EMPLOYMENT EFFECTS OF TELECOMMUNICATIONS CAPITAL: THE CASE OF DEVELOPED AND TRANSITIONAL COUNTRIES

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Arts in Economics

National University "Kyiv-Mohyla Academy"
Economics Education and Research Consortium
Master's Program in Economics

2004

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Program Authorized
to Offer Degree Master's Program in Economics, NaUKMA

Date ____

National University "Kyiv-Mohyla Academy"

Abstract

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This paper analyzes the effect of investment in telecommunications capital on the economy-wide employment. It uses a two-equation model, which links telecommunications capital investment and employment (as well as output) growth. The major distinction of the model is that the relationship between telecommunications capital and employment, as well as output growth is non-linear, which allows the estimation of the employment-growth and output-growth maximizing levels of telecommunications capital. The model is estimated empirically using a sample of 47 developed, developing, and transitional countries for the period of 1990 to 2001. The results contain evidence of statistically significant, generally positive effects of telecommunications capital on output and employment growth. Furthermore, the employment growth maximizing ratio of telecommunications capital to non-telecommunications capital was estimated to be 5.434%, while the output growth maximizing level of telecom capital to non-telecommunications capital was estimated to be 4.038%. Finally, results indicate underinvestment in telecommunications capital for an average country in the sample.

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ACKNOWLEDGMENTS

The author wishes to thank Lilia Maliar, the thesis advisor for this paper, for her invaluable contribution to this research effort. Furthermore, a special acknowledgement is due to the International Telecommunications Union, the organization that provided telecommunications investment data; without this contribution, this work would not be possible. Finally, the author would like to express his gratitude to Tom Coupe for valuable advice and general assistance in this project.

Chapter 1

INTRODUCTION

Telecommunications have been a driving force in economic development for the last hundred years. In the recent decade, advances in computing power and information technology, the proliferation of mobile networks, as well as the development of telecommunications technology as a whole have increased the interest of economists in telecommunications. As a result, economists have started studying the effects that development of telecommunications has on the global economy, as well as on individual countries or groups of countries.

A number of studies have identified a strong positive relationship between investment in telecommunications stock and economic growth (see Chapter 2). This link has been identified for developed economies, and, more recently, for a group of transitional countries. However, a number of questions as to the effect of telecommunications on other economic variables remain unanswered. Among such variables, employment is of prime focus. Specifically, it is of significant interest for researchers as well as policymakers to determine what effect investment in telecommunications has on the economy-wide employment.

The main motivation for producing this paper is to identify this poorly studied link in the case of both developed countries in the form of OECD members, transitional countries, in the form of Central and Eastern European countries including Ukraine and the Russian Federation, and some developing countries.

Specifically, a positive effect of telecommunications development involves the creation of new jobs needed to service the telecoms infrastructure, as well as employment spillover effects from increased economic growth due to investment in telecoms. Therefore, investment in telecommunications infrastructure can be expected to increase employment growth. At the same time, as investment in telecommunications continues to increase, it can be expected that this investment will exhibit declining positive effect on output growth (one explanation offered in the literature is declining network externalities, e.g. Krugman (1999)), and therefore employment. At a certain point, this investment may start to have a negative impact on employment growth. This negative effect can result if investment in telecoms is performed at the expense of other more economically productive investment (i.e. marginal product from telecom investment is lower than marginal product from other capital investments, which results in investment misallocation; following an argument put forth by Arrow and Kurz (1970) for public capital), thus reducing economic growth, and as a result employment growth.

In other words there exists a nonlinear relationship between employment and investment in telecom capital, and, specifically, there exists an employment-maximizing level of investment in telecommunications capital, the knowledge of which would be of great use to policymakers. To study this effect and estimate the optimal level of telecom capital, we have adopted a model developed by Aschauer (2001), which analyzes output and employment effects of investment in public capital. Just as in our case, Aschauer postulates that there is a nonlinear relationship between investment in public capital and output and employment growth, and there are output-growth and employment-growth maximizing levels of public capital.

There is an additional bonus of using Aschauer's model in that it allows to specifically model output effects, and thus avoid misattributing changes in employment to changes in output (more detailed description of the model is found in Chapters 2 and 3). By using this model, we estimate the effects of telecommunications investment on output and employment growth, and find two optimal levels of telecom investment, which maximize output growth and employment growth respectively.

In this respect, our paper is one of the first steps in assessing the effect of telecommunications on economy-wide employment in transitional, as well as developed countries. A better understanding of this relationship would be beneficial in a number of ways. First, since the telecom sector represents an important element of the new economy, this research would enhance the understanding of what effects the new economy has on employment. Second, a better understanding of this relationship would help governments conduct effective labor policies in the light of growing importance and magnitude of the new economy sectors in the global economy.

Finally, the knowledge of the employment and output-maximizing levels of telecom investment would help policymakers encourage investment in telecoms in a way to fully benefit from the new technology, and at the same time, not to divert investment from more productive opportunities. In other words, it would help governments target the optimal level of telecom investment, which would bring maximum benefit (in terms of employment and economic growth) for the economy.

Relevance for transitional countries

This research is especially relevant for countries in transition, since a large proportion of investment in these countries comes into the telecom sector. Furthermore, the growth of the telecom sector in these countries is frequently higher than in developed countries, as transitional countries upgrade their infrastructure to modern "Western" levels. As a result, telecommunications have an especially pronounced effect on transitional economies.

Therefore, a better understanding of the relationship between telecommunications infrastructure development and job creation, as well as the estimation of the optimal level of telecommunications investment, would help predict the effect of telecom development on employment and assist governments in adjusting their labor policies to account for that effect.

The next chapter (Chapter 2) describes the body of literature related to our work. Chapter 3 presents the theoretical model, as well as the model for estimation and describes the data. Chapter 4 contains estimation results and their interpretation. Chapter 5 concludes.

C h a p t e r   2

LITERATURE REVIEW

The effect of investment in telecommunications on job creation — both economy-wide as well on the level of individual sectors — is a poorly studied phenomenon to date, and little literature exists on the subject. This is true about developed countries as well as transitional ones, with transitional countries especially suffering from the dearth of reliable data to conduct quality research. As a result, no literature directly dealing with the issue of employment effects from telecommunications investment exists that has been published or can be readily identified.

At the same time, since our work involves elements of a number of subfields of economics and borrows a model from the field of general infrastructure economics, it is related to the previous body of research in these broad areas. This previous research can be classified into three major categories: (1) previous research on the effects of investment into telecommunications and technology on economic growth, that is the part of research related to growth economics as well as infrastructure studies (this body of literature is especially relevant, since this study borrows a model from this literature and modifies for the purposes of researching the effect of telecommunications investment on employment); (2) research of the effects on advances in new technology on employment (new technology or "new economy" labor economics); (3) labor studies in the context of transitional economies.

This section outlines major literature in each of the broad three categories. Rather than to be exhaustive, the goal of the section is to identify seminal papers in each category so as to better delineate the larger context of related to out work research. We begin by first reviewing the literature in the growth category and then proceed to summarize major works in the other categories in the order listed above.

Estimating the effect of telecommunications on growth

A number of studies have been produced over the years that attempted to determine the effect that investment in telecommunications has on economic growth. Excellent literature reviews (and in far greater detail) in this category can be found in Roller and Waverman (2001) and Chervachidze (2003) Early studies, such as works by Hardy (1980) and Leff (1984), determined statistically significant effects of telecoms on economic growth. These coefficients tended to exhibit large magnitudes. These authors, along with a major work by Capello and Nijkamp (1996), used the concepts of network externalities, the reduction in costs, and spillover effects to provide theoretical justifications for the positive effect of telecommunications on growth.

