% of all transport areas in the observed states.[17] The increasing supply of transport infrastructure in the East German states was caused mainly by the expansion of motorways, whereas other roads only experienced modernisation. The quality of transport infrastructure is not considered in the data.

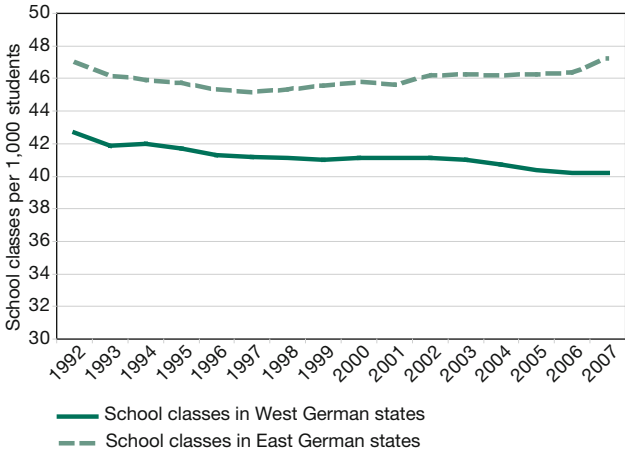
The supply of education infrastructure as measured by the number of classes indicates different results. Schools provide the conditions for productivity effects of the education system to pay off after a considerable number of years. For historical reasons, the East German school system is not comparable to the school system of the

15 G. Ganelli, J. Tervala: Public Infrastructures, Public Consumption, and Welfare in a New-Open-Economy-Macro Model, in: HECER – Helsinki Center of Economic Research (ed.): Discussion Papers, Nr. 211, Helsinki 2008.

16 See Deutsches Institut für Wirtschaftsforschung (DIW): Infrastrukturausstattung und Nachholbedarf in Ostdeutschland, Berlin 2000 for more information.

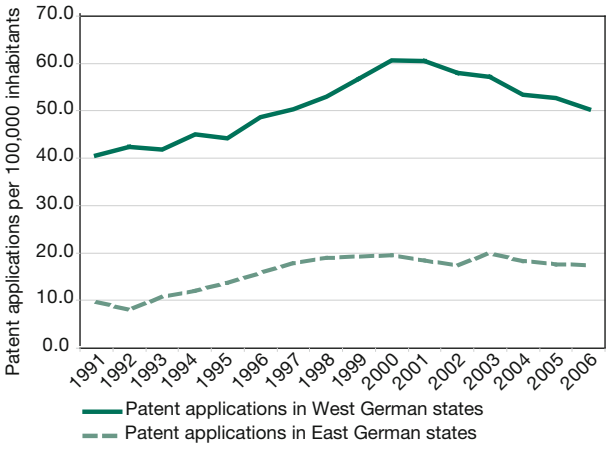
17 Statistisches Bundesamt: Berichtsmodul Verkehr und Umwelt, in: Beiträge zu den Umweltökonomischen Gesamtrechnungen, Vol. 14, Wiesbaden 2004, p. 22.

Figure 3
Endowment with Physical Education Infrastructure



Source: Federal Statistical Office and the Statistical Offices of the Länder.

Figure 4
Approximation of the Stock of Human Capital by Patent Applications



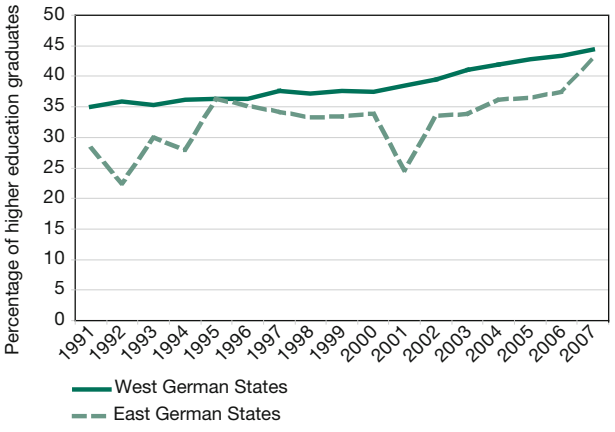
Source: German Patent and Trademark Office.

