Infrastructure Policies and Economic Development in East European Transition Countries:

First Evidence

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Keywords: public utilities, economic development, Eastern Europe, transition

JEL Classification: H54, O11, L90 , P20

ABSTRACT

This paper provides initial evidence of the relation between infrastructure policies and economic development in the transition countries of Eastern Europe and the CIS (15 countries, 1993-2000). We use an aggregate production function to test how GDP in transition countries is related to total capital (proxied by net electricity consumption), infrastructure capital (proxied by telephone mainlines), and the speed of liberalization in major infrastructure sectors (telecommunication, transport, energy, water). The basic model is estimated using panel data fixed effects. In the second model, by estimating a stochastic frontier production function, we also estimate the technical inefficiencies of the individual countries. Although significant data problems remain, the models suggest that early liberalization of infrastructure sectors is conducive to economic growth. As transition progresses, most countries increase their productive efficiency. Unexpectedly, investments in telecommunication do not seem to impact growth particularly. The paper concludes that institutional reform in infrastructure sectors is at least as important as the modernization of physical capital.

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This paper results from a research project on infrastructure policy in transition countries, carried out jointly between DIW Berlin and the German Advisory Group/Institute for Economic Research in Kiev, Ukraine, partly funded by the German TRANSFORM program for technical assistance to Central/Eastern Europe and the CIS. We thank Jürgen Bitzer, Alexander Scherbakov, Borris Siliversovs, Andreas Stephan, Volkhart Vincentz, participants of the conference on 'Fostering Sustainable Growth in Ukraine' (Kiev, June 2001) and seminar audiences at the University of Kent at Canterbury and DIW Berlin for comments and suggestions. The usual disclaimer applies.

1. INTRODUCTION

Infrastructure is generally considered to be an important determinant of economic development (World Bank, 1994, Gramlich, 1994, Aschauer, 1999, Canning, 1998, 1999). The relation between material infrastructure (such as telecommunication, energy, and transport) and economic growth has been analyzed extensively for industrial countries. Even though research results do not converge, there is a broad consensus that infrastructure is a necessary but not sufficient ingredient of economic growth, and that the efficient supply of the right kind of infrastructure (material and institutional) in the right place is more important than the amount of money disbursed or the pure quantitative infrastructure capacities created (Hull, 1999). Little is known though on this relationship in the *transition countries* of Eastern Europe and the Commonwealth of Independent States (CIS), where the often dismal state of infrastructure has sometimes been considered as one of the most important obstacles to recovery and growth. Although most transition countries have by now overcome the crisis of the early 1990s and embarked on a path of economic growth, the role of infrastructure policy in the transition process is still the subject of debate in economic theory and policymaking. Some theoretical approaches have suggested that the impact of infrastructure investments in Eastern Europe would be particularly strong (Aghion and Schankerman, 1999, Meissner, 1999), whereas anecdotal evidence and empirical case studies have not always confirmed this argument (Hirschhausen, 1999, 2002).

A second controversial issue has been the optimal *sequencing* of infrastructure sector reforms and its impact on investments and on growth in transition countries. Proponents of orthodox regulatory economics have argued for the rapid privatization and liberalization of network infrastructure. By contrast, Armstrong and Vickers (1996) suggested that a more conservative approach to liberalization create higher incentives to invest into desperately needed infrastructure. Pittman (2001) argued that due to different levels of institutional and technical development among the East European transition countries, ‘one-size-fits-all’ solutions to infrastructure sector reforms were inappropriate. However, the empirical evidence on the issue of sequencing has also remained scarce thus far.

This paper is the first attempt to quantify the relation between infrastructure sector reforms and economic development in the transition countries in the 1990s. We test how GDP in Eastern Europe and the CIS is related to infrastructure capital and the speed of sectoral reforms. The paper is structured in the following way: Section 2 surveys the recent literature on infrastructure and growth, and summarizes the existing theoretical models for transition countries. Section 3 specifies the basic model and describes the required data and assumptions. We use an aggregate Cobb-Douglas production function including proxies for infrastructure and non-infrastructure capital, and an indicator of market-oriented reforms in five infrastructure sectors (telecommunication, power, gas, water, railways, roads). The basic model is estimated using a fixed effects panel regression (or: least squares with dummy variables, LSDV). In Section 4: We use a stochastic frontier production function (SFPF), which incorporates an estimation of technical efficiency effects, and simultaneously estimates all parameters involved. Overall, the analysis indicates a positive impact of the speed of reforms on economic growth once a critical threshold of reforms is passed. On the other hand, teledensity does not seem to have a higher impact than other capital. Section 5 concludes.

2. THE ISSUE: INFRASTRUCTURE SECTOR REFORM AND ECONOMIC DEVELOPMENT IN THE TRANSITION CONTEXT

2.1 Infrastructure and growth

The debate on the role of infrastructure in economic development goes back to the Rostow-Hirschman controversy on development through infrastructure abundance vs. infrastructure shortage. The debate has been revived by Aschauer's (1989) assertion of a positive relation between infrastructure investments and productivity in the U.S. and other OECD countries. Further research on the link between infrastructure development and economic growth in the US demonstrated that the evidence is mixed, especially for panel data when fixed effects are included (Holtz-Eakin, 1994, Garcia-Mila, McGuire, and Porter 1996). Barro (1990) found no separate effect on growth from the break-down of total investment between private an public components. In contrast Easterly and Rebelo (1993) found that investments in transport and telecommunication, which can be considered as proxy for infrastructure capital, are correlated with economic growth.

