TELECOMMUNICATION INFRASTRUCTURE AS A DETERMINANT OF WORLDWIDE ECONOMIC GROWTH

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

2007

Approved by ____
Ms. Serhiy Korablin (Head of the State Examination Committee)

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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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by Olena Stetsenko

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In recent years telecommunication infrastructure (TI) became an important determinant of economic growth and development worldwide. This important role is justified by the fact that TI creates global telecommunication connection and promotes favorable conditions for knowledge and technology diffusion, increases market efficiency and becomes an integrated part of the production process. The evidence of positive gains to economic growth from previous studies is unambiguous for high income countries, while the results for the rest of the world are controversial. This research finds that for medium and lower income countries, TI contributes to total growth. The elasticity coefficient of GDP with respect to TI is about 0.1, which is consistent with findings from previous research. The intensive growth of TI in the period (2001-2005), has resulted in a large impact on GDP growth.

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

I wish to express my immense gratitude to my supervisor, Professor Gardner, for his enthusiasm and support in thesis writing. Special thanks to Professor Tom Coupé for his willingness in providing consultation and giving valuable suggestions concerning the development of my work.

I am grateful to Tamara Russkih for her assistance in launching GMID Euromonitor database at EERC.

I also want to thank my group-mates and friends Vitliy Provotorov, Sergiu Frunze and Hanna Kuznetsova who always found a time to help me in case of emergent problems and difficulties and drew me away from writing my thesis, when I was overloaded.

Special acknowledgement is to my family for their support and encouragement throughout this academic year.

GLOSSARY

Fixed Lines- telephone lines connecting the subscribers' terminal equipment to the public switched network and which have a dedicated port in the telephone exchange equipment

Mainlines – [see fixed lines]

Mobile subscribers- user of portable telephones subscribing to an automatic public mobile telephone service, which provides to the public switched telephone network using cellular technology, this can include analogue and digital cellular systems

Mobile telephone users - [see mobile subscribers]

Chapter 1

INTRODUCTION

Economists have already agreed upon the fact that economic growth is not only determined by capital and labor accumulation, there is a number of factors and conditions that promote economic growth worldwide. In recent years many researchers became very enthusiastic about the importance of "understanding the conditions" that facilitate information and knowledge expansion to economic growth and development.(Glaeser 1996). Caning (1999) analyzed the contribution of different factors of production to total output of the economy for a sample of 57 countries of the world and concluded that there exist "high productivity benefit" from investment in telecommunication infrastructure (TI), which is higher than that from "investment in roads, electricity and even education". In my thesis I will concentrate on information and telecommunication infrastructure as an important determinant of economic growth.

Due to a number of historical, political and economic factors that determine technological development, the evidence of information and communication technologies (ICT) impact on economic growth was first found in developed countries, particularly in the USA. The first wave of studies happened in 1980s and early 1990s (Dedrick *et.al* 2003). From that time on the economic research of the role of ICT in the economy evolves in four directions: multi-country studies, single country studies, industry- level and firm-level studies. The first deals with macro data, all the rest with micro time series and cross sections. My research is based on macro data for a sample of countries, hence,s I will be using multi-country approach.

There exist various macro studies that examine the ICT impacts on economic development on different scales, i.e. for different countries and groups of countries. Economists investigate the GDP growth dividend generated by investments in ICT (Economist Intelligence Unit 2004). New ICT have been spread to developing countries and as a result we can see a positive "impact of telecom penetration on total output" found for a group of developing countries (Sridhar 2004). The research made for countries with transition economies indicates a positive effect from network externalities (Chervachidze 2003). Moreover, an evidence of positive impact of ICT economic growth was shown for South Africa (Breitenbach *et al.* 2005) and other low income countries (Waverman et.al 2005).

I consider telecommunication infrastructure to play an essential role in overall ICT development, because it is a base for information transmission.

Researchers use different proxies for telecommunication infrastructure in their studies. Most of them take the penetration of fixed telephone lines, because of the availability of data (Wavermen 2001). Some papers use mobile and fixed lines penetration variables in separate specifications (Breitenbach et al. 2005) and conclude that there is no contribution to economic growth from mobile penetration. This can happen because the mobile telephones were not widespread in the first part of the time span, for which the data is available. "Mobile phones have now become the first globally affordable communication technologies"(Bienaime 2006). The number of mobile users all over the world has reached two billion people and every minute 1000 more subscribers are added, as a result "mobile telecommunications have become an integral part of the global economy"(Barrak 2006). Therefore, it is difficult to capture the influence of TI by just looking at fixed lines penetration or just mobile telecommunication. In my research, I will use an aggregate penetration variable to approximate teledensity, which sums up data for fixed lines penetration and mobile penetration. The idea of such proxy was taken from Chervachidze (2003). I will use yearly data for the period 1996-2005 and expect that in the second period (1996-2005) TI has stronger effect on economic growth due to the fact that in this period mobile telecommunication penetration level increased reasonably and started playing an important role in economies of many countries. I will test this hypothesis by including the time dummy into the model. I will also examine the influence of telecommunication penetration on economic growth for four groups of countries: high income, upper medium income, lower medium income and low income.

For the estimation the Waverman (2005) framework based on aggregate production function (APF) approach will be used. This model is the simplified version of four-equation model introduced by Roller and Waverman in 2001. The difference is that it was reduced by one equation and is appropriate for analysis of countries with different levels of development.

The research is summarizing and extending previous studies. The inclusion of countries of high range of income (from lowest to highest) in one panel allows increasing the number of observations and regarding TI as one of the factors of worldwide economic growth.

The paper includes several chapters. The following chapter is a review of papers concerning the ICT diffusion over the last years and it touches upon the studies that will allow to solve some econometric problems that will be encountered while estimation of macro-level data. The third chapter describes the reasons why TI can influence economic growth, talks about possible relevance of this study to Ukraine and analyses the data that will be used for estimation. The model will be presented in the forth chapter. The sixth chapter includes estimation procedure and results. The last part of this study is conclusions based on the results of empirical estimation.

Chapter 2

LITERATURE REVIEW

In the first part of this chapter I would like to illustrate how ICT diffusion is reflected in empirical and theoretical literature. To trace the spread of information technologies from USA and other developed countries to developing and transition countries, I will use papers that examine the evidence of ICT influence on economic growth. That will establish the foundation for making multi – country investigation. Then I will emphasize the importance of TI for economic development to motivate the usage of the aggregate telecommunication penetration rate as a proxy for ICT in my thesis.

In the second part of this chapter I will discuss possible problems that emerge, when making macro data analysis concerning the new technologies. There will be presented the solutions proposed by different researchers and methods that will be used in my thesis.