West German states. The latter is a three-part system and consists of secondary modern schools, junior high schools and academic high schools. The former is a binominal consolidated school system where students are spread out over fewer school forms, which means that in the case of a decreasing number of pupils, schools can be maintained more easily. As a result, there are more school classes there than in the West German states, where the number of classes is decreasing. East German students also benefit from smaller class sizes (2006: 21.6 students in the East German states vs. 24.6 in the West German states).[18]

Varying endowment levels between East and West German states can also be found in the numbers of patent applications and high school graduates, which indicate different output effects. The number of patent applications is higher in the old West German states, which indicates a higher level of human capital quality. The employed variables approximate the human capital of large parts of the population by covering all age classes and multiple groups of persons, including those entering the employment market and those who are already working.

As in the case of patent applications, the East German states lag behind the old West German states concerning the percentage of higher education graduates. Since 2002 the gap has remained constant between the two regions. Even so, both regions benefit from a rising share of graduates who qualify for entry into higher education.

Figure 5
Approximation of the Stock of Human Capital by Graduates with Higher Education Degree



Source: Federal Statistical Office.

Empirical Design

A special characteristic of the employed data is that there is no unidirectional effect between explanatory and dependent variables. Reverse causality prompts inconsistent OLS estimators, and coefficients might be overestimated.

Another special characteristic in the data is that some variables may have a delayed impact on the output of the

18 Statistisches Bundesamt: Internationale Bildungsindikatoren im Ländervergleich, Wiesbaden 2008, p. 107.

economy. This especially applies in the case of physical infrastructures, which need to be built and put in operation first as a precondition for the appearance of output or productivity effects.

Both phenomena have to be taken into consideration in the estimated model. A solution to the problem of reverse causality is the estimation of simultaneous equations which explicitly express the relationships between the employed variables. The Linear Dynamic Vector Autoregression Model (VAR(p)-model) does just that. It focuses on dynamic processes in the formed economic system, which simulates the interaction among different macroeconomic values and the behaviour of the employed variables at the appearance of exogenous shocks.[19] All variables are incorporated in the model as endogenous values and lagged by p time periods, which means that all variables depend on one another.

VAR models are used to conceive interdependencies between different time series, but they can be used for the analysis of panel data as well, applying the mean group estimator developed by Pesaran and Smith.[20] Kireyev points out that the mean group estimation technique will not convey losses with the consistency of estimation results.[21]

The functional expression of a Panel VAR model is:

$$(1) \qquad {}_{\gamma i,t} = A_{1,1\,\gamma 1,t-1} = +\ldots +A_{i,p\gamma i,t-p}+B\chi_{i,t}+\varepsilon_{i,t}$$

where ${}_{\gamma i,t}$ is the vector of all endogenous variables of state i and time period t. χ is a vector of potential exogenous explanatory variables, $A_{1,1}$ ... $A_{i,p}$ and B present the estimation coefficients and ε is a vector of exogenous innovations which are correlated in t but which are neither correlated with their own lags nor with the explanatory variables.

As long as the employed data do not follow a trend, the OLS estimation technique will deliver consistent results. Data were tested for non-stationarity using the Im-Pesaran-Shin test for individual unit roots and an ADF test. The results do not support the assumption of unit roots,[22] and they indicate that the OLS estimator will deliver consistent results.

The optimal number of lags of the endogenous variables was determined to be one period by the Schwartz information criterion test. In view of economic considerations, this is an appropriate lag structure because infrastructures like roads will provide services shortly after their completion. In contrast, education infrastructure is used for more than one year before scholars enter the employment market and their human capital can be evaluated as an input factor for production. A time lag of 8-13 periods for the average school time would be ideal, but cannot be employed due to the present observation period.

VAR models enable the inclusion of exogenous variables as output predictors. In the following estimation, year dummies and a regional dummy were included as exogenous variables. As a means to form explanatory variables, interaction terms were used to examine whether the effects of infrastructures are significantly different in East German states compared to the West German states.

Results

The results of the estimates only partially verify the hypothesis established above. Because the analysis was aimed at estimating the output effect of infrastructure variables, Table 1 only presents the results of the equation in which the logarithm of per capita GDP is the dependent variable. All other equations are omitted for reasons of simplification and clarity.

The negative output effects of transport areas (over all states) and per capita capital stock are the most striking. The results indicate that an expansion of transport areas and capital stock by 1% will decrease per capita output by 4.7% in the long run. However, the transport area interaction term, multiplied by the regional dummy variable, shows that East German states still benefit from positive output effects of transport infrastructures. The joint negative effect can be put down to the argument that expansions of transport infrastructures and of the capital stock are accompanied by a withdrawal of resources from more productive dispositions, leading to a long-term decline in output. The absence of positive effects from transport networks could also be explained by Germany's large infrastructure endowment, which is already sufficient for the transport of goods and persons

19 J. Breitung: Neuere Entwicklungen auf dem Gebiet ökonometrischer Strukturmodelle: Strukturelle Vektorautoregression, in: Ifo-Studien: Zeitschrift für empirische Wirtschaftsforschung, Vol. 44, No. 4, 1998, pp. 371-392.

