THE IMPACT OF TELECOMMUNICATIONS INFRASTRUCTURE INVESTMENT ON SECTORAL GROWTH[1]

Serdar Yilmaz
The World Bank, 1818 H Street NW, Washington, DC 20433, USA.

Kingsley Haynes
School of Public Policy, George Mason University, MS 3C6, 4400 University Drive, Fairfax, VA 22030-4444, USA.

Mustafa Dinc
The World Bank, 1818 H Street NW, Washington, DC 20433, USA.

ABSTRACT The impact of telecommunications infrastructure on output has been analyzed at the aggregate level. However, aggregate level studies provide little insight on the role of telecommunications infrastructure investment at the sectoral level. This study examines the impact of telecommunications infrastructure on economic growth both at the aggregate and sectoral levels. Findings suggest that the accumulation of telecommunications infrastructure improves the overall productive capacity of a region but the magnitude of the impact varies significantly by sector. Not surprisingly, sectors with imbedded intermediate information management services, such as wholesale trade, FIRE, retail trade and other services, appeared to receive the strongest positive impact from information infrastructure investment.

1. INTRODUCTION

In the past two decades, regional telecommunications infrastructures became an essential ingredient of many local economic activities. Through the digitalisation of the economic activities and generation of external economies by wider market access, reduced intermarket barriers, larger labour markets, and convenient secondary and auxiliary markets, telecommunication facilities have been an important component of regional infrastructure systems that provide localized benefits (OTA, 1995).

Today, telecommunications infrastructure contributes regional economic growth at both the aggregate and sectoral levels. However, certain industries increasingly require modern telecommunications infrastructure to transmit voice, data, and video quickly and reliably more than others. If the accumulation of telecommunications infrastructure improves the overall productive capacity of a region, the impact of such investments on individual industries might be different

---

[1] The findings, interpretations, and conclusions are entirely those of authors, and do not represent the views of the World Bank, its executive directors, or the countries they represent.

than for the economy as a whole depending on a given sector's telecommunications dependency. Since the economy-wide productivity effect of telecommunications infrastructure is assessed as the weighted average of the underlying sectoral productivity gains (losses), it is reasonable to expect that the magnitude of the impact will vary by region.

This paper examines the impact of telecommunications infrastructure on economic growth at both the aggregate and sectoral level. First, the paper analyzes the impact of telecommunications infrastructure on aggregate output, and then identifies the sectors that are most sensitive to telecommunications investment. The paper is organized into five sections. After the introduction, section 2 reviews the literature and discusses the conceptual framework and the econometric model employed. The data set and the results of empirical analysis are presented in the following section. Section 4 discusses the impact of telecommunications infrastructure on individual sectors. Section 5 concludes the paper.

2. LITERATURE REVIEW, CONCEPTUAL FRAMEWORK AND ECONOMETRIC MODEL SPECIFICATION

In the last two decades, telecommunications infrastructure emerged as an important factor in interregional economic activities. Advancements in information technology have provided new opportunities to businesses by enabling them to establish and maintain contacts with suppliers and customers over greater distance and remote locations. Furthermore, developments in information and communications technologies provide increasing support for locational freedom by diminishing the importance of geographic proximity. Cairncross (1997), for example, argues that with the revolution in information technology, electronic proximity will replace geographic proximity and bring the "death of distance." If her argument holds and electronic proximity provides a lower cost substitute for physical proximity in transactions, search by firms for better telecommunications infrastructure is likely to reshape regional development patterns, leading to higher rates of growth for better-endowed regions. However, it is quite unlikely that the advancements in information and communications technologies will provide similar opportunities in different sectors.

The present literature on telecommunications regulation provides little insight on the differential impact of telecommunications investment on sectoral output. These studies typically recognize the importance of state and federal regulations on the level of infrastructure provision, but fail to adequately address the role of telecommunications infrastructure on sectoral performance and interregional economic development patterns.

The lack of research on the relationship between local telecommunications policymaking and regional growth contrasts starkly with the growing interest in the policymaking world on assessment of the role of telecommunications infrastructure in sectoral economic activities. For example, within the United States, over the last two decades, many states have commissioned studies on how to use telecommunications infrastructure strategically in promoting different sectors as part of their economic development efforts[2].

