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Abstract

The antiquated state of the telecommunications network in the transitional economies of Central and Eastern Europe has been identified by the OECD (1993) and the ITU (1994) as a significant impediment to regional productivity, international competitiveness and trade performance. This situation suggests that the upgrading and extension of the telecommunications network should be a priority objective for policy-makers in order to facilitate growth. This paper empirically examines the relationship between gross fixed investment, telecommunications infrastructure investment and economic growth for a sample of transitional economies in Central and Eastern Europe. In particular, the paper focuses on empirically determining the direction of influence, and timing, between investment and growth. © 1998 Elsevier Science B.V.

Keywords: Economies in transition; Investment and growth; Telecommunications infrastructure

JEL Classification: L96; O05

1. Introduction

The finding of a strong relationship between fixed investment and economic growth rates has led many economists to conclude that the rate of capital formation determines the rate of economic growth (DeLong and Summers, 1991;

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Wolff, 1991; Levine and Renelt, 1992). Further, Aschauer (1989), and DeLong and Summers (1991) argue that specific types of investment, such as public infrastructure and machinery and equipment, have a strong association with productivity and growth. Consequently, the optimal allocation of investment funds to sector-specific infrastructures is an important policy issue. In particular, investment in telecommunications infrastructure has the potential to improve national productivity and economic growth. Economy-wide gains occur through the reduction of transport and transaction costs, improved marketing information and the accelerated diffusion of information and knowledge.

The antiquated state of the telecommunications network in the transitional economies of Central and Eastern Europe (CEE) has been identified by the International Telecommunications Union (ITU, 1994) as a significant impediment to regional growth. In 1992 the average teledensity (number of main telephone lines per 100 inhabitants) in CEE was 14, about one-third the level of Western Europe[1]. The percentage of main telephone lines connected to digital exchanges was approximately 10% (compared to over 50% in Western Europe), while an estimated 23 million persons were waiting for connection to the telephone network (ITU, 1994). In 1991, Poland had among the lowest telephone line ownership in Central Europe, with a teledensity of 9.64 and 3.6 million national subscribers. The closest comparison in Western Europe is Portugal with a teledensity of 20. Further, more than 3000 villages in Poland had no access to telephones, and even in the richest Warsaw suburbs there are an estimated 600 businesses without a telephone line. International communications has also been a major problem in CEE. For example, until recently all foreign calls in the former USSR were routed through one exchange in Moscow, which had only 16 circuits to the United States (US) and 34 to the United Kingdom, creating major bottlenecks (Gibbs, 1994).

These findings suggest that upgrading and extending the telecommunications network should be a priority objective for policy-makers in order to facilitate growth in the region. The European Community (EC, 1987, 1988, 1995) has published a series of reports on the role of telecommunications and the community's relations with the countries in CEE. These reports set out the instruments available to access capital and help in the current change in CEE, including coordinated assistance by the European Bank for Reconstruction and Development (EBRD), the EC, the European Investment Bank (EIB), the Organisation for Economic Cooperation and Development (OECD), and the World Bank.

This paper empirically examines the relationship between gross fixed investment, telecommunications infrastructure investment and economic growth for a sample of 27 transitional economies in CEE. The analysis proceeds in two stages.

[1] Main telephone lines refers to telephone lines connecting a customers equipment to the Public Switched Telephone Network and which have a dedicated port on a telephone exchange (ITU, 1994).

First, given the unique historical development of CEE economies, the relationship between growth and economy-wide investment is examined. Anecdotal evidence suggests that supporting infrastructure, such as telecommunications, is necessary to coordinate the efficient use of economy-wide investment as the transitional countries of CEE move towards a decentralised market economy. For example, survey data from the OECD (1994) shows that the poor state of telecommunications is ranked by business managers in Russia, Lithuanian, Romania, Poland and Latvia as the main internal barrier to trade, outranking high interest rates, unstable exchange rates and transportation problems. Therefore, the second stage of the analysis is concerned with examining the relationship between economic growth and telecommunications infrastructure. In particular, the direction of influence and timing are considered.

The volatility and changing circumstances of CEE economies, which are suffering extreme dislocation, are described here using short run data series. First, we argue that econometric analysis is sensible, whether or not the economies are on a stable growth path, since the directional response to the supply-side impact should be the same but have a greater variance. On this point, Fischer et al. (1996a) argue that the length and severity of recession depends on initial conditions facing the economy such as the share of military output, the lack of a legal framework supporting markets and private property, subsequent shocks, the external environment (including aid), and economic policy. Second, the use of a short term time frame to measure the response is reasonable because the main focus of reforms has been network coverage, rather than making available advanced networks, both to rural regions and poorly serviced metropolitan areas. Since the work of Jipp (1963) it has been commonly found that the greatest impact of telecommunications investment on growth has been in lower income economies.

The paper is organised as follows. Section 2 reviews the state of telecommunications in the transitional economies of CEE. In Section 3, gross domestic product (GDP) per capita, fixed investment and telecommunications data are examined for a sample of 27 transitional economies. Econometric analysis of the relationship between economic growth, fixed investment and telecommunications investment is provided in Section 4, while Section 5 examines the directions of influence and timing between investment and rates of growth. Concluding remarks are presented in Section 6.

2. Telecommunications in central and eastern Europe

The services sector, and particularly telecommunications services, had a relatively low priority in the centrally planned investment decision processes of the CEE governments. Because socialist systems were hierarchically organised,

vertical communication lines in industry were provided by public telecommunications operators, however, the individual horizontal communications links vital for competing firms in market economies were neglected. Further, investment in telecommunications infrastructure was low and the investment that was forthcoming was used to connect new telephone lines rather than maintain, replace, and strengthen the underlying infrastructure. Although firms and public enterprises had a workable level of telecommunications infrastructure there was almost a complete absence of modern business services such as data transmission services, fibre-optical networks, and modern multi-functional terminal equipment (Muller and Nyevrikel, 1996). Consequently, by the late 1980s most CEE countries had obsolete and unbalanced networks. Telecommunications services in the CEE countries are characterised by few if any nationwide dialling facilities, low service quality, slow fault clearance, high noise and distortion ratios, and frequent disconnections. Although subscriber charges and basic telephone service prices were low in CMEA countries, the huge excess demand among potential telephone subscribers effectively invalidated the existence of cheap uniform domestic call rates[2]. International traffic flows were also impaired by low quality and insufficient digitisation, which not only reduced personal international communication but prevented the expansion of trade and international investment (Welfens, 1995).