Generally, the research of the effect of telecommunications on economic growth has followed in the footsteps of other infrastructure studies, where telecommunications is frequently defined as public good. Among infrastructure studies of note are works by Aschauer (1989), which found that the growth effects of infrastructure are positive and characterized by significant magnitudes, and Gramlich (1994), whose work also supports this result.

However, since these ground-breaking studies used relatively unsophisticated methods of estimation, most of these early studies were subsequently subjected to criticism on the ground of faulty econometric procedures. Specifically, early papers are said to suffer from non-stationarity, faulty specification, and reverse causality. In response to this critique, a number of recent research works have been produced that attempt to solve econometric problems associated with earlier works.

One common method adopted by these later authors is the use of simultaneous equations, which improve specification and eliminate reverse causality. Among the first such works was the work by Hulten (1994). However, one landmark work on telecommunications has been recently produced by Roller and Waverman (2001).

In their work, Roller and Waverman use a system of simultaneous equations to model the effect of investment in telecommunications on economic growth. They estimate this relationship for the group of OECD countries using panel data methods. Perhaps unsurprisingly, their result, obtained using the latest econometric techniques, is similar to result obtained in the early literature—they find that telecommunications have a significant effect on economic growth. Just like previous authors, they use the argument of network externalities to explain this positive relationship.

Roller and Waverman's research is taken one step further by Chervachidze (2003) who extends Roller and Waverman's analysis to the case of transitional countries. Chervachidze uses the same theoretical framework and a similar method of panel estimation to show that, just as is the case with developed countries, "growth effects of telecoms in transitional countries are indeed positive." She reports the estimated elasticity of economic growth with regard to telecommunication stock of 0.50, which confirms previous literature results with elasticity coefficients in the range of 0.38 to 0.56.

Our work is a further extension of the work by Roller and Waverman and Chervachidze. Specifically, Roller and Waverman (2001) in their work suggest a further extension of their research in terms of identifying a link between investment in telecommunications infrastructure and job creation: "A related issue of considerable interest is the relationship between telecommunications infrastructure and job creation." This is what our study attempts to accomplish by examining this link both for developed, as well as transitional countries

Finally, two papers by David Aschauer (2001, 1997a, 1997b, 2002) have a direct relation to this work, since a modified model from Aschauer's papers is used in this research. First, in one paper Aschauer (2001, 1997a-an earlier version) uses a two-equation model, which links public capital to employment and output growth. The model is used to estimate the effect that investment in public capital has on output growth and employment growth. Furthermore, by specifying a nonlinear relationship between the level of public capital stock, relative to private capital stock, output and employment level, Aschauer estimates the amount of public capital, which maximizes employment and output growth respectively.

Aschauer explains the nonlinear relationship by the fact that (1) the benefits of public capital rise at a diminishing rate, but the costs of providing public capital (taxation) rise at constant rate; (2) the argument that at any particular point in time the aggregate capital stock is misallocated unless the marginal product of public capital equals the marginal product of private capital. These two arguments imply that "there should exist an output, and by extension, an employment, growth maximizing level of the public capital stock relative to the private capital stock"(Aschauer 2001). This implies that "for relatively low levels of public capital, increased public investment raises the economic growth rate; but for relatively high levels of public capital, increased public investment decreases growth."

The analysis described above is a static one, taking the long-term view and ignoring transitional dynamics. Second, in his other work, Aschauer (2002, 1997b-an earlier version) takes the model described above as a basis and studies the behavior of the relevant variables in a dynamic setting, accounting for transitional effects.

In our work, we used a modified version of Aschauer's first model described above. For more information on our model, refer to Chapter 3.

New technology, innovation and employment

Another segment of literature to which our work is related is the literature on the employment effects of new technology and innovation. This field in economics is relatively new and has become popular in the last five to ten years. The interest in studying such effects has, to a large extent, been generated by a wide proliferation of information technology in the form of computers, the Internet, and telecommunications capacity.

As a result of this technological development, economists have been interested in studying the effects of technology on economic variables, notably productivity, efficiency and growth. Somewhat later, the interest broadened to include the effects of technological development on economy-wide, as well as sector-level employment. In this sense, our work, as well as other work concentrating on analyzing the effects of technology on jobs, is part of the larger body of work on innovation, technological development, and the "new economy".

Since this field is relatively new, the volume of literature concentrating on the effects of technological innovation and the adoption of new technologies on employment is limited. Furthermore, even fewer studies of this type analyze these effects in the context of transitional countries. Finally, no studies have been published to date (although it is possible that such research may be in progress) that deal with the specific issue of the effect of telecommunications technology development on employment.

Despite this relatively limited amount of previous research, a number of representative works can be identified, which adopt various approaches to analyzing the effects of technological development on jobs. This section summarizes these works. Far from being complete and exhaustive, this summary is designed to show the various approaches adopted by authors to analyzing the issue of technological progress and employment. Since this field is a promising area of economic research, it is reasonable to expect that the number of such works will increase in the near future, and we hope that our research will contribute to the development of knowledge in this specific area.

One paper that can represent the approach adopted by some researches is the work by Blanchflower and Burgess (1995) who use comparative evidences from two countries to study the effect of new technology on jobs. Specifically, the authors attempt to examine the effect of introduction of new technology on employment growth and profitability. They use two datasets in the form of two firm-level large cross-section sets of data from Britain and Australia in 1990 and 1989.

In their paper, the authors address the main question of whether the introduction of new technology is associated with higher or lower employment growth rates. They further analyze the effect that regulatory environment and workplace organization have on job growth associated with the introduction of technology. They answer this question by examining the series of means of relevant variables for each country, presenting employment regressions for each country, and examining and interpreting the differences between the two countries.

The result of the author's study suggest that "there is some evidence that the introduction of new technology is associated with higher employment growth." Furthermore, the authors find that this effect varies by the size of the firm, with larger firms benefiting from a "bigger impact on employment growth" from the introduction of new technologies.

Another paper that represents an interesting approach to addressing the issue of technological innovation and jobs is the work by Garcia, Jaumandreu, and Rodriquez (2002). Their paper is aimed at "structurally assessing the employment effects of innovative activities of firms." The authors estimate a structural econometric model designed to account for the firm-level displacement and compensation effects of innovation, where "the stock of knowledge capital raises firm relative efficiency through process innovations and firm demand through product innovations." The authors estimate displacement from the elasticity of employment with respect to innovation in the (conditional Hicksian) demand for labor. Compensation effects are estimated from a firm-specific demand relationship. The data are an unbalanced panel of representative Spanish firms during the nineties.

The authors arrive at a somewhat ambiguous result. While "innovation displaces labor," it also creates "the firm-level conditions to overcompensate this displacement." Furthermore, the researchers find that wage and pricing behavior can hamper the work of productivity-growth mechanism, with the resulting "negative net effects for employment."

A third representative work, which also concentrates on micro firm level, is the paper by Breshahan, Brynjolfsson, and Hitt (1999). This work focuses on information technology, workplace organization, and the demand for skilled labor. The authors attempt to investigate the causes of skill-based technical change. Specifically, they test the hypothesis that "it is a cluster of complementary changes involving IT, workplace organization and services that is the key skill-based technical change." To test the hypothesis they examine US firm-level data linking several indicators of IT use, workplace organization, and demand for skilled labor. Utilizing a somewhat involved technique, the authors find the evidence for complementarity "in both short-run factor demand and a production function framework."

The data used was a mixture of a panel and a cross-section of organizational and human capital variables. The empirical strategy was the following: (1) "to look at correlations across firms in the use of hypothesized complements; (2) examine short-run conditional input-output equations; (3) analyze simple production functions."

This study is representative in that it uses both firm-level data and instead of estimating economy-wide net employment effect, it analyses the effect on the type of labor – skilled and unskilled.

