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Telecommunications infrastructure and GDP /Jipp curve/

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Abstract. The relationship between telecommunications infrastructure and economic activity is under discussion in many scientific papers. Most of the authors use for research and analysis the Jipp curve. A lot of doubts about the correctness of the Jipp curve appear in terms of applying econometric models.

The aim of this study is a review of the Jipp curve, refining the possibility of its application in modern conditions. The methodology used in the study is based on dynamic econometric models, including tests for nonstationarity and tests for causality. The focus of this study is directed to methodological problems in measuring the local density types of telecommunication networks. This study offers a specific methodology for assessing the Jipp law, through VAR-approach and Granger causality tests.

It is proved that mechanical substitution of time-series data: momentary aggregated variables (such as the number of subscribers of a telecommunication network at the end of the year) and periodically aggregated variables (such as GDP) in the Jipp's curve is methodologically wrong. Researchers have to reconsider the relationship set in the Jipp's curve by including additional variables that characterize the Telecommunications sector and the economic activity in a particular country within a specified time period. GDP per capita should not be regarded as a single factor for the local density of telecommunications infrastructure.

New econometric models studying the relationship between the investments in telecommunications infrastructure and economic development may be not only linear regression models, but also other econometric models. New econometric models should be proposed after testing and validating with sound economic theory and econometric methodology.

A previous version of this paper is published in Bulgarian language in the Economics and Computer Science journal in 2016. Due to great interest to it from different researchers, it is translated into English, revised and slightly shortened.

Key words: Jipp curve; econometric model teledensity, VAR approach, Granger causality.

1. Introduction

The connection between telecommunications infrastructure and economic activity has been object of discussion in numerous scientific works. The prevailing concept is that a positive correlation exists between the indicators of the public telecommunications sector and the indicators of economic development. Numerous scientific researches prove that the levels of economic activity are directly proportional to those of telecommunications infrastructure distribution at the level of a country and/or region. A very large share of the works researching the relationship between telecommunications infrastructure and economic development use for their analysis the Jipp curve (Jipp, 1963) (Jeunhomme, 2000).

The Jipp curve has been derived from the function:

$$Teledensity_i = f(GDP_i, \varepsilon_i)$$

Where:

- $Teledensity_i$ – is an indicator measuring the level of telecommunications infrastructure distribution in economy, called "density of the population";
- (GDP_i)- Gross Domestic Product (total for the economy) or GD6P per capita is an indicator measuring the "wealth of the nation."

ε_i – is **a random error term** (random component) related to the operation of other possible independent (input) variables which are not included in this model.

The empirical implementation has been carried through a single regression model. The model has been built with the use of information from "a sample of 47 industrialized countries" – members of the International Telecommunication Union. We try to estimate the following function: $Teledensity_i = f(GDP_i, \varepsilon_i)$

It has gained popularity as Jipp law and its graphic expression is known as Jipp curve.

The Jipp curve that was drawn and approbated in 1963 is still used in its generic form. The results from the Jipp's research are used for the development of a "tool" intended to facilitate the formulation of criteria concerning the amount of investments in telecommunications networks, which the individual countries need to make. The amount of these investments should be in proportion to the "wealth" of the respective country; it has to be proportional to the rate of that country's economic growth. It is assumed that the building of telecommunications networks of approximately identical technical and technological parameters would lead to easier and more active communication between the subscribers of the individual networks (telecommunications networks in the individual countries).

The Jipp curve is used as a tool for "prediction" of missing data concerning the telecommunications network distribution in countries that do not publish detailed information because of the lack of statistical reporting, other reasons, or because such data are treated as confidential by those countries' national laws.

The law derived by Jipp settles the public relations in connection with the development of electronic communication networks and physical infrastructure only in respect of assurance of certain levels of access when certain volume of GDP has been reached. Jipp law is used as grounds for the planning of telecommunications networks' distribution in the individual countries, i.e. when GDP of "*X*" volume is reached, "*Y*" level of telephone density (number of telephone lines per 100 residents) must be achieved.

The public relations between the subscribers of public-telecommunications networks and the operators of such networks are not settled through this so-called law. The rights of telecommunications service users and their right to use the networks and services therein at good quality and affordable price are not settled, either. The increased interest in this subject matter can be explained with a number of interrelated reasons:

- *First*: From theoretical point of view: To what extent the drawn constructions for the connection between telecommunications infrastructure and GDP are correctly, properly specified from econometric point of view and are there grounds to interpret and use the obtained results as criteria for determining the telecommunications network levels of penetration? We cannot agree with the derived "rules" and criteria for infrastructure development, because they have been derived and formulated on the grounds of "samples" of countries and the formed aggregates are highly heterogeneous as regards those countries' economic level, the state of their infrastructure and even their geographic location.
- *Second*: The different level of economic development of individual countries, the different level with which the contemporary communications in the individual countries are being accepted and intraduced, and the different territorial location of the countries do not allow their inclusion in a single "statistical" aggregation. It would be appropriate to study the connection between telecommunications infrastructure and GDP through the means and tools for time series analysis for an individually taken country. The results derived from panel-data analysis of a group of countries, e.g. the European Union, in view of the development of a single market for electronic communication services should be perceived as useful.

Third: The variables participating in the Jipp law. The indicators used to measure infrastructure distribution should be re-assessed; they need to be updated through the inclusion of indicators from the modern telecommunications infrastructure. We cannot agree that nowadays, the density of fixed telephone lines should be considered as the single measure for telecommunications network distribution in the individual economies.

The topicality of the discussed subject matter is defined by the role and significance of telecommunications as means for communication and interaction between people. Nowadays it is accepted that the development of telecommunications is amongst the significant indicators for each country's level of economic prosperity.

The *Object* of this research is the telecommunications infrastructure of the European countries, expressed by its density per population for the period from 1990 to 2015.

The *Subject* of this research is the relationship between telecommunications infrastructure and economic activity for the period 1990 – 2015.

The objective of this work is to re-assess the Jipp curve and to give precision to the possibility for its application in contemporary conditions.

The research is based on the Jipp law, the economic theory and the results obtained by researchers such as Amitava Dutta (Dutta, 2001), (Madden and Savage, 1998; Madden, Savage and Madden, 2008) (Alleman *et al.*, 1994; Mankin N. Gregory, David Romer, 1997; Dutta, 2001; Colecchia and Schreyer, 2002; Carlaw, Chu and Oxley, 2005; Lee, Gholami and Tong, 2005; Sridhar and Sridhar, 2007; Agiakloglou and Karkalakos, 2009; Koutroumpis, 2009a, 2009b; Chakraborty and Nandi, 2011; Ward and Zheng, 2015)(Mankin N. Gregory, David Romer, 1997; Chakraborty and Nandi, 2011) (Lee, Gholami and Tong, 2005; Chen, Lee and Zeng, 2014) (Lars-Hendrik Röller, 1996) and ect. The countries included in this research are: Bulgaria, Great Britain, Germany, Greece, Denmark, France, Turkey, Spain, Italy, Russia, Sweden and Switzerland. The reason for these countries' selection is not their qualitative homogeneity as regards their economic development or telecommunications infrastructure. These countries, with the exception of Bulgaria, participate as "sample units" in many of the researches on the subject under consideration. The results from those researches are highly controversial, ranging from total acceptance of the statements derived by Jipp to total rejection of his conclusions. The period of the research covers twenty six years: from 1990 to 2015. This choice has been predetermined by the circumstance that the main technical, technological, legal and economic changes in the “Telecommunications” sector were introduced in all of the reviewed countries during that period. Information support has been provided through the ITU-T, World Bank and Euromonitor International databases. The used databases are selected in connection with this author’s attempts to provide the highest synchronicity between the empirical data used in previous researches and this work. The calculation procedures have been completed with applied statistical and econometric software: EViews 9.5.0 and MS Excel.

