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Infrastructure Policies and Economic Development in East European Transition Countries: First Evidence

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Infrastructure Policies and Economic Development in Transition Countries: First Evidence

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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 prevailing in the individual countries. The models suggest that early liberalization of infrastructure sectors is conducive to economic growth.

Keywords: deregulation, economic development, infrastructure, transition

JEL Classification: P20, H54, O11, L90

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1. INTRODUCTION

Infrastructure is generally considered to be an important determinant of economic development (World Bank, 1994, Gramlich, 1994, Aschauer, 1989, Canning, 1998, 1999). 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. 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. Krichel and Levine (1995) found that the mix of government spending between infrastructure and public consumption goods can significantly affect the long-run growth rate of a country. In a panel data study Canning (1999) found infrastructure productivity rates to be comparative to observable private capital productivity rates. 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 externalities of telephone mainlines in industrial countries.

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 (2002) 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. All in all, there is a broad consensus that for industrial countries, 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 (Hulten, 1996).

Little is known, however, on the relation between infrastructure and economic development in the *transition countries* of Eastern Europe and the Commonwealth of Independent States (CIS), though it is common knowledge that infrastructure is a key factor for economic recovery in this area of the world (EBRD, 1996, Aghion and Schankerman, 1999). In fact, the often dismal state of infrastructure has sometimes been considered as one of the most important obstacles to recovery and growth in transition countries. 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), but there is little empirical evidence on the issue thus far. A second controversial issue has been the optimal *sequencing* of infrastructure sector reforms and its impact on investments and on growth in transition countries. Armstrong and Vickers (1996) suggested that a more conservative approach to liberalization might create higher incentives to invest into 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.

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 level of sectoral reforms. The paper is structured in the following way: Section 2 surveys the recent literature on infrastructure and growth 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. 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 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

Whereas the literature on infrastructure and development abounds for Western industrial countries, little has been said on the topic on *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 and 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. Falcetti, Raiser and Sanfey (2002) find that the positive impact of reforms (defined as a composite of price liberalization, trade liberalization, and small-scale privatization) is less robust than previously thought; in particular, "the impact of reforms on growth is nonlinear having a negative contemporaneous effect and a positive effect with a 1-year lag" (Falcetti, et al., 2002, p. 229). Along similar lines, Radulescu and Barlow (2002) found no long-term relationship between liberalization (taken as an average of eight liberalization indicators published by EBRD) and growth, but they concede that "the long-term benefits from liberalization may be indirect, via macro stability" (Radulescu and Barlow, 2002, p. 719).

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, pointing to a potential obstacle to sustained growth (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 in favor of immediate liberalization and privatization, 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,[1] 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, p. 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 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 in transition countries: 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. With respect to the European transition countries, 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 (Armstrong and Vickers, 1999, 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.[2]

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 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 quality of the infrastructure policy in 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 infrastructure reforms 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.

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

where $\delta IIR+2\phi IIR^2$ measures the elasticity of aggregate output with respect to the IIR. The advantage of the proposed specification of the model is that it allows incorporating the influence on GDP growth of the achieved *level* of infrastructure reform and estimating the threshold beyond which institutional reform in infrastructure industries has either negative or positive impact on GDP growth.[3]

3.2 Data

The data set includes 15 East European and CIS transition countries[4] 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.[5] 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.[6] 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.[7] The idea is that 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 are difficult to determine both in socialist and in transition times, electricity consumption is easy to measure; our data comes from the U.S. Energy Information Administration.

- 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).[8]

- Data on *labor force* and population was obtained from the Economist Intelligence Unit database.[9]

- 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).[10] For the years before 1998, the IIR was estimated based on its correlation with the more general indicator of institutional reforms.[11]

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

Table 2: Summary statistics of the data

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:

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

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 measure the impact of 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[12].

Table 3: Regression output of the basic fixed effects model

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 1 with the estimated fixed effects from equation 5).[13] 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.[14] Carrying out White's test for heteroskedasticity we cannot reject the null-hypothesis of homoskedasticity at the 10% significance 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.[15] 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 coefficient of the residual from the auxiliary regression in the augmented one is not significantly different from zero, so we cannot reject the null hypothesis of no endogeneity at the 10% significance level (see Table 3).