The political changes and restructuring efforts in CEE countries, from centrally planned to market economies, has focussed government priority towards the telecommunications sector. Many CEE economies have recognised that a well functioning market system depends critically on the quantity and quality of information flows, especially the generation and productive exploitation of new information (Haddad, 1994). The number of small and medium size business enterprises is growing in many CEE countries as a result of economic restructuring. This growth in private enterprise, combined with the increased role of information technology in management, has led to a substantial increase in demand for telephone lines.

To respond to these demands CEE governments have: installed new digital international switches to decongest a critical bottleneck; constructed overlay digital networks to relieve congestion in the trunk networks, provided high-quality service to large users; constructed the skeleton for long-term network modernisation; licensed cellular operators; and licensed the building of packet-switched data networks for large data users (Nulty, 1996). The building of cellular networks is a quick way of providing business with telephones. When fixed networks are in place, the cellular networks can be used for mobile communications. In the longer term, all CEE countries are aiming to at least double the rate of investment and network growth, with a view to achieving a teledensity of 30 mainlines by 2000 (Nulty, 1996). To put this resource requirement into perspective it is informative

[2] CMEA is the Council for Mutual Economic Assistance, a regional trading arrangement comprising the former USSR and nine other Soviet bloc countries.

to note that many CEE countries have an official GDP per capita in the order of 2,000 to 2,500 US dollars (USD). Should GDP in CEE countries (optimistically) grow at 2.5% per annum, the average GDP per capita would reach 3,200 USD (in 1991 dollars) by 2000, which is similar to that of Portugal in 1990, and Austria in 1960. To achieve the present level of Spanish telephone penetration by 2000, CEE countries would have to divert a significant amount of resources to the telecommunications sector and seek a substantial increase in outside financing. To reach a higher growth level would require investments in the neighbourhood of 2.5% of GDP. However, most CEE countries past growth rates are only about one-third of that required.

Institutions such as the World Bank, the EIB, and the EBRD will continue to both finance and act as a catalyst for other sources through co-financing arrangements. However, it is unlikely that these institutions can contribute more than 50% of the total foreign exchange financing requirement. This means that approximately three to six billion USD of hard currency imports to the region will need to be financed from other services (Nulty, 1996). Although Western companies have expressed considerable interest, little progress has been made to date. In large part, this is due to a lack of legal and political clarity regarding the ownership of existing assets (and mechanisms for transferring them); and of regulatory frameworks governing franchises, tariffs, service obligations, frequency allocation, and interconnection. There is also considerable ambivalence in CEE, despite the professed desire for Western management expertise, about granting ownership control of telecommunications networks to international interests (Nulty, 1996).

Accordingly, the second stage of the empirical analysis is concerned with examining the relationship between economic growth and telecommunications infrastructure. In particular, should telecommunication investment be related to economic growth it would lend support to EBRD, World Bank and EIB programs that have provided substantial, but as yet inadequate, investment towards telecommunications network development and deployment. The empirical results may prove useful to transitional governments, international organisations and foreign investors as they consider the large investment required to develop telecommunications infrastructure in CEE.

3. Data

The study uses data from 27 CEE transitional economies. Central Europe consists of Albania, Bosnia, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovak Republic, Slovenia, and the Former Yugoslav Republic of Macedonia (FYRM). Estonia, Latvia and Lithuania comprise the Baltic States, while the Regional Commonwealth of Communications (RCC) consists of Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Rus-

sia, Tajikstan, Turkmenistan, Ukraine and Uzbekistan (see Table 1 for a complete list of countries and their designation). Annual data for GDP in local dollars and USD, the GDP deflator, gross fixed investment, government consumption and population were obtained from the World Bank (1995a), (1995b) and the EBRD (1995) for the period 1990 through 1995. Additional data on telecommunications

Table 1
List of countries

Official designation	Official in document
Albania (Republic of)	Albania
Bosnia and Herzegovina (Republic of)	Bosnia
Bulgaria (Republic of)	Bulgaria
Croatia (Republic of)	Croatia
Czech Republic	Czech Republic
Hungary (Republic of)	Hungary
Poland (Republic of)	Poland
Romania	Romania
Slovak Republic	Slovak Republic
Slovenia (Republic of)	Slovenia
The Former Yugoslav Republic of Macedonia	FYRM
Yugoslavia (Federal Republic of)	Yugoslavia
Central Europe	Central Europe
Estonia (Republic of)	Estonia
Latvia (Republic of)	Latvia
Lithuania (Republic of)	Lithuania
Baltic States	Baltic States
Armenia (Republic of)	Armenia
Azerbaijan Republic	Azerbaijan
Belarus (Republic of)	Belarus
Georgia (Republic of)	Georgia
Kazakhstan (Republic of)	Kazakhstan
Kyrgyzstan (Republic of)	Kyrgyzstan
Moldova (Republic of)	Moldova
Russian Federation	Russia
Tajikistan (Republic of)	Tajikistan
Turkmenistan	Turkmenistan
Ukraine	Ukraine
Uzbekistan	Uzbekistan
Regional Commonwealth of Communications	RCC
Former Union of Soviet Socialist Republics	Former USSR
Economies in Transition	Economies in Transition

Source: ITU (1994).

investment and main telephone lines is provided by the ITU (1994), (1995)[3]. Table 2 reports basic indicators for wealth, gross fixed capital formation (GFCF) and telecommunications for 1991 (the beginning of transition) and 1993, respectively[4].

Inspection of these data show that countries from the Baltics and RCC experienced severe recessions in 1992 and 1993. Between 1991 and 1993 average GDP per capita declined by 45% in the Baltic states and 34% in the RCC[5]. The sharpest declines were in countries affected by war, such as Armenia and Georgia. Between 1991 and 1993 GDP per capita in Armenia decreased from 1970 USD to 660 USD, while Georgia suffered a decline from 1820 USD to 580 USD. On average, the transitionary recession in the countries of Central Europe has been shorter and less pronounced, though still deeper than the typical recession in market economies. This quickness of transition is determined in part by economic policy. Fischer et al. (1996a), (1996b) argue that countries of Central Europe have grown faster, and reduced the transitionary period, because of their early commitment to macroeconomic stabilisation and microeconomic reforms. For example, Poland inaugurated its stabilisation and reform program in January 1990, Hungary in March 1990, and the Czech Republic in January 1991. The first country from the RCC to implement a stabilisation program was Kyrgyzstan in May 1993.