In contrast to the interest in the policymaking world, academic research examining the relationship between telecommunications infrastructure and economic growth typically focuses on national level aggregate estimates[3] and ignores the role of telecommunications infrastructure investment in explaining the divergent path of sectoral growth patterns[4]. In general, the literature on the impact of telecommunications infrastructure on national productivity reports a positive relationship between telecommunications infrastructure and economic growth.

A central question in the theory of economic growth is the contribution of the different factors of production to aggregate output. In a perfectly competitive economy, contribution of a factor to private production is rewarded according to its marginal contribution. The reward earned by a factor is equal to its marginal product. However, some factor inputs generate spillovers or externalities that make their marginal social benefit and effect on output deviate from their marginal benefit as measured by the rewards they earn in private production. Infrastructure services are certainly this type of factor inputs and it is difficult to precisely charge the true marginal cost of service to a user as measured only by the marginal benefit to individual users (Diewert, 1986). It is possible, however, to estimate the marginal benefit of infrastructure services for all users. Therefore estimation of aggregate production function has become the dominant method for evaluating the social returns to infrastructure investments. However, production function studies have been criticized on the grounds of econometric problems.[5] Subsequently, more recent refinements of the production function approach are focused on the model's statistical properties[6].

---

[2] Some of these policy reports are: Armstrong (1995); Howe and Gardner (1992); Wisconsin Governor's Blue Ribbon Telecommunications Infrastructure Task Force (1993); Washington Governor's Telecommunications Policy Coordination Task Force (1996); and Kansas Telecommunications Strategic Planning Committee (1996).

[3] Cronin, Parker, Colleran, and Gold (1991), Cronin, Gold, Hebert, and Lewitzky (1993), Cronin, Colleran, Herbert, and Lewitzky (1993), Cronin, Gold, Mace, Sigalos (1994), Dholakia and Harlam (1994), Cronin, McGovern, Miller, and Parker (1995), Nadiri and Nandi (1997), Cronin, Colleran, and Gold (1997), Resende (1999).

[4] The only two studies to our knowledge that analyze this relationship at the subnational level are Greenstein and Spiller (1995) and Cronin *et al*. (1995). Greenstein and Spiller (1995) find a positive impact of telecommunications infrastructure on economic performance in local exchange carriers' service areas. In a different study on the impact of telecommunications infrastructure investment on rural counties of Pennsylvania, Cronin *et. al.* (1995) argue that reduction in business cost resulting from telecommunications modernization generated more than 70,000 jobs in the state.

[5] In general, these problems can be classified under four broad headings: serial correlation, measurement errors, endogeneity and spatial autocorrelation.

[6] Evans and Karras (1994), Holtz-Eakin (1994), Garcia-Mila, McGuire and Porter (1996).

2.1 Econometric Model Specification

Production function specification has widely been used in examining the contribution of infrastructure to economic growth (Aschauer, 1989; Munnell, 1992; Holtz-Eakin, 1994; Garcia-Mila, McGuire, and Porter, 1996). A common approach is to estimate a Cobb-Douglas production function in which infrastructure investment is treated as an input. The production function with telecommunications capital stock can be written as:

$$Q_{it} = \alpha_0 K_{it}^{\beta_1} L_{it}^{\beta_2} G_{it}^{\beta_3} TK_{it}^{\beta_4} e^{\varepsilon_{it}} \tag{1}$$

Taking logs of both sides of the production function, and denoting the operational variables for private capital stock, private employment, public capital stock and telecommunications infrastructure stock gives:

$$\ln Q_{it} = \ln \alpha_0 + \ln K_{it}^{\beta_1} + \ln L_{it}^{\beta_2} + \ln G_{it}^{\beta_3} + \ln TK_{it}^{\beta_4} + \varepsilon_{it} \tag{2}$$

where Q_{it} is output; K_{it} is private capital stock; L_{it} is private sector employment; G_{it} is public capital stock and TK_{it} is telecommunications infrastructure stock in region i, time t.