Both Gramlich (1994) and World Bank (1994) concluded that the ambiguous results were due to the fact that macroeconomic production function studies were used instead of more dis-aggregated rate of return studies and studies of the impact of different policy changes. In contrast Canning and Bennathan (2000) found that microeconomic cost-benefit studies did not capture externalities associated with infrastructure development. In a panel data study Canning (1999) found infrastructure productivity rates to be comparative to observable private capital productivity rates. This suggests that the impact of infrastructure investments can be better studied at the macroeconomic level. Canning used direct infrastructure stock measurement variables, such as the number of telephones, the electricity generating capacity, and the length of transport routes. The impact of telephone density (mainlines/100 inhabitants) appeared to be statistically significant, which suggests above-average productivity and large externalities to telephones. This converges with the results obtained by Röller and Waverman (2001) on positive network externality of telephone mainlines in industrial countries. In addition, Canning, Fay, and Perotti (1994) found that for roads and railways, the evidence is rather problematic.

In addition to the break-down of capital into public and private components, there is a growing number of studies that explicitly take into account institutional developments (e.g. Canning, Fay, and Perotti, 1994). In an extensive panel data study, Henisz (2000) found a long-run link between government policy credibility and infrastructure growth rates. He concluded that an important component in explaining investment levels within a country is its ability to commit to a given policy environment. Thus, we can conclude that substantial uncertainty still exists about the relationship between infrastructure and growth both in developed and in developing economies, but it is likely that the institutional environment is a very important complement for translating infrastructure investments into economic growth.

2.2 Approaches for transition countries

The empirical research on economic growth in *transition countries* has thus far taken into account mainly the conventional factors of the institutional infrastructure or the policy environment, such as initial conditions, privatization, and the legal environment. Havrylyshyn et al. (1999) related recovery and sustained growth in transition countries to the initial conditions of an economy at the outset of reforms, the speed of macro-stabilization, and the degree of structural reforms. Piazolo (1999) explicitly integrated a qualitative indicator of institutional change developed by EBRD (reflecting privatization and competition policy, amongst other policies) into cross-section estimations of an aggregate production function; he found institutional change to be a significant factor of growth in transition countries, suggesting that a more market-oriented approach would foster growth in the transition countries; Piazolo also concluded that an important component in explaining investment levels within a country is its ability to commit to a given policy environment.

In addition to the traditional institutional factors of growth, it has been argued that for transition countries, the growth impact of material infrastructure investments and the liberalization of infrastructure sectors are particularly strong. Under socialism, infrastructure development was concentrated in few sectors, and the qualitative state was incompatible with the requirements of a market economy (EBRD, 1996). Estimates of the investment needed in transition countries to reach the average level of the European Union were above EUR 1,000 bn., or over 6% of annual GDP for at least 15 years. By contrast, real infrastructure investments during the 1990s covered not even 10% of the estimated requirements (Hirschhausen, 2002).

Several *theoretical* models on the link between infrastructure investment and growth have been developed. Aghion and Schankerman (1999) suggest a particularly important role for infrastructure investments in transition countries; this is due to the extensive cost asymmetry between old, post-socialist firms (high-cost) and new, potentially more efficient firms (low-cost, e.g. unbundled parts of former combines, start-up firms). Infrastructure investments in transition countries then induce an *expansion* effect, leading to an increase in aggregate output, a *selection* effect whereby the low-cost firms increase their market share, and a *market entry* effect whereby new low-cost firms enter the market. According to this model, the dynamic effects of infrastructure investments increase with higher cost asymmetry between the firms, the initial market share of firms with high costs, the effort required for restructuring, and low costs of market entry for new firms; this constellation is exactly given in the transition countries.

Apart from the *absolute* level of infrastructure equipment, the *regulation* of infrastructure sectors is also likely to affect the development of an economy. Contrary to the orthodox approach that requires immediate reforms, Armstrong and Vickers (1996) argue that *delaying* liberalization in transition countries can be justified if short-term investment requirements are high, and the institutional environment is unstable (high regulatory risk). In that model, the optimal timing of liberalization is a function of the two risks that an investor faces in the transition context: the *expropriation risk*, i.e. the danger of losing revenue once the investment is sunk,[2] and the *liberalization risk*, i.e. the fact that the formerly monopolistic market can be opened without prior notice, and that the expected monopolistic profits therefore do not come about. Armstrong and Vickers (1996, 315) conclude that early liberalization has a *positive* effect on infrastructure capacity, and thus on investment, if and only if revenue with liberalization exceeds regulated monopoly revenue adjusted for regulatory risk. This holds if the expropriation risk is high in relation to the liberalization risk; on the other hand, a low expropriation risk would suggest that a *later* date of liberalization is conducive to increasing investments.

The *empirical* evidence on the transition countries is scattered and thus far without conclusive results. Meissner (1999) is the only sectoral econometric study available to-date, it covers the relation between the amount of *road* infrastructure and the competitiveness of the East European transition countries. Meissner finds a positive relation between the network density of roads (expressed in km of roads/km^2) and the

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[2] This can occur through ex-post modifications of the regulated price structure, or, in the extreme case, by expropriation of the investor by the regulator. Several examples of this type of expropriation were observed in transition countries.

inflow of net foreign direct investment (which is taken as an indicator for competitiveness). This lends some support to the assertion of a selection effect à la Aghion and Schankerman. Dutz and Vagliasindi (1999) provide one piece of evidence in favor of a competition-oriented infrastructure policy: they find a robust relation between the *institutional infrastructure* for competition policy (measured by the capacity to implement laws, the competition orientation of competition policy and the political independence of the anti-monopoly offices) and the structural change towards efficient private enterprises. Finally, some anecdotal evidence on the structural effects of early infrastructure investment comes from Hungary, where the privatization of infrastructure proceeded particularly quickly, e.g. in banking, telecommunication, and the energy sectors, but where most private investors were granted temporary monopoly status. This infrastructure plus the boost in reputation that Hungary achieved may have spurred the market entry effect by attracting significant amounts of foreign direct investment (Hirschhausen, 2002). However, this anecdotal evidence may not be generally valid and this is why the next two sections present approaches to test the relation econometrically.[3]