A final noteworthy paper, which represents an entirely different approach is the study by Mokyr (1997), which looks at the political-economy side of technological change. In his work, Mokyr examines the economic history of technological innovations and societal resistance to these innovations. This paper is prominent in that it represents a philosophical-historical (rather than empirical) approach to examining the economic effects of new technologies. Rather than substituting hard-core empirical and theoretical work, such literature serves as a good compliment to the more conventional literature and enhances the understanding of economic phenomena associated with the introduction of new technology and innovation examined more formally in empirical research.

Transitional labor economics

Another major body of literature related to our work is labor economics studies done on transitional countries. As has been mentioned, no directly related work on the effects of investment in telecommunications on employment has been done in the context of transitional countries. Furthermore, there is generally very little work done on the effect of new technologies in transitional economies, although this is beginning to change, as some researchers are taking on this promising area of research. As in the previous sections, the representative works are summarized in this section.

One representative paper is the work on labor reallocation (the reallocation of labor between private and state sectors of the economy, as well as reallocation between different industries) by Boeri and Terell (2002). This work concentrates on studying the institutional determinants of labor reallocation in transitional economies. Specifically, the paper compares the transition experiences in the two sets of countries – Central and Eastern European countries and the countries of the former Soviet Union – in terms of reallocation of labor from the old (state-owned) sector to the new (private) sector, the extent of real wage decline and responsiveness to output changes.

The authors conclude that the transition experiences in the two set of countries were fundamentally different. Specifically, the CEE countries adopted social policies that upheld minimum wages, thus forcing the unproductive old sector to restructure and shed labor. In the longer-term, it proved instrumental to faster transition. FSU countries, on the other hand, did not adopt minimum-wage social policies, which allowed the old sector to survive by simply lowering wages rather than a forced restructuring. In the longer-term, it protracted the needed restructuring process in these countries. This study is representative of the volume of work in transitional labor economics, which concentrates on explaining restructuring processes in transition, as well as comparative analysis between different transitional countries.

Two other papers—Earle and Sabrianova (2000) and Lehmann, Wadsworth, and Acquisti (1999)—are representative of another segment of transitional labor research – the issue of wage arrears. Both papers examine (in a complemantary fashion) the economic reasoning behind wage arrears in Russian Federation prevalent in early and middle nineties. Lehmann et al explain the phenomenon of wage arrears by the adoption by Russian firms of delayed payment of wages as a "labor market adjustment" strategy. Earle et al, complement this analysis by linking the existence and extent of wage arrears to such factors as worker's job tenure, shareholdings in the firm, firm age, size, state ownership and performance. They state that the ability of firms to use wage arrears as the adjustment mechanism is determined by these factors.

Another segment of work in transitional labor economics deals with the evaluation of active labor market policies – policies such as training and job search assistance initiated by the government with the goal of decreasing employment. Three papers – Vodopivec (1999), Klueve, Lehmann, Schmidt (1999), and Schidt (1999) – deal with the issue of evaluating the overall effectiveness of such programs. While these works employ different estimation techniques to evaluate effectiveness, all three arrive at the same conclusion: the results of program evaluation are mixed. While increasing the possibility of finding a job in the short and medium term, the long term effect of such programs is ambiguous.

The final major segment of transitional labor economics deals with specific country analysis. A good example of such work is the paper by Kupets, Konigs, and Lehmann (2003), which analyze job flows in Ukraine as a result of size, ownership and trade effects of Ukrainian firms. This study is representative in that it uses firm-level data to explore sector-level job flows.

This section concludes our literature review. As has been stated in the beginning of the chapter, no work analyzing the effect of investment in telecommunications on employment, which would naturally be related to our paper, has been identified. At the same time, our research is related to economic literature in three major categories: work on the effect of telecommunications on economic growth as well as general infrastructure studies (we adopt our model from this literature; i.e. Aschauer's work on public infrastructure), work on the effect of new technology and innovation on employment and demand for workers, and work in transitional labor economics. Our research draws on this wide body of literature in numerous ways, and the ultimate goal of our paper is to further economic knowledge in the area of new technologies and infrastructure, with specific application to transitional setting.

Chapter 3

METHODOLOGY AND DATA

The model

As has been stated above, this paper has adopted a model deployed by Aschauer (2001), who used a two-equation model to estimate the effects of investment in public capital on output and employment (using the data for 48 US States). The model developed by Aschauer has been modified to investigate the effect of telecom capital on output and employment in the following way. Specifically, the analysis assumes a constant-returns-to-scale production function, which is written in natural algorithms:

$$Y = A + aFK + (1-a)E \qquad (1)$$

where Y = natural logarithm of output of goods and services (GDP), FK = natural logarithm of total physical capital stock (both telecommunications and non-telecommunications capital stock; from now on called *full capital*), E = natural logarithm of employment, and A = natural logarithm of total factor productivity.

The basic notion used in Aschauer's model is that there is "a nonlinear relationship between the level of the public capital stock, relative to the private capital stock, and output and employment growth at [US] state level." (Aschauer 2001).

The same nonlinear relationship can be expected to exist between the level of telecommunications capital stock (i.e. investment in telecommunications infrastructure), relative to general capital stock (non-telecom capital, which includes both private and public capital), and output and employment growth at country level. Hence, following Aschauer, we define the total factor productivity as a function of the ratio of telecommunications capital TK (natural logarithm of telecommunications capital stock, from now on simply *telecommunications capital*), to non-telecommunications capital K (K = natural logarithm of the non-telecommunications capital stock; that is both private and public capital stock excluding telecommunications stock; from now on called *general capital*) capital:

$$A = A(\frac{TK}{K}), A'' < 0 \qquad (2)$$

At low levels of telecom capital in relation to general capital, the telecom capital's marginal product exceeds the marginal product of general capital and output increases with an increase in telecom capital; therefore, $A' > 0$. However, at sufficiently high levels of telecom capital relative to general capital, the marginal product of telecom capital is exceeded by that of general capital and output falls with an increase in telecom capital; thus, $A' < 0$.

This nonlinear relationship can exist because the benefits of telecom capital rise at a diminishing rate. The diminishing returns to telecom capital are explained by the concept of network effects—positive externalities from the telecommunications network. Krugman (1999) argues that diminishing network effects are likely, due to decreasing economies of scale in that the most productive connections are made first, followed by less productive ones, which leads to decreasing marginal usefulness of every next connection. Results by Chervachidze (2003) confirm the diminishing marginal benefits of telecommunications capital in transitional countries.

In other words, telecom stock cannot exist in a vacuum to be useful. It needs general capital stock for increases in telecoms stock to generate positive output and employment effects. Simply speaking, a developed telecommunications network is useless without other capital infrastructure.

Furthermore, the increasing provision of telecom capital will exhibit rising marginal costs (including opportunity costs), as scarce resources are diverted from more productive uses to the provision of telecoms capital. A related explanation (following a similar argument for public capital in Arrow and Kurz (1970)) is that at any particular point in time the aggregate capital stock is misallocated unless the marginal product of telecommunications capital equals the marginal product of general capital.

This reasoning implies that there exists an employment and output growth maximizing levels of telecom capital relative to general capital. For relatively low levels of telecom capital, increased investment in telecommunications infrastructure raises the economic growth rate and employment, but for relatively high levels of telecom capital, increased telecom investment decreases output and employment growth. Finally, this approach has a major advantage in that it models the GDP growth explicitly, and the model allows to isolate the effect of telecom stock investment on employment without misattributing employment changes to GDP fluctuations.

Following Aschauer (2001), for the purposes of empirical analysis, this paper will use A in the quadratic form:

$$A = l(\frac{TK}{K})(1 - \frac{1}{2m}\frac{TK}{K}), \quad (3)$$

where

$$\frac{TK}{K} < (>)m \Rightarrow A' > (<)0,$$

which means that an estimate of parameter m is an estimate of the level of the telecom capital stock (relative to the general capital stock) which maximizes output. As will be shown later in this chapter, there also exists an employment-maximizing level of telecom capital to general capital, which can be estimated. This level is the prime focus of this work.