2.1 Empirical Evidence and Theoretical Background

In the late1990s the acceleration of ICT diffusion stimulated fast output growth and held inflation rate down in the USA. (Gordon 2002) Interested in this "economic miracle", many economists started exploring this phenomenon by incorporating ICT variable into econometric models. Therefore, lots of literature on ICT influencing economic growth is available now. Moreover, different economists used different proxies for ICT. The first studies examined the influence of the number of fixed telephone lines on the economic growth (Roller and Waverman 2001) or the influence of ICT capital, such as personal computers and other telecommunication equipment on productivity growth (Jorgeson et al 2000, Gordon 2002), the latter works looked at the Internet diffusion (Menkova 2004) and mobile telecommunication influence on per-capita income (Waverman et al 2005).

The first studies investigated ICT's influence for developed countries. Jorgenson et al.(2000) examined the determinants of economic growth in the US during the period 1959-1998. They observed a persistent decline in prices for computer hardware, new software developments and Internet diffusion since 1995 resulting in "change of structure of the economy" together with increase in "standards of living and decline in unemployment". To examine this evidence they used time series provided by National Income and Production Account (NIPA) as primary source of data. What is interesting about the results of the analysis is that they contradict Solow paradox that says: "you can see computers everywhere, but in the productivity statistic", i.e. since 1995 "productivity statistics" begins to reveal investment in "computers, software and other communication equipment" being an important source of economic growth (labor productivity and total factor productivity).(Jorgenson et al. 2001)

The macroeconomic studies of the ICT impact on economic growth demonstrate similar results for developed countries. The research proposed by Economist Intelligence Unit (2004) makes a cross section analysis of 60 countries (26 developed and 34 developing), the data used is averaged over the period 1995-2002. They define ICT by a composite indicator constructed on basis of the following data: fixed telephone line penetration (lines per 100 citizens), mobile phone penetration (per 100 citizens), personal computers (per 100 citizens) and internet users (per 100 citizens). This study also includes such "demographic variables" such as "population growth rate and measure of education" as explanatory variables. The researchers find a strong evidence of the positive influence of ICT on economic growth for developed countries: however no influence or even a negative influence was found in the case of developing countries. The research of the Economist Intelligence Unit (2004) attributes such paradox to the fact that "ICT penetration needs to attain some critical mass" in order to have a "positive impact on country's economy". For both cases population growth has a negative effect and education has positive impact on economic growth. (The Economist Intelligence Unit 2004)

The method for investigation of telecommunication infrastructure influence on economic growth was introduced by Roller and Waverman (2001). This approach is very popular among the researchers, because it mitigates the endogeneity problem. This method is based on the synthesis of macroeconomic aggregate production function and microeconomic demand function. These functions are estimated simultaneously. The analysis was made for 21 OECD countries using the data for the twenty years period (1970-1990) and mainline telephones penetration as a proxy for ICT. The results show a positive causal relationship between telecommunication infrastructures and aggregate output. To be more precise, one third of output growth was attributed to the spread of fixed - line telecommunications. The authors also discussed the fact that countries with higher penetration of fixed telephone lines (critical mass accumulated) experience higher return from investments in telecommunication.

In recent times empirical studies reveal the evidence of telecommunication infrastructure influencing economic growth for developing economies as well. Bedi(1999) claims that the diffusion of new information and communication technologies is associated with "lowering of communication costs and costs of information transmission". This reduction in transaction costs results in increase in efficiency and promote market activity in developing countries. Furthermore, this paper suggests that the “increase in use of ICT improve the performance” of private firms as well as public establishments in these countries.(Bedi 1999)

There is some literature illustrating this idea empirically. A positive “impact of telecom penetration on total output” was found for the case of developing countries by Kala and Varadharajan Sridhar in 2004. They used a system of simultaneous equations and macroeconomic data for 63 developing countries covering the period 1990-2001. In the paper the demand-supply framework for mainline and mobile communication services is analyzed. In addition to evidence of ICT impact on total output they found that “traditional economic factors (like income per capita and price of services) explain demand” for mainlines, however, “do not explain the demand” for mobile phones.

Similar empirical analysis was conducted for transition countries by Chervachidze (2003). The empirical part analyses for 22 transition countries for the period 1995-1999. The notion of threshold that was touched upon earlier plays its role in this research. The author included dummy variable for countries that reached 40% main telephone lines penetration rate. The system of 4 equation analyzing demand and supply for ICT looks like an extended system discussed earlier, that accounts for “size of market” and “investment attractiveness of the country”, these aspects were not discussed explicitly. The main result is illustration of positive impact on growth and “diminishing network effect “for countries that overcome 40% penetration rate. (Chervachidze 2003). Recently an evidence of positive impact of ICT on economic growth was shown for South Africa. The author made a cross section analysis and found a positive casual relationship between GDP and ICT using the number of telephone mainlines per 1000 citizens.(Breitenbach et al 2005)

So we can see that "new ICTs are already expanding to developing countries transforming them into information societies".(Coyle 2005). Moreover, Wavernan et al.(2005) state that the "growth impact of mobiles is large both in developed and developing countries, but around twice as important for developing countries". In the research the simultaneous approach and macro-micro synthesis mentioned above was used. In addition the researchers used a pure cross-section model. The investigation was made for 38 developing countries –members of ITU that had low fixed telephone lines penetration rate in 1995 for the period 1995-2003. The results show that mobile telecommunication penetration rates explain some differences in economic growth rates of developing countries.

As the review of related literature shows, there exist studies investigating different groups of countries separately. In my research I will make the estimation for the sample of countries with different levels of development, using both mobile and fixed line penetration to form a proxy for ICT.

2.2 Estimation Methods and Techniques

So far, we had focused our attention mostly on macro studies. The authors of empirical papers approached the problem of telecommunication infrastructure development and economic growth from different sides. But in any case there is a potential reverse causality problem. The intuition behind this I that higher level of development promotes higher well-being for people and the country with high standards of living is always expected to have higher level of development. In our case, higher level of economic growth can be caused partly by mobile telecommunication diffusion and at the same time with increase of economic growth people's ability to afford buying cellular phones and acquiring fixed network connections increase causing the telecommunication infrastructure to develop. Thus, it should be interesting to discuss the solution to this problem and some other interesting pitfalls of data analysis associated with analysis on macro level.

Addressing again the fact of novelty of the studies concerning new digital technologies, authors talk about scarcity of data (Chervachidze 2003, Menkova 2004, Waverman et. al 2005). The shortness of time series is attributed to "low previous interest of researchers" to this sector. This problem can be partially alleviated using longitudinal (panel data) analysis. (Chervachidze 2003, Roller and Waverman 2001). In my thesis I will use panel data for the period 1996 -2005 for 103 countries of the world to provide appropriate number of observations for reliable estimation.