3. THE DATA SET AND EMPIRICAL ANALYSIS

Using the econometric specification of regional gross benefit specification of equation (2) and the data set described below, a regional production function for each state is estimated for analyzing the role of telecommunications in economic growth. The analysis is confined with the sample period 1984-1997 in order to avoid complications that might arise by considering the pre-divestiture period. 1984 marks the beginning of a new era in telecommunications policymaking. Since the break-up of the AT&T in 1984, the primary responsibility of telecommunications policymaking has been increasingly shifting to the states. This power shift has increased the ability of state authorities to manipulate the quality and the level of telecommunication investment in a way that maximizes the localized benefits from telecommunications facilities.

The unit of analysis in this study is individual states because State regulatory commissions regulate not just prices and profits but also set the incentives for modern infrastructure deployment. In fact, state level policies and regulation have a considerable impact on the quality and level of telecommunications infrastructure, especially since the break-up of AT&T[7].

In fact, increased localized benefits from telecommunications infrastructure may indeed provide a strong incentive for state regulators to use their rate setting power in a way to benefit the state's economic activities. In a recent study,

---

[7] Federal regulations by FCC generally deal with equity issues such as universal service. It is the state regulatory commissions' responsibility to ensure reasonable price levels and to determine levels of return to telecommunications investment (National Governors' Association, 1994). For a more detailed discussion see Dinc *et al.* (1998).

Yilmaz, Haynes and Dinc (2002) show that a state's output growth rate is positively related to its rate of telecommunications investment, and negatively related to the rate of telecommunications investment by other states. Their findings suggest that telecommunications investment is an important factor for a state's output growth, but it has a negative spillover effect for other states. The impact of negative spillovers is stronger at the regional level. States located in the same region have stronger negative effects on their neighbors than other states located in different regions.

3.1 Data

The output variable is represented by the total output value of private industries. The labour variable represents the total number of employees by place of work in a state for a given year. Since there is no readily available public capital stock data for individual states, this variable is estimated by apportioning the national estimates of the Bureau of Economic Analysis (BEA) to states. The ratio of state total capital outlay expenditure to national total for each year is used to apportion total US public capital to respective states. The state expenditure patterns and the aggregate national expenditure from 1984 and 1997 followed the same trend, which confirms that each state's share in national capital outlay is a good proxy for the size of its public capital. See Yilmaz, Haynes, and Dinc (2002) and Lall and Yilmaz (2001) for similar treatment.

Similar to public capital there is no readily available private capital stock data at the state level. The estimation of private capital stock is relatively more problematic than public capital because with the exception of manufacturing sector there is no annual data for private capital investment at the state level. Therefore, state fixed private capital stock (K_i) is estimated by using the following formula:

$$K_i = [(VADD_i - WS_i) / (VADD_n - WS_n)] * K_n \tag{3}$$

where i indexes state and n indexes the nation. *VADD* is total value added (output) of private industries. *WS* is total wages and salaries for private industries. In this equation, *(VADD - WS)* represents returns to capital, which is assumed to be an indicator of the size of private capital stock in a state. It is expected that, in a perfectly competitive environment and long-term equilibrium, the ratio of $\frac{(VADD_i - WS_i)}{K_i} = \frac{(VADD_n - WS_n)}{K_n}$ holds. For each state, the ratio of $\frac{(VADD_i - WS_i)}{(VADD_n - WS_n)}$ has been steady over the study period. By using this equation, private capital stock, K_i, is calculated for each state.

The estimation of telecommunications capital stock in each state is similar to the methodology specified by Resende (1999) and Shin and Ying (1992). Telecommunications capital stock in each state is obtained by using the automated reporting management information system (ARMIS) of the Federal Communications Commission (FCC). The real capital stock is obtained by subtracting accumulated depreciation from gross communications plant figure for each local exchange provider.

Output, labour, public and private fixed capital stock and telecommunications stock data are from the U.S Department of Labour's Bureau of Economic Analysis (BEA). Both the state and national public capital outlay data are from the Government Finance files of the Bureau of Census. All monetary values are in constant 1996 dollars.

3.2 Empirical Analysis

Table 1 presents the results of OLS estimation of the first-difference form of the model[8]. The estimates are based on a least squares dummy variable (LSDV) with time dummies[9]. The coefficients of all variables are positive and significant at 1 percent level and estimation results support constant returns to scale argument made in the literature. The magnitudes of private capital stock and labour coefficients are also consistent with the estimates in the infrastructure literature (Holtz-Eakin and Schwartz, 1995; Evans and Karras, 1994; Boarnet, 1998).