2. Classifications and measures of telecommunications infrastructure and economic activity

Several indicators have been used according to their role for the drawing of the Jipp curve and because they have been used by other researchers throughout the years. The indicators have been organized in two groups: i) indicators characterising the Telecommunications sector; ii) indicators characterising the economic activity.

The main database for the research and analysis of the public telecommunications sector is the system of indicators that has been developed and maintained by the World Telecommunication Union. The indicators for the Telecommunications sector have been structured in the form of time series. Each observation in the series refers to a concrete date or period of time (e.g. monthly, quarterly, semi-annual and annual data) and, in the ideal case; it has to be kept in this frame in order to facilitate the analysis of trends in the sector.

As a rule, in the larger number of UTI (International Telecommunication Union) member states data concerning the Telecommunications sector/ICT are provided by the operators in the form of questionnaires. At the next stage, the data are summarized at country level. In the individual ITU member states, the information concerning individual networks, individual network operators and services is being collected and stored at a local level. In Bulgaria this information is provided by the Communications Regulation Commission. The data aggregated at country level is the data used for international comparisons in the sector, for planning and forecasting of the networks and their services in the individual countries, and for connecting the countries’ networks in a single Global Telecommunication Infrastructure. This information base aims to assure comparability of results (by time and scope) from the activities of the public telecommunication sector in the individual countries, regardless of their geographic location. The term “public” refers to the means for access to the network and not to the network’s ownership.

A public telecommunications network is an electronic communication network used for providing of publicly accessible telephone services; it provides a possibility for the transfer of voice, text and video services, and for the combining of individual points within itself, regardless of their geographic location.

The manufacturing of telecommunication equipment is excluded from the public telecommunications sector. The indicators in the database are grouped by individual fields of activity, which provides broader outlook to the telecommunications sector. A significant number of the indicators included in the database refer to the physical infrastructure of the telecommunications network, in its section dealing with the subscribers of individual networks: fixed, mobile and cellular; the Internet – (absolute number); density by subscribers of individual networks (% of the total population access to the network. The other groups of indicators refer to: – use of networks (measured by the traffic carried through them); – tariffs for the use of networks and services; – income/costs from/for services; investments in the “Telecommunications” sector (ITU, 2011). A separate group includes certain indicators from the demographic and macroeconomic statistics – population, incl. population of the large cities; some indicatiors focused on households.

The exposition discusses only those of the ITU-database indicators that are directly related to the concrete research, such indicators from which the Jipp curve has been derived and constructed. Indicators that characterise the contemporary means of communication are also included.

Indicators that characterise the fixed telecommunications network (PSTN) are: number of network subscribers; number of organised stations, centres; length of connecting chains between them, etc. The fixed telephony is one of the oldest communication networks with history of over 125 years. It has been in the focus of telecommunications statistic for many years.

The main indicator which Jipp uses is “fixed-network subscribers” [number] – this is a telephone line with specially appointed port in the telephone station that connects the subscriber’s end device to the public network. This indicator is synonymous for “individual subscriber line” or “fixed telephone line.”

The indicator for the fixed telephone lines is the sum of the number of the following groups of active (used at least once during the latest month) subscriber lines: analogue fixed telephone lines; IP subscriber lines for voice services (VoIP); subscriber lines for fixed wireless access to the network (WLL); ISDN voice-channel equivalents, and the fixed public-telephone units. We have to point out that there is a difference between subscribers and users of fixed telecommunications network. One subscriber can use numerous subscription lines and a number of users can use one line. This indicator accounts only for the number of subscribers of subscription lines.

Another large group of indicators that serves to measure the access of the residents and the businesses to telecommunications infrastructure is the group of cellular networks. Out of this group, of interest for this particular research is the number of mobile network subscribers. In its composition, this indicator includes subscribers of voice services, including short message service, subscribers of mobile-data and Internet, and subscribers with contracts for the use of voice services, mobile data and Internet.

The composition of this indicator includes subscribers who use prepaid access to the network and subscribers who have contracts with the service operator. Each of these two groups is additionally subdivided according to the speed of data transfer into subscribers using low and medium speed, and high-speed subscribers. This division of the cellular networks subscribers is comparatively recent (2005-2008); 4G subscribers have been included since 2015). The data included in the ITU-T database are still being “adapted” to this classification. Because of this inconvenience, many researchers “neglect” this classification of the subscribers. In this research we, too, use the total number of cell-network subscribers regardless of whether they use mobile data and at what speed. The total number of subscribers is significant for this study.

The next group of indicators included in this research are those that take in consideration the distribution of the global network Internet. These indicators have been organized in a separate group (according to ITU classification). Their composition includes the total number of Internet subscribers and Internet users, and also by groups of residents and businesses. The indicators characterising the Internet distribution in the individual countries are divided in two main groups: *i)* according to the technology of Internet connection – fixed access (incl. fixed broadband access), wireless access (incl. subscribers of satellite broadband access, land fixed wireless broadband Internet and active mobile broadband public Internet subscribers; *ii)* according to the speed of data transfer – standard-access subscribers and broadband-access subscribers. This last group of indicators has become especially popular in connection with the Information society concept.

The ITU-T database includes a total of 180 indicators that refer to the Telecommunications sector. The object of the research is characterised with this limited number of indicators because they have been included in a large number of research works; they are used to prove, respectively reject, the operation of Jipp law for a group of countries.

On the grounds of the absolute indicators, the indicators for infrastructural density (distribution) among the residents and the businesses are calculated. Historically, the oldest indicator in this group (relative indicators) is the “telephone density by fixed telephone lines” (the number of telephone lines per 100 residents), measured in %.

1. $$D_{FIX} = \frac{\begin{matrix} Fixed\ telephone\ subscriptions \\ (at\ the\ moment, T) \end{matrix}}{Populatiion\ (average\ annual)} \ .\ 100\ [\%]$$

This indicator “provides comparability in regard of the PSTN-network distribution by population in individual countries.” The indicator calculated in this way is in the basis for the deriving of the Jipp curve. In the 1960s, its composition included solely and only the number of active analogue fixed telephone lines and the public fixed telephone lines. With the development of the techniques and technologies, the composition of this indicator has been expanded to include IP voice-service subscription lines (VoIP); subscription lines for fixed wireless access (WLL); ISDN voice-channel equivalents. In this sense, the use of this indicator for international comparisons of groups of countries included in one cross-section is unjustified. This indicator could be used to research one particular country and, through it, to research the dynamic in density along the fixed network, or, through it, to study the connection between such network and the economic activity.

In a similar way have calculated the indicators referring to other types of networks: subscriber density by cell networks and the Internet.