Another problem that flow out from the lack of data is the selectivity bias problem discussed by Menkova (2004). When data on some ICT indicators for some countries is missing we should drop these countries from the sample. It is possible that the information for ICT is not available for countries with low economic development. To avoid the problem of selectivity bias we should pay attention to growth indicators of countries that are not in the sample making sure that we not just exclude countries with low level of development.(Menkova 2004) It is noted by Micevska (2005) and Waverman et al.(2005) that the lack of data puts some limitations on inclusion of some control variables into the model, those for which information is not available for all countries from the sample. To ensure availability of ICT – penetration data I have chosen 103 countries of the world that are the members of ITU and that have the desirable indicators available for the whole time period at GMID Euromonitor database. I intend to mitigate the problem of selectivity bias by analyzing the structure of the population of 205 countries available in the database and control for the representativness of the chosen sample.

As datasets are not as rich and homogeneous on macro-level as they could be on country level, Schreyer (2000) claims that we have to use different sources for different variables. Therefore when analyzing macro data we should make "a number of simplifying assumptions for comparison purposes". (Schreyer 2000). Of cause, these assumptions can lead to reduction in reliability of results. This problem will be partially alleviated in my case, because almost all variables that I use come from one source, which is Euromonitor Global Market Information Database (GMID). This database comprises indicators from different sources. But it was processed by the specialists from Euromonitor that had put their effort to make the data more homogeneous and reliable. In addition, before downloading the database I used the online facilities to convert data into the same units of measurement and per-capita terms.

Two basic approaches to macro data analysis can be inferred from the literature discussed above. These are panel data analysis (Chervachidze 2003, Sidhar 2000, Waverman et. al 2005, Roller 2001) and cross-section estimation (Economist Intelligence Unit 2004, Waverman et.al. 2005). Only Brentenbach(2005) uses simplified model with time series of GDP and ICT-indicator. In any case, there always exists a danger of omitted variables bias. As there was mentioned above, I will make panel data analysis, which can also help to control for country specific effects and mitigate this problem. But fixed effect model is reported to be rather sensitive to inclusion of additional explanatory variables (Waverman et. al. 2005). Therefore, I will also estimate the influence of telecommunication infrastructure on economic growth using cross section model, which should be more robust. However, while interpretation of the estimation results I will still be aware of the omitted variable bias problem.

To deal with the problem of endogeneity of key indicators of development and reverse causality bias many researchers use instrumental variables (IV) – approach. To address these issues together with possible measurement errors problem, they use the model of simultaneous equations estimated using two stage least squares (2SLS) procedure (Chervachidze 2003, Sidhar 2004, Roller 2001). Authors that use cross-section approach also apply IV –concept (Waverman et.al 2005, Economic Intelligence Unit 2004). One specification of IV estimation used in many macro studies is the dynamic panel data Arellano - Bond estimator. The application of this method allows improving the quality of estimators, i.e. avoid omitted variables bias and reverse causality problem (Temple *et al*. 2001). I will be using generalized method of moments (GMM) estimation concept in the empirical part of my thesis, which is a more general case of IV approach.

Another problem that was mentioned in some literature is the problem of high correlation among explanatory variables. This can cause troubles if we include them in one regression. Therefore, Menkova (2004) proposed to include highly correlated variables in different specifications of the model. In my thesis I will check the explanatory variables for correlation and will not include highly correlated variables in one regression. However, some correlation between explanatory variables always exists and we should be aware of that while claiming the reliability of obtained results.

Chapter 3

TELECOMMUNICATION AND ECONOMIC GROWTH

In this chapter I will give some reasons why there can be a casual relationship between the level of telecommunication development and GDP growth. In the second part of the chapter I will discuss the contribution of middle and low income countries TI to worldwide economic growth.

3.1 Telecommunication Effect on Economic Growth

Macro Environment and Telecommunications (2004) came up with the six ways in which telecommunication development can influence economic growth:

- *Diffusion of new ideas and knowledge*:

  This effect deals with the process of globalization, which helps transmission of new ideas and know-how to different countries of the world.

- *Reduction of regional infrastructure and development gap:*

  This aspect concerns digital divide reduction. The rural people can get the whole picture of agricultural market and their opportunities to increase their competitiveness.

- *Telecommunication as an input to economic production process:*

  Telecommunication being a substitute for "information handling labour" in some businesses and compliment in some production processes.

- *Market efficiency effect* :

  Developed telecommunication infrastructure facilitates interaction between the main players on the market.

- *Spill over and externality effect::*

TI once established imposes positive externalities on different industries and lowers transaction and search costs, increases arbitrage opportunities.

- *Coordination of economic activity* :

TI creates a possibility of long-distance communication, facilitating the "globalization of different corporations". It increases the efficiency and decreases costs of "social planners" in coordinating their economic activities.

- *Global telecommunication connections*:

Improve of information flows on new production technologies between countries results in higher productivity. These connection do make "global division of labour" and "international capital markets" more efficient

- *Rural and urban development*:

Similar to the "market efficiency" influence and in addition is about the possibility of rural agents getting consultation and support from agricultural and farming specialist located in urban areas. ". (Macro Environment and Telecommunications 2004)

Economists of Macro Environment and Telecommunications (2004) also define some indirect effect of telecommunication on economic growth that is connected with telecommunication's "improving the coverage of services like health, education and environmental protection".

3.2 Contribution of Upper-medium, lower-medium and low income countries

As it was described in the previous chapter an empirical evidence of positive dividend from telecommunication to GDP was shown for the period up to 1990.(Roller and Waverman 2001) While the results for middle and low income countries are rather ambiguous. These groups of countries play an important role in worldwide development, constituting about 75% of total number of countries and are accounted for about 19% of total GDP in our sample. Telecommunication infrastructure developed significantly in these countries, we can see it on figure 1. Averaged percentage of TI of the world TI over the period (1996-2005) is about 25%. The direct and indirect of telecommunication influence on economic growth described in the first part of this chapter are realized in these countries, especially because they have a large percentage of rural population. Therefore, we can expect a positive casual relationship of TI and GDP for these groups of countries.

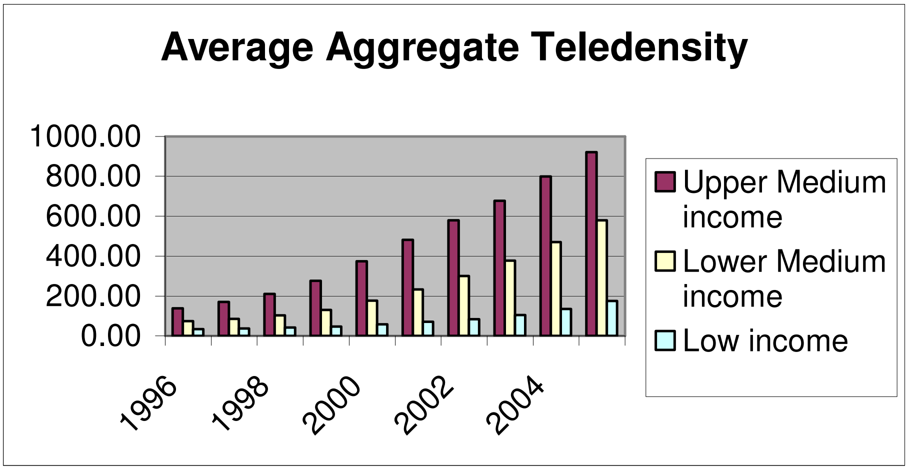

Figure 1.Average aggregate teledensity in medium and low income countries. (Average number of users per 100 people)

Ukraine belongs to lower medium income group. As it was reported, it had reached 100% penetration rate in mobile telecommunication. (Mashchenko 2007). In addition, new digital technologies are being implemented by mainline-operators, resulting in increase of quality and density of aggregate telecommunication. Thus, when making the conclusions about lower-medium income countries we can think of Ukraine having the same or even higher benefits from TI.