Public capital variable suffers from measurement error problem[10]. To correct for measurement error, an instrumental variable (lagged public capital) is included into the analysis[11]. Table 1 reports estimation results corrected for measurement error problem in the public capital variable.

---

[8] Due to serial correlation problem, we used first different form of the model specification. Bhargava, Franzini, and Narendranathan (1982) provide a test for serial correlation in panel data sets. The BFN statistics for level form of the model is d_P = 0.316, which suggests that the variables should be transformed into differences. The estimations for BFN test are available from the authors upon request.

[9] Studies on the role of public infrastructure have emphasized the importance of inclusion of time dummies into regression analysis in order to control for time specific events (Boarnet, 1998; Holtz-Eakin and Schwartz, 1995; Kelejian and Robinson, 1997). Time dummies control for time specific events that effect states as a group such as recessions. Before deciding whether the final form of model should include time dummies, we performed F tests designed to test the significance of group effects (Greene, 1993).

[10] A test for measurement error is suggested by Griliches and Hausman (1986) and involves comparing differenced estimates of different length. The estimations for measurement error test are available from the authors upon request.

[11] There are two alternative treatment methods for the errors-in-variables: instrumental variable approach and covariance transformation (Hsiao, 1986). We used both models to correct for measurement error. Both models produced very similar results and the magnitude of the coefficient for public capital variable is very similar in both them. Therefore, we report estimation results of instrumental variable model in the paper however estimations for covariance transformation are available upon request also.

Table 1. Regression Results

Variable	**Estimated Coefficient**
Public Capital	0.010*
	(0.002)
Lagged Public Capital	0.006*
	(0.002)
Labour	0.440*
	(0.020)
Private Capital	0.531*
	(0.007)
Telecommunications Capital	0.016*
	(0.004)
Adj. R^2	0.97
N	624
RSS	0.023
F	1389*

* 1 percent significant; **5 percent significant.
Standard errors are in parentheses.
All regressions include a set of time dummy variables.

Before turning to discussions about estimation results, we need to discuss two points about diagnostics of estimation results. First, the infrastructure literature suggests that endogeneity of the dependent variable is a major concern in production function estimations: the relationship between the interested variable (telecommunications in this case) and the dependent variable might be subject to reserve causality, creating more demand for telecommunications services as the output grows rather than more telecommunications services increasing output. Then the question is whether infrastructure services contribute to output or output creates demand for infrastructure services. However, the test results show that our estimation results do not suffer from endogenity problem[12].

The last point about diagnosis of estimation results is the spatial dependence issue. The presence of spatial dependence may lead to misspecification of models and spatial heterogeneity can cause instability of behavioral relationships. One of the main reasons for spatial correlation or dependence in the error terms of regional econometric models is omitted variables that may be relate to the connectivity of neighboring regions (Kelejian and Robinson, 1997). In a properly specified model, it is quite likely that spatial dependence would be reduced or eliminated.

[12] The test for endogeneity is a Hausman test (Hausman, 1983), which is very similar to Granger causality test. These estimations for endogeneity are available from the authors upon request.

Table 2. Moran's *I* Tests for Error Dependency

Year	**Moran's *I***	***z*-value**	**Probability**
1984	0.045	0.691	0.48
1985	0.032	0.548	0.58
1986	0.068	0.918	0.35
1987	0.171	1.979	0.05
1988	-0.024	-0.032	0.97
1989	0.060	0.835	0.40
1990	-0.186	-1.700	0.09
1991	-0.140	-1.230	0.22
1992	0.024	0.465	0.64
1993	-0.028	-0.069	0.95
1994	0.167	1.943	0.05
1995	-0.054	-0.340	0.73
1996	-0.206	-1.902	0.06
1997	-0.024	-0.036	0.97

To control for spatial error dependency, Moran's *I* test is carried out on residual values of each year[13]. As seen in Table 2, spatial error dependence is not a major concern for our empirical analysis in general. Moran's *I* statistics are highly insignificant for all the years except for 1987, 1990, 1994 and 1996. For 1987 and 1994, Moran's *I* values are significant at the five percent level whereas for 1990 and 1996, these values are significant at the ten percent level. However, the spatial autocorrelation problem seen in these years might be coming from a mismatch between spatial boundaries of explanatory variables and administrative boundaries used to compile data. Therefore in order to control for nuisance dependency, the model reported in Table1 is run with spatially lagged variables.