3. ESTIMATION OF AN AGGREGATE PRODUCTION FUNCTION

3.1 Basic Model

This section sketches out a basic approach to testing the effect of infrastructure on growth in the transition countries during the 1990s. Following Barro (1990), we modify the aggregate production function to separate the private capital from the public capital, the latter is considered as a proxy for infrastructure capital. We assume that a country's

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[3] In a preliminary version of this research, we have found a positive relation between the speed of institutional reforms and per capita growth rates in transition countries, but this was not robust (Dodonov, et al., 2002, 152 sq.).

aggregate output (Y) is produced using capital and labor, where the capital consists of infrastructure capital (G) and other capital (K)

$$Y = A K^{\alpha} G^{\beta} L^{\gamma} \quad (1)$$

where A is total factor productivity and α, β and γ are the elasticities of aggregate output with respect to non-infrastructure capital (K), infrastructure capital (G) and labor (L), respectively.

We expand the model to include a variable reflecting changes in the infrastructure policy of a country. The variable is derived from the European Bank for Reconstruction and Development's (EBRD) measurement of the degree of market-oriented reform in the major infrastructure sectors. Incorporation of the indicator of infrastructure reform (IIR) allows us to test whether or not rapid reforms in the infrastructure sectors are conductive to growth. Thus, in our basic model, the dependent variable – aggregate output – is a function of private capital, infrastructure capital, labor, and infrastructure policy.

$$Y = AK^{\alpha}G^{\beta}L^{\gamma}e^{\delta IIR + \phi IIR^2} \quad (2)$$

where δ and ϕ measure the elasticities of aggregate output with respect to the IIR in linear and in squared form. The advantage of the proposed specification of the model is that it allows incorporating the influence on GDP growth of both the achieved *level* of infrastructure reform and the *speed* of institutional reform in infrastructure industries.[4]

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[4] The reason to do so is that we assume a non-linear relation between infrastructure reforms and economic development: below a certain threshold, a little bit of reform may be worse than no reform at all, the so-called Balcerowicz-effect (1990). In that case, a little bit of reforms in infrastructure sector may have a *negative* impact on economic development, in that they might (temporarily) break up the coherence of an inefficient sector, but one that is at least working. Examples are the Romanian gas sector or the Ukrainian electricity sector.

3.2 Data

We construct a data set including 15 East European and CIS transition countries[5] for the years 1993-2000 (see summary statistics in Table 2). *Output* is represented by GDP; we use purchasing power parity USD GDP data from the Economist Intelligence Unit database.[6] The major problem in the data set concerns *capital*, both total capital and infrastructure capital. Neither is directly available in an economically meaningful way for the base year (1993), due to distorted socialist data, absence of market values for capital, and hyperinflation in the early years of transition. Besides, existing data on capital stock in transition economies is unreliable. This is caused by changing principles of capital accounting, which has highly distorted information on capital availability.[7] Given the short period of data availability, an approximation of initial capital values as a fraction of GDP causes severe statistical problems of collinearity. To avoid this problem, we introduce a proxy for non-infrastructure and for infrastructure capital, respectively:

- *Capital* services, or capital utilization, are proxied by *net electricity consumption* (i.e. total electricity consumption minus network losses). This approximation has been suggested by a number of authors, not only for transition countries.[8] The idea is that

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[5] Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Poland, Romania, Slovak Republic, Slovenia, Russian Federation and Ukraine.

[6] Canning (1999) and Canning/Bennathan (2000) used purchasing power GDP from the World Bank's World Development Indicators; data from EBRD is also available. We prefer the data from the Economist Intelligence Unit database, since it produces similar results as those by the World Bank, but is available for more recent time periods. Moreover, this data almost completely fit GDP growth rates in constant prices across the countries reported by the VIIES.

[7] In that case, one might try, following Canning (1999, 4), to apply a perpetual inventory method using available data on total investments and on infrastructure investments, and to make assumptions of the initial stock of capital and capital depreciation rates. Both Canning (1999) and Piazolo (1999) assumed the capital to GDP ratio to be 3 for the base year. However, there is quite a variation in the capital/output ratios in transition countries, ranging from 1.5-13. Thus, the choice of 3 is rather arbitrary, although Canning (1999, 4) finds that his results are "remarkably robust to variations in the initial choice of capital-output ratio and the depreciation rate." A similar problem regards the initial value of the infrastructure capital stock. Earlier estimations of our results using capital data and the perpetual inventory method is available upon request.

[8] See Heathfield (1972, The Measurement of Capital Usage through Electricity Consumption. Journal of The Royal Statistical Society, Series A, General, Vol. 134, 2); Burnside, Craig, Martin Eichenbaum, and Sergio

running machines longer and keeping factories open longer involves increased use of electricity ("keep the lights on and the machines running"). If one assumes that the use of the capital stock requires a certain (proportional) amount of electricity, then electricity consumption is a good measure of the services provided by the capital stock. Contrary to the capital stock, the book values of which were determined quite mysteriously both in socialist and in transition times, electricity consumption is easy to measure; our data comes from the U.S. Energy Information Administration.[9]

- Several proxies are available for *infrastructure*. A proxy used in recent studies such as Canning (1998, 1999) and Canning and Bennathan (2000) is *physical* infrastructure, such as the number of telephone lines, megawatts of electricity generating capacity, and the length of transport infrastructure (roads, railways). The apparent overcapacity in the electricity sector and in railway infrastructure (EBRD, 1996) prevent these two indicators from properly reflecting the marginal productivity of infrastructure capital in transition countries. Thus we restrict ourselves to telecommunications infrastructure, namely telephone mainlines. This proxy was found to be a significant in a number of international studies (Easterly and Rebelo, 1995, Canning, Fay, and Perotti, 1994, Canning, 1999, and Röller and Waverman, 2001).[10]

Rebelo (1995, Capital Utilization and Returns to Scale. Cambridge, MA, NBER Working Paper No. 5125), and Baxter, Marianne, and Dorsey D. Farr (2001, The Effects of Variable Capital Utilization on the Measurement and Properties of Sectoral Productivity: Some International Evidence. Cambridge, MA, NBER Working Paper 8475).