Chapter 4

METHODOLOGY

As it was mentioned earlier economic growth is influenced by various factors besides labor and capital, so we would not be able to account for all of them and will narrow down to classical labor and capital plus telecommunication. First I will address panel data analysis and the Aggregate production function approach proposed by Waverman et al.(2005). However, this model is claimed to be very sensitive to any changes in specification (Waverman *et. al.*, Sidhar 2004), for this reason I will also discuss the cross section model, which should be more robust.

4.1 Methodology for Panel Data

To estimate the impact of mobile telecommunication on economic growth there will be used a Roller - Waverman (2001) framework modified in such a way that it could be used for analysis of countries with different levels of development by Waverman et al. (2005). The model is based on the combination of the aggregate production function approach (APF) and micro demand function in one system. The system consists of three equations. APF framework's main idea is to determine annual GDP growth by "aggregate capital, aggregate labor", telecom penetration and other factors concerning social overhead capital (SOC). It will measure the annual contribution of mobile telecommunication to GDP growth.(Waverman et al. 2005). Main advantage of this model is that it determines mobile telecommunication variable endogenously.

The system has the following form:

$$\begin{cases} \log GDP = a_1 \log(K) \ + a_2 \log(L) + a_3 \log(Tel) + u_1 \\ \log(Tel) = b_0 + b_1 \log(GDP\_PC) + b_2 \log(Telp) + u_2 \\ \log(Mpen_t) - \log(Mpen_{t-1}) = c_0 + c_1 GA + c_2 \log(Telp) + u_3 \end{cases} \quad (4.1)$$

The model was simplified by Waverman *et.al.*(2005) . I will use this model to make estimation for the sample of countries with different level of development, moreover I will capture the effect of mobile telecommunication growth for four groups of countries classified by the World bank according to their income (High income, upper medium income, lower medium income and low income) using interactive dummy variables.

Despite the Euromonitor database is abundant, it was still difficult to find data for all the variables that would be available for all 103 countries for this period. That is why, using economic intuition, I came up with some proxies for the missing variables.

The variables used:

GDP- Real GDP (in US$ in y-to-y rate)

GDP_PC- Real GDP in per capita terms (in US$ in y-to-y rate), determining per-capita income

L – total labor force, because of numerous gaps in data was proxied by total population aged 15-64, assuming it is highly correlated with economically active population;

K- telecommunication capital stock, calculated using perpetual inventory method (see below);

Tel – aggregate penetration rate, the fixed telephone lines penetration rate plus the mobile telecommunication penetration rate.

Telp – price of telecoms, total telecommunication revenue per person;

GA – geographic area in square kilometers;

ui- error term.

Telecommunication capital calculation

The data was only available for investment into telecommunication, therefore, I had to calculate telecommunication capital using perpetual inventory method (Meinen et.al.1998). The following formula was used:

$$K_T = (1-\varphi)^T K_0 + \sum_{t=0}^{T} I_t (1-\varphi)^{T-t} \quad (4.2),$$

where $$K_0 = \frac{I_0}{(\varepsilon + \varphi)} \quad (4.3)$$

K_0-initial telecommunication capital;

φ -depreciation rate;

ε -average geometric growth rate of investment series;

$\varepsilon = \left[\prod r_t\right]^{\frac{1}{n}} - 1$, $r_t = \frac{I_t}{I_{t-1}}$, n is the number of periods.

The depreciation rate was assumed to be 0.075, which is applicable to the multi-countries data (Summers and Heston 1991).

First equation:

The output equation - aggregate production function. This equation explains the level of GDP as a function of mobile telecommunication capital stock (K), the total labor force (L) and mobile telecommunications penetration rate (Tel).

Second equation:

Demand equation: expresses the level of mobile telecommunications penetration as a function of per- capita income (GDP_PC), average telecommunication price (Telp).

Third equation:

The scale equation, which is simplifies the original model proposed by Roller The growth-rate of mobile penetration is expressed as a function of telecom prices (the relationship is expected to be positive, because higher induce higher supply) and geographic area(the relationship is expected to be negative).

4.2 Methodology for Cross Section Estimation

I will refer to a cross section model proposed by Waverman et.al(2005), which is based on the endogenous growth model of Barro(1991). The model to be used in this thesis is as follows:

$$l\_GDP = l\_Tel + l\_K + l\_L + l\_GDP96 + l\_(i/GDP) + l\_edu \quad (4.4)$$

where,

GDP-total GDP averaged over the period (1996-2005);

Tel - aggregate TI average over the period (1996-2005);

K -telecommunication capital averaged over the period (1996-2005);

L - total labor force averaged over the period (1996-2005);

GDP96- total GDP at the beginning of the reference period;

i/GDP- investment in telecommunication as a percentage of total GDP averaged over the period (1996-2005);

edu – level of education proxied by the total number of secondary school students and averaged over the period (1996-2005).

We can expect positive impact from labor, capital, TI and education level. The influence of initial GDP at the beginning of the period is ambiguous: we can expect either positive or negative impact. Barro(1991) suggests that poor countries grow faster resulting in negative impact of this variables, but for our sample and time span of only 10 years, initial GDP can intuitively result in higher overall GDP over the period. Increase in percentage of investment in TI should be positive according to Waverman et.al.(2005). I will also interact Tel variable with dummy variable for income

Chapter 5

ESTIMATION PROCEDURE AND RESULTS

To establish the floor for empirical manipulations I will describe the data that will be used. Then I will describe the estimation techniques for panel data followed by results, analyze the sensitivity of this model and perform cross section model estimation.

5.1 Sample Description

Euromonitor Global Market International Database (GMID) provides with data on Mobile telecom and fixed telephone lines penetration per 1000 inhabitants. In my research I will be using the annual panel data for the period 1996-2005. Despite the rapid growth of mobile telecommunication s in recent years there are still some gaps in data especially in the beginning of the period. Therefore, out of 205 countries available in Euromonitor database those for which data was not available had to be excluded. I finally came up with 103 countries. Out of these countries: 43 are high income countries including OECD and non-OECD;25 are upper medium income countries;38 –lower medium income countries and 31-low income counties. This classification was made according to the World Bank WDI (2005).