In analysing spatial error dependency, the clustering of independent variables is treated as having an interpretative value, rather than being a nuisance parameter. Thus, taking into account the effect of independent variables in neighboring states on the output of state *i*, spatially lagged values of independent variables have been created for state *i*[14]. As a modeling choice, the lag of the

[13] A well-known test for spatial autocorrelation in the regression error term is Moran's *I* test, which was developed by Cliff and Ord (1972). This statistic is given by: $I = e'We/e'e$ where e is an R by 1 vector of regression residuals. W is an R by R row standardized spatial weights matrix. The weights matrix was constructed by assigning 1 to all *j*s that are contiguous to *i*, and 0 to all others.

[14] Spatially lagged variables for a region are computed by taking the average value of the region's immediately contiguous neighbors.

Table 3. Spatial Interaction Effects

Variable	**Estimated Coefficient**
Public Capital	0.010*
	(0.003)
Public Capital (Spatially Lagged)	0.005
	(0.005)
Lagged Public Capital	0.006*
	(0.002)
Lagged Public Capital (Spatially Lagged)	0.005
	(0.005)
Labour	0.436*
	(0.022)
Labour (Spatially Lagged)	0.017
	(0.030)
Private Capital	0.530*
	(0.007)
Private Capital (Spatially Lagged)	0.012
	(0.014)
Telecommunications Capital	0.017*
	(0.004)
Telecommunications Capital (Spatially Lagged)	0.010
	(0.009)
Adj. R^2	0.97
N	624
RSS	0.023
F	1092*

*1 percent significant; **5 percent significant.
Standard errors are in parentheses.
All regressions include a set of time dummy variables.

independent variables rather than the dependent variable are being used. This type of spatial econometric model being estimated here is part of a family of models reported in Anselin (1999).

Table 3 reports estimation results using spatially lagged variables. As seen in the table, spatially lagged values of independent variables are not statistically significant. Insignificance of spatially lagged variables confirms the previous findings in Table 2.

As mentioned previously, the econometric problems of production function estimation are a major source of criticism for this type of analysis. However, the test results in this section provide support for the robustness of the analysis and the findings. In general estimation results show that telecommunications infrastructure has a significant positive impact on private output. The coefficient on telecommunications capital is positive and statistically significant, suggesting that states benefit from an increase in their telecommunications capital stock. This finding is consistent with the existing literature on telecommunications infrastructure and growth. However, the comparison of the magnitude of telecommunications and public capital variables suggests that returns to investments are higher in telecommunications than public sector.

Although returns to telecommunications investment is positive in general, there still exists large variation in the usage and dependency on telecommunications services across sectors. The economy wide impact of telecommunications infrastructure is a weighted average of the underlying sectoral impacts. As more economic functions are conducted electronically, being able to transmit and receive large amounts of information is critical to certain industries and the expected impact of telecommunications infrastructure on the output of these industries should be different than other industries where telecommunications is not a crucial production input. The analysis in the next section presents the contribution of telecommunication infrastructure on sectoral output.

4. THE IMPACT OF TELECOMMUNICATIONS ON SECTORAL OUTPUT

The main hypothesis being tested in this section is that the relative contribution of telecommunications infrastructure on sectoral output will be sensitive to the importance of telecommunications infrastructure as a sector specific input. For example, one would expect that the impact of telecommunications infrastructure would be larger on telecommunications intensive sectors that represent the fastest growing component of the U.S. economy.

In order to assess the relative importance of telecommunications infrastructure on sectoral output, industrial sectors are divided into two groups. The first group was composed of the agriculture, mining, construction and manufacturing sectors. For this group of industries, telecommunications services are not expected to be an important input. The second group consisted of wholesale and retail trade, finance, insurance and real estate, and services. Here, we believe telecommunications service is a very important input.