In this analysis, the marginal products of full capital and of employment are given by:

$$mp_{FK} = \ln a + A - (1-a)(FK - E) \qquad (4)$$

and

$$mp_{E} = \ln(1-a) + A + a(FK - E) \qquad (5)$$

Therefore, an increase in the stock of telecom capital also increases the marginal products of both factors of production as long as the telecom capital stock ratio lies below the output-maximizing level of *m*.

Furthermore, similarly to Aschauer (2001), we define the growth rates of full capital and employment, *DFK* and *DE* respectively, in the following manner. Given that there are increasing costs of adjusting the full capital stock and employment, an increase in the telecommunications capital stock will cause a persistent differential between the marginal products of full capital and employment and their respective costs (the user cost of capital and the wage) and will generate persistent increases in the growth rates of full capital and employment. Analytically, we have the following:

$$DFK = DFK(A, FK, E), \frac{\partial DFK}{\partial A} > 0 \, for \, \frac{TK}{K} < m, \qquad (6)$$

$$\frac{\partial DFK}{\partial A} < 0 \, for \, \frac{TK}{K} > m$$

and

$$DE = DE(A, FK, E), \frac{\partial DE}{\partial A} > 0 \, for \, \frac{TK}{K} < m, \qquad (7)$$

$$\frac{\partial DE}{\partial A} < 0 \, for \, \frac{TK}{K} > m$$

Again, deploying Aschauer's (2001) approach we can use the form of the production function to write the growth rate of output DY as the sum of three components—the growth rate of total factor productivity, the growth rate of the full capital stock relative to employment (weighted by the output elasticity of full capital), and the growth rate of employment. Thus,

$$DY = DA + aDFK + (1-a)DE \qquad (8)$$

or

$$DY = DA + a(DFK(A, FK, E) - DE(A, FK, E)) + DE(A, FK, E) \quad (9)$$

and

$$DE = DE(A, FK, E) \qquad (10) \text{ (the same as (7))}$$

Finally, by inverting the production function to write the full capital stock as a function of output, total factor productivity, and employment:

$$FK = \frac{1}{a}[Y - A - (1-a)E] \qquad (10.1)$$

and substitution of (10.1) into (9) and (10), the full capital stock may be eliminated to obtain a two equation (reduced form) system in the growth rates of output and employment given by:

$$DY = DY(A, Y, E) \qquad (11)$$

$$DE = DL(A, Y, E) \qquad (12)$$

These two reduced form equations can be used for empirical investigation. Following Aschauer (2001), these equations can be written in vector form as:

$$DX = l_x(\frac{TK}{K})(1 - \frac{1}{2m_x}\frac{TK}{K}) + a_x z + e_x \quad (13)$$

where x represents output *Y* and employment *E*. The vector z, common to both growth rate expressions, includes the initial (1990 and 1996) levels of (the natural logs of) output (*Y*) and employment (*E*), as well as the unemployment rate (*U*). The unemployment rate (which is not part of the original equations (11) and (12)) is included to remove cyclical effects on the growth rates of output and employment.

From this specification, we can estimate parameters m_Y and m_E, which give output and employment growth-maximizing levels of telecom capital relative to general capital.

These are the parameters of prime interest. Also, we can estimate l_Y and l_E, which give impacts of total factor productivity on output and employment growth. However, further algebraic manipulations are needed with l_Y and l_E in order to correctly ascertain the marginal effects of telecom capital as a ratio to general capital on employment and output growth. This is performed in the next chapter following estimation results.

As Aschauer (2001) notes, the effect of the initial levels of output and employment on the growth rates of the respective variables in equations (11) and (12) will be ambiguous, depending on such factors as the relative speeds of adjustment of capital and employment to their steady state values and the strength of income effects in the determinants of labor supply. These latter features lie beyond the scope of the present study and may provide the basis for subsequent research. Nonetheless, this conceptual framework is suited for uncovering the reduced form impacts of telecom capital on output and employment growth, given initial values of output and employment.

Empirical method

The equation (13) (that is two equations written as one in vector form) is estimated using nonlinear least squares (NLS) and then (jointly) estimated using nonlinear seemingly unrelated regressions (SUR) using the data panels for 47 developed, transitional, and developing countries. The method of estimation for both cases is pooled LS (non-linear least squares in the first case, and SUR LS in the second). The list of countries used for estimation is found in Table 5 in Appendix A.

Although the model is nonlinear in parameters, the form of the model is such that the coefficients are identified and can be extracted from the coefficients of the linear model (estimated using linear methods). Therefore, both nonlinear and linear methods yield identical results (this is shown explicitly in the next chapter). Output from estimation is included in the next chapter (see Table 2). As has been stated above, the estimate of m_X, gives the estimates of telecom capital levels, which maximize output and employment (two estimates, one for output max and one for employment max) respectively.

Subsequently, a Breusch and Pagan (1980) LM test is performed to check whether panel data techniques (random effects, fixed effects) should be used instead of pooled LS estimation. The test fails to reject the hypothesis that pooled estimation is the more efficient one, and hence, only pooled estimation is used (i.e. the test indicates that the pooled method with a common constant term is the best one (Greene (2000), Kennedy (2001)).

Data description

This subsection describes the data used for estimation. The data set for 47 countries is from 1990 to 2001. As has been stated, the list of countries used for estimation is included in the Appendix A. Following Aschauer, the data was broken down into two periods – 1990 to 1995 and 1996 to 2001 – and variables *DY, DE*, and *U* were averaged over each period to isolate long-term effects. As has been said, beginning of period (1990 and 1996) levels of (natural logarithms of) output and employment are included in the regression.

Output growth *DY* is measured as average annual growth in real gross domestic product (GDP). GDP figures for both data sets are from the World Development Indicators database (for developed countries), expressed in constant 1995 dollars, as well as from WIIW—Vienna Research Institute—(for transitional countries). Employment growth *DE* is measured as average annual growth in non-agricultural employment and is also taken from WDI and WIIW databases. Two stock series, both for general capital and telecommunications capital, have been calculated using the perpetual inventory methodology (Hall and Jones (1999) p.89; which uses capital formation, capital depreciation and average capital for general capital calculation; and telecoms investment, telecoms depreciation, and telecoms average growth for telecoms capital calculation). The appropriate data for capital are from the WDI and WIIW databases, while the telecommunications investment data are from Information Telecommunications Union (ITU) database.

Finally, the unemployment rate—used to control for persistent, though essentially cyclical effects — on the growth rates is again taken from WDI and WIIW.

Table 1 below provides summary statistics for the data. As can be seen from the table, output growth (*DY*) exhibited the average of 2.1 percent per year with the range between -13 percent and 12 percent for the entire sample. Employment growth (*DE*) had an average of 1% per year and ranged between -7% and 8% in the sample. The telecommunications capital stock as a ratio to general (non-telecom) capital stock averaged 1.6% with the maximum of 7.5% and the minimum of 0.078%. Finally, the unemployment rate had an average of 8.5%, with the minimum of 1.6% and the maximum of 21.24%.

Table 1

Descriptive Statistics 47 Countries (entire sample) 1990-1995 and 1996-2001 94 observations				
	Mean	Standard Deviation	Minimum	Maximum
DY	0.0213595	0.038838	-0.134786	0.12
DE	0.0106467	0.0230387	-0.0701307	0.0813491
TK/K	0.0159653	0.0119981	0.0007759	0.0754958
U	0.08496791	0.04378804	0.016	0.2124
Descriptive Statistics Transitional Countries (12 countries)				
	Mean	Standard Deviation	Minimum	Maximum
DY	-0.0100919	0.0551506	-0.134786	0.0568214
DE	-0.0123151	0.025383	-0.0701307	0.0157264
TK/K	0.0099689	0.0059141	0.0007759	0.0224932
U	0.1036306	0.0409462	0.01675	0.169

The table also depicts summary statistics for 12 transitional countries included in the sample. As can be seen from the table, the average output growth was -1%, which can be attributed to the fall in output in most countries at the outset of transition. Similarly, transitional countries exhibited an average employment decline of -1.2% percent. The average ratio of *TK/K* is 0.99%, which is much lower than the sample average of 1.6%. This can be explained by underinvestment in telecommunications (in comparison to developed countries) in most transitional countries prior to and following transition.