For the purpose of estimating the active Internet users, the national statistic offices, jointly with ITU, conduct periodic observations. The observations aim to estimate the achieved level in Information society development. The indicator used to measure the Internet accessibility among the residents and the businesses has been the result of such observations – “active Internet users” – calculated as percent of the total number of residents in individual countries.

One indicator, which is often used as substitute for infrastructure indicators, is called “Investments in the ICT Sector.” These investments are associated with the costs for acquisition of own property (including intellectual and intangible property such as software). This indicator includes costs for initial installations and costs for services that are added to existing services, where the expectations are that their use will continue over an extended period of time. Because of its value expression, this indicator should be used with great caution in the analysis of time series. The indicators used in this work to characterise the physical infrastructure are as follows (see Table 1).

Table 1.

Telecommunication indicators

Indicator	Unit	Source/DataBase	Code
Fixed telephone subscriber	thousands	World Telecommunication/ Database 19th Edition, 2015,	FTS
Mobile cellular Telephone subscriptions	thousands		MTS
Total Internet subscribers	thousands		IS
Internet users (Estimated)	% of Population, Estimated		IU
Total annual investment in telecommunications	Historic Constant Prices (2015), million units of national currency		Invest

GDP is used to measure economic activity. In economy, the gross domestic product (GDP) is a measure for the quantity of goods and services produced over a certain period of time in a certain geographic region. This is one of the ways to measure the national income and production. In the meaning of the Jipp curve, this indicator measures the "wealth of the nations." Again, according to the Jipp curve, GDP is a determinative factor for the development of telecommunications infrastructure.

In this publication, GDP conforms to the scale of the population and is presented as actual GDP per capita, by national-currency prices of the countries included in this research; by the prices for 2015 (GDP information is taken from the Euromonitor International database).

Table 2.

Indicators of Economic activity / Indicators of "wealth of the nations"

Indicator	Unit	Source/DataBase	Code
GDP	Historic Constant Prices (2015), million units of national currency	Euromonitor International http://www.euromonitor.com/	GDP
GDP per capita	Historic Constant Prices (2015), units of national currency		GDP_cap

The main theoretical questions which answers are empirically sought through the system of indicators are: Can it be assumed that Jipp curve is an adequate expression of the relationship between telecommunications infrastructure and economic development in the contemporary conditions? Is this (generic) methodology of static cross-section suitable for analysis of the discussed dependency towards the year 2016?

3. GDP-Telecommunications Infrastructure – generalised conclusions from empirical researches

In a publication titled "The wealth of the nations and teledensity" Jipp A. (1963) proves the existence of a relationship between telephonic density (number of telephone lines per 100 residents) and economic development measured as GDP per capita of the population. The author also proves that the direction of interaction is from "wealth of the nations" to "teledensity." In the same period, possibly under the influence of the Jipp's publications, CCITT (Consultative Comminitee for International Telephony and Telegraphy) organised (1964) a specialised autonomous group – GAS-5 – assigned with the task to develop indicators and propose methods for quantitative estimation of the interactions between telecommunications and economic development. In the middle of the 1960s, CCITT published the results from empirical researches where econometric methods had been applied. Based on an exponential model, a proposal was made that the telephonic density should be related to GDP per capita of the population. The estimates were made using information for ITU member-states for the years 1955, 1960 and 1965 – total for all countries; for countries from Europe; for countries located in Europe and Central Asia.

The results from the application of Simple linear regression models in which "telephonic density by residents" is included as dependent variable and GDP per capita is included as independent variable, have led to "models" – benchmarks, standards, which CCITT recommends to be used when planning telecommunications networks in the developing countries in case that there are no data about the telephone-network development. ITU recommends these models to be also used as means for the obtaining of approximate estimation of the investments in Telecommunications. The construction of appropriate models for describing dependencies needs to be done using formal descrition and graphical presentation (Kuyumdzhiev, 2016). The graphical presentation gives an idea of the initial assumption on input and output of the model. Further investigation should be done in terms of findng causal dependencies and constructing a model according to statisitical and econometric rules.

Increases in GDP usually lead to an increase in investments in telecommunications and higher tepelphone density (teledensity). The unknown levels of telephone density, respectively the volume of telecommunications investments, i.e. their approximate estimation, are obtained through the theoretical, expected values for the effect *Y* (telephone density or investments) when the levels of *X* (GDP or Gross National Income) are known. The last two macroeconomic indicators have been monitored by the national statistic offices, by international organizations such as the World Bank and others; the information about them is of relatively long history and the monitoring periods have been of uniform length. These are the exact reasons why these indicators are included in the composition of a model intended to estimate the levels of penetration of telecommunications infrastructure in individual countries. Sometimes the process of monitoring may be done using one moment of time (Vasilev and Stoyanova, 2017). In this case the conducted analysis of the momentary variables is valid for the certain moment of collecting data. Researchers should not try to make future forecasts of the analysed variables using this concrete momentary data.

The variations in the findings of telecommunications infrastructure (measured through telephone density) in different countries are explained with the variations of GDP per capita (elasticity of finding in respect of income).

Defined in this way, the direction of dependency between telecommunications infrastructure immediately raises questions, such as:

Is reverse causality from Telecommunications structure to GDP possible? Is two-direction causality possible? Additional questions are raised in regard of the model’s specifics and the variables participating in the model. Do the models meet the statistical criteria for actuality and relevance of the obtained results? What errors in estimation burden the parameters of the econometric model? What is the shape of the dependency between the participating variables – is it linear or non-linear? Have the most relevant independent / input variables been selected for the building, testing and verifying of a model intended to be used for the most precise planning of investments in telecommunications infrastructure?

The Jipp‘s law has been derived and proven in the conditions of monopolistic presence of a single telecommunications operator in a particular country (with the exception of the USA and Canada) with telecommunications systems being property and responsibility of the states, represented by their governments. Currently, the telecommunications services market is deregulated in a large number of countries worldwide. As a result, the Telecommunications sector developed at unprecedented speed. Suspicions arise concerning the action of Jipp law in the conditions of contemporary communications.

Contemporary publications increasingly pay attention to the indicators that characterise the level of penetration (distribution) of the cellular networks, of the global network Internet, and of the satellite networks. Attention is also paid to indicators such as traffic, for example, that characterise the use of these networks for the transfer of information. In contemporary publications, attention is also paid to the skills of the residents and the businesses to use the potential, which contemporary telecommunications offer.

When studying the literature, our attention has been drawn mainly to publications where results at macro-level are presented, such that have been developed at the level of a country or a group of countries. This has been dictated by our attempt to estimate the operation of Jipp’s law in the 21^{st} century, its effect where the “new” telecommunications are concerned, and also by out attempt to find out whether reverse causality is possible, i.e. from telecommunications infrastructure to economic development.