[9] Different electricity intensities across countries might be captured in the country-specific intercepts of the fixed effects model. A major drawback of this approach is that it does not account for capital improvements, which increase its efficiency. Another argument against the use of electricity as a proxy for capital utilization might be that consumption is also determined by reactions to price changes, income changes, and structural change, and that the evolution of net electricity consumption differs from the change of *industrial* electricity consumption. However, price adaptation to cost-covering levels was slow in most transition countries, at least until the late 1990s, and structural change should impact electricity consumption significantly only if new, energy conserving equipment would be introduced massively, which was not the case in most transition countries in the 1990s.

[10] Slight distortions might be introduced since some transition countries featured over equipment of telecommunication (e.g. Bulgaria), and because qualitative differences and the increasing use of mobile communication are not accounted for.

- Data on *labor force* and population was obtained from the Economist Intelligence Unit database for all countries except Belarus. For Belarus the labor force was calculated on the basis of information on population under the assumption that labor force comprises the same share of population as in Ukraine.

- The *indicator of infrastructure reform* (IIR) is calculated as the yearly average of the EBRD indicators in five major sectors (telecommunications, power, roads, railways, water) (see Table 1). The scale for this indicator ranges from 1 (no market economy oriented reforms at all) to 4.3 (full implementation of market-oriented infrastructure policies, the reference being the average developed market economy).[11] For the years before 1998, the IIR was estimated based on its correlation with the more general indicator of institutional reforms.[12] The correlation between the infrastructure and the institutional indicator is high (R^2 = 87%).[13]

Table 1: Average indicator of infrastructure reforms (IIR) (1993-2000)

[11] More specifically, the evaluation is based on three criteria:
- Tariff reform, i.e. the introduction of cost-covering and allocative efficient price structures;
- commercialization, i.e. the transformation of corporate governance structures, the introduction of hard budget constraints and, eventually, privatization;
- regulatory and institutional reform, i.e. the setting-up of independent regulatory agencies with appropriate checks and balances, the definition of the formal institutional framework, etc.

See for more details EBRD (2001, 14 sq.).

[12] This is a feasible second-best estimate, since institutional reforms comprise similar reform areas as the infrastructure indicator (the EBRD indicator of institutional reforms includes: price liberalization, privatization, enterprise reform, and competition policy, trade liberalization, banking sector reform, and non-banking financial institutional reforms). Work is under way at the EBRD to trace the series of infrastructure indicators back to 1992 directly.

[13] The backward estimation of the indicator of infrastructure reform (1998 to 1993) was based on growth rates estimation for the general indicator of institutional reforms. Hence the level of infrastructure reforms was slightly overestimated and we made an additional assumption about the initial level of infrastructure reforms in 1993. The transition countries where divided into three groups and assigned initial values of 1.0, 1.5 and 2.0 (see Table 1). Afterwards the growth rates were revised so that the level of infrastructure reforms in 1998 was achieved. The relation between the estimated infrastructure indicator and the institutional indicator is presented in Figure 1.

Table 2: Summary statistics of the data

Figure 1: Relation between the average of eight institutional indicators of the EBRD and the indicator of infrastructure reform (IIR)

3.3 Estimations and Results of the Basic Model

We assume constant returns to scale ($\alpha + \beta + \gamma = 1$). Then equation (2) can be specified in *per worker* terms, which reduces potential heteroscedasticity between the countries that differ considerable in GDP, infrastructure equipment, etc. Taking into account the above modifications of (1), the model to be estimated has become the following:

$$y = a \ tcel^{\alpha} \ tel^{\beta} \ e^{\delta IIR + \phi IIR^2} \qquad (3)$$

where

- y is per worker GDP,

- a is a constant

- tcel is per worker electricity consumption, used as a proxy for non-infrastructure capital utilization,

- tel is the number of telephone mainlines per worker, used as a proxy for infrastructure capital,

- IRR (IRR^2) is the (squared) indicator of infrastructure sector reform,

- α and β are the elasticities of GDP with respect to the inputs,

- δ and ϕ are the coefficients of the change in IIR and IIR^2, respectively, on the logarithm of GDP.

The model is estimated in logarithmic form

$$\ln(y)_{it}=\ln(a_i)+\alpha\ln(tcel)_{it}+\beta\ln(tel)_{it}+\delta(IIR)_{it}+\phi(IIR^2)_{it}+\psi T \quad (4)$$

where indexes i and t represent a country and a year in a panel data estimation (i=1,…,15 and t=1993, …, 2000), and T is a time trend.

Table 3: Regression output of the fixed effects models

We estimated five variations of the basic model. In order to check differences between countries we test the hypothesis that the fixed coefficients are zero (F-test, Table 3); as a result we cannot conclude that fixed effects are insignificant (see Figure 2 with the estimated fixed effects from equation 5).[14] The Hausman specification test rejects the random effect model in favor of the fixed effect one (see Table 3), so the random effect model was not estimated.[15] Carrying out White's test for heteroskedasticity we cannot reject the null-hypothesis of homoskedasticity at the 10% level (see Table 3 where χ^2 is presented).

In order to test the possible endogeneity between GDP on the one hand, and electricity consumption on the other, we used the version of the Hausman test proposed by Davidson and MacKinnon.[16] This version carried out the test by running an auxiliary regression. As instrumental variable for electricity consumption we used its lagged value. In our case the

[14] The fixed effects for EU accession countries except for the Baltic states as well as Croatia are positive, whereas they are negative or close to zero for the other countries.