Among transitional countries, Ukraine had the lowest amount of telecom capital (0.078% for the period of 1991-1995), while Hungary had the highest amount of telecom capital (2.25%) as a ratio to general capital for the period of 1996-2001. For the period of 1996-2001, Ukraine exhibited the average of 0.52% for TK/K, and Ukraine's figure for the entire period (1991 to 2001) was 0.3%. The latest available ratio for Ukraine is 0.7% for the year of 2000.

EMPIRICAL INVESTIGATION AND RESULTS

Estimation approach and results

Table 2 below depicts estimation results for the pooled least squares method (i.e. both pooled NLS and pooled SUR LS). As has been stated, both linear and nonlinear least squares estimation using seemingly unrelated regressions methodology yield the same results. Therefore, Table 2 depicts (identical) estimation results from both methods.

The nonlinear specification for estimation, following equation (13) was as follows:

$$\begin{aligned} DY &= \beta_{Y0} + l_Y \frac{TK}{K}(1 - \beta_{Y1}\frac{TK}{K}) + \beta_{Y2}Y + \beta_{Y3}E + \beta_{Y4}U + \varepsilon_Y \\ DE &= \beta_0 + l_E \frac{TK}{K}(1 - \beta_{E1}\frac{TK}{K}) + \beta_{E2}Y + \beta_{E3}E + \beta_{E4}U + \varepsilon_E \end{aligned} \quad (14)$$

where

$$\begin{aligned} \beta_{Y1} &= \frac{1}{2m_Y} \\ \beta_{E1} &= \frac{1}{2m_E} \end{aligned} \quad (15)$$

The m_X coefficients were extracted algebraically from this model using (15).

In turn, the linear specification that was estimated was as follows:

$$\begin{aligned} DY &= \beta_{Y0} + l_Y \frac{TK}{K} + \beta_{Y1.1}(\frac{TK}{K})^2 + \beta_{Y2}Y + \beta_{Y3}E + \beta_{Y4}U + \varepsilon_Y \\ DE &= \beta_0 + l_1 \frac{TK}{K} + \beta_{E1.1}(\frac{TK}{K})^2 + \beta_{E2}Y + \beta_{E3}E + \beta_{E4}U + \varepsilon_E \end{aligned} \quad (16)$$

Table 2

Estimation Results: Output and Employment Effects of Telecommunications Capital		
	Methods: SUR NLS (pooled) and SUR linear (pooled)	
	DY	DE
C	**-0.0148** (0.032) (t=-0.47) (p=0.639)	**-0.00033** (0.018) (t= -0.02) (p=0.985)
l_X	**3.311** (1.033) (t=3.20) (P=0.001)	**2.03806** (0.587) (t=3.47) (p=0.001)
m_X	**0.04038** (0.005) (t=8.15) (p=0.000)	**0.05434** (0.010) (t=5.47) (p=0.000)
Y	**-0.00055** (0.004) (t=-0.15) (p=0.883)	**-0.00088** (0.002) (t=-0.41) (p=0.680)
E	**0.00220** (0.004) (t=0.51) (p=0.610)	**0.00156** (0.002) (t=0.64) (p=0.524)
U	**-0.15205** (0.001) (t=-1.47) (p=0.141)	**-0.20425** (0.001) (t=-3.48) (p=0.001)
R^2	0.119	0.191
SER	0.037	0.021
SSR	0.124	0.040

Notes: Coefficient values in bold print; standard errors in brackets, t-statistics and p-values as indicated.

Standard errors, t-statistics, and p-values for coefficients m_E and m_Y have been calculated using "delta method" built-into Stata 8.0 software (see Appendix B for details).

where

$$\beta_{Y1} = -\frac{\beta_{Y1.1}}{l_Y} = \frac{1}{2m_Y}$$
$$\beta_{E1} = -\frac{\beta_{E1.1}}{l_E} = \frac{1}{2m_E} \quad (17)$$

The m_X coefficients were extracted from the model using the relationship (17).

Both estimation approaches yield the same coefficients. This is possible because in this particular nonlinear specification (13), coefficients are identified and can be extracted from an estimated linear model. Hence for this nonlinear specification, the use of nonlinear estimation is not mandatory.

Since the parameter m_X is extracted algebraically for both approaches (through (15) and (17)), standard errors, t-statistics, and p-values calculated for β_{X1} and $\beta_{X1.1}$ must be transformed (to take into account the relationships (15) and (17)) to yield the appropriate standard errors, t-statistics, and p-values for m_X. This is done by using a "delta method" built-into Stata software (nlcom command; see Appendix B for details), and after the transformation, both the nonlinear least squares specification (14) and the linear version (16) yield the same results for these statistics.

All in all, these two approaches yield identical results in both: coefficient estimates, and standard errors (as well as t-statistics, and p-values). Therefore, to ease the estimation task and avoid problems with nonlinear iteration-based methods, all subsequent specifications (the random effects specification used to compute LM Breusch and Pagan (1980) included in the Appendix B) are linear.

Next, the test for the appropriateness of panel estimation (fixed effects, random effects) is performed. Specifically, to test whether panel estimation is appropriate, one must test whether country-specific intercepts (i.e. idiosyncratic fixed effects) are equal. If the hypothesis that the intercepts are equal (in other words there is one common constant intercept) cannot be rejected, then the pooled OLS estimator is efficient and should be used instead of panel estimation (Greene (2000) p562, p572-573; Kennedy (2001)). If this hypothesis is rejected, panel data estimation is more efficient and should be used. The next step in the case of better efficiency of panel methods would be to use Hausman test to choose between fixed and random effects.

Table 3

Breusch and Pagan LM Test	
Employment equation (DE dependent variable)	Output equation (DY dependent variable)
Test: Var(u) = 0	Test: Var(u) = 0
chi2(1) = 0.93	chi2(1) = 0.36
Prob > chi2 = 0.3354	Prob > chi2 = 0.5466
H_0 cannot be rejected	H_0 cannot be rejected
Use pooled LS	Use pooled LS
See Appendix B for test details	

There are two methods to test for equality of intercepts (Greene (2000), Kennedy (2001)). The first is to perform the fixed effects estimation and then perform the F test for the equality of cross-section-specific intercepts. The second method is to perform random effects estimation and subsequently perform a Lagrange Multiplier Breusch and Pagan (1980) test, which tests whether var(u)=0. If this hypothesis cannot be rejected, then pooled LS is the estimator of choice; otherwise, panel data estimation must be used (Greene (2000), p 572-573). In this work, the LM Breusch and Pagan test is used. As can be seen from Table 3 above, the test indicates that the pooled LS should be used (i.e. the test indicates that the classical regression model with a single constant term is most appropriate for this data (Greene (2000) p 573)). As a result, we use only pooled LS results in this work.

Interpretation of results

As can be seen from Table 2, the coefficients of primary interest—l_X and m_X—are significant and have the expected magnitudes and signs. The coefficients for the beginning of period levels of output and employment are not significant. This might be due to a number of reasons. First, the quality of data, especially for transitional countries, is rather poor, and there may be errors in measurement. Second, relatively short time periods used in this study (two 5-year periods) may be responsible for this result. In other words, the emphasis of the model is on longer-term effects of the initial levels, which required long-term periods, while the data available for transitional countries is only for relatively short period (10 years).