Table 4 presents estimation results for the first group of sectors that represents the old economy in which their importance have been declining in economic performance over the last two decades[15]. As seen in Table 4, telecommunications infrastructure does not have a significant impact on output in the sectors that are classified as old economy sectors. Given the importance of telecommunication in the process of production in agriculture, mining, construction and manufacturing, insignificance of the telecommunications variable on output in these sectors is not surprising.

---

[15] Following the test results from the previous section, Tables 2 and 3 report estimation results for the first difference model.

Table 4. Sectoral Level Analysis

Variable	Agriculture	Mining	Construction	Manufacturing
Public Capital	0.014*	-0.005	0.014	0.002
	(0.005)	(0.022)	(0.009)	(0.004)
Lagged Public Capital	-0.008	0.048	0.008	0.007
	(0.005)	(0.025)	(0.008)	(0.003)
Labour	0.034**	0.274*	0.848*	0.461*
	(0.014)	(0.092)	(0.075)	(0.025)
Private Capital	0.916*	0.489*	0.358*	0.523*
	(0.008)	(0.037)	(0.068)	(0.010)
Telecommunications Capital	0.012	-0.050	0.010	0.000
	(0.011)	(0.046)	(0.014)	(0.010)
Adj. R^2	0.99	0.87	0.95	0.96
N	624	624	624	624
RSS	0.119	2.799	0.219	0.123
F	5581*	258*	808*	1107*

* 1 percent significant; **5 percent significant.
Standard errors are in parentheses.
All regressions include a set of time dummy variables.

Table 5 present estimation results for the second group of sectors in which their relative importance in total output is growing much faster than the first group of sectors and telecommunications services are very important component of their production process. Therefore, it is expected that telecommunications infrastructure variable should have a stronger effect on sectoral output in this group of sectors than the first group.

As seen in Table 5, the coefficient for telecommunications infrastructure is positive and significant for all the sectors in this group. In the case of wholesale trade the positive coefficient of telecommunications variable is significant at 5 percent level whereas for retail trade and finance, insurance, real estate (FIRE), the coefficient is significant at 1 percent level. As seen in the table, the magnitude of telecommunication infrastructure variable’s coefficient is similar for wholesale trade, FIRE and services, but it is lower for retail trade.

The explanation for the magnitude change in telecommunications variable for retail trade might be developments in information and communications technologies. In the last two decades, advances in information and communications technology have altered the geography of economic activities. Some functions of wholesale trade, FIRE and services have been decentralized and transactions are done over the electronic highway rather than face-to-face interactions. Therefore, telecommunications have become an important input for these industries. However, in retail sale sector face-to-face interaction is still an important form of transaction.

Table 5. Sectoral Level Analysis

Variable	Wholesale Trade	Retail Trade	FIRE	Services
Public Capital	0.009**	0.005	0.005	0.006
	(0.004)	(0.002)	(0.002)	(0.003)
Lagged Public Capital	0.006	-0.009	0.004	0.007
	(0.003)	(0.003)	(0.001)	(0.003)
Labour	0.381*	0.474*	0.061*	0.367*
	(0.035)	(0.022)	(0.010)	(0.032)
Private Capital	0.654*	0.629*	0.882*	0.595*
	(0.029)	(0.015)	(0.006)	(0.020)
Telecommunications	0.015**	0.005*	0.013*	0.014**
Capital	(0.007)	(0.000)	(0.003)	(0.007)
Adj. R^2	0.96	0.97	0.98	0.88
N	624	624	624	624
RSS	0.053	0.029	0.015	0.046
F	1147*	1591*	2977*	274*

* 1 percent significant; **5 percent significant.
Standard errors are in parentheses.
All regressions include a set of time dummy variables.

Overall, the empirical analyses show the positive impact of telecommunications infrastructure on aggregate output. However, the positive impact of telecommunications infrastructure varies across industries. According to the sectoral level analysis, telecommunications infrastructure has stronger impacts on the service related sectors of the U.S. economy. The significant impact of telecommunications infrastructure on service industries stems from the application of new information technologies that are transforming the operations of many functions in telecommunications-intensive service industries. These transformations have important regional development implications, potentially leading to new locational patterns.