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 (IIR) is insignificant in a linear form (equation 2) whereas it is significant in a quadratic form (equation 3). If both linear and quadratic forms of the 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.[16] At the same time the significance of IIR in quadratic form provides evidence that market restructuring of the infrastructure sectors is conductive for economic growth in transition economies independent of investments in physical capital.

Significance of the IIR in both linear and quadratic forms (equations 4 and 5) at 1% significance level provides some evidence in favor of the "threshold effect" similar to Balcerowicz (1990). Solving for the partial derivative of GDP with respect to IIR ($\partial Y/\partial \text{ IIR} = \delta + 2\phi \text{ IIR}=0$), we find that below a threshold of ($\text{IIR} = -\delta/2\phi$), 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 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. Also, in reality technical efficiency might vary over time (most likely increasing) and also across countries (with reforming countries more 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), which has been applied to productivity analysis in transition countries by Piesse and Thirtle (2000)[21]:

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

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 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.[22] It is introduced since the SFPF is estimated with maximum-likelihood estimator and country-specific effects might be lost in the 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.[23] Table 4 and Figure 2 present the efficiency of input utilization in each country, estimated using equation 3.[24]

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.[25] 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 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 EU dummy variable on country's efficiency is positive while the impact of IIR follows the same pattern as in the previous model, 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.

Table 5: Results of the stochastic frontier production function

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 question of whether 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 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 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 conducive 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.

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

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

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		Mean	Std. Dev.	Min	Max	Observations
ln_gdp	overall	9.316039	0.447136	8.384269	10.31939	N = 120
	between		0.448778	8.522368	10.16552	n = 15
	within		0.101861	9.107171	9.686986	T = 8
ln_elec	overall	8.927934	0.29809	8.254594	9.445978	N = 120
	between		0.294812	8.439799	9.339068	n = 15
	within		0.084002	8.696551	9.324181	T = 8
ln_tel	overall	-0.68445	0.402584	-1.591	0.031073	N = 120
	between		0.367745	-1.49641	-0.09155	n = 15
	within		0.186529	-1.29016	-0.20672	T = 8
iir	overall	2.272325	0.671076	1	4	N = 120
	between		0.497559	1.212384	3.082508	n = 15
	within		0.466198	1.189817	3.281969	T = 8
iir2	overall	5.61005	3.211967	1	16	N = 120
	between		2.319749	1.492415	9.912896	n = 15
	within		2.291732	-0.30285	12.26902	T = 8

Table 3: Regression output of the basic fixed effects 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	$\chi_3^2 = 6.56$	$\chi_4^2 = 11.44$ [a]	$\chi_4^2 = 5.32$	$\chi_5^2 = 7.72$	$\chi_4^2 = 2.17$
Hausman endogeneity test (t-statistics for residual from the auxiliary regression in the original model)	-.315 (-1.44)	-.324 (-1.31)	-.252 (-1.05)	-.107 (-0.46)	-.098 (-0.45)

* significant at the 10%-level

** significant at the 5%-level

*** significant at the 1%-level

[a] Prob>chi^2 = 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 [a]			
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

a: 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 1: Estimated fixed effects from the basic model