A basic characteristic of telecommunication services during the last decade is the merge between telecommunication and information services. This convergence has been the result from the development of digital technologies. The liberalized telecommunication services market prompts the operators to pay greater attention to the building and maintenance of reliable infrastructure, to the diversity and quality of their services and to the services offered by their competitors. In the recent ten years, researchers’ attention has been channelled in this direction. The number of publications discussing the impact of the new communications on the economic development increases during the last five years. We are interested in the way the economic development may contribute to the development of the new communications. Can it be assumed that the Jipp law is valid for the new means of communication as well? Can it be assumed that the Internet and the mobile communications are engines for economic growth, or is their relationship reversed? The evaluation of the impact of new communications on the economic development may be studied through online surveys (Stoyanova and Vasilev, 2017) or through analysing data from ITU or other data sources of tellecommunicaiton data. The online surveys focus mainly on the subjective opinion of the respondents, whereas data from ITU or other data sources of tellecommunicaiton data may be used for exploring the dependencies between new communications and economic development using sound econometeic models.

The thing in common between all those publications (which we managed to review) is the significant influence on the economic development, which their authors attribute to telecommunications infrastructure and to the sector overall. In their larger number, these works do not accept that the direction of relationship is from economic growth to telecommunications. They prove that this dependency is exactly the opposite direction. Causality tests have been used in some of these publications, and in small number of cases two-directional (causal) dependency between sectoral levels and economic-activity levels has been proven. Various econometric techniques have been used, as well as “samples” of countries. The latter have been included in the empirical research for no special reason; this so-called “sample” has been, again, made of highly heterogeneous countries as regards their development, access to mobile services and the Internet, and the aspect of their economic development. The research results are used for the development of recommendations to the governments and the international organizations aimed at the overcoming of digital segregation and digital poverty. Details concerning the results from the empirical researches can be found in the references to this article. It is hard to adhere to certain standpoints of the authors because strong incomparability of the results has been established – both in regard of the temporal period for which they were conducted and in regard of the cross-section that was used. The only thing in common between them is the base Jipp model:

$$Teledensity_i = f\left(GDP_i, \varepsilon_i\right).$$

4. Methodology

The relationship between telecommunications infrastructure and economic development has been derived as:

(1.) $Teledensity_i = f(GDP_i, \varepsilon_i)$

The following **e**conometric **model for the population** (single linear regression model) has been used for analytical purposes:

(2.)$Teledensity_i = \beta_0 + \beta_1 . GDP_i + \varepsilon_i,$

Where:

$Teledensity_i$ – density of subscribers per 100 residents in a country *i*;

- *GDPi* – Gross Domestic Product per capita in a certain country *i:*
- ε – **random error term**; (e = residuals)

The method of estimation used by previous researchers is a regression analysis model implemented by cross-section data for a certain year while the information backup has been provided through ITU database. The participating variables are: Teledensity – telephone density (telephone lines per 100 residents), GDP – gross domestic product per capita, US dollars converted to the national currency of each country included in the research (by exchange rates for a certain year). The methodology that was used and approbated in Jipp’s research had been constructed through static cross-section data. The inclusion of qualitatively non-homogeneous units in the aggregates violates the theoretical requirements in regard of statistical methodology. Additional confusion is introduced by the use of average values for the indicators GDP (USD) and telephone density (in %) calculated from aggregates that contain qualitatively non-homogeneous units (countries), e.g. China, USA, India, Denmark, France, Finland, Greece and others. Similar confusion, as regards the value of information and its statistical significance, arises where “growth patterns” are used, containing a number of equations in which average values for investments in Telecommunications sector, domestic consumption and governmental consumption, foreign trade commodity exchange etc. are used, but for a group of countries that are often located in different continents.

The strength and the direction of the causality between indicators for telecommunications infrastructure and economic activity should be studied. Our attention is focused on the methods for times series analysis. The research is based on (Dolado, Tim and Sosvilla-rivero, 1990); (Drakopoulos and Torrance, 1994); (Dutta, 2001); (Kunst, 2007); (Rodríguez-Caballero and Ventosa-Santaulària, 2014); (Sims, 1980); (Lee, Gholami and Tong, 2005); (Nosko, 2002); and ect. Methods that do not set a precondition for the direction of the dependency and for distinguishing of the participating indicators (variables) into dependent and independent. Methods that create possibility for simultaneous assessment of the dependency:

(3.) $TI_{t,i} = f\left(GDP_{t,i}, u_{t,i}\right)$,

$GDP_{t,i} = f\left(TI_{t,i}, v_{t,i}\right)$

Where:

- $TI_{t,i}$ – an indicator characterising the distribution of telecommunications infrastructure in a certain country for a period of time t.
- $GDP_{t,i}$ – an indicator characterising the economic activity – GDP, GDP per capita of the population in a concrete country for a period of time t.

$u_{t,i}$ and $v_{t,i}$ – random error term (residuals, random component).

Yet another preference is raised to the methods of analysis: they should possess an inbuilt capacity for analysis of the “telecommunications – GDP” relationship in both short-term and long-term aspect.

Among the diversity of methods for time series analysis, special preference has been given to the Vector Autoregressive Method. This method was introduced by Sims (Sims, 1980, 1980, 1996) as a technique to be used by researchers for characterisation of the joint, dynamic behaviour of a group of macroeconomic variables without imposing strict limitations for differentiation of the variables into endogenous and exogenous (as in the systems of simulant equations). In VAR-systems, all participating variables are assumed to be endogenous by default. Each endogenous variable is a function of the current lag values of all endogenous variables and of the current exogenous ones (if any). The VAR-approach that was offered by Sims and found its way into practice is a summation of one-dimensional autoregression in a mutli-dimensional case. Each equation in the system is nothing more than an ordinary regression estimated by the least-squares method for one variable with its lags, and the other variables in the system. This approach provides a possibility for internal coordination of multivariate time series while the statistical toolkit that accompanies it is convenient and easy-to-interpret. In the cases where a stable VAR-system is achieved (i.e. system in which the residual components of each of the equations and of the system as a whole satisfy the requirements for the presence of normal distribution, absence of autocorrelations of different orders, absence of heteroscedasticity, etc.), an opportunity is presented to study the impact of a single shock (impulse) in one variable on all participating variables, and how long this impact will be. In cases where co-integration relationship between the variables is established, an error-correction mechanism can be embedded in the VAR-model (Sims, 1980, 1980)(Kunst, 2007); i.e. it can be further developed into VECM (Vector Error Correction Model), estimating in this way the relationship between the variables in long-term and short-term perspective. This method creates yet another convenience – a possibility to determine the direction of the relationship between the participating variables, plus a possibility to determine whether the variables are interdependent. It is through the VAR-approach that one of the most popular causality tests – the Granger test (Granger, 1969) (Granger and Newbold, 1974; C.W.J. Granger, 1980, 1988) – can be conducted. The Granger test has been used as a tool to check the operation of Jipp law in dynamic, at the level of a certain country.

In the context of the discussed subject matter, we construct a VAR-system of two variables – one that characterises telecommunications infrastructure and one that characterises economic activity, both reviewed over the same period of time. Let's assume that only one lag has been included for each of those, i.e. lag = 1 (this assumption will partially explain the inertia accumulated in each of them). The inclusion of only two variables, each of which participates with a lag of only one period, contributes for a lighter presentation in regard of the theoretical requirements for the structuring and use of VAR-systems for practical purposes. One lag may be one year or quarter, or month.