Between 1991 and 1993 the share of investment in GDP for all transitional economies declined by 25%. In contrast to gross fixed investment, telecommunications infrastructure investment in the CEE economies increased between 1991 and 1993. As part of the microeconomic process, many countries began to restructure the telecommunications sector and expand their telecommunications networks[6]. Investment in network expansion is reflected by teledensity data. Between 1991 and 1993 teledensity increased by 11% in Central Europe, 8% in the Baltics, and

[3] Telecommunications investment refers to annual expenditures associated with acquiring ownership of property and plant used for telecommunications services, and includes land and buildings.

[4] To gain consistent series, this study uses 1991 as the beginning of transition. Fischer et al. (1996a) date the transition process from 1990. An alternative approach would be to date the Eastern European transition from 1990, that of the Baltics from 1991, and that of the other republics from 1992.

[5] Fischer et al. (1996a), (1996b) note that the magnitude and length of the transitionary recession for all countries are likely to be overstated for two main reasons. First, given the rapid changes in relative prices that took place in these economies, the rate of change is likely to be heavily dependent on the base period. Second, official statistical services record output more completely in the declining state sector than in the growing private sector. Therefore, both biases will tend to overstate rates of decline and understate growth rates. While it is likely that the reported decline in GDP per capita in the Baltics and the RCC is an overestimate, the decline is substantial. A useful comparison is the 34% fall in output in the United States during the Great Depression.

[6] The separation of posts and telecommunications has already taken place in most Central European countries and a few of the RCC countries.

Table 2
CEE indicators of economic performance

Country	GDP		GFCF		Telecommunications[a]	
	GDP per capita (USD) 1991	GDP per capita (USD) 1993	Investment share of GDP (%) 1991	Investment share of GDP (%) 1993	Main lines per 100 inhabitants 1991	Main lines per 100 inhabitants 1993
Central Europe						
Albania	340	340	6	14	1.27	1.37
Bosnia	—	—	—	—	—	13.53
Bulgaria	1510	1140	28	19	24.65	27.19
Croatia	2673	2602	14	14	18.64	20.08
Czech Rep.	2358	7700	30	18	16.57	19.02
Hungary	3030	3350	20	20	10.94	14.55
Poland	1840	2260	20	16	9.34	11.49
Romania	1460	1140	28	27	10.78	11.53
Slovak Rep.	2320	1950	35	22	14.39	16.75
Slovenia	6581	6490	15	20	22.92	25.93
FYRM	2431	820	15	18	14.29	15.64
Yugoslavia	—	3390	—	—	17.32	18.34
Average	2454	2804	21	17	14.64	16.29
Baltics						
Estonia	4340	3080	25	32	21.20	22.92
Latvia	4260	2010	34	09	24.29	26.97
Lithuania	3030	1320	22	18	21.95	22.94
Average	3877	2137	27	20	22.48	24.28
RCC						
Armenia	1970	660	27	08	15.80	15.60
Azerbaijan	1400	730	14	20	8.71	9.54
Belarus	3440	2870	30	35	16.41	17.32

Georgia	1820	580	28	24	10.26	9.25
Kazakhstan	2210	1560	31	—	8.51	11.70
Kyrgyzstan	1290	850	32	30	7.48	8.18
Moldova	1880	1060	31	07	11.33	12.03
Russia	3650	2340	39	28	15.16	15.59
Tajikistan	810	470	18	—	4.73	4.64
Turkmenistan	1490	1410	46	—	6.34	6.02
Ukraine	2640	2210	19	08	14.24	14.97
Uzebekistan	1100	970	27	29	6.98	6.70
Average	1975	1309	29	19	9.69	10.12
Transitional economies						
Average	2395	2050	25	20	13.50	14.68
West Europe						
France	20961	21699	21	19	51.00	53.60
Germany	19890	23597	21	18	42.10	45.70
UK	17555	16317	17	15	45.00	47.10

Source: EBRD (1995), ITU (1994), (1995), World Bank (1995a), (1995b).

[a]Main lines per 100 inhabitants is calculated by dividing the number of main telephone lines by the population and multiplying by 100.

about 4% in the RCC. Despite this growth, average teledensity for all transitional economies remains low and is a major barrier to improved competitiveness, trade performance and economic growth. While many transitional economies have increased investment in their telecommunications networks, the size of this investment is significantly lower than that of European market economies. In 1993, the most substantial telecommunications investments in Central Europe, the Baltics and RCC were Hungary (451 million USD), Estonia (46 million USD) and Russia (390 million USD), respectively. In comparison, the developed market economies of Western Europe typically invest around five billion USD in telecommunications per annum.

An indication of the relationship between the indicators found in Table 2 can be provided by plotting the investment share and teledensity against GDP per capita for 1993. The patterns in Figs. 1 and 2 indicate a positive relationship between investment and GDP, and a positive relationship between teledensity and GDP. The patterns are more appropriate for the economies with a GDP per capita below 4000 USD. The inclusion of a regression line shows the positive relationship between teledensity and GDP to be more pronounced than that of investment and GDP. This suggests that telecommunications sector investment may provide an important determinant of economic growth.

A general description of the transitionary period for countries of CEE is provided by Figs. 3–8. Fig. 3 shows that the average rate of economic growth is negative from 1990 through 1995. The depth of the recession occurred in 1992, coinciding with the fragmentation of the former USSR and the collapse of CMEA trade. Since 1992, the aggregate growth rate has steadily become less negative on

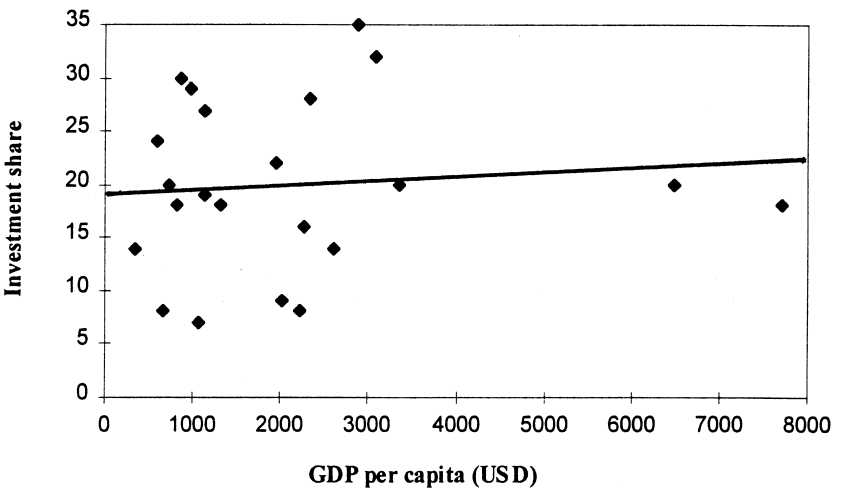

Fig. 1. Investment share and GDP per capita 1993. Regression line: Investment share = 19.2 + 0.00029GDP per capita. Source: EBRD (1995); World Bank (1995a, 1995b).