[15] The null hypothesis that the difference in coefficients is not systematic cannot be rejected at the 10% significance level in equations 3-5. In equation 1 it cannot be rejected at the 8% and in equation 2 at the 2% level.

[16] Davidson, Russel, and James G. MacKinnon (1993, Estimation and Inference in Econometrics. Oxford University Press); Davidson, Russel, and James G. MacKinnon (1989, Testing for Consistence using Artificial Regression. Econometric Theory, No.5, 363-384).

coefficient of the residual in the auxiliary regression is not significantly different from zero, which indicates the absence of endogeneity in the model.

Total capital utilization (electricity consumption) is significant at the 1% significance level in all five equations and the elasticity of GDP with respect to it is in a range 0.47-0.54 which corresponds to the expected values. The coefficient on infrastructure capital (number of phone lines per capita) is statistically insignificant in all estimated equations. The indicator of infrastructure reform is insignificant if it is in a linear form (IIR) (equation 2) whereas it is significant if it is in squared form (IIR^2 in equation 3). If both linear and squared forms of indicator are estimated together both variables are significant (equations 4 and 5).

One interpretation of the low significance of telecommunication is that it may have been included in the production function twice, once by itself and once as a part of physical capital. The coefficient on infrastructure capital then measures the impact of infrastructure capital on total output keeping other capital constant. The insignificance of infrastructure capital variable then may merely imply that productivity of infrastructure capital is not larger than productivity of other capital in the economy – there are no immediate externalities to telecommunications. At the same time the significance of IIR^2 provides evidence that market restructuring of the infrastructure sectors is conductive for economic growth in transition economies independent of investments in physical capital.

Focusing on the effects of infrastructure reforms, the results obtained in equations 4 and 5, where IIR and IIR^2 were estimated together, are most interesting. Both coefficients on IIR and IIR^2 are significant at the 1% level. The coefficient on IIR is negative while the coefficient on IIR^2 is positive. This provides some evidence in favor of the "Balcerowicz-effect" (1990): Taking the partial derivative of logarithm GDP with respect to IIR (∂

$\ln\_Y/\partial \ln\_IIR = \delta + 2\phi\ IIR$), we find that below a threshold of ($IIR = -\delta/2\phi$), reforming infrastructure seems to have a negative effect on output. Concretely, we obtain a threshold value for IIR of 2.24 in equation 4 and 2.29 in equation 5, respectively. Thus, countries that failed to achieve substantial progress in infrastructure deregulation experienced negative impact of reforms on economic growth. In the year 2000 only Belarus was substantially below estimated threshold in our sample (EBRD of 1.40); the indicator for Kazakhstan, Slovakia and Ukraine was in the range 2.12–2.18 in 2000, which was slightly below the estimated threshold. On the contrary, the countries with the higher level of infrastructure deregulation are currently benefiting the most from implemented reforms.[17] In essence, this first basic model implies that market-oriented restructuring of infrastructure sectors is conducive to economic growth in transition economies.

4. ESTIMATION USING A STOCHASTIC FRONTIER PRODUCTION FUNCTION

4.1 The Model

The above model, though yielding fairly reasonable results, was based on an assumption of *productive efficiency*: output was supposed to be *on* the production possibility frontier for all observations.[18] However, in most cases, and in particular for transition economies, one has to assume that neither capital nor labor and other inputs are employed at their optimal productivity levels. Even though the use of electricity consumption as a proxy for real capital utilization took into account lower capital utilization ratios, the assumption of efficient use of inputs remains strong. Also, in reality technical efficiency might vary over time (most likely increasing) and also across countries (with reforming countries more

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[17] The negative impact of infrastructure reforms can lead to two different policy conclusions: either there is no way to avoid the "valley of tears" in the first phase of reform, which would imply to proceed with reforms as fast as possible, in order to cross the valley; or it may suggest to jump to a relatively high level of reforms right away.

likely to show higher efficiency). In this section we shall drop the assumption of productive efficiency and carry out the regressions presented in the previous section based on a stochastic frontier production function (SFPF).[19]

The feature of this estimation method is that it allows measuring the utilization of the available production inputs in the country.[20] In our estimations we use the SFPF following Coelli (1996):

$$Y_{it} = f(X_{it}, \beta)\, e^{-U_{it} + v_{it}} \qquad (5)$$

where

- $i = 1, \ldots, N$ and N is the total number of countries,

- $t = 1, \ldots, T$ is the year of observation,

- Y_{it} is the GDP of country i in period t,

- X_{it} is a vector of inputs, namely private capital, labor and infrastructure capital of country i in period t,

- β is a vector of parameters to be estimated,

- U_{it} is asymmetric non-negative random error, which accounts for the technical inefficiency, and

- v_{it} is a symmetric random error.

In our model specification, we come back to the traditional estimation of capital and labor as inputs, whereas the infrastructure variable (TEL) is used once as an input and once as a

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[18] In addition, the model implies that prices reflected marginal rates of transformation (allocative efficiency); this latter assumption will be maintained.

[19] Special thanks to Alexandr Scherbakov for suggesting this procedure and introducing us to the estimation technique.

regressor of a country's inefficiency. The inefficiency is also explained by the indicator of infrastructure reform. Thus, the following form of the production function is estimated:

$$\ln(GDP)_{it}=\ln(A)+\alpha\ln(TCEL)_{it}+\gamma\ln(L)_{it}-U_{it}+v_{it} \qquad (6a)$$

where

$$U_{it}=\beta\ln(TEL)_{it}+\delta IIR_{it}+\phi IIR_{it}^{2}+\zeta EU. \qquad (6b)$$

EU is a dummy variable which takes the value of 1 if the country is an EU accession country and the value of zero otherwise.[21] It is introduced since the SFPF is estimated with maximum-likelihood estimator and country-specific effects might be lost in process of estimation.