The new technology system is creating an ever more spatially dispersed and footloose economy by connecting economic activities and enabling them to be physically farther apart. Therefore, developments in the technological front have increased the importance of telecommunications infrastructure in the economic performance of states. In order to be competitive in attracting new businesses and increasing output in the fastest growing sectors, states need to invest in their telecommunications infrastructure.

5. FURTHER DISCUSSIONS AND IMPLICATIONS

As more economic functions are conducted electronically, telecommunications infrastructure is going to be an important component of the production process in certain industries. Although advanced telecommunications infrastructure is rapidly diffusing, there exists large variations in the dependency of telecommunications network across sectors. Because of the perceived importance of telecommunications infrastructure in aggregate output, there has not been a need to demonstrate the differential impacts of telecommunications infrastructure on sectoral output. In the past, surprisingly little work has been done to characterize and compare the relationships between telecommunications infrastructure and sectoral growth. This paper is a step towards better understanding of the role of telecommunications infrastructure in the growth patterns of different sectors.

The paper documented that overall telecommunications capital stock has a positive impact on output growth at the aggregate level. However, the magnitude and statistical significance of this impact varies across sectors. Telecommunications capital stock has significant impact on output growth in the wholesale trade, retail trade, FIRE, and services sectors.

Aggregate production function estimations reflect general trends in the economy. However, an aggregated relationship between inputs and outputs do not capture all the aspects of micro behavioral underpinnings of interregional economic activities. A detailed analysis of industries at disaggregated (e.g. four digit SIC) level would provide more insights about industrial trends across the states. This has important policy implications in terms of targeting industries in designing economic development policies.

A related topic to disaggregated analysis is to analyze welfare effects of telecommunications infrastructure. The exact nature of the relation between the marginal products of physical capital, labour and telecommunications investments is an empirical question, and it is very hard to obtain data on the marginal rate of substitution between these inputs. Therefore, in order to estimate the impact of an increase in telecommunications capital on output, a cost function framework might be used to estimate shadow values where a negative shadow value for telecommunications capital stock would imply cost savings effects. Further empirical research on the welfare effects of telecommunications infrastructure and rate-of-return regulation would greatly benefit our understanding of locational effects telecommunications infrastructure.

REFERENCES

Anselin, L. (1999) *Spatial Econometrics*. Mimeograph.

Armstrong, R. (1995) *Creating Climate for the Information Age: The Nebraska Statewide Telecommunications Infrastructure Plan*. Nebraska Information Technology Commission: Lincoln, Nebraska.

Aschauer, D.A. (1989) Is public infrastructure productive? *Journal of Monetary Economics*, 23(2), pp. 177-200.

Bhargava, A., Franzini, L. and Narendranathan, W. (1982). Serial correlation and the fixed effects model. *Review of Economic Studies*, 49, pp. 533-49.

Boarnet, M.G. (1998) Spillovers and the locational effects of public infrastructure. *Journal of Regional Science*, 38, pp. 381-400.

Cairncross, Frances. (1997) *The Death Distance*. Harvard Business School Press: Boston.

Cliff, A. and Ord, K. (1972) Testing for spatial autocorrelation among regression residuals. *Geographical Analysis*, 4, pp. 267-284.

Cronin, F.J., Parker, E.B., Colleran, E.K. and Gold, M.A. (1991) Telecommunications infrastructure and economic growth: An analysis of causality. *Telecommunications Policy*, 15(6), pp. 529-535.

Cronin, F.J., Colleran, E.K., Herbert, P.L. and Lewitzky, S. (1993) Telecommunications and growth the contributions of telecommunications infrastructure investment to aggregate and sectoral productivity. *Telecommunications Policy*, 17 (9), pp. 677-690.

Cronin, F.J., Gold, M.A., Hebert, P.L. and Lewitzky, S. (1993) Factor prices, factor substitution, and the relative demand for telecommunications across US states. *Information Economics and Policy*, 5, pp. 73-85.

Cronin, F.J., Gold, M.A., Mace, B.B., Sigalos, J.L. (1994) Telecommunications and cost savings in educational services. *Information Economics and Policy*, 6, pp. 53-75.

Cronin, F J., McGovern, P.M., Miller, M.R., and Parker, E.B. (1995) The rural economic development implications of telecommunications: Evidence from Pennsylvania. *Telecommunications Policy*, 19(7), pp. 545-559.