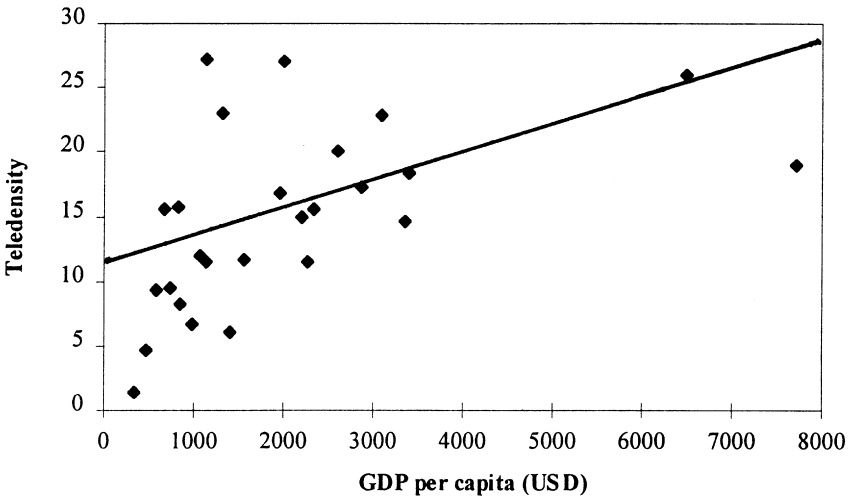

Fig. 2. Teledensity and GDP per capita 1993. Regression line: Teledensity = 11.05 + 0.002GDP per capita. Source: EBRD (1995); ITU (1994, 1995); World Bank (1995a, 1995b).

average, and positive for some Central European countries. A similar growth path is apparent for the industrial and services sectors, and is reflected in Figs. 4 and 5, respectively, with the services sector showing strong positive growth in 1994.

Fig. 6 shows that a decline in investment occurred between 1990 and 1992. The decline continued after 1992, albeit at a lesser rate, even though many economies were beginning to show signs of stabilising GDP. Telecommunications investment,

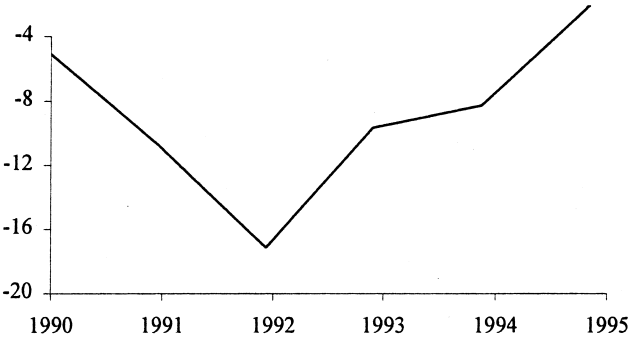

Fig. 3. Rate of growth of real GDP (%). Source: EBRD (1995). Sample of countries include: Albania; Armenia; Azerbaijan; Belarus; Bulgaria; Croatia; Czech Republic; Estonia; Georgia; Hungary; Kazakhstan; Kyrgyzstan; Latvia; Lithuania; FYRM; Moldova; Poland; Romania; Russia; Slovak Republic; Slovenia; Tajikistan; Turkmenistan; Ukraine; and Uzebekistan.

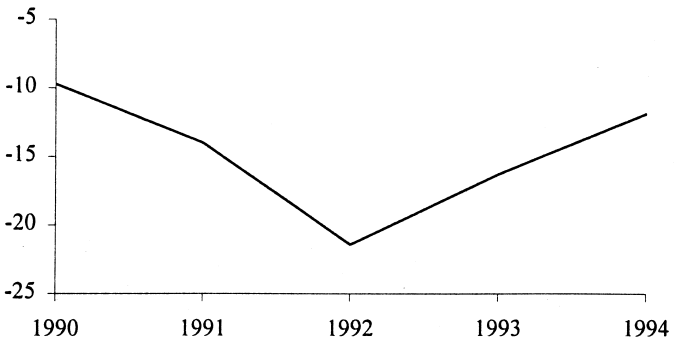

Fig. 4. Rate of growth of real GDP for industrial sector (%). Source: EBRD (1995); World Bank (1995b). Sample of countries include: Albania; Armenia; Azerbaijan; Bulgaria; Estonia; Hungary; Kyrgyzstan; Lithuania; Moldova; Poland; Romania; Russia; Slovak Republic; Slovenia; and Ukraine.

represented in Figs. 7 and 8, respectively, exhibit a similar pattern to that of output growth found in Figs. 3–5. The telecommunications investment share of GDP and growth rate of teledensity declined initially, reaching a trough in 1992. After 1992 telecommunications investment increased, coinciding with the improvement in economic growth at both the aggregate and sectoral level. Fischer et al. (1996b) argue that fixed exchange rates and smaller fiscal deficits were important in reducing inflation and raising growth rates in 1995. Whilst not discounting this claim, an examination of the growth paths of real GDP and telecommunications investment suggests that microeconomic action, in the form of telecommunications investment, also coincided with the period of improved economic growth.

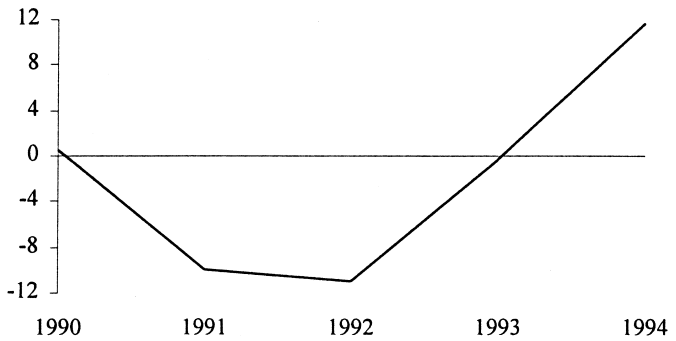

Fig. 5. Rate of growth of real GDP for services sector (%). Source: EBRD (1995); World Bank (1995b). Sample of countries include: Albania; Armenia; Bulgaria; Hungary; Kyrgyzstan; Moldova; Poland; Romania; Russia; Slovenia; and Ukraine.