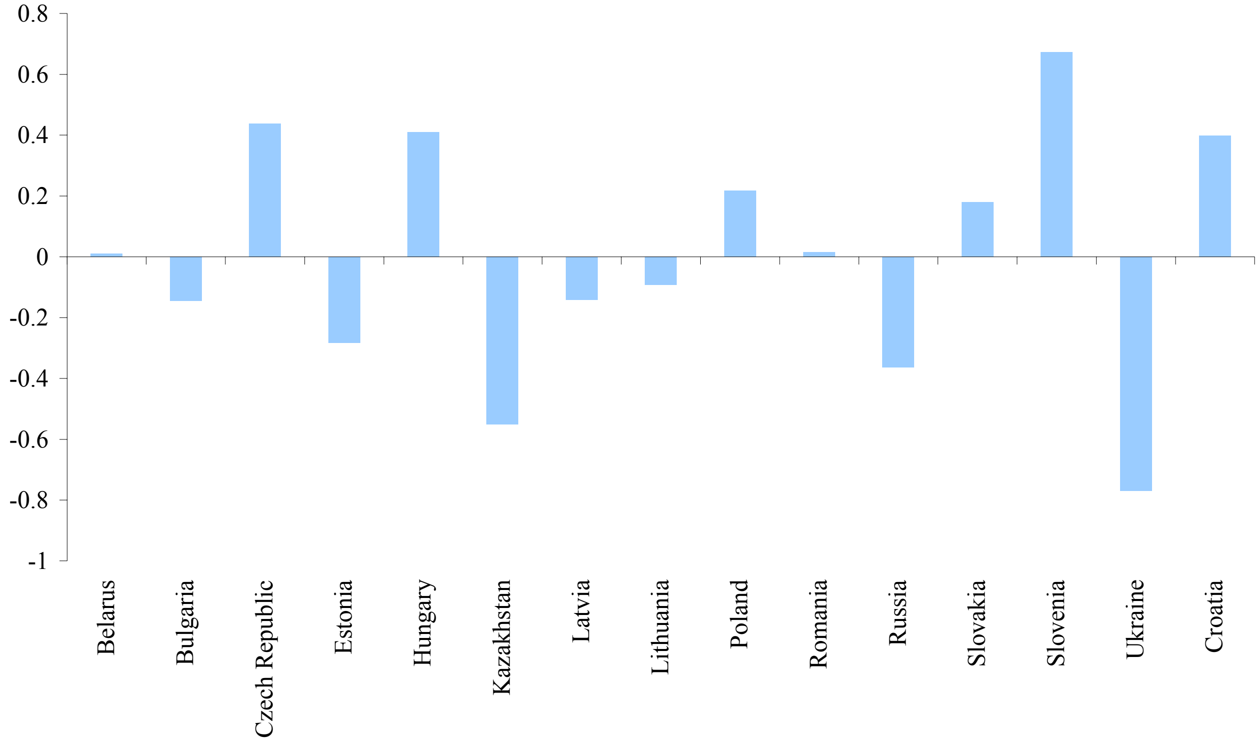
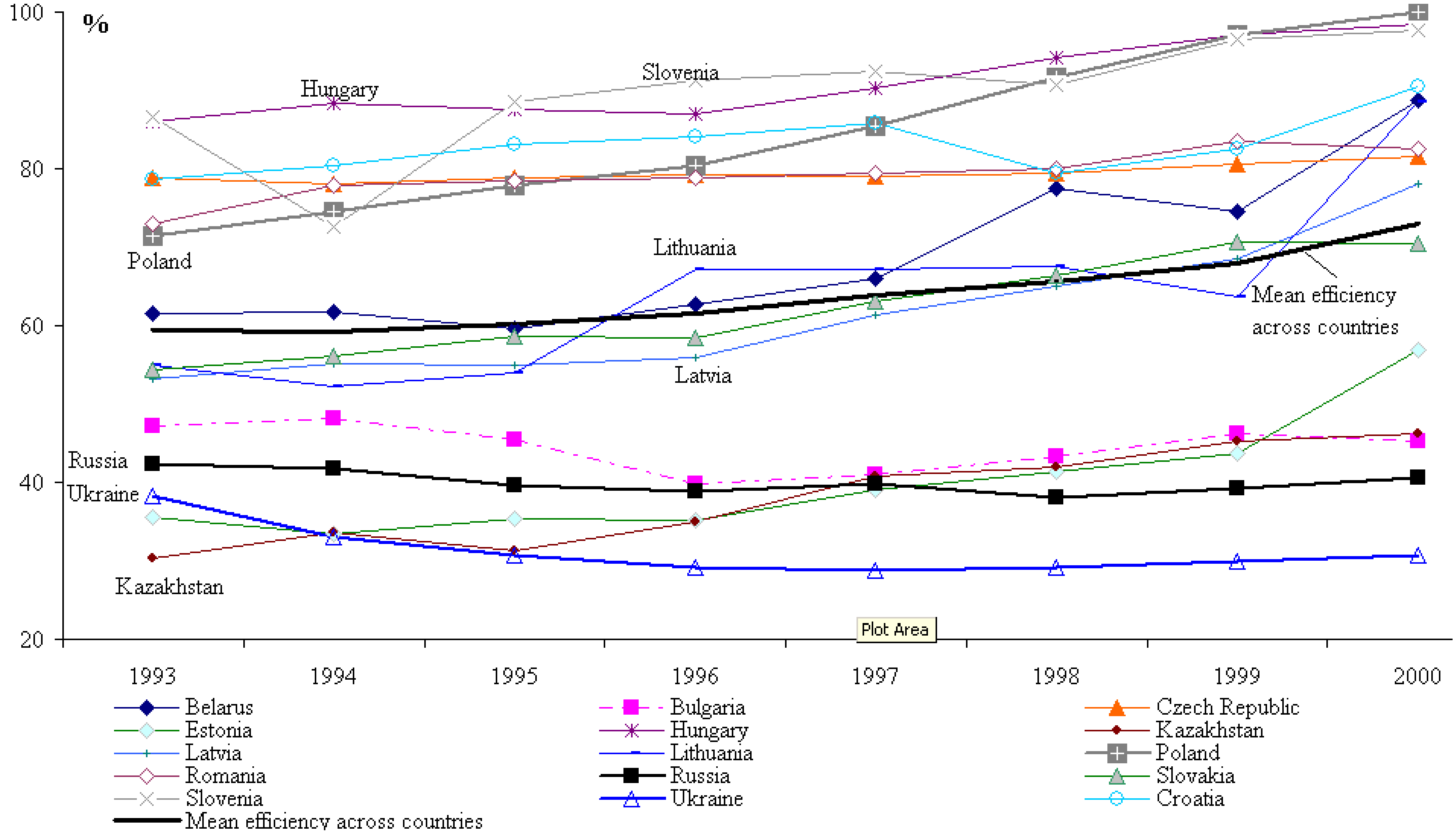