In this case, the system can be written down in the following way:

$$(4.)\quad \begin{array}{ll} TI_t = \beta_{10} + \beta_{11} GDP_t + \beta_{12} TI_{t-1} + u_t & u_t \sim N\left(0, \sigma_u^2\right) \\ GDP_t = \beta_{20} + \beta_{21} TI_t + \beta_{22} GDP_{t-1} + v_t & v_t \sim N\left(0, \sigma_v^2\right) \end{array},$$

Where:

- TI_t is each of the indicators presented in Table 1 (number of subscribers of the individual networks; indicators for density of the individual networks per residents or investments in the "Telecommunications" sector) for a period of time t.
- GDP_t – Gross Domestic Product, GDP per capita of the population for a period of time t.
- u_t and v_t **– random error term** (random component, residual component).

It is obvious that each of the equations can be viewed as an autoregression model and as such, its parameters can be calculated through the least-squares method (while observing the conditions of the method).

From VAR(1) system (with lag = 1), the following relationships between coefficients and residues can be drawn:

$$(5.)\quad \begin{array}{l} \delta_1 = \dfrac{\beta_{10} + \beta_{11}.\beta_{20}}{1-\beta_{11}.\beta_{21}};\ \theta_{11} = \dfrac{\beta_{12}}{1-\beta_{11}.\beta_{21}};\ \theta_{12} = \dfrac{\beta_{11}.\beta_{12}}{1-\beta_{11}.\beta_{21}} \\ \delta_2 = \dfrac{\beta_{20} + \beta_{21}.\beta_{10}}{1-\beta_{11}.\beta_{21}};\ \theta_{21} = \dfrac{\beta_{21}.\beta_{12}}{1-\beta_{11}.\beta_{21}};\ \theta_{22} = \dfrac{\beta_{22}}{1-\beta_{11}.\beta_{21}} \\ \eta_{1t} = \dfrac{u_t + \beta_{11}.v_t}{1-\beta_{11}.\beta_{21}};\ \eta_{2t} = \dfrac{v_t + \beta_{11}.u_t}{1-\beta_{21}.\beta_{11}}; \end{array}$$

The expressions represented through (5) which, in concrete applications, are estimates of the coefficients and residues of a VAR-system, are proof that all "new" VAR systems are already based on a presumptive system of equations. The system should include logically justified and theoretically grounded participating variables (economic indicators) so that the obtained estimates could be of practical value.

The variables included in the concrete VAR-system can be selected through correlation analysis and Granger "causality" tests (C.W.J. Granger, 1980). This research uses the Granger test to examine the operation of Jipp law in a dynamically developing system. "Causality by Granger" is a term, which is somewhat incorrectly understood owing to the literal translation of "causality" that has become popular in practice. It is often confused with the cause-and-effect relationships in the common meaning, where a phenomenon (X) is a factor, cause or condition for another phenomenon (Y), which is perceived to be the result or consequence from the influence of the factor, i.e. $(X \rightarrow Y)$. In the cases where the consequence, in its turn, acts upon the factor, we talk about interdependencies marked with $\left(X \rightleftarrows Y\right)$.

"Causality by Granger" is a wider notion, compared to the generally accepted one, and is related to the concept that "the past can influence the future but not the other way round." This postulate of Granger has been reviewed in informational aspect in order to clarify what part of the variation of the current meanings of (Y) can be explained with the preceding meanings of (Y) itself and, can this explanation be improved with the addition of previous meanings of (X). The variable (X) is called "cause" for (Y) if it improves significantly the foretelling of (Y) from the perspective of diminished variation. Granger test (Granger and Newbold, 1974); (C.W.J. Granger, 1988) derived through a VAR-model of the type:

$$\begin{aligned} TI_t &= cons_{TI} + \sum_{j=1}^{p} \alpha_j TI_{t-j} + \sum_{j=1}^{p} \beta_j GDP_{t-j} + \eta_{TIt} \\ GDP_t &= cons_{GDP} + \sum_{j=1}^{p} \alpha_j TI_{t-j} + \sum_{j=1}^{p} \beta_j GDP_{t-j} + \eta_{GDPt} \end{aligned} \tag{6.}$$

The verification in its essence consists of checking the source hypothesis for equality at zero for a group of coefficients, i.e.

$H_{0(1)} : \alpha_1 = \alpha_2 = ...\alpha_p = 0$ and $H_{0(2)} : \beta_1 = \beta_2 = ...\beta_p = 0$

For the verification, the full and shortened form of (6.) is constructed and the residual sums are compared through F-test. According to the results from Granger test, the following situations are possible in regard of telecommunications infrastructure and economic activity:

- Not a single variable can be classified as a cause by Granger. Such result would correspond to the statement that no dependency exists between the access and distribution of the telecommunications infrastructure and the economic activity, or that such dependency cannot be proven for the reviewed period.

- One-way causation from (GDP) to (IT), but not the other way round, i.e. $(X \rightarrow Y)$. The obtaining of such result, the acceptance of this result would mean that the law derived by Jipp can be accepted as operable in the conditions of dynamic environment as well.

- One-way causation from (IT) to (GDP) but not the other way round, i.e. $(X \leftarrow Y)$. Such result would indicate that in a certain country there is return of investments in the sector for the researched period and that the development of telecommunications infrastructure supports the communication between the individual network subscribers in both personal and business (economic) aspect. Such result would mean that, when studying the relationship between telecommunications and economic development in a pattern of growth, as one of the participating variables should be included the respective one from the telecommunications structure.

- The variables (GDP) and (TI) represent, by Ganger, a cause towards each other $\left(X \rightleftarrows Y\right)$. This bilateral causality provides grounds to study the relationship between the two groups of variables in both short-term and long-term aspect. This result would be yet another confirmation for the mutual interdependency between the economic and "technical" indicators in the framework of a dynamic system such as economy is.

The proposed methodology realised through the VAR-approach is a good solution for problems related to the researched subject matter: relationship between telecommunications infrastructure and economic activity in a concrete country. The results obtained from the applying of such approach are useful for both individual telecommunications operators and for the regulatory bodies in connection with the networks, which they develop and offer, and for the economy overall.

5. Results and discussion

In result of Jipp's research, the relationship between telecommunications infrastructure and GDP has been accepted to be correlational.

In scientific literature, prevalent are publications in which the results have been obtained through models constructed by cross-sectional models. In a small number of macro level researches, attention is paid to the fact that the connection between telecommunications infrastructure levels and economic activity is a dynamic process of "communication" between the parts of a single whole – the economy of a concrete country.

The changes that occur in telecommunications networks lead to development of the services offered through them. Those services are not limited to the transfer of voice, signals or messages at a distance; instead, they unite the transfer of voice, messages, data and video in a "single service."

Jipp curve, derived through the fixed (historical) networks, should be, consequently, "re-drawn" to include the new means of communication.

On the other hand, the wealth of the nations measured through GDP/per capita cannot be accepted to be the single causative agent for the distribution of telecommunications networks in individual countries. The magnitude of the random component derived from Jipp relations $Teledensity_i = \beta_0 + \beta_1 . GDP_i + \varepsilon_i$, takes increasingly larger value as it departs from the period for which it was derived. This latter can be taken as a proof of the “weakening” of the “strong positive correlation” between the participating indicators that has been derived by Jipp and other researchers, but a more probable explanation is the impact exerted by other factorial influences on the telephone density, such that are not included in the model.