4.2 Estimations and Results

The unknown parameters in the above stochastic frontier production function are simultaneously estimated by the maximum likelihood method.[22] The FRONTIER 4.1 software was used for the estimation. Table 4 and Figure 3 present the efficiency of input utilization in each country, estimated using equation 3: The average efficiency of inputs utilization rose from 60% (1993) to about 73% in 2000. This means that in 1993 the countries produced 60% of potential output using the given amount of available production inputs, while in 2000 this figure has grown to 73%. The countries might be divided into 3 main groups according to their efficiency. The first group of countries – Hungary, Croatia,

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[20] Comprehensive literature review devoted to stochastic frontier estimation method is provided by Bauer (1990) and Green (1993).

[21] EU-accession countries are the following: Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic, Slovenia. Bulgaria and Romania are placed in the group of non-accession countries, since they are not among the first-round enlargement candidates but are facing an undefined date of their accession.

Czech Republic, Poland and Slovenia – have the highest efficiency of inputs utilization (efficiency level in the range of 72% – 99%). The second group of countries consists of Belarus, Latvia, Lithuania, Romania and Slovakia. Their output fluctuated in the range 54% - 89% of potential during 1993 – 2000. The third group of countries is Bulgaria, Estonia, Kazakhstan, Russia and Ukraine; for the latter two, the efficiency has even declined over the last decade. During 1993-2000, the efficiency ratio increased in the first and second groups while it was the same or even declined for most countries in the third group.

The results of the model estimation are presented in Table 5. In equation 1, teledensity (LN_TEL) was used as a factor of production and in equation 2 it was used as a factor explaining the inefficiency of factor utilization. However, in both cases it was insignificant, similar to the model estimation with fixed effects.[23]

The coefficient on labor force is statistically insignificant and in equation 1 it is even negative. This insignificancy of the labor force may be explained by the process of structural change in the transition countries: production in post-socialist economies is labor-intensive, but the transition period is characterized by short-run layoffs and structural unemployment. At the same time most of the countries in our sample demonstrated economic growth during the estimation period. The insignificance of the coefficient for labor force may also explain why the coefficient on total capital is rather close to unity.

According to the obtained estimates in equation 1 and 2, EU accession countries have achieved higher economic efficiency compared to non-accession countries, but the

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[22] We apply the one-stage estimation approach described by Coelli (1996b). This helps to avoid inconsistency typical for a two-stage estimation, where inefficiency terms are assumed to be independent and identically distributed (iid), which is not true for the second stage regression, see Coelli (1996a).

coefficient is statistically significant in equation 2 and insignificant in equation 1. On the contrary, coefficients on IIR and IIR^2 are insignificant in equation 2 and significant in equation 1. For reasons of low significance, equation 3 was estimated without the LN_TEL variable. The impact of IIR^2 and EU on country's efficiency was positive while the coefficient on IIR was negative, similar to the model specification estimated with fixed effects; all three coefficients are statistically significant. The threshold of infrastructure reform is equal to 1.69 and 1.75 in equations 1 and 3, respectively. Thus, the level of reform required to translate infrastructure reform into economic growth might not be as high as estimated in the model with fixed effects.

5. CONCLUSIONS AND FURTHER RESEARCH

This paper provides the first econometric evidence on the link between infrastructure policies and economic development for the transition countries of Eastern Europe and the CIS. In particular, it addresses the politically sensitive question of whether more investment in physical infrastructure and/or more rapid liberalization of infrastructure sectors, might enhance economic growth in the region. We have developed two models based on an aggregate Cobb-Douglas production function: one which assumes productive efficiency and, because this seems to be a strong assumption, one that does *not* assume productive efficiency and explicitly estimates the determinants of this inefficiency.

Total capital utilization, proxied by electricity consumption, is a significant factor of production. Curiously, infrastructure capital, proxied by teledensity, does not turn out to have a significant impact on growth; this may eventually be explained by double counting of infrastructure capital. Both models provide evidence of a positive impact of infrastructure sector reform on economic growth in transition countries. However, it occurs

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[23] As was explained in the previous subsection this may be due to absence of substantial externalities to

only if some threshold of reforms has been passed; beyond this threshold, a higher level of deregulation leads to a larger positive impact on GDP. Overall, there is evidence that institutional reforms in infrastructure industries are conductive for economic growth in transition economies independent of physical infrastructure capital accumulation. The second model (stochastic frontier) also supports the idea of a significant difference *between* transition countries. In general, EU-accession countries have a higher productive efficiency; this may be explained their institutional reforms that are faster and more consistent than in those countries without a firm policy perspective.

The first look at the data suggests that indeed infrastructure policies do have an impact on economic growth in Eastern Europe. In further research, the data base should be extended to include about 20 of the 26 transition countries for which reasonably reliable data is available, and eventually additional infrastructure variables might be included. Also, a more subtle distinction between short-run and long-run effects should be carried out. A disaggregation of the data into production sectors might yield more differentiated results (e.g. different impact of different infrastructure sectors), but may be difficult due to data constraints.

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infrastructure investments (telephone mainlines in our case).