0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
Belarus
Bulgaria
Czech Republic
Estonia
Hungary
Kazakhstan
Latvia
Lithuania
Poland
Romania
Russia
Slovakia
Slovenia
Ukraine
Croatia

Figure 2. Estimated level of inputs utilisation efficiency across countries


%
100
80
60
40
20
Hungary
Slovenia
Poland
Lithuania
Mean efficiency across countries
Latvia
Russia
Ukraine
Kazakhstan
Plot Area
1993
1994
1995
1996
1997
1998
1999
2000
Belarus
Estonia
Latvia
Romania
Slovenia
Mean efficiency across countries
Bulgaria
Hungary
Lithuania
Russia
Ukraine
Czech Republic
Kazakhstan
Poland
Slovakia
Croatia

[1] 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 indeed observed in transition countries.

[2] In preliminary estimations, 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.

[3] 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. Radulescu and Barlow (2002) also pointed to the necessity of testing thresholds for certain independent variables.

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

[5] Canning (1999) and Canning and 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.

[6] In that case, one might try, following Canning (1999, p. 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, p. 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.

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

[8] 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.

[9] One exception: 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.

[10] 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.).

[11] 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). 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. Work is under way at the EBRD to trace the series of infrastructure indicators back to 1992 directly, but it is unlikely that these modification change the estimation results significantly.

[12] After the model was estimated with time dummies the linear trend was chosen as an appropriate approximation of the time factor.

[13] 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.

[14] 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.

[15] 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).

[16] It has been suggested that this result is due to not taking into account the increasing use of mobile telecommunication in the transition countries. However, preliminary estimates have not supported this hypothesis; besides, data on mobile telecommunication in transition countries is particularly unreliable.

[17] The negative impact of infrastructure reforms below the estimated threshold can lead to straightforward policy conclusions. 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.

[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 Alexander Scherbakov for suggesting this procedure and introducing us to the estimation technique.

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

[21] Another application of stochastic frontier analysis to transition countries is Koop, Osiewalsi, and Steel (2000), who analyze aggregate data to estimate the relative efficiency of Poland and Yugoslavia with respect to West European countries.

[22] 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.

[23] 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). The FRONTIER 4.1 software was used for the estimation.

[24] 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: i) Hungary, Croatia, Czech Republic, Poland and Slovenia (efficiency level in the range of 72% – 99%); ii) Belarus, Latvia, Lithuania, Romania and Slovakia (54% - 89% of potential during 1993 – 2000); iii) Bulgaria, Estonia, Kazakhstan, Russia and Ukraine. 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.

[25] As was explained in the previous subsection this may be due to absence of substantial externalities to infrastructure investments (telephone mainlines in our case).