The structure of the GMID dataset is as follows: 54- high income countries, 37 - upper medium income countries, 56- lower medium income countries, 59 - low income counties. The proportion then: 1: 0,7 : 1 : 1,1. For the selected sample the proportion is as follows: 1: 0.6: 0.9 : 0.7. Though, the representation of low income countries is lower than in the whole dataset, the structure of the sample is close to that of the original dataset. By keeping the structure I intend to mitigate the selectivity bias.

5.2 Data

The descriptive statistic for the panel data model is presented in table 1. From the table we can see that sample is not homogeneous, there is variation in all dependent and explanatory variables.

Table 1.Descriptive statistics

Variable name	***Description***	***Mean***	***St.Dev***	***Min-Max***
GDP	***total GDP,1000$***	***325019.7***	***1115559***	***367.2…1.25e+07***
pc_GDP	***Per-capita GDP,$***	***10595.92***	***12873.08***	***103.1…79273.7***
L	***Human capital,1000 people***	***32950.7***	***106367.5***	***116.3… 937542.1***
K	***Telecommunication capital stock ,$***	***889794.8***	***1961112***	***116.08…2.51e+07***
Tel	***Aggregate teledensity (mobile+fixed) per 1000 people***	***539.62***	***504.84***	***2.3… 1868.3***
Mobile	***Number of mobile subscribers per 1000 people***	***283.2***	***318.94***	***0 … 1244.6***
Fixed	***Number of fixed lines per 1000 people***	***256.43***	***225.42***	***2 … 801.5***

Telp	***Telecommunication price,$***	***49.98***	***155.56***	***.01… 1699.99***
ga	***Geographic area,sq km***	***1029846***	***2524819***	***10.5…1.71e+07***
trate	***Telecommunication diffusion rate***	***1.24***	***0.299***	***.672 … 4.89***

Using this kind of data we should think about controlling for specific country characteristics that are fixed over time, but not over individuals. In addition we can expect reverse causality to occur. This issue is still being discussed, but most of the times researchers assume there can be two way casual relationship between TI and economic growth. Countries with high level of economic growth can afford better TI and in its turn TI creates positive benefit to economic growth as was shown in Chapter 3. For this reason we should think about proper instruments to control for this problem. The instruments should be highly correlated with Tel and do not much correlate with GDP.

Let us motivate the usage of aggregate teledensity as a proxy for TI. For this purpose we will use the statistics for telecommunications and illustrate the tendencies in the development of TI over the reference period (1996-2005).

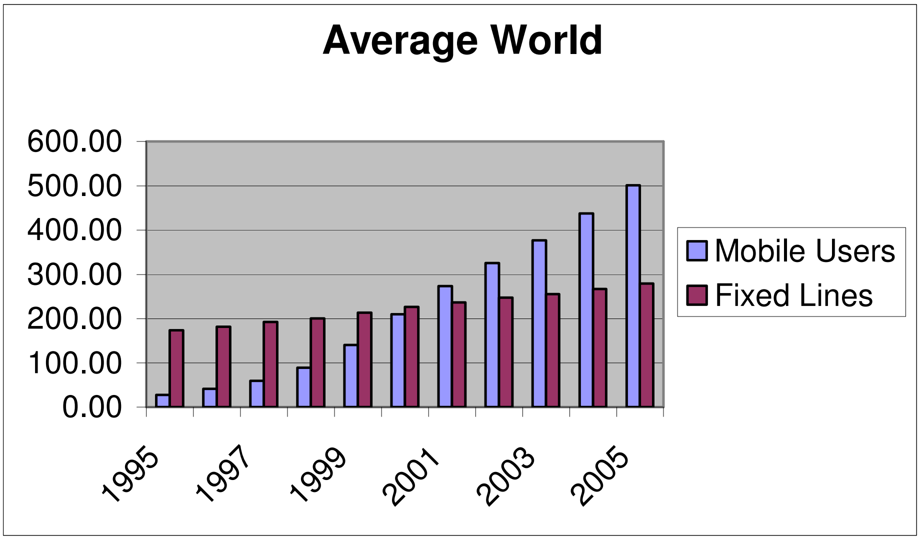

Figure 2.Changes in the average number of mobile telephone users (per 1000 citizens) and fixed telephone lines(per 1000 citizens) in the given sample of countries during the decade 1995-2005

On one hand, it is seen that there was an intensive growth of mobile telecommunication over this period (Figure 2). Number of mobile subscribers has finally "overshot the number of fixed-line on global scale" and "mobile became the dominant technology for voice communication" in four groups of countries that I consider in my thesis.(ITU Internet Reports 2004). So we should account for mobiles as an important part of TI. On the other hand, we cannot just exclude fixed lines from IT aggregate variable. They do not grow, but it can be only because the number had reached some satiation point, but its quality is being improved and they are still an important part of TI. Changes of mobile and fixed lines users for the period 1996-2005 are shown in Appendix A.

The averaged aggregate telecommunication infrastructure improved significantly over the reference period (Figure 3). In year 2000 it had reached 50% penetration (500 users per 1000 people) and in the next years overshot this point approaching 100% penetration rate.

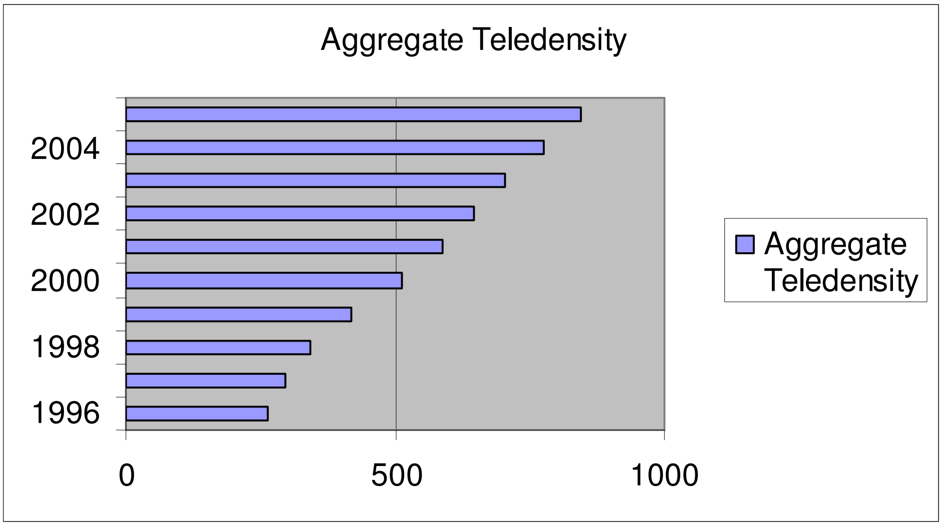

Figure 3. Changes in the average aggregate teledensity in a given sample of countries during the decade 1996-2005

This statistics made me assume that IT had higher impact on economic growth over the second part of the period (2001-2005). I will test this hypothesis by including an interactive dummy for this period into my model.