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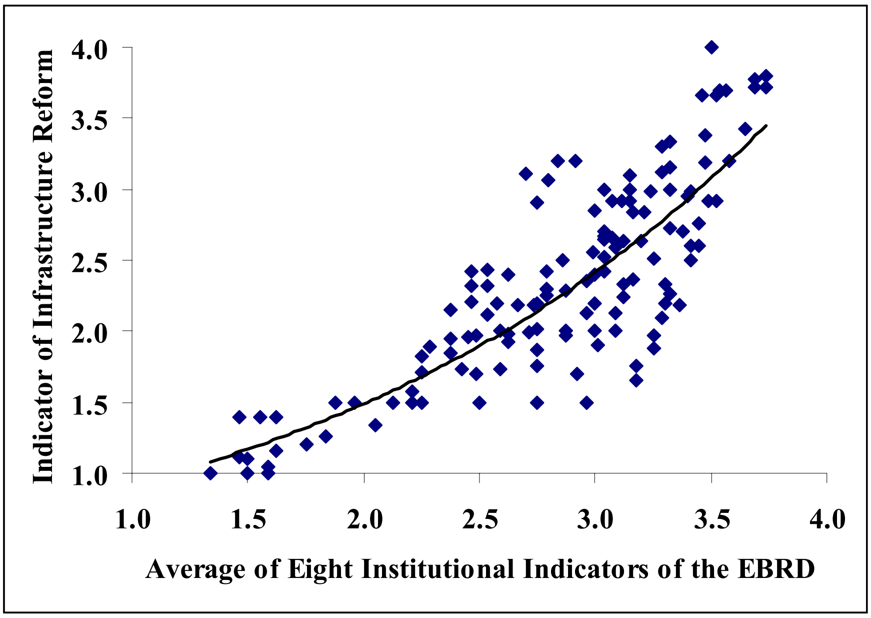
Table 1: Average indicator of infrastructure reforms by EBRD since 1998 and estimated indicator of infrastructure reform before 1998

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Belarus	1.0	1.0	1.3	1.3	1.2	1.1	1.4	1.4	1.4
Bulgaria	1.5	1.8	2.0	2.2	2.2	2.3	2.5	2.7	3.0
Croatia	1.5	1.7	2.0	2.1	2.5	2.7	2.7	2.9	3.0
Czech Republic	2.0	2.2	2.3	2.5	2.6	2.8	2.9	2.9	3.2
Estonia	2.0	2.3	2.6	2.8	3.1	3.3	3.7	4.0	3.7
Hungary	2.0	2.3	2.7	3.0	3.4	3.8	3.7	3.7	3.8
Kazakhstan	1.0	1.2	1.6	1.9	2.2	2.4	2.2	2.2	2.3
Latvia	1.5	1.9	2.0	2.4	2.6	2.8	2.9	2.9	3.1
Lithuania	1.5	1.8	2.0	2.2	2.4	2.6	2.6	2.8	3.0
Poland	2.0	2.2	2.5	2.7	2.9	3.2	3.4	3.7	3.7
Romania	1.5	1.9	2.2	2.4	2.9	3.1	3.1	3.2	3.2
Russia	1.5	1.7	2.0	2.3	2.6	2.4	2.3	2.3	2.4
Slovakia	1.5	1.7	1.8	1.9	2.0	2.1	2.3	2.2	2.6
Slovenia	1.5	1.7	1.9	2.1	2.4	2.6	3.0	3.1	3.3
Ukraine	1.0	1.1	1.7	1.8	2.0	2.0	1.7	2.1	2.2

Source: EBRD, Transition Report (1998, p. 44, 1999, p. 50, 2000, p. 41, 2001, p.14), own estimations

Figure 1: Relation between the average of eight institutional indicators of the EBRD and the indicator of infrastructure reform



Source: EBRD, Transition Report (1998, p. 44, 1999, p. 50, 2000, p. 41, 2001, p.14), own estimations

Table 2: Summary statistics of the data

Variable	Obs	Mean	Std. Dev.	Min	Max
ln_GDP	120	9.316039	.4471358	8.384269	10.31939
ln_TCEL	120	8.927934	.2980903	8.254594	9.445978
ln_TEL	120	-.6844466	.4025844	-1.590997	.0310733
IIR	120	2.272325	.6710758	1	4
IIR^2	120	5.61005	3.211967	1	16

Table 3: Regression output of the basic model

Equation No.	**1**	**2**	**3**	**4**	**5**
Dep. var.	**LN_GDP**	**LN_GDP**	**LN_GDP**	**LN_GDP**	**LN_GDP**
Estimation Method	Fixed-effects (within) regression	Fixed-effects (within) regression	Fixed-effects (within) regression	Fixed-effects (within) regression	Fixed-effects (within) regression
No. obs.	120	120	120	120	120
Intercept. (LN(A))	4.52*** (5.26)	4.48*** (5.05)	4.31*** (5.00)	5.09*** (6.13)	5.32*** (7.06)
LN_TCEL	.534*** (5.72)	.537*** (5.66)	.549*** (5.91)	.495*** (5.62)	.474*** (5.82)
LN_TEL	.059 (0.91)	.054 (0.76)	.073 (0.01)	-.048 (-0.70)	
IIR		.006 (0.20)		-.294*** (-3.84)	-.286*** (-3.80)
IIR^2			.006* (1.71)	.066*** (4.25)	.063*** (4.29)
TIME	.003*** (4.46)	.002*** (3.53)	.002*** (3.02)	.002*** (4.31)	.003*** (4.45)
R^2 WITHIN	0.52	0.52	0.53	0.59	0.59
R^2 OVERALL	0.36	0.36	0.34	0.26	0.30
***F* test**	F(14,102)= 145.00	F(14,101)= 136.11	F(14,101)= 140.15	F(14,100)= 160.23	F(14,101) =203.16
White test for heteroskedasticity	$\chi_9^2 = 4.45$	$\chi_{12}^2 = 9.13$	$\chi_{12}^2 = 7.57$	$\chi_{19}^2 = 11.75$	$\chi_{13}^2 = 14.98$
Hausman specification test	$\chi_3^2 = 6.56$	$\chi_4^2 = 11.44$[24]	$\chi_4^2 = 5.32$	$\chi_5^2 = 7.72$	$\chi_2^2 = 2.17$

* significant at the 10%-level
** significant at the 5%-level
*** significant at the 1%-level