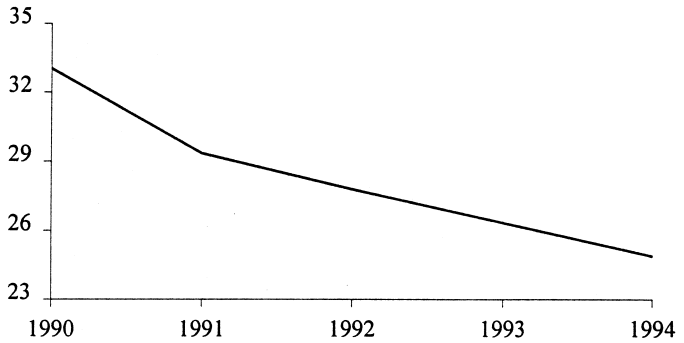

Fig. 6. Investment share of GDP (%). Source: EBRD (1995); World Bank (1995a), (1995b). Sample of countries include: Albania; Armenia; Bulgaria; Croatia; Czech Republic; Estonia; Georgia; Hungary; FYRM; Poland; Romania; Russia; Slovak Republic; Slovenia; Ukraine; and Uzebekistan.

4. Investment and economic growth

A more formal examination of the determinants of economic growth for the transitional economies is conducted through the use of an econometric model below. The model is developed from the cross-country economic growth equation used by Kormedi and Meguire (1985), Barro (1991) and Levine and Renelt (1992). Following the general approach of DeLong and Summers (1991), the growth equation is extended to the sectoral level to allow examination of the

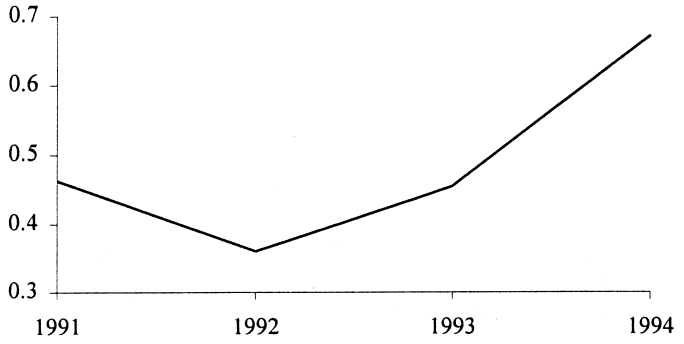

Fig. 7. Telecommunications investment share of GDP (%). Source: ITU (1994), (1995). Sample of countries include: Albania; Armenia; Bulgaria; Croatia; Czech Republic; Estonia; Georgia; Hungary; Kazakhstan; Kyrgyzstan; Latvia; Lithuania; Romania; Russia; Slovak Republic; and Tajikistan.

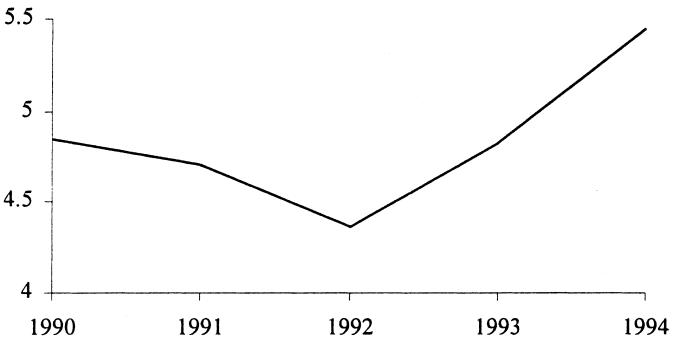

Fig. 8. Growth rate of teledensity. Source: ITU (1994), (1995). Sample of countries include: Albania; Armenia; Azerbaijan; Belarus; Bulgaria; Croatia; Czech Republic; Estonia; Georgia; Hungary; Kazakhstan; Kyrgyzstan; Latvia; Lithuania; FYRM; Moldova; Poland; Romania; Russia; Slovak Republic; Slovenia; Tajikistan; Turkmenistan; Ukraine; and Uzebekistan.

relationship between telecommunications infrastructure investment and economic growth[7]. The aggregate economic growth equation is:

$$\mathrm{RGDP}_{it} = \alpha_1 + \alpha_2 \mathrm{GDP91}_{it} + \alpha_3 \mathrm{POP}_{it} + \alpha_4 \mathrm{GOV}_{it} + \alpha_5 \mathrm{INV}_{it} + \alpha_6 \mathrm{TEL}_{it} + \alpha_7 \mathrm{BRCC}_{it} + u_{it}, \quad (1)$$

where i indexes countries; t indexes time; RGDP is the rate of growth of real GDP per capita; GDP91 is initial real GDP per capita in USD in 1991; POP is the rate of growth of the population; GOV is the share of government consumption in GDP; INV is the share of fixed investment in GDP; TEL is the share of telecommunications investment in GDP; and BRCC is a dummy variable that equals one if the country is from the Baltic States or the RCC, and zero if the country is from Central Europe. The dummy variable BRCC is included to capture the different growth paths of the two sub-samples of countries respectively. The unknown parameters α_i are to be estimated, and u_{it} is a white noise error.

Eq. (1) is estimated by ordinary least squares (OLS) using annual data from 11 transitional economies for the period 1991 through 1994. The White (1980) estimated covariance matrix is used to correct the standard errors under hetero-skedasticty. The results from estimating the model are reported in Table 3. The coefficient for BRCC is both negative and significant and excluding it from the model sees the estimated coefficients for GDP91, POP and GOV change substantially. In regression (i) the sign on the coefficient for GDP91 is negative but not significant. The estimated coefficients for POP and GOV are both positive but also insignificant. The impact of the two investment variables appear to

[7] DeLong and Summers (1991) use three different disaggregations of investment: transport equipment; electrical machinery and non-electrical machinery.