5.3 Estimation and Results

5.3.1 Panel Data Estimation

First step was to test whether we can just pool the data or we need to control for country fixed effect. Therefore, we run LSDV regression and look at F-test, the p-value is close to zero, that tells us that we reject the hypothesis that all the coefficients near country dummies equal zero simultaneously and we choose fixed effect(FE) estimation. Second step, to decide which estimation will be consistent and efficient. We run Hausman test (FE vs. RE) and get a zero p-value that tells us that RE estimates will be biased in this case and we chose FE.

Table 2. Aggregate production function FE estimation results

Variable name	Coefficient	P-value (st. error)	R-squared
l_K	0.12	0.000 (0..027)	R-sq: within=0.2107 between = 0.7318 overall = 0.7221
l_L	0.71	0.001 (0.223)	
l_Tel	**0.10**	0.000 (0.020)	
Cons	2.36	0.210 (1.887)	

All explanatory variables are highly significant, while the constant term is not significant at 10% level of significance. One percent increase in aggregate telecommunication infrastructure leads to 0.1 percentage-point increase in GDP.

To account for the potential endogeneity problem I will use GMM estimation. To instrument TI -variable I will use the its first and second lags and mobile price, which is highly correlated with Tel (correlation coefficient is about 0.8) and do not correlate much with GDP (correlation coefficient is about 0.4).

The results of GMM estimation in Table 3 are close to those without IV. The effect from Tel is 0.01 percentage points higher. Contribution from human capital is higher that that of physical, however when we control for reverse causality the sum of coefficients near L and K are roughly equal to 1. That is consistent with the assumption of constant return to scale (CRS) of the economy as a whole.

Table 3. Aggregate production function FE GMM estimation

Variable name	Coefficient	P-value (st. error)	R-squared
l_K	0.12	0.000 (0.024)	R-sq: within = 0.2106 between = 0.7543 overall = 0.7436
l_L	0.93	0.005 (0.210)	
l_Tel	**0.11**	0.000 (0.019)	
Cons	2.90	0.138 (1.791)	

Now I add an interactive dummy for the second part of the period (2001-2005) into the model.

Period2=D2*l_Tel (4.1)

$$D2 = \begin{cases} 0, year = 1996...2000 \\ 1, year = 2001...2005 \end{cases} \quad (4.2)$$

Table 4. APF with interactive period dummy FE estimation

Variable name	Coefficient	P-value (st. error)	R-squared
l_K	0.10	0.000 (0.105)	R-sq: within = 0.2476 between = 0.8180 overall = 0.7976
l_L	0.46	0.041 (0.227)	

Period2	**0.02**	**0.000 (0.004)**	
l_Tel	0.06	0.007 (0.021)	
Cons	4.86	0.210 (1.943)	

The result proves our hypothesis, TI has 0.02 percentage points higher influence that that in the first period.

Now we include interactive dummies for groups of countries. We use high income countries as a reference category.

um_Tel=um*l_Tel;

lm_Tel=lm*l_Tel;

low_Tel=low*l_Tel

um,lm,low are dummies that take value 1 for upper medium, lower medium and low income countries respectively and zero for others.

Table 5. APF with interactive income dummies FE estimation

Variable name	Coefficient	P-value	R-squared
l_K	0.12	0.000 (0.02)	R-sq: within = 0.2156 between = 0.9014 overall = 0.8877
l_L	0.63	0.006 (0.230)	
low_Tel	**-0.10**	**0.024 (0.045)**	
lm_Tel	**-0.10**	**0.028**	

		(0.045)	
um_Tel	**-0.08**	**0.081** **(0.046)**	
l_Tel	0.19	0.000 (0.047)	
Cons	2.84	0.141 (1.932)	

Our dummy variables are all significant at 10% significance level. The influence of low, lower medium and upper medium countries is lower than that of high income, in fact, almost twice as low. These three groups of countries differ from the reference category by the same number of percentage points: 0.1 percentage points for low and lower medium income countries and 0.08 percentage points for upper medium countries.

Even after controlling for fixed effect, there could exist a problem of heteroskedasticity, because we deal with grouped data. We can check it running LSDV and standard Breuch-Pagan test for heteroskedasticity afterwards. Very low p-value makes us reject the hypothesis of constant variance of error terms. Heteroskedasticity can result in unreliability of standard errors. To control for this problem we use robust estimation.

Table 6. APF LSDV robust estimation results

Variable name	Coefficient	P-value	R-squared
l_K	0.12	0.000 (0.027)	0.89

l_L	0.71	0.019 (0.303)	
l_Tel	**0.10**	0.000 (0.021)	
Cons	3.92	0.170 (2.86)	

The results are similar to those obtained without robust estimation, but LSDV estimation consumes more degrees of freedom. Therefore controlling for FE is just enough to deal with grouped data in our case.

Before estimation of the demand equation we perform the same tests as with aggregate production function and choose FE estimation as well.

Table 7. Demand equation FE estimation results.

Variable name	Coefficient	P-value	R-squared
l_pcgdp	1.36	0.000 (0.098)	R-sq: within = 0.1767 between = 0.8556 overall = 0.7319
l_Telp	-0.07	0.035 (0.032)	
Cons	-5.12	0.000 (0.779)	

According to our results, TI is a luxury good, as 1% increase in per capita income results in 1.36 % increase in TI demand (more than one percent increase). Interesting result was to look at own price elasticity of demand for TI, i.e. it is less than zero, that means that demand for TI is inelastic. That can be explained by the fact that TI has become an essential attribute of modern humanity.

Table 8. Scale equation estimation results

Variable name	Coefficient	P-value	R-squared
l_ga	-0.002	0.252 (0.005)	R-sq: within = 0.1767 between = 0.8556 overall = 0.7319
l_Telp	0.02	0.015 (0.007)	
Cons	-5.45	0.000 (0100)	

We estimate scale effect equation using LSDV regression, because it allows controlling for FE, but does not drop GA-variable. The results tell us that geographic area does not influence the rate of telecommunication penetration, while price of telecommunication has a positive effect on rate of diffusion, because higher price induce additional supply.

Looking at the results of aggregate production function estimation we can see that the model is rather sensitive to any changes in specification, even the inclusion of dummies leads to changes in the coefficients near labor and capital variables. For this reason we could not include more explanatory variables.

Further, we will make cross section estimation, it will only have 103 observations, but is claimed to be more robust allowing the inclusion of more explanatory variables.

5.3.2 Cross Section Model Estimation

To make the cross section estimation each variable should be averaged over the reference period. There is a potential problem of reverse causality. We can use Hausman test for endogeneity and choose OLS regression in this case. The results of estimation are presented in Table 9.