We have estimated the dependency between the density by fixed-network subscribers and GDP/per capita in the manner derived by Jipp, by using information from ITU World Database for individual years for the countries from Europe and Central Asia. We established that the values of Pearson-Brave correlation coefficient decrease from 0.91 for 1960 to 0.49 for 2015.

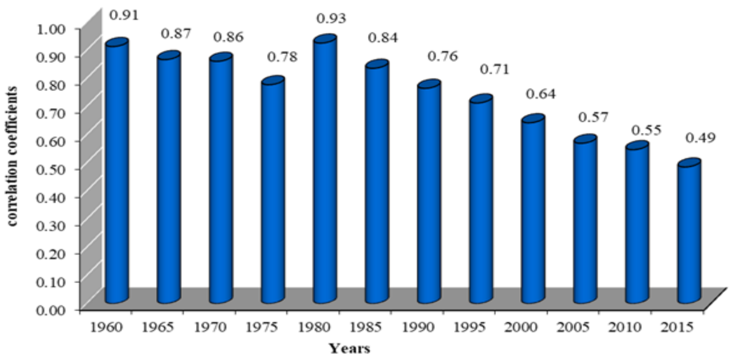

Figure 1. Correlation coefficients between telephone density and GDP /per capital
Source: Own calculations based on ITU World Database.

The summarised results show that in the years when the telephone was basic means of (voice) communication, the variation in the “wealth of the population” could explain nearly 82% of the variation in the telephone-network distribution. After 2000, the explainable variation in the subscriber density by fixed networks is below 40%, while for 2015 it is only 24%. The regression models, from which the coefficients have been calculated, turned out to be relevant in respect of the linear form of dependency between the indicators but the remainder (the random component ε) does not have normal distribution; the presence of heteroscedasticity has also been established. This example is a sufficient cause to make us reflect on the reliability of the curve derived by Jipp. Can we assume that the curve is a good tool for analysis of the dependency between the participating variables? Can only GDP/per capita be used as a factor for the achievement of high levels of telephone density? Other proofs may be found that this dependency cannot be estimated only through the means of common linear regression (by cross sectional data) with pre-appointed of the variables as dependent and independent.

In this work, a methodology for time series analysis has been adopted as a basic tool to verify the direction of the interaction between indicators characterizing “subscriber density” and indicators characterizing “economic activity” of individual European countries over a period of 26 years. The operation of Jipp law has been tested from the standpoint of a concrete country, in dynamic aspect. The research uses results from the salutary works of (Dutta, 2001); (Lee, Gholami and Tong, 2005); (Jeunhomme, 2000) and others working in this area who pay attention to the specifics that accompany the time series.

The indicators, through which the telecommunications infrastructure is characterised according to the Jipp curve, are indicators for density per population (measured in percent): the so-called subscribed access. Here, the calculation itself has been made in a way different from the adopted one, the purpose being to assure for the comparability between the indicators for density and economic activity in individual countries. The density by subscribers of fixed telecommunications networks is calculated through the relationship:

(8.) $$D_{FTS_t} = \frac{FTS_t}{N_t} . 100\ [\%] \quad ,$$

Where: D_{FTS_t} density by fixed telecommunications networks for year t, [%]; FTS_t – absolute number of active subscribers of cellular networks by the end of the calendar year t; N_t – average annual number of Population per year t.

Calculated in this way, the indicator “density by subscribers of fixed telecommunications networks” measures the penetration, the density by fixed networks per 100 residents, i.e. the number of fixed-network subscribers per 100 residents. Calculated in this way, the indicator is included in econometric models wherein it is an “effect” caused by GDP. The numerator in the above formula – FTS_t – is the number of fixed-telecommunications network subscribers (in the international database) referred to the end of each calendar year. This is a momentous aggregate of the subscribers in each country at 31.12 (31st of December) of the respective calendar year. The average annual number of residents in the individual countries is a periodic aggregate obtained through taking into consideration the demographic processes that occurred in the respective year. The immediate juxtaposing of (telephone density) and (GDP/per capita) is methodologically incorrect, improper. It is incorrect also in regard of the denominator in the formula – the average annual number of residents. In order to assure for the comparability with the other indicators of economic activity, the momentous aggregate – fixed-telecommunications network subscribers – has been transformed into a periodic one through the use of data for two adjacent periods, i.e. the average value of the number of subscribers for two adjacent periods has been calculated:

(9.) $$\mathrm{F\bar{T}S} = \frac{FTS_{t-1} + FTS_t}{2} ,$$

Where: FTS_{t-1} and FTS_t are the number of fixed-network subscribers by the end of the preceding and current year, respectively.

In this research, the density of fixed-network subscribers has been calculated through the relationship:

(10.) $$D_{FTS_t} = \frac{F\bar{T}S_t}{N_t}.100\ [\%] ,$$

Where: D_{FTS_t} is density by fixed telecommunications networks per year t, [%]; FTS_t – average annual number of active cell-network subscribers for the respective year, t; N_t – average annual number of residents for year t. Calculated in this way, the indicator measures the penetration, average annual density by fixed networks, i.e. the number of fixed-network subscribers per 100 residents of the population.

To estimate the distribution of cellular networks, the density indicator in each country has been calculated in a similar way in this research.

(11.) $$D_{MTS_t} = \frac{M\bar{T}S_t}{N_t}.100\ [\%] ,$$

Where: D_{MTS_t} is density by cell-telecommunications network subscribers for year t, [‰]; $M\bar{T}S_t$ – average annual number of cell-network active subscribers for the respective year, t. Calculated in this way, the indicator measures the number of cell-network subscribers per 100 residents of the population.

The distribution of the Internet network has been estimated through indicators for density of network subscribers. The relationships that are used are analogous to the preceding ones:

(12.) $$D_{IS_t} = \frac{I\bar{S}_t}{N_t}.100\ [\%] ,$$

Where: D_{IS_t} is density by Internet subscribers for year t, [%]; $I\bar{S}_t$ – average annual number of active Internet subscribers for the respective year t. In this research, the number of active Internet subscribers is the sum of the standard and broadband access subscribers without further differentiation by manner of access. The average annual number of subscribers has been calculated as a mean arithmetic value through the method outlined herein above. N_t – average annual number of population for year t.

The outlined indicators build the database of this research. For each individual country, the database contains absolute and relative indicators for telecommunications infrastructure, as well as economic indicators – actual GDP and GDP per capita of the population. The average annual number of the population in the individual countries corresponds to the information taken from the databases of the national statistic offices. The information about GDP and GDP per capita of the population is taken from Euromonitor database.

The series with indicators for the fixed telecommunications network are momentary aggregated variables forming a time series for nearly all 215 member states of the International Telecommunications Union since 1960. This research is limited only to the period 1990 – 2015, because this is the period when fundamental technical and technological changes took place in telecommunications. The beginning of the 1990s is the period when the first cellular networks were launched in operation in many European countries; this is the period when the Internet network was commercialized and its numerous applications for practically each and every area of contemporary life were promoted.