Table 3
Estimates for aggregate economic growth

Independent variable		Regression (i): Estimated coefficients
Constant	α_1	−0.229[a] (−3.082)
GDP91	α_2	−0.2E−4 (−0.814)
POP	α_3	1.009 (0.256)
GOV	α_4	0.268 (1.094)
INV	α_5	0.434[b] (1.746)
TEL	α_6	12.96[a] (3.330)
BRCC	α_7	−0.109[a] (−2.241)
Adjusted R^2		0.36
F-test		13.52[a]
Number of observations		44

Standard errors are estimated using the White (1980) Heteroscedastic-consistent covariance matrix. t-statistics in brackets.
[a]Statistical significance at the 5% level; [b]Statistical significance at the 10% level.
The sample of countries used to estimate regression (i) are: Albania; Armenia; Bulgaria; Croatia; Czech Republic; Estonia; Georgia; Hungary; Romania; Russia; and the Slovak Republic.

dominate the model. The coefficient for INV is positive and significant at the 10% level, while the coefficient for TEL is positive and significant at the 5% level. These findings are consistent with DeLong and Summers (1991), Levine and Renelt (1992) and Fischer et al. (1996a), (1996b) whom suggest that the rate of investment, and policies that promote capital formation, can determine national economic growth rates.

An assumption of the model used in Table 3 is that the parameters are constant across all the sample observations. However, the significant coefficient on the variable BRCC indicates that it may be appropriate to estimate separate growth equations for countries from Central Europe, and those countries from the Baltic States and RCC. An F-test rejects the hypothesis of equality of the parameters for the two sub-samples at the 5% level, and accordingly separate regressions are estimated ($F_{\text{calc}} = 8.374$). Regression (ii) uses data for the seven Central European countries, while (iii) uses data for the four countries from the Baltic States and RCC. Coefficient estimates are contained in Table 4. The explanatory power of regression (ii) is poor. This may mean that different factors determine growth in Central Europe, or that the sub-sample shows little variation in growth, across countries and time, for systematic patterns to be linked to the independent variables. The coefficient for GDP91 is both negative and significant at the 5% level (which is consistent with endogenous growth theory), while the coefficient for TEL is positive and significant at the 5% level. In regression (iii), the sign of the coefficient for GOV is positive and significant at the 10% level, while TEL is positive and significant at the 5% level. Again, investment, or more particularly telecommunications investment, dominates the explanation of both models.

Table 4
Estimates for aggregate economic growth: Central Europe and BRCC samples

Independent variable		Estimated coefficients	
		Regression (ii) Central Europe	Regression (iii) BRCC
Constant	α_1	−0.018 (−0.243)	−0.584[a] (−5.238)
GDP91	α_2	−0.7E−4[a] (−2.024)	0.7E−6 (0.013)
POP	α_3	0.055 (0.014)	−0.609 (−0.094)
GOV	α_4	−0.230 (−0.625)	0.810[b] (2.068)
INV	α_5	0.224 (0.908)	0.747 (1.430)
TEL	α_6	15.06[a] (2.929)	13.82[a] (3.365)
Adjusted R^2		0.03	0.43
F-test		2.651[a]	8.521[a]
Number of observations		28	16

Standard errors are estimated using the White (1980) Heteroscedastic-consistent covariance matrix. t-statistics in brackets.
[a]statistical significance at the 5% level; [b]Statistical significance at the 10% level.
The sub-sample of countries used to estimate regression (ii) are Albania; Bulgaria; Croatia; Czech Republic; Hungary; Romania; and the Slovak Republic. The sub-sample of countries used to estimate regression (iii) are: Armenia; Estonia; Georgia; and Russia.

Investment in telecommunications can improve productivity and enhance growth at both the aggregate and sectoral level (Cronin et al., 1993; Greenstein and Spiller, 1995). While data unavailability inhibit the estimation of sector-specific models in transitional economies, it is possible to run regressions for the industrial and services sectors. The sectoral economic growth equation is:

$$\mathrm{SGDP}_{it} = \beta_1 + \beta_2 \mathrm{SGDP91}_{it} + \beta_3 \mathrm{GOV}_{it} + \beta_4 \mathrm{GML}_{it} + u_{it}, \quad (2)$$

where SGDP is the rate of growth of real GDP per capita in the industrial and services sectors respectively; SGDP91 is initial real GDP per capita in USD in 1991 for each sector; GOV is the share of government consumption in GDP; and GML is the growth rate of main telephone lines per 100 inhabitants[8]. The unknown parameters β_i are to be estimated, and u_{it} is a white noise error.

Eq. (2) is estimated by OLS using annual data from 1991 through 1994 for eight countries: Albania; Armenia; Bulgaria; Estonia; Hungary; Romania; Russia; and the Slovak Republic. The results from estimating separate models for the industrial and services sector respectively are reported in Table 5[9]. In regression

[8] Because of data quality in transitional and developing countries it is the practice of the ITU and World Bank to count the number of main lines as a measure of telecommunications infrastructure.

[9] The small sample size prevented estimation of separate models for the sub-sample of countries from the Baltic States and RCC, and the sub-sample of countries from Central Europe. The dummy variable BRCC was originally included in each regression to capture the different growth paths of the sub-samples of countries. This variable was not statistically significant in either of the regression equations.

Table 5
Estimates from sectoral economic growth model

Independent variable		Estimated coefficients	
		Regression (iv) industrial	Regression (v) services
Constant	β_1	−0.061 (−0.623)	0.171 (0.669)
GDP91	β_2	0.3E−5 (0.052)	−0.2E−4 (0.277)
GOV	β_3	−0.793[a] (−2.208)	−0.803 (−0.451)
GML	β_4	0.918[a] (2.208)	0.301 (0.376)
Adjusted R^2		0.13	−0.09
F-test		12.63[a]	0.190
Number of observations		32	28

Standard errors are estimated using the White (1980) Heteroscedastic-consistent covariance matrix. t-statistics in brackets.
[a]Statistical significance at the 5% level; [b]statistical significance at the 10% level.
The sample of countries used to estimate regression (iv) are: Albania; Armenia; Bulgaria; Estonia; Hungary; Romania; Russia; and the Slovak Republic. The sample of countries used to estimate regression (v) are: Albania; Armenia; Bulgaria; Hungary; Romania; Russia; and the Slovak Republic.

(iv) the estimated coefficient for GOV is negative and significant at the 5% level. This suggests that a reduction in government consumption expenditure coincides with an improvement in output growth of the industrial sector. Coefficient estimates for telecommunications investment continues to play an important role in explaining growth. The sign on the GML coefficient is both positive and significant at the 5% level. The services sector regression contains no explanatory power. Given the embryonic stage of the CEE service sector development this result is not surprising.

In regression (i) through regression (iv) the underlying relationship between telecommunications investment and economic growth appears quite robust for alternative model specifications and samples. The finding of a strong and positive relationship between telecommunications investment and economic growth suggests that the allocation of investment funds to productive infrastructures, such as telecommunications is important. An obvious extension of this work is to determine the relative importance of other sector investment on economic growth (for example, investment in electrical machinery and equipment, non-electrical machinery, and/or transport).