Table 9. Results of cross section estimation

Variable name	Coefficient	P-value	R-squared
l_K	0.049	0.010 (0.040)	R-squared= 0.9939
l_L	0.064	0.006 (0.046)	
l_Tel	**0.15**	**0.000 (0.034)**	
l_edu	-0.26	0.295 (0.025)	
l_GDP96	0.81	0.000 (0.051)	
l_IpGDP	0.13	0.000 (0.047)	
Cons	0.26	0.281 (0.244)	

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Table 10 Results of cross section estimation with income dummies.

Variable name	Coefficient	P-value	R-squared
l_K	0.13	0.010 (0.040)	R-squared= 0.9883
l_L	0.36	0.006 (0.046)	
l_Tel	**0.36**	**0.000 (0.035)**	
low_Tel	**-0.12**	**0.002 (0.026)**	
lm_Tel	**-0.08**	**0.000**	

		(0.015)	
um_Tel	**-0.03**	**0.100 (0.010)**	
l_edu	-0.17	0.643 (0.025)	
l_GDP96	0.46	0.000 (0.053)	
l_IpGDP	0.15	0.000 (0.047)	
Cons	2.84	0.141 (0.241)	

Again we see that there is a positive and significant impact from TI as well as from labour and capital accumulation. Education influence appeared to be insignificant: I attribute this to the fact that number of secondary school pupils is not a good proxy for average level of education. Initial GDP has a positive impact on total GDP over the period, it contradicts Barro(1991) model of endogenous growth, because the time period is too small and cross section model includes only 103 observations. As the amount of investment TI as a percentage of GDP, Total GDP increases by 0.15 percentage points.

We see higher effect from TI. Including dummies for groups of countries, high income countries were taking as a reference category again. Contribution from low, lower-medium, upper-medium income countries is 0.12, 0.08 and 0.03 percentage points lower than that from high income countries. Intuitively, these results are more reliable, because the contribution is less homogeneous than in panel data estimation and the lowest contribution is from low income countries.

Chapter 6

CONCLUSION

In recent years the issue of influence of TI on economic growth was speculated upon by different researchers. TI experienced a significant growth and development over the last 10-15 years, mostly because of digital technologies implementation and growth of mobile networks all over the world. Many researchers came up with the idea of positive benefit to aggregate output from TI in developed (Roller and Waverman 2001), developing (Waverman et.al. 2005) and transition countries (Chervachidze 2003). In this thesis TI level of development was regarded as one of the determinant of worldwide growth in modern society. The influence of aggregate telecommunication variable on economic growth proved to be positive and significant, accounting for about 0.1% (panel data estimation) to 0.15%(cross section estimation) increase in economic growth. The influence appeared to be positive from all four groups of countries of WDI classification (high, upper- medium, lower –medium and low income countries). These results are consistent with those for separate groups estimation conducted previously, the elasticity coefficient falls in a range of 0.075(for developing countries) to (0.56 for developed countries).

The full data for mobile and fixed telecommunication was available for the period (1996-2005). The TI experienced higher growth and development in the second part of this period. The hypothesis of this phenomenon having a higher impact on economic growth was supported by empirical evidence.

We should pay special attention to the lower-medium income group, because Ukraine belongs to it. Ukraine almost approached 100% telecommunication penetration rate in 2006 (Mashchenko 2007). If we assume that all the rest countries of this group experienced roughly the same growth in 2006, we can infer that lower income group TI contributed about 6% to worldwide growth, in that Ukraine's TI contribution is about 0.1%. This result indicates that there exists developed TI that can allow Ukraine to integrate into the global society, participate in international information and technology sharing projects as well as to host global international companies.

BIBLIOGRAPHY

Arellano, M. and S. Bond. 1991. *Some Tests of Specification for Panel Data: Monte Carlo Evidence and Application to Employment Equations.* Review of Economic Studies #58, pp. 277-297

Barrak, Al. 2006. *Mobile Phone Growth is Boosting Economies All Round the Globe.* www.ameinfo.com/89888.html

Barro, R. 1991.*Economic Growth in a Cross Section of Countries.* The Quarterly Journal of Econometrics, 106(2), pp.407-43

Bedi S.A.1999. *The Role of Information and Communication Technologies in Economic Development.* Discussion Papers on Development Policy #7, Center for Development Research, Bonn,pp.42

Bond, S., A. Hoeffler, J. Temple. 2001.*GMM Estimation of Empirical Growth Models.* www.nuff.ox.ac.uk/Economics/papers/2001/w21/bht10.pdf

Breitenbach M, O. Aderibigbe and D. Muzungu. 2005. *The Impact of Information and Communication Technology(ICT) on Economic Growth in South Africa: Analysis of evidence.* www.essa.org.za/download/**2005**Conference/Breitenbach.pdf

Beienaime 2006. *Extending IMT 2000/UMTS Mobile Coverage in Developing Countries.* www.3g.com.uk./pk/March2006/275/Extending IMT 2000-UMTS Mobile Coverage in Developing Countries.htm

Caning, D. 1999 *Infrastructure's Contribution to Aggregate Output.* The World Bank Development Research Group, Policy Research Working Paper #2246

Capello, R.. and P.Nijkamp.2001.*Telecommunications. Technologies and Regional Development: A*

Simultaneous Approach. American Economic Review, pp. 909-923

Chervachidze I. 2003. *Network Externalities in Telecommunications and Economic Growth*, EERC MA Thesis.

Chervachidze, S.2004. *Employment Effects of Telecommunications Capital: The Case of Developed and Transitional Countries.*EERC MA Thesis

Coyle, D. 2005. *Overview . Africa: The Impact of mobile Phones.* The Vodafone Policy Paper Series, #2, p.3-10

Dedrick, J., V. Gurbaxani and K.L Kraemer.2003.*Information Technology Performance: A Critical Review of Empirical Evidence.* MCM Computing surveys, vol.35 #1

Economist Intelligence Unit. 2004. *Reaping the Benefits of ICT. Europe's Productivity Challenge.* Report Sponsored by Microsoft

Euromonitor International, GMI Database, www.gmid.euromonitor.com

Glaeser,E. 1996.*Cities, Information and Economic Growth,* http://www.huduser.org/Periodicals/CITYSCPE/VOL1NUM1/ch2.pdf

Gordon ,R.J. 2000. *Technology and Economic Performance in the American Economy*, http://www.nber.org/papers/w8771

Harris,R.G.2002. *Social Policy and Productivity Growth: What are the Linkages?.* Industry Canada Research Publications Program, Discussion Paper#11

Hisiao, C. 2003. *Analysis of Panel Data* (2nd Edition), Cambridge University Press

ITU Internet Reports 2004.*The Portable Internet,* http://www.itu.int/osg/spu/ni/futuremobile/

Jorgenson, D. W. and K. J. Stiroh. 2000. *Raising the Speed Limit: US Economic Growth in the Information Age, OECD Economics Department Working Papers*, # 261, OECD Publishing.