[24] Prob>chi2 = 0.0220

Table 4: Estimated level of inputs utilization efficiency across countries

	1993	1994	1995	1996	1997	1998	1999	2000
Belarus	61.54	61.68	59.65	62.67	65.93	77.40	74.53	88.79
Bulgaria	47.20	48.16	45.46	39.75	41.06	43.33	46.17	45.29
Czech Republic	78.82	78.13	78.77	79.19	78.97	79.42	80.55	81.54
Estonia	35.62	33.45	35.29	35.19	39.04	41.32	43.65	56.99
Hungary	86.09	88.29	87.65	86.97	90.37	94.09	97.15	98.53
Kazakhstan	30.33	33.64	31.20	35.05	40.86	41.95	45.29	46.16
Latvia	53.28	55.20	54.87	55.98	61.41	65.14	68.59	78.03
Lithuania	54.94	52.27	54.06	67.10	67.22	67.54	63.77	88.61
Poland	71.55	74.58	77.82	80.39	85.37	91.72	97.15	99.97
Romania	72.99	77.88	78.42	78.90	79.34	80.03	83.54	82.59
Russia	42.42	41.80	39.70	38.84	39.71	38.07	39.27	40.64
Slovakia	54.29	56.03	58.63	58.49	63.09	66.40	70.74	70.54
Slovenia	86.54	72.60	88.50	91.33	92.40	90.75	96.45	97.71
Ukraine	38.31	33.03	30.59	29.07	28.68	29.09	29.82	30.62
Croatia	78.63	80.35	83.06	84.02	85.79	79.47	82.50	90.51
Mean efficiency across countries	**59.50**	**59.14**	**60.24**	**61.53**	**63.95**	**65.72**	**67.95**	**73.10**

Table 5: Results of the stochastic frontier production function

Equation No.	**1**	**2**	**3**
Dep. var.	**LN_GDP**	**LN_GDP**	**LN_GDP**
Estimation Method	Maximum likelihood estimation	Maximum likelihood estimation	Maximum likelihood estimation
No. obs.	120	120	120
Intercept (LN(A))	0.72 (0.26)	1.5*** (2.7)	0.14*** (3.8)
LN_TCEL	1.02*** (3.7)	0.93 (16.1)***	0.95 (19.9)***
LN_L	-0.176 (-1.55)	0.032 (0.61)	0.88 (0.16)
LN_TEL	0.154 (1.30)		
Inefficiency component[25]			
LN_TEL		0.91 (1.5)	
IIR	0.63*** (5.2)	0.23 (1.2)	0.79*** (8.1)
IIR^2	-0.19*** (-5.9)	-0.69 (1.3)	-0.23*** (-5.8)
EU	-0.69 (-1.16)	-0.55* (-1.9)	-0.35** (-2.1)
Log-likelihood	-3.11	-20.20	-16.12

* significant at the 10%-level
** significant at the 5%-level
*** significant at the 1%-level

[25] As was pointed out, according to model specification, the negative sign in inefficiency component implies that the variable has positive impact on country's technical efficiency and vice versa.

Figure 2: Estimated fixed effects from the basic model

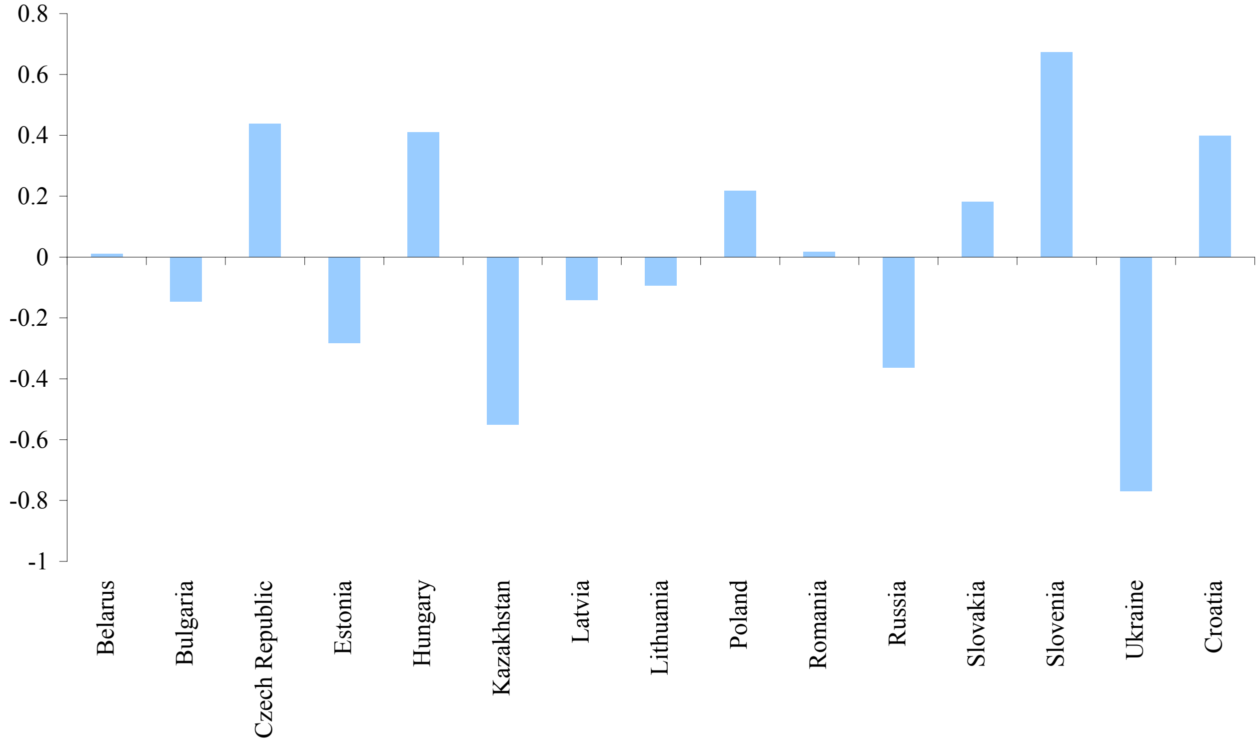


Figure 3. Estimated level of inputs utilisation efficiency across countries