5. Chronological precedence

The strong positive relationship between telecommunications and growth suggests that telecommunications investment is an important determinant of the rate of economic growth. However, as explained by Blomstrom et al. (1996) the finding of a strong association between investment and growth does not necessarily imply a ‘causal’ relationship. The relationship may very well run from

Table 6
Aggregate economic growth and gross fixed investment

(vi) Investment share of GDP ($n=32$)	Adj. R^2	FPE	F
$RGDP_t = 0.028 + 0.704RGDP_{t-1}$	0.61	0.0057	—
$RGDP_t = 0.057 + 0.701RGDP_{t-1} - 0.143INV_{t-1}$	0.61	0.0059	0.63
$INV_t = 0.059 + 0.635INV_{t-1}$	0.73	0.0013	—
$INV_t = 0.068 + 0.640INV_{t-1} + 0.097RGDP_{t-1}$	0.76	0.0012	9.66[a]
Conclusion	RGDP − -INV, RGDP⇒INV		

Standard errors are estimated using the White (1980) Heteroscedastic-consistent covariance matrix.
[a]Significance at the 5% level; [b]significance at the 10% level.
n denotes the number of observations.
The sample of countries used to estimate regression (vi) are: Albania; Armenia; Bulgaria; Croatia; Czech Republic; Hungary; Slovak Republic; Estonia; Georgia; Russia; FYRM; Poland; Romania; Slovenia; Ukraine; and Uzebekistan.

economic growth to telecommunications investment (the accelerator principal), and/or from telecommunications to growth. Hardy (1980a), (1980b), Cronin et al. (1991), Lee (1994), and Edirisurija (1995) have shown there exists a mutual, or two-way, causal relationship between telecommunications investment and economic development. Telecommunications infrastructure investment enhances economic activity and growth. While growth results in a higher proportion of national income spent on telecommunications services and stimulates further telecommunications investment[10].

Tests for precedence are conducted using the framework developed by Granger (1969) and Hsiao (1981)[11]. For example, to test whether x precedes y, the following procedure is used. First, OLS is used to regress y_t on y_{t-1} and y_{t-2} and the optimal lag length, m, is determined on the basis of minimising the Final Prediction Error (FPE) criterion of Akaike (1969). Second, the variable y_t is treated as controlled and is regressed on m lagged values of itself and x_{t-1} and x_{t-2}. Third, the optimal lag length for x in the regression in step (2), n, is determined by minimising the FPE criterion. Fourth, the FPEs from the regressions in step (1) and step (2), respectively, are compared. If the FPE in the latter regression is less than the FPE in the former regression then there is weak evidence supporting the hypothesis that x precedes y. That is, $x \rightarrow y$. Fifth, an F-test (F) is used to test the hypothesis in regression (2) that the lagged values of x are jointly equal to zero. If this hypothesis is rejected, there is weak evidence supporting the hypothesis that x precedes y. That is, $x \rightarrow y$. Finally, if the

[10] For a more detailed review of the relationship between telecommunications and economic growth see Alleman et al. (1994).

[11] Granger (1969) starts from the premise that the future cannot cause the present or the past. When two events, x and y, are observed, x may precede y, or y may precede x, or they be contemporaneous. This definition is not causality as it is usually understood, but in fact precedence or 'Granger-causality'. To avoid confusion, the paper uses the term (chronological) precedence, as suggested by Leamer (1985).

Table 7
Aggregate economic growth and telecommunications investment

(vii) Telecommunications investment share of GDP ($n=22$)	Adj. R^2	FPE	F
$RGDP_t = 0.037 + 0.677RGDP_{t-1}$	0.61	0.0068	—
$RGDP_t = 0.036 + 0.674RGDP_{t-1} + 0.175TEL_{t-1}$	0.59	0.0074	0.01
$TEL_t = 0.003 + 0.898TEL_{t-1}$	0.44	0.216−E4	—
$TEL_t = 0.3 - E3 + 1.005TEL_{t-1} + 0.06RGDP_{t-1} - 0.183RGDP_{t-2}$	0.50	0.211−E4	4.30
Conclusion	RGDP−-TEL, RGDP→TEL		
(viii) Rate of growth of main lines per 100 inhabitants ($n=50$)	**Adj. R^2**	**FPE**	**F**
$RGDP_t = -0.003 + 0.622RGDP_{t-1}$	0.41	0.878−E2	—
$RGDP_t = -0.020 + 0.597RGDP_{t-1} - 0.225GML_{t-1} + 0.533GML_{t-2}$	0.41	0.850−E2	1.02
$GML_t = -0.006 - 0.054GML_{t-1} + 1.313GML_{t-2}$	0.31	0.409−E2	—
$GML_t = 0.05 - 0.12GML_{t-1} + 0.95GML_{t-1} + 0.18RGDP_{t-1} + 0.12RGDP_{t-1}$	0.40	0.368−E2	8.45[a]
Conclusion	RGDP⇐GML, RGDP⇒GML		
(ix) Main lines per 100 inhabitants ($n=50$)	**Adj. R^2**	**FPE**	**F**
$RGDP_t = -0.003 + 0.622RGDP_{t-1}$	0.41	0.878−E2	—
$RGDP_t = -0.064 + 0.624RGDP_{t-1} + 0.004ML_{t-1}$	0.46	0.822−E2	5.13[a]
$ML_t = -0.456 + 1.091ML_{t-1}$	0.98	1.2133	—
$ML_t = 0.398 + 1.093ML_{t-1} + 3.325RGDP_{t-1} + 3.156RGDP_{t-2}$	0.99	0.8942	17.6[a]
Conclusion	RGDP⇐ML, RGDP⇒ML		

Standard errors are estimated using the White (1980) Heteroscedastic-consistent covariance matrix.
[a]Significance at the 5% level; [b]significance at the 10% level.
n denotes the number of observations.
The sample of countries used to estimate regression (vii) are: Albania; Bulgaria; Croatia; Czech Republic; Hungary; Romania; Slovak Republic; Armenia; Estonia; Georgia; and Russia. The sample of countries used to estimate regressions (viii) and (ix) are Albania; Armenia; Azerbaijan; Belarus; Bulgaria; Croatia; Czech Republic; Estonia; Georgia; Hungary; Kazakhstan; Kyrgyzstan; Latvia; Lithuania; FYRM; Moldova; Poland; Romania; Russia; Slovak Republic; Slovenia; Tajikistan; Turkmenistan; Ukraine; and Uzebekistan.

conditions in steps (4) and (5) are both satisfied there is strong evidence that x precedes y. That is, $x \Rightarrow y$. If neither conditions are satisfied then x does not precede y. That is, $x - y$.