For example, Aschauer (2001), from whom this model was adopted, used two ten-year periods (as has been described in the literature review above) and included the initial beginning of decade levels of output and employment. In our study, such a long-term analysis was not possible due to lack of long-term data. Hence, two five-year periods have been used.

However, during these two periods, the effects of initial levels of output and employment are less visible from the data (for example the difference between the levels of output and employment from 1990 to 1995 is not large for a large portion of observations), and although this *per se* does not render the coefficients insignificant, it might contribute (by lowering the overall variation of these variables) to reducing the explanatory power of these variables. Finally, it might be postulated that for this data sample, these level variables do not exhibit a significant effect on our dependent variables.

It is also important to note that the expected signs for the coefficients of initial levels of output and employment are ambiguous in this model. As Aschauer explains, this model is designed for "uncovering the reduced form impacts of public [in this case telecommunications] capital on output and employment growth, given initial values of output and employment," (Aschauer 2001, p139), while "the influence of the initial levels of output and employment on the growth rates of the respective variables [output growth and employment growth] will be ambiguous, depending upon factors such as the relative speeds of adjustment of capital and employment to their steady state values and the strength of income effects in the determination of labor supply" (Ibid). Aschauer (2002, 1997b) offers an extension of the model which captures these dynamics, but this lies beyond the scope of this work.

It is interesting to note that the unemployment rate, included to remove short-term cyclical effects on the variables of interest, is significant for the changes in output, and the coefficient is negative. This implies that including this factor indeed removed a part of short-term cyclical element.

The results for the parameter m_X show that the output growth maximizing ratio of telecommunications capital to general capital is 4.038%. When compared with the average value of TK/K of approximately 1.597%, it becomes clear that an average country in the sample still needs to increase its telecommunications capital in order to achieve the output growth maximizing value. The telecom capital discrepancy is even more pronounced for an average transitional country, where the average sample value of TK/K is 0.997%.

Furthermore, formula (18) depicted below allows to calculate the degree to which the output growth maximizing value of telecommunications stock exceeds the average value of telecom capital stock (1.597%)—the so-called telecommunications capital gap.

For the average sample country, the gap is 0.02441 or 2.441%, while for the average transitional country in the sample the gap is 0.03041 or 3.041%. Table 4 below summarizes these results.

$$g_{mx} = m - (\overline{\frac{TK}{K}}) \quad (18)$$

where the bar indicates a sample average value

Of more interest to this study is the employment growth maximizing level of telecom capital. The estimation yields the employment-maximizing value of 5.434%. This ratio is larger than the ratio for output maximization (4.038%), which implies that an average country needs to increase its capital by a greater amount in order to achieve the employment growth maximizing value. The telecom capital gap for employment maximization is 0.03837 or 3.837% for an average country in the sample and 0.04437 or 4.437% for an average country in transition.

Table 4

Output and Employment Effects of Telecom Capital $g_{mx} = m - (\overline{\frac{TK}{K}})$ (18) $g_{lX} = l_X (1 - (\frac{1}{m_X})(\overline{\frac{TK}{K}}))$ (19)				
	Entire sample		Transitional Countries	
Dependent Var	DY	DE	DY	DE
m_X	4.038%	5.434%	4.038%	5.434%
Mean TK/K	1.597%		0.997%	
St. Dev. TK/K	1.200%		0.591%	
Gap g_m	2.441%	3.837%	3.041%	4.437%
Marginal Effect g_{lX}	2.002	1.439	2.494	1.664
1-St Dev increase effect (for mid-point value)	1.812%	1.457%	1.331%	0.919%

One possible explanation for the greater telecom capital investment required for employment maximization (i.e. $m_E > m_Y$) may be the fact that the positive effects of investment in telecommunications capital on output growth are higher than the positive effects on job creation. Specifically, increases in telecom stock might cause only a relatively small increase in labor demand—since telecom capital, which relies heavily on information technology and automation—may require relatively few people to service, while the positive effect on the economy, through positive network externalities, may be relatively high. Therefore, to maximize employment growth, more investment in telecom capital is required than might be needed to maximize output growth. This is, however, only one plausible explanation, and further research is necessary to uncover the factors behind the differences in maximizing levels of telecommunications capital.

In summary, it can be seen that an average country in the sample underinvests in telecommunications infrastructure. Two general reasons can be plausibly postulated to explain this underinvestment. First, since telecom capital possesses qualities of a public good, it is natural to expect that a degree of free-riding on telecom investment may exist, and economic agents may be reluctant to invest in telecommunications. Second, in case of transitional countries, the underinvestment may also be partially attributed to the failure of capital markets. Specifically, the undeveloped state of capital markets in such countries—the kind of markets needed to finance long-term investment required for telecom capital formation—prevents the productive investment in telecommunications that would otherwise take place. These are only two, and not exhaustive, possible explanations for the underinvestment in telecommunications, and a more detailed study of factors behind this underinvestment offers an attractive opportunity for further research.

The l_X coefficients indicate the effects of increases in total factor productivity on output and employment growth rates respectively. However, in order to truly ascertain the effects of investment in telecommunications capital on growth rates of interest, the following formula (19) for marginal growth effects must be used. This formula was derived by differentiation of (13) with respect to the ratio of telecom capital to general capital and is given by:

$$g_{IX} = \frac{\partial DX}{\partial\left(\frac{TK}{K}\right)} = l_X(1-(\frac{1}{m_X})(\overline{\frac{TK}{K}})) \quad (19)$$

The calculated marginal growth effect (see Table 4 below for summary of results) for output for an average country in the sample is:

$$g_{IY} = l_Y(1-(\frac{1}{m_Y})(\overline{\frac{TK}{K}})) = 3.311\left(1-\frac{0.016}{0.0404}\right) = 2.001$$

and, in the same way, 2.494 for an average transitional country. The calculated marginal employment growth effect is:

$$g_{IE} = l_E(1-(\frac{1}{m_E})(\overline{\frac{TK}{K}})) = 2.038\left(1-\frac{0.016}{0.054}\right) = 1.439$$

for an average country in the sample and 1.664 for an average transitional country. This means that, for example, a 1 percentage point (0.01) increase in the telecom stock (relative to general capital stock) has an impact on employment given by (19)—the marginal effect that equals 1.439—times the increase in capital stock (0.01) and equals 0.01439 or 1.439% per year for an average country in the sample.

It is important to note that for larger increases in the ratio of telecom capital to general capital, one must take into account the nonlinear relationship between telecom capital and output and employment growth (in the previous example, since a 1% increase in *TK/K* was relatively small, we ignored nonlinearity). For example, a 3.8 percentage-points (0.038) increase in the telecom capital ratio from the current average sample value of 0.016 would reach the employment-maximizing value of 0.054, and it would be appropriate to use the average value of the original (0.016) and new (0.054) telecom ratios—0.035—to determine that the effect on the employment growth rate would be:

$$g_{lE} = l_E(1-(\frac{1}{m_E})(\frac{TK}{K}) = 2.038\left(1-\left(\frac{0.035}{0.054}\right)\right) = 0.717$$

0.717 times 3.8% (the increase in telecom capital) or 2.725% per year.

The regression estimates also allow the calculation of the effect of a 1-standard deviation (0.012) increase in the telecommunications capital ratio (from its average of 0.016 to 0.028) on output and employment growth for an average country in the sample. As has been explained above, one has to take account of the nonlinear relationship to ascertain the effect correctly (since a 1-standard deviation increase in the ratio is relatively large). For this purpose, the growth rates are calculated for the mid-point value of 0.022 ((0.016+0.028)/2) of telecommunications capital stock ratio.

The implied output growth effect is calculated as 1.51 (marginal effect calculated by (19) for the mid value 0.022) times the standard deviation (0.012), and equals 0.01812 or 1.812% per year for an average sample country. Similarly, the implied employment growth effect of 1-standard deviation increase in *TK/K* is 0.01457 or 1.457% per year for an average sample country. For an average country in transition, the output growth effect is 1.331% per year, while the employment growth effect is 0.919% per year. Table 4 summarizes these results.