In this research, the absolute number of Internet users and Internet subscribers has been used as a measure for the distribution of the network. The density of this network has been calculated by the use of data for all Internet subscribers – both standard and broadband-access. The time series composed of telecommunications infrastructure indicators are available in the form of annual data. For the purpose of meeting the theoretical requirements of econometric methods, they have been disaggregated in quarterly series by using the possibilities for shifting from higher to lower frequency via interpolation through spline functions. In this way, the number of observations along the individual indicators has been “increased” and, being disaggregated in this way, the series cover the minimum-required threshold of observations for the econometric methods that have been selected for this research. The indicators which build the database have been logarithmically transformed. The logarithmic transformation provides compatibility of the researched indicators, averagely situated within the limits of a range, and the non-stationarity of time series in regard of dispersion is removed. In the cases where their first differences need to be used, they appear as an approximation of the growth rates for the respective variable.

The database established for each of the researched countries is used in connection with the revision of Jipp curve, precising the possibility for its application in contemporary conditions. The corelograms, together with the descriptive and graphic analysis of the time series of fixed-telecommunications network subscribers conducted-in-advance, plus the indicators for density of this kind of subscribers, provide grounds to state that non-stationarity of these series (in all of the researched countries) is present. The descriptive and graphic analyses give grounds for yet another statement: structural discontinuity is present in the series with density values along the fixed network in the following countries: Bulgaria, Switzerland, Denmark, Italy and Great Britain, (see Fig.2).

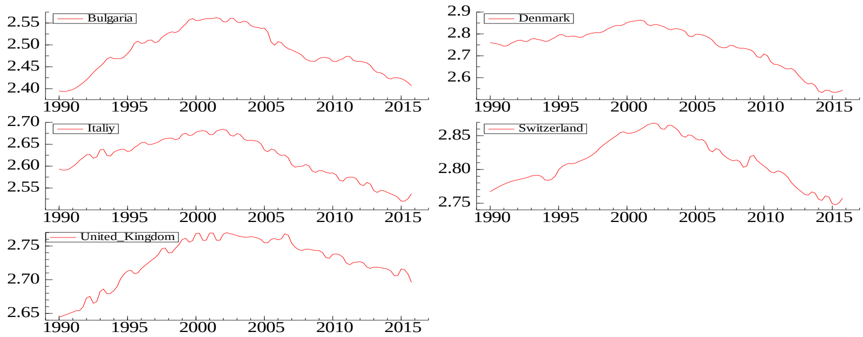

Figure 2. Density of fixed telecommunication networks (subscribers) in Bulgaria, Switzerland, Denmark and Italy 1990-2015; telephone density – Y axis; years – X axis

The time series of fixed-network subscribers show prominent change in the direction of trend: from growth in the beginning of the researched period, to decrease after 2000. The calculated density indicators reproduce almost exactly the trend of the absolute number of subscribers. In the individual countries included in the research, this change of the trend occurs at different times – 2000 – 2001 – 2002, but the breakpoint is not equally prominent. The change in subscriber density is the result from a complexity of reasons. One such reason is the change in the number of residents in the individual countries. Within the frame of the researched period, the number of population changed in the individual countries. In the countries from the researched group (with the exception of Bulgaria and Russia) it increased and this circumstance reflected on the value of subscriber density by fixed networks. Another reason for the changed value of this indicator is the developing cellular networks: their infrastructure replaces (almost entirely) the fixed-network’s infrastructure (in the period 2000 – 2004, the subscriber density by cellular networks reached over 50% in the individual countries).

In order to determine the periods of statistically significant change in trend, the procedure for Global Multiple Structural Changes (Bai, 1997); (Bai and Perron, 2006) has been first applied, followed by the classical Chow test (Chow, 1960) for structural break. The Chow test is used to verify the hypothesis for the absence of change in the trend of development or the absence of specific points of discontinuity in the trend, opposed to the alternative statement– such change does exist and it is statistically significant. The verification is made through the maximum-likelihood method, Wald criterion and F-criterion. The results from the Chow-test show that the change established trough the graphic method is statistically significant in the five countries. This means that in the subsequent analyses the time series need to be divided according to the obtained results. The Chow test was applied in the rest of the researched countries in respect of the fixed-density indicators, but no abrupt change in the trend’s direction was observed. In the rest of the countries, decrease in the growth rate was registered both in respect of absolute number of fixed-network subscribers and density.

The tests for Global Multiple Structural Changes, Chow test, have been applied in respect of all time series that are included in the research. The dynamic of the economic indicators calls for verification of the structural discontinuity in the GDP and GDP/per capita indicators, too, but such discontinuity has not been proven with the used methodology. The test results for the remaining indicators for both telecommunications infrastructure and economic activity do not give grounds to state the existence of a significant change in the direction of the trend of development of the researched indicators.

In connection with the set objective, at the next stage of this research it would be necessary to identify the time series from the standpoint of the trend of development contained in them. This is not a matter of proving whether a trend is present in a given time series. The presence (absence) of a trend can be successfully proven through the possibilities of autocorrelation analysis and (partially) with the graphic method. The presence of non-stationarity can be due to the presence of stochastic and/or deterministic trend. The referring of the time series to the respective class of models – TS (Trend Stationarity) or DS (Difference Stationarity) is done on the grounds of multitude of statistical procedures. This research uses an iterative procedure to determine the nature of a trend in the time series and, alongside with it, to determine the order of integrity. The check has been conducted through the multiple-version procedure proposed by (Dolado J. J., 1990; Dolado, Tim and Sosvilla-rivero, 1990); (Dolado J. J., 1990; Dolado, Tim and Sosvilla-rivero, 1990); (Fuller, 1979; Dolado, Tim and Sosvilla-rivero, 1990; Byrne and Perman, 2006; Glynn, Perera and Verma, 2007); (Nosko, 2002) which, in its essence, uses the expanded version of (Fuller, 1979) test. Preference has been given to this scheme because it can be used to determine, apart from the order of line integrity, the type of the trend contained in the series – either TS (Trend Stationarity) or DS (Difference Stationarity).

The conducted tests established that the series constructed from fixed-telecommunications network subscribers and the density of this kind of subscribers follow a similar decreasing trend for the researched period. The general outlook of their dynamic and the results from the conducted tests provide grounds for these time series to be determined as having stochastic trend and, alongside with it – a deterministic component (in certain countries). As regards the order of integrity, the density indicators for the fixed-network subscribers are defined as second-order integrated for Greece, Turkey, Russia and Germany. The time series with these indicators are determined as first-order integrated for Spain, France and Sweden. For Spain and France, there is no established decline in the density of fixed network subscribers. In Sweden, the rate of decline in density for this type of subscribers is the most significant amongst all surveyed countries. In 1990, the number of subscribers in Sweden was 70 subscribers/100 residents while by the end of the period it was 38/100 residents. Such levels of density in the country – 38/100 residents were typical for the end of the 1960s. Sweden, as a country from the Scandinavian Peninsula, had strongly developed cellular network of high telephonic density (over 50%) as early as the beginning of the 1990s and this circumstance reflected on the rates by which the subscribers/density of fixed networks declined. In Bulgaria, Greece, Italy, Russia and Turkey, the development of the fixed network in 2000 – 2004 did not provide for density by population higher than 55-56 subscribers per 100 residents. For Bulgaria, the highest density (the largest distribution) by PSTN (fixed) network subscribers was reached in the period 1997 – 2004: 36-37 subscribers per 100 residents. In Turkey, the density was 28-30 subscribers per 100 residents for the same period. The provided technological possibility (in all researched countries) for interconnection of the various telecommunications networks and for termination of services from one network into another, the convenience which cellular networks offer – user mobility – is a prerequisite for withdrawal from the fixed subscriber lines.