The results from testing precedence between growth and economy-wide investment, and growth and telecommunications infrastructure investment are reported in Tables 6–9, respectively. Tables 6 and 7 provide strong evidence supporting an accelerator mechanism at the aggregate level. That is, changes in growth precede changes in economy-wide investment and changes in telecommunications investment. There is no support for changes in economy-wide investment preceding growth, which is consistent with Blomstrom et al. (1996). However, there is weak evidence that changes in GML precede changes in RGDP and strong evidence that changes in ML precede changes RGDP. Overall, there appears to be two-way, or mutual precedence between telecommunications investment and real economic growth at the aggregate level. Precedence is strongest when using main lines data as the proxy for investment in telecommunications infrastructure. This is expected given that the accelerated development of CEE telecommunications infrastructure has been through the expansion of basic telephony rather than the roll-out of integrated networks (Wellenius and Stern, 1996). The addition of main telephone lines increases the value of the network through the enhanced network externality and has a direct impact on productivity and growth at the aggregate level.

The results from testing for precedence between growth in the industrial and services sectors and telecommunications network expansion are provided in Tables 8 and 9. There is strong evidence that changes in GML and ML precede changes

Table 8
Industrial sector growth and telecommunications investment

(x) Rate of growth of main lines per 100 inhabitants ($n=22$)	Adj. R^2	FPE	F
$SGDP_t = -0.091 + 0.113SGDP_{t-1}$	−0.04	0.0268	—
$SGDP_t = -0.287 - 0.227SGDP_{t-1} + 0.113GML_t + 2.305GML_{t-2}$	0.18	0.0230	3.98[a]
$GML_t = 0.006 - 0.164GML_{t-1} + 1.294GML_{t-1}$	0.46	0.261 − E2	—
$GML_t = 0.016 - 0.142GML_{t-1} + 1.211GML_{t-2} + 0.033SGDP_{t-1}$	0.43	0.284 − E2	0.17
Conclusion	SGDP⇐GML, SGDP − -GML		
(xi) Main lines per 100 inhabitants ($n=22$)	Adj. R^2	FPE	F
$SGDP_t = -0.091 + 0.113SGDP_{t-1}$	−0.04	0.0268	—
$SGDP_t = -0.020 - 0.111SGDP_{t-1} + 0.122ML_{t-1} - 0.133ML_{t-2}$	0.19	0.0230	5.38[a]
$ML_t = -0.506 + 1.109ML_{t-1}$	0.98	1.5667	—
$ML_t = -0.279 + 1.108ML_{t-1} + 1.167SGDP_{t-1}$	0.98	1.6820	0.84
Conclusion	SGDP⇐ML, SGDP–ML		

Standard errors are estimated using the White (1980) Heteroscedastic-consistent covariance matrix.
[a]Significance at the 5% level; [b]significance at the 10% level.
n denotes the number of observations.
The sample of countries used to estimate regressions (x) and (xi) are: Albania; Armenia; Bulgaria; Estonia; Hungary; Poland; Romania; Russia; Slovak Republic; Slovenia; and Ukraine.

Table 9
Services sector growth and telecommunications investment

(xii) Rate of growth of main lines per 100 inhabitants ($n=18$)	Adj. R^2	FPE	F
$SGDP_t = 0.067 - 0.146SGDP_{t-1}$	−0.04	0.124	—
$SGDP_t = 0.075 - 0.137SGDP_{t-1} - 0.131GML_t$	−0.11	0.138	0.06
$GML_t = 0.006 - 0.164GML_{t-1} + 1.294GML_{t-1}$	0.46	0.261 − E2	—
$GML_t = 0.013 - 0.293GML_{t-1} + 1.283GML_{t-2} + 0.067SGDP_{t-1}$	0.52	0.301 − E2	3.62[b]
Conclusion	SGDP–GML, SGDP→GML		
(xiii) Main lines per 100 inhabitants ($n=18$)	Adj. R^2	FPE	F
$SGDP_t = 0.067 - 0.146SGDP_{t-1}$	−0.04	0.124	—
$SGDP_t = 0.083 - 0.148SGDP_{t-1} - 0.001ML_{t-1}$	−0.11	0.139	0.13
$ML_t = -0.787 + 1.785ML_{t-1} - 0.685ML_{t-2}$	0.97	1.832	—
$ML_t = -0.723 + 1.301ML_{t-1} - 0.172ML_{t-2} + 2.172SGDP_{t-1}$	0.98	1.579	3.91[b]
Conclusion	SGDP–ML, SGDP→ML		

Standard errors are estimated using the White (1980) Heteroscedastic-consistent covariance matrix.
[a]Significance at the 5% level; [b]significance at the 10% level.
n denotes the number of observations.
The sample of countries used to estimate regressions (xii) and (xiii) are: Albania; Armenia; Bulgaria; Hungary; Poland; Romania; Russia; Slovak Republic; and Ukraine.

in SGDP in the industrial sector and weak evidence that changes in SGDP precede GML and ML in the services sector.

6. Conclusions

The empirical analysis in this study proceeded in two stages. First, given the unique historical development of CEE economies, the relationship between growth and economy-wide investment is examined and a positive relationship between aggregate investment and growth is found. There is evidence of growth preceding investment, indicating an accelerator type mechanism, however, support for investment preceding growth is not gained. This phenomena is not unexpected as CEE growth for the period is either very low, negative or static. In this context, it is reasonable to expect that internal investment would closely track economic performance. However, since 1991, CEE has been the recipient of a substantial inward flow of investment funds. This foreign investment has not led to immediate improvements in growth across the sample of countries. Among the reasons for this is that supporting infrastructure, such as telecommunications, is necessary to coordinate the efficient use of economy-wide investment as the transitional countries of CEE move towards a decentralised market economy. Therefore, the second stage of the analysis is concerned with examining the relationship between economic growth and telecommunications infrastructure. In particular, the direction of influence and timing are considered. The finding that telecommunication investment, especially when measure by main telephone lines, is related to

economic growth is important. It lends support to EBRD, EC, EIB and World Bank programs that have provided substantial, but as yet inadequate, investment towards telecommunications network development and deployment. This result suggests that improving the chronic underinvestment in the telecommunications infrastructures of CEE countries may ultimately improve the channel between aggregate investment and growth, economy-wide.

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