It is important to reiterate that these effects are static in nature and depict only the initial effect on output and employment. As Aschauer (2001 p 145) notes in the description of his model, a complete analysis would account for the subsequent (dynamic) effects of (in the case of this paper) telecommunications capital on economic growth. These effects, in turn, depend critically on two factors. First, they depend on the degree to which output and employment growth are related to the initial levels of output and employment. Second, they depend on the extent to which output and employment growth interact with one another over time (Aschauer 2001). As has been stated before, these effects lie beyond the scope of this work.

For reasons of comparison, it is worth noting that Aschauer (2001) obtains similar magnitudes of employment and output effects of investment in public capital. Specifically, a 1 standard deviation increase in the public capital ratio has an output growth effects between 1.6% and 1.9% per year, and the employment effect of between 0.5% to 0.6% per year.

The output and employment growth maximizing values of public capital to private capital are much higher than the respective maximizing ratios of telecom capital to general non-telecom capital. Specifically, Aschauer obtains the values of 60% for output maximization and 56% for employment growth maximization. However, this difference between results is in line with economic theory.

Because public capital infrastructure is much broader than telecommunications capital infrastructure and includes much more assets in the economy, it is reasonable to expect that the optimal ratios of public capital to private capital will be much higher than the optimal ratios of telecommunications capital to general non-telecommunications capital.

The major lesson that can be drawn from this research is that most countries need to encourage investment in telecommunications capital, since, on average, such investment would increase output and employment growth. This is especially true for transitional countries characterized by marked underinvestment in telecommunications infrastructure. The level of telecommunications capital that must be achieved, however, will depend on the policy objectives in each given country—that is an assignment of preference by policymakers to the objectives of employment and output maximization. However, in an average case, investment in telecommunications infrastructure would initially bring increases in both employment and output growth.

Chapter 5

CONCLUSIONS AND POLICY IMPLICATIONS

This paper set out to establish the link between investment in telecommunications capital and the economy-wide employment effects. To this end, a model (developed by Aschauer (1997a, 2001)) stipulating a nonlinear relationship between telecommunications capital and employment growth (which also accounts for output growth effects) has been employed. A panel of 47 transitional, developing, and developed countries has been used with the emphasis on long-term effects.

The results contain evidence of statistically significant, positive effects of telecommunications capital on output and employment growth. Specifically, for an average country in the sample over 1990 to 1995 and 1996 to 2001, a static impact of a 1-standard deviation increase in telecommunications is estimated to increase employment growth by 1.457% per year. Similarly, the static effect of a 1-standard deviation increase in telecom capital in an average transitional country increases employment growth by 0.919% per year. Additionally, it was determined that the same 1-standard deviation increase in telecom capital increases output by 1.812% per year in an average sample country and 1.331% in an average country in transition.

Furthermore, the employment growth maximizing ratio of telecommunications capital to general capital was estimated to be 5.434%, while the output growth maximizing level of telecom capital to general capital was estimated to be 4.038%. The data also show that most countries in the sample (most developed and all transitional countries) exhibit underinvestment in telecommunications (i.e. the ratio of telecom capital to general capital is lower than either the employment or output maximizing ratio). This can be possibly explained by the public good attributes of telecommunications, as well capital market failure in transitional countries. Further research, however, is needed to better ascertain the causes of underinvestment.

This paper examined the static effects of telecom capital on employment (and output) growth. Further area of research might include the study of dynamic impact of telecommunications capital. Additionally, another attractive direction of research might be the micro-level study of transition mechanisms by which investment in telecommunications capital translates into employment, as well as output changes.

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Appendix A

LIST OF COUNTRIES

Table 5

List of 47 countries used in the work	
Australia	Latvia
Austria	Lithuania
Barbados	Netherlands
Belgium	New Zealand
Bulgaria	Norway
Canada	Pakistan
China	Peru
Colombia	Philippines
Costa Rica	Poland
Czech Republic	Portugal
Denmark	Romania
Estonia	Russian Federation
Finland	Singapore
France	Slovak Republic
Germany	Slovenia
Greece	Spain
Hong Kong, China	Sweden
Hungary	Switzerland
Ireland	Thailand
Israel	Turkey
Italy	Ukraine
Jamaica	United Kingdom
Japan	United States
Korea, Rep.	

ADDITIONAL ESTIMATION DETAILS

Test for equal st errors, t-stats, p-values for linear and nonlinear specifications

Description of nlcom command

nlcom computes point estimates, standard errors, t and Z statistics, p-values, and confidence intervals for nonlinear combinations of coefficients after any estimation command. Results are displayed in the usual table format used for displaying estimation results. The standard errors are based on the "delta method", an approximation appropriate in large samples. Source (Stata 8.0 manual)

Employment

```
. sureg (DE_FR = R R_2 Y E U ) (DY_FR = R R_2 Y E U )

Seemingly unrelated regression
----------------------------------------------------------------------
Equation          Obs  Parms        RMSE    "R-sq"       chi2        P
----------------------------------------------------------------------
DE_FR              94      5    .0206139    0.1908      22.17   0.0005
DY_FR              94      5    .0362647    0.1188      12.67   0.0267
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DE_FR        |
           R |   2.038056    .587352     3.47   0.001     .8868671    3.189245
         R_2 |  -18.75357   7.836431    -2.39   0.017    -34.11269   -3.394444
           Y |   -.000877   .0021298    -0.41   0.680    -.0050513    .0032972
           E |   .0015611   .0024486     0.64   0.524    -.0032382    .0063603
           U |  -.0020425   .0005874    -3.48   0.001    -.0031937   -.0008913
       _cons |  -.0003287   .0179106    -0.02   0.985    -.0354329    .0347755
-------------+----------------------------------------------------------------
DY_FR        |
           R |   3.310597   1.033289     3.20   0.001     1.285389    5.335806
         R_2 |  -40.99338   13.78611    -2.97   0.003    -68.01365   -13.97311
           Y |  -.0005514   .0037467    -0.15   0.883    -.0078949     .006792
           E |   .0021959   .0043077     0.51   0.610    -.0062472    .0106389
           U |  -.0015205   .0010333    -1.47   0.141    -.0035457    .0005048
       _cons |  -.0148027   .0315089    -0.47   0.639    -.0765591    .0469537
------------------------------------------------------------------------------

. nlcom (-_b[R_2]/_b[ R])

       _nl_1:  -_b[R_2]/_b[ R]

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   9.201695   1.682246     5.47   0.000     5.904554    12.49884
------------------------------------------------------------------------------
```

Which is the same as for nonlinear approach for SUR for C(3).