20 M.H. Pesaran, S. Smith: Estimating Long-Run Relationships from Dynamic Heterogenous Panels, in: Journal of econometrics, Vol. 68, 1995, pp. 79-113.

21 A. Kireyev: Comparative Macroeconomic Dynamics in the Arab World: A Panel VAR Approach, in: International Monetary Fund (ed.): IMF Working Paper, No. WP/00/54, Washington 2000.

22 For the logarithm of the per capita capital stock, the result was significant at the 10%-level only, using the Im-Pesaran-Shin test.

Table 1
Long-term Output Effects of Physical Infrastructures and Human Capital Variables

Variable	Coefficient	T-statistic
Transport infrastructures	-0.047***	[-3.119]
Transport infrastructures*dum_east	0.086***	[2.686]
Classes	-0,023	[-0.409]
Classes*dum_east	0.045	[0.556]
Patent applications	0.034***	[2.986]
Patent appl.*dum_east	-0.033**	[-1.862]
Higher educ. degree	0.056***	[2.682]
Higher educ. degree*dum_east	-0.075***	[-2.970]
Modernity rate*capital stock	-0.014***	[-3.742]
Unemployment rate	-0,004	[-0.195]
Public consumption	-0.107***	[-2.936]
No. Obs.: 209		
F-Statistic: 1,092.4***		

Notes: T-statistics in [ ]. *** significant at 1% level; ** significant at 5% level; * significant at 10% level. The label (-1) indictes a lag of one period.

and therefore induces merely small or even negative marginal returns on capital.

A critical view of the quality of the data set must be considered, however. Germany's transport area endowment suffers from insufficient modernisation, which leads to traffic jams and obstructions. Potentially, an expansion of transport infrastructure might yield positive output effects here. However, the real capacity and modernity is not expressed by the variable. Due to the low modernity rate, the assumed over-endowment problem might not necessarily exist in reality. Unfortunately, controlling for the efficiency of infrastructures through the use of particular modernity rates is not possible because corresponding data is not available. The conclusion is that the output results presented are not likely to be reliable. If it were possible to take the actual efficiency of transport infrastructures into account, the output effect might change.

The impact of the per capita capital stock is negative as well, although to a lesser degree. The capital stock consists not only of productive but also of consumptive capital like residential buildings. Therefore, output effects are limited *a priori*. Classical economic theory reveals that capital is an important determinant of growth. It is supposed that capital is productive and has a positive but diminishing marginal return. Contrarily, the estimation results provide evidence of an over-endowment of capital. Moreover, it is tied up in unproductive dispositions but could produce positive output effects if reallocated.

Education infrastructure (school classes) has no significant impact on output. This could be explained by the inappropriate lag structure, which does not sufficiently depict the long-term output effects of the education system.

Both human capital variables indicate positive effects of the populations' mental abilities. A 1% increase in the number of patent applications or in the share of graduates causes a long-term increase in the output level of 3.4% and 5.6% respectively. It is a striking result that effects are lower for the East German states. A possible explanation is that human capital cannot be utilised completely, because adequate jobs and industries are missing in the East German states as a result of the previous controlled economic system. Graduates with qualifications for higher education entry require relatively long periods to find suitable apprenticeship positions or must accept jobs with lower qualification requirements than graduates in the West German states. Similarly, patents also seem to provide smaller output effects in the East, which might be associated with the firms' inability to fully utilise patents in their production. Moreover, diminished knowledge spillovers, due to the immobility of employees, may be assumed.

Public consumption has a clear negative effect on output, which is compatible with the results of recent literature.

Conclusion

The analysis of output effects of infrastructures reveals heterogeneous results. The output effect of transport infrastructures is negative for the entirety of federal states but positive for East German states as a result of an infrastructure gap. Education infrastructures have no significant output effect but human capital raises output. Despite the low stock of human capital in the East German states, the impact on output is smaller there. The results of the analysis ratify the need for sophisticated infrastructure planning. The region-wide development of infrastructures, as proposed in the recent economic stimulus package, will not yield the expected growth and output effects.

A more detailed spatial analysis would be advisable because some regions have an obsolete infrastructure endowment. Inadequate data availability led to several constraints and underlines the need to enlarge the database at the federal state level. This would improve future estimations.