Lockyer L., J.Patterson and B. Harper. 2001.*ICT in Higher education: Evaluating Outcomes for Health Education.* Jornal of Computer Assisted learning #17,pp.275-283

Macro Environment and Telecommunications 2004 *Direct Effects of Telecommunications on Economic Development* ,Telecommunications and Social development,Ch6,Module5,pp.66,: http://cbdd.wsu.edu/kewlcontent/cdoutput/TR501/page66.htm

Macro Environment and Telecommunications 2004 *Inirect Effects of Telecommunications on Economic Development* ,Telecommunications and Social development,Ch6,Module5,pp.67,: http://cbdd.wsu.edu/kewlcontent/cdoutput/TR501/page67.htm

Mashchenko, V. 2007 *Retail Sales of Mobile Phones Up*. Kyiv Post Vol.12, Issue 7, Feb. 2007,pp.7

Meinen ,G., P. Veibiest, P. Wolf. 1998 *Perpetual Inventory Method: Services lives, Discard Patterns and Depreciation Methods*. Statistic Department Nth., National Accounts.

Menkova, V..2004. *Digital Divide and Cross Country Diffusion of the Internet.* EERC MA Thesis

Micevska,M. 2005. *Telecommunications , Public Health and Demand for Health-Related Information and Infrastructure.* The MIT, IT and International Development, Vol.2 #3,pp. 57-72

Nicoleta, I. 2005. *The Development of ICT Applications in Transport and Social Informatics Approach.* Center for Transport and Society

Roller.,L. and L.Waverman 2001. *Telecommunications Infrastructure and Economic Development: A Simultaneous Approach.* American Economic Review, pp. 909 -923

Schreyer, P. 2000. *The Contribution of Information and Communication Technology to Output Growth: A Study of the G7 Countries.* OECD Science, Technology and Industry Working Papers, 2000/2, OECD Publishing

Sidhar, Kala Setharam and Varadnarajan Sidhar.2004.*Telecommunications Infrastructure and Economic Growth: Evidence from Developing Countries.* http://ideas.repec.org/p/ind/nipfwp/14.html

Summers, Robert and Allen Heston. 1991. *The Penn World Table (Mark 5): An expanded set of international comparisons, 1950-1988.* Quarterly Journal of Economics 106: 327-68.

The Global Information Technology Report.2005-2004. The Network Readiness Index, Overview and Analysis FrameworkUnited Nations Economic and Social Council.2000. New York, http://www.weforum.org

Waverman, L., Mesch M. and Fuss M. 2005. *The impact of Telecoms on Economic Growth in Developing Countries.* The Vodafone Policy Paper Series, #2, p. 10-24

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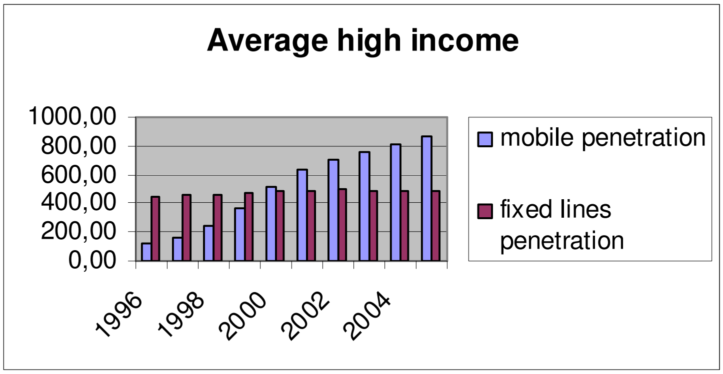
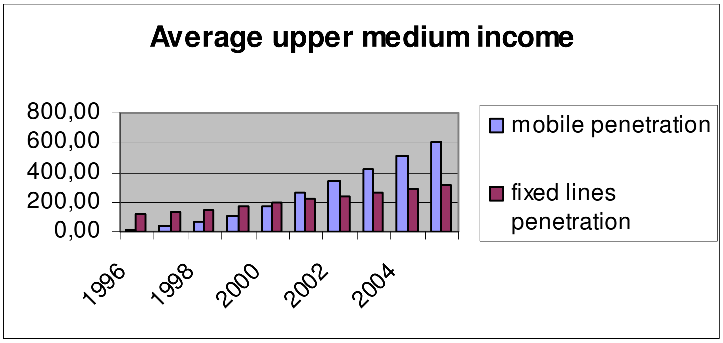
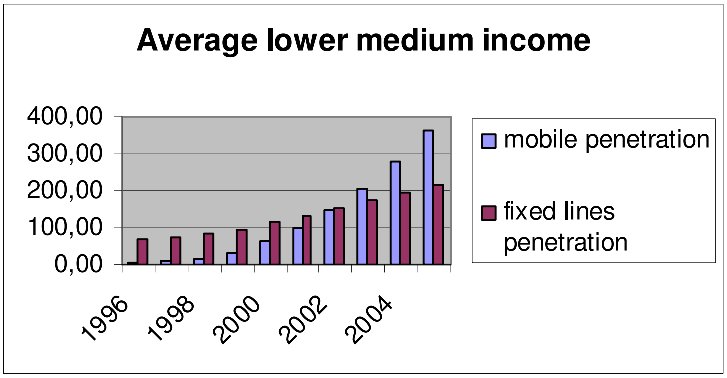
APPENDIX A



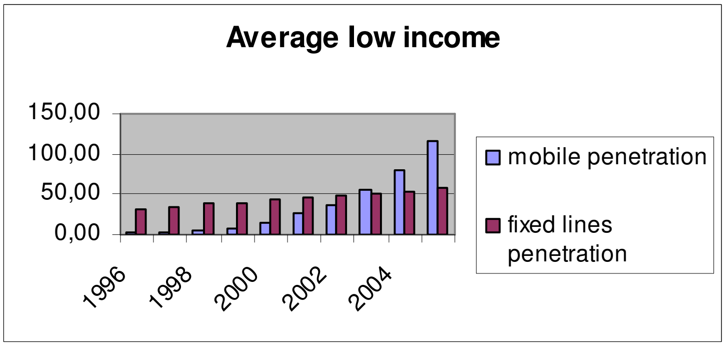
Changes in the mean number of mobile telephone users(per 1000 citizens) and fixed telephone lines(per 1000 citizens) in high income countries from the given sample of countries during the decade 1996-2005



Changes in the mean number of mobile telephone users(per 1000 citizens) and fixed telephone lines(per 1000 citizens) in upper medium income countries from the given sample of countries during the decade 1996-2005



Changes in the mean number of mobile telephone users(per 1000 citizens) and fixed telephone lines(per 1000 citizens) in lower medium income countries from the given sample of countries during the decade 1996-2005



Changes in the mean number of mobile telephone users(per 1000 citizens) and fixed telephone lines(per 1000 citizens) in low income countries from the given sample of countries during the decade 1996-2005