Output

```
. sureg (DY_FR = R R_2 Y E U ) (DE_FR = R R_2 Y E U )

Seemingly unrelated regression
----------------------------------------------------------------------
Equation          Obs  Parms        RMSE    "R-sq"       chi2        P
----------------------------------------------------------------------
DY_FR              94      5    .0362647    0.1188      12.67   0.0267
DE_FR              94      5    .0206139    0.1908      22.17   0.0005
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DY_FR        |
           R |   3.310597   1.033289     3.20   0.001     1.285389    5.335806
         R_2 |  -40.99338   13.78611    -2.97   0.003    -68.01365   -13.97311
           Y |  -.0005514   .0037467    -0.15   0.883    -.0078949     .006792
           E |   .0021959   .0043077     0.51   0.610    -.0062472    .0106389
           U |  -.0015205   .0010333    -1.47   0.141    -.0035457    .0005048
       _cons |  -.0148027   .0315089    -0.47   0.639    -.0765591    .0469537
-------------+----------------------------------------------------------------
DE_FR        |
           R |   2.038056    .587352     3.47   0.001     .8868671    3.189245
         R_2 |  -18.75357   7.836431    -2.39   0.017    -34.11269   -3.394444
           Y |   -.000877   .0021298    -0.41   0.680    -.0050513    .0032972
           E |   .0015611   .0024486     0.64   0.524    -.0032382    .0063603
           U |  -.0020425   .0005874    -3.48   0.001    -.0031937   -.0008913
       _cons |  -.0003287   .0179106    -0.02   0.985    -.0354329    .0347755
------------------------------------------------------------------------------

. nlcom (-_b[R_2]/_b[ R])

       _nl_1:  -_b[R_2]/_b[ R]

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   12.38247   1.519615     8.15   0.000     9.404084    15.36086
------------------------------------------------------------------------------
```

. Which is the same as for nonlinear approach for SUR for C(9)

Calculating std. errors, t-stats, p-values for m_x

SUR Linear (Pooled); Equivalent to SUR NLS (Pooled)

Employment

```
. sureg (DE_FR = R R_2 Y E U ) (DY_FR = R R_2 Y E U )

Seemingly unrelated regression
----------------------------------------------------------------------
Equation          Obs  Parms        RMSE    "R-sq"       chi2        P
----------------------------------------------------------------------
DE_FR              94      5    .0206139    0.1908      22.17   0.0005
DY_FR              94      5    .0362647    0.1188      12.67   0.0267
```

```
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DE_FR        |
           R |   2.038056    .587352     3.47   0.001     .8868671    3.189245
         R_2 |  -18.75357   7.836431    -2.39   0.017    -34.11269   -3.394444
           Y |   -.000877   .0021298    -0.41   0.680    -.0050513    .0032972
           E |   .0015611   .0024486     0.64   0.524    -.0032382    .0063603
           U |  -.0020425   .0005874    -3.48   0.001    -.0031937   -.0008913
       _cons |  -.0003287   .0179106    -0.02   0.985    -.0354329    .0347755
-------------+----------------------------------------------------------------
DY_FR        |
           R |   3.310597   1.033289     3.20   0.001     1.285389    5.335806
         R_2 |  -40.99338   13.78611    -2.97   0.003    -68.01365   -13.97311
           Y |  -.0005514   .0037467    -0.15   0.883    -.0078949     .006792
           E |   .0021959   .0043077     0.51   0.610    -.0062472    .0106389
           U |  -.0015205   .0010333    -1.47   0.141    -.0035457    .0005048
       _cons |  -.0148027   .0315089    -0.47   0.639    -.0765591    .0469537
------------------------------------------------------------------------------

. nlcom (_b[R]/-(_b[R_2]*2))

       _nl_1:  _b[R]/-(_b[R_2]*2)

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .0543378    .009934     5.47   0.000     .0348676    .0738081
------------------------------------------------------------------------------

.
```

Output

```
. sureg (DY_FR = R R_2 Y E U ) (DE_FR = R R_2 Y E U )

Seemingly unrelated regression
----------------------------------------------------------------------
Equation          Obs  Parms        RMSE    "R-sq"       chi2        P
----------------------------------------------------------------------
DY_FR              94      5    .0362647    0.1188      12.67   0.0267
DE_FR              94      5    .0206139    0.1908      22.17   0.0005
----------------------------------------------------------------------

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
DY_FR        |
           R |   3.310597   1.033289     3.20   0.001     1.285389    5.335806
         R_2 |  -40.99338   13.78611    -2.97   0.003    -68.01365   -13.97311
           Y |  -.0005514   .0037467    -0.15   0.883    -.0078949     .006792
           E |   .0021959   .0043077     0.51   0.610    -.0062472    .0106389
           U |  -.0015205   .0010333    -1.47   0.141    -.0035457    .0005048
       _cons |  -.0148027   .0315089    -0.47   0.639    -.0765591    .0469537
-------------+----------------------------------------------------------------
DE_FR        |
           R |   2.038056    .587352     3.47   0.001     .8868671    3.189245
         R_2 |  -18.75357   7.836431    -2.39   0.017    -34.11269   -3.394444
           Y |   -.000877   .0021298    -0.41   0.680    -.0050513    .0032972
           E |   .0015611   .0024486     0.64   0.524    -.0032382    .0063603
           U |  -.0020425   .0005874    -3.48   0.001    -.0031937   -.0008913
       _cons |  -.0003287   .0179106    -0.02   0.985    -.0354329    .0347755
------------------------------------------------------------------------------

. nlcom (_b[R]/-(_b[R_2]*2))
```

```
       _nl_1:  _b[R]/-(_b[R_2]*2)

------------------------------------------------------------------------------
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _nl_1 |   .0403797   .0049555     8.15   0.000      .030667    .0500923
------------------------------------------------------------------------------
```

LM Test by Breusch and Pagan (1980) (Pooled OLS vs. Panel (FE); test for common intercept)

Employment

```
. db xtreg

. xtreg DE_FR R R_2 Y E U, re

Random-effects GLS regression                   Number of obs      =        94
Group variable (i): S                           Number of groups   =        47

R-sq:  within  = 0.0004                         Obs per group: min =         2
       between = 0.3171                                        avg =       2.0
       overall = 0.1854                                        max =         2

Random effects u_i ~ Gaussian                   Wald chi2(5)       =      7.96
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.1582

------------------------------------------------------------------------------
       DE_FR |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           R |   1.687684   .6763221     2.50   0.013     .3621172    3.013251
         R_2 |  -17.04485   8.574988    -1.99   0.047    -33.85152   -.2381815
           Y |  -.0014077   .0029422    -0.48   0.632    -.0071744    .0043589
           E |   .0012573   .0034209     0.37   0.713    -.0054476    .0079622
           U |  -.0015427   .0007588    -2.03   0.042    -.0030299   -.0000555
       _cons |   .0091459   .0244465     0.37   0.708    -.0387684    .0570601
-------------+----------------------------------------------------------------
     sigma_u |  .01370095
     sigma_e |  .01322445
         rho |   .5176915   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects:

        DE_FR[S,t] = Xb + u[S] + e[S,t]

        Estimated results:
                        |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                   DE_FR |   .0005308       .0230387
                       e |   .0001749       .0132245
                       u |   .0001877        .013701

        Test:   Var(u) = 0
                              chi2(1) =     0.93
                          Prob > chi2 =     0.3354
.
```

Output

```
. xtreg DY_FR R R_2 Y E U, re

Random-effects GLS regression                   Number of obs      =        94
Group variable (i): S                           Number of groups   =        47

R-sq:  within  = 0.0461                         Obs per group: min =         2
       between = 0.1388                                        avg =       2.0
       overall = 0.0948                                        max =         2
```

```
Random effects u_i ~ Gaussian                   Wald chi2(5)       =      7.01
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.2199

------------------------------------------------------------------------------
       DY_FR |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           R |   2.940121    1.22102     2.41   0.016     .5469659    5.333275
         R_2 |  -39.92113   15.66368    -2.55   0.011    -70.62138   -9.220883
           Y |   -.002029   .0051097    -0.40   0.691    -.0120439    .0079859
           E |   .0034067   .0059295     0.57   0.566    -.0082148    .0150282
           U |  -.0000742   .0013408    -0.06   0.956    -.0027021    .0025536
       _cons |  -.0148245   .0426117    -0.35   0.728    -.0983418    .0686929
-------------+----------------------------------------------------------------
     sigma_u |  .02017325
     sigma_e |  .02266011
         rho |  .44213612   (fraction of variance due to u_i)
------------------------------------------------------------------------------

. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects:

        DY_FR[S,t] = Xb + u[S] + e[S,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                   DY_FR |   .0015084        .038838
                       e |   .0005135       .0226601
                       u |    .000407       .0201733

        Test:   Var(u) = 0
                             chi2(1) =     0.36
                         Prob > chi2 =     0.5466

.
```