Cronin, F.J., Colleran, E.B., and Gold, M.A. (1997) Telecommunications, factor substitution and economic growth. *Contemporary Economic Policy*, XV, pp. 21-31.

Diewert, Walter E. (1986) *The Measurement of the Economic Benefits of Infrastructure Services.* Lecture Notes in Economics and Mathematical Systems No.278. (Springer-Verlag: Berlin).

Dinc, M., Haynes, K., Stough, R. and Yilmaz, S. (1998) Regional universal telecommunication service provisions in the US: Efficiency versus penetration. *Telecommunications Policy*, 22(6), pp. 541-553.

Evans, P. and Karras, G. (1994) Are government activities productive? Evidence from a panel of U.S. states. *Review of Economics and Statistics*, 76, pp. 1-11.

Garcia-Mila, T., McGuire, T. and Porter, R. H. (1996) The effect of public capital in state-level production functions reconsidered. *Review of Economics and Statistics*, 78, pp. 177-180.

Greene, W.H. (1993) *Econometric Analysis*. Prentice Hall: New Jersey.

Greenstein, S. and Spiller, P.T. (1995) Modern telecommunications infrastructure and economic activity: An empirical investigation. *Industrial and Corporate Change*, 4, pp. 647-665.

Griliches, Z. and Hausman, J.A. (1986) Errors in variables in panel data. *Journal of Econometrics*, 31, pp. 93-118.

Howe, L. and Gardner, M. (1992) *Telecom'92: Connecting Idaho to the Future.* Department of Administration: Boise, Idaho.

Hsiao, C. (1986) *Analysis of Panel Data*. Cambridge University Press: Cambridge.

Hausman, J.A. (1983) Specification and estimation of simultaneous equation models. In Zvi Griliches and M.D. Intriligator (eds), *Handbook of Econometrics Vol. 1*. North Holland: Amsterdam.

Holtz-Eakin, D. (1994) Public-sector capital and the productivity puzzle. *Review of Economics and Statistics*, 76, pp. 12-21.

Holtz-Eakin, D. and Schwartz, A.E. (1995) Spatial productivity spillovers from public infrastructure: Evidence from state highways. *International Tax and Public Finance*, 2, pp. 459-468.

Kansas Telecommunications Strategic Planning Committee. (1996) *Connections to the Future: A Telecommunications Strategic Plan for Kansas.* Telecommunications Strategic Planning Committee: Topeka, Kansas.

Kelejian, H.H. and Robinson, D.P. (1997) Infrastructure productivity estimation and its underlying econometric specifications: A sensitivity analysis. *Papers in Regional Science*, 76, pp. 115-131.

Lall, S. and Yilmaz, S. (2001) Regional economic convergence: Do policy instruments make a difference? *Annals of Regional Science*, 35(1), pp. 153-166.

Munnell, A. (1992) Infrastructure investment and economic growth. *Journal of Economic Perspectives*, Fall, pp. 189-198.

Nadiri, M.I. and Nandi, B. (1997) The changing structure of cost and demand for the U.S. telecommunications industry. *Information Economics and Policy*, 9, pp. 319-347.

National Governors' Association. (1994) *Telecommunications: The Next American Revolution*. NGA: Washington, DC.

Resende, M. (1999) Productivity growth and regulation in U.S. local telephony. *Information Economics and Policy*, 11, pp. 23-44.

Shin, R.T. and Ying, J.S. (1992) Unnatural monopolies in local telephone. *Rand Journal of Economics*, 23(2), pp. 171-83.

U. S. Congress, Office of Technology Assessment. (1995) *The Technological Reshaping of Metropolitan America*. U.S. Government Printing Office: Washington, DC.

Washington Governor's Telecommunications Policy Coordination Task Force (1996) *Building The Road Ahead: Telecommunications Infrastructure in Washington.* Department of Revenue: Olympia, Washington.

Wisconsin Governor's Blue Ribbon Telecommunications Task Force (1993) *Convergence, Competition, Cooperation*. Department of Administration: Madison, Wisconsin.

Yilmaz, S., Haynes, K.E., and Dinc, M. (2002) Geographic and network neighbors: spillover effects of telecommunications infrastructure. *Journal of Regional Science,* 35, pp. 216-27.