We need to specify that the established linear (declining) trend is characteristic for the end, fixed lines for access to infrastructure, and not for the infrastructure in general. The fixed networks build the backbone of a communications network upon which the contemporary networks are being constructed, developed and maintained. For countries in which discontinuity of the trend for concrete periods has been established, the single-root tests have been conducted for each sub-period, individually for each country. The trend, which accompanies subscriber density by fixed networks, is determined as stochastic with deterministic linear trend. The series with the absolute number of subscribers by the fixed telecommunications networks in the individual countries have a trend similar to that of the density. In those series, the stochastic component is less pronounced than the deterministic trend. This is fully understandable because the number of residents in the individual countries has not been taken into consideration for these series. The number of residents serves as an indirect evaluator for subscriber migration from one telecommunications-services operator to another.

The procedure for determining the order of integrity for the density indicators for cell-network subscribers and Global-Network subscribers is analogous to the one already described. A well-expressed growing trend of development is characteristic for the subscribers of cellular networks. The density of this type of subscribers outreached 100% by the end of 2015 (with the exception of Turkey: 95%). The conducted check established that the trend, which is in the basis for this type of subscribers, is stochastic with deterministic trend and the series themselves are first-order integrated. No structural changes have been established (through the Chow test). The length of these time series is different for the different countries. This difference results from the difference in time when the cellular networks were introduced in the different countries. For the researched period, in four countries – Bulgaria, Greece, Russia and Turkey – the cellular networks were launched in operation after 1992 and the line length in those countries is between levels 92-96, depending on the time when this type of networks were inaugurated. In Bulgaria, the first subscribers of wireless telecommunications networks were registered in 1993. The results from the conducted ADF-test revealed that the time series with density indicators for the mobile operators are stationary in respect of the first differences (of logarithms). This circumstance qualifies them as first-order integrated. The presence of a constant and a trend in the test regression of the ADF-test is indicative for the presence of stochastic and, alongside with it, deterministic trend in the time series. The presence of a deterministic trend is justified by the technological development of the networks, which is also a policy of the governments and regulatory authorities in respective countries, aimed to stimulate the development of this type of communications. The stochastic trend is assumed to be the result of subscriber migration from one telecommunications services provider to another when searching for a suitable provider who is able to guarantee good quality of services at a reasonable price.

Another group of indicators to which the research is directed, is distribution indicators of the Internet network. The Internet distribution is measured through Internet subscribers and active Internet users. In its database, ITU publishes both the number of users and the number of subscribers. The number of Internet users is a historically older indicator than the number of subscribers. The use of the Internet in the mid 1990s happened though dial-up access to the Internet via a modem for the fixed-network (PSTN) subscribers. Practically, until the mid 1990s, one fixed-telephone network subscriber who had a computer and Internet-connection modem was reported twice: i) as PSTN-network subscriber and ii) as Internet user, but not as a single subscriber using two services –voice and data transfer. With the development of technologies and shift to digital telecommunications networks, it is possible to differentiate between subscribers and users of various types of telecommunication services, Because of this reason, information for Internet users in the beginning of the 1990s is available while data for Internet subscribers. It became available as late as the year 2000. One user can have more than one subscription, and a couple of users can share one subscription.

The number of Internet users in the group of the studied countries has been growing avalanche-like since the moment when the possibility for network-access has been provided.

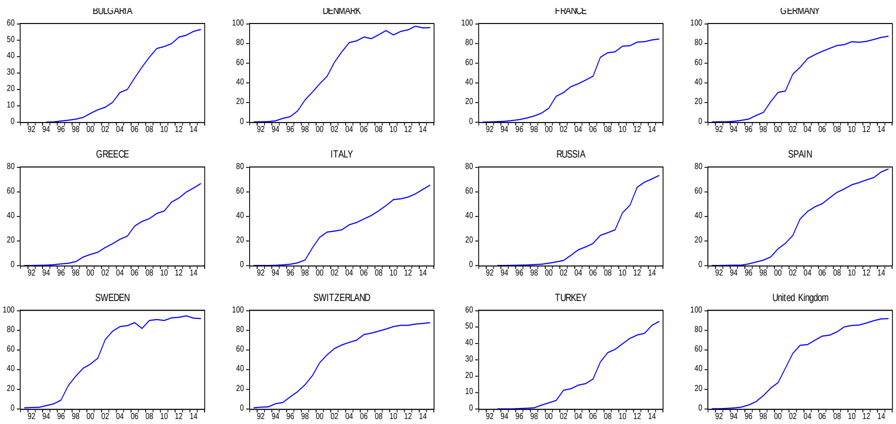

Figure 3. Internet users (Estimated) % of Population; Estimated – Y axis; years – X axis

The trend, which is in the basis of the series for Internet users, has been determined for some countries as deterministic linear and for other countries – non-linear. The clearly expressed deterministic trend of development is explained with the network development and with the technical and technological possibilities for network access. Another reason for this trend is methodological – a single user is reported multiple times across different surveys. This inaccuracy of the indicator is potentially embedded in its formation. The composition of this indicator includes “active Internet users” i.e. users who have access to the network from home and/or workplace (without being contractual subscribers for the provision of this service) and have connected to the Internet at least once in the recent three months.

Table 3.

Density for Internet users, % of total population

Countries	Years				
	1995	**2000**	**2005**	**2010**	**2015**
Bulgaria	0,120	5,370	19,970	46,230	56,660
Denmark	3,830	39,170	82,740	88,720	96,330
France	1,640	14,310	42,870	77,280	84,690
Germany	1,840	30,220	68,710	82,000	87,590
Greece	0,750	9,140	24,000	44,400	66,840
Italy	0,520	23,110	35,000	53,680	65,570
Russia	0,150	1,980	15,230	43,000	73,410
Spain	0,380	13,620	47,880	65,800	78,690
Switzerland	6,600	47,100	70,100	83,900	87,910
Sweden	5,100	45,690	84,830	90,000	92,000
Turkey	0,080	3,760	15,460	39,820	53,470
England	1,900	26,820	70,000	85,000	92,000

Source: Own calculations based on ITU World Database

The data for this indicator (see Table 3) published in ITU database, are result from sample surveys conducted in the individual countries. The samples have been formed by aggregates of households, small and medium size, and large enterprises, institutions and administration bodies. In 1995 in Bulgaria, out of 1000 residents one was identified as an active user while by the end of 2015 this ratio was 570 users/1000 residents. In 1995 in Great Britain, this ratio was approximately 2/100 residents and for 2015 it was 92/100 residents. When estimating the relationship between subscriber density and GDP/per capita, from methodological point of view it would be more correct to use network subscribers instead of network users. The subscribers are those physical persons and/or legal entities who are in contractual relationship with an operator/service provider. For the delivery of the service, each subscriber pays the respective fee: for connection to the network and for its use (as a typical case). The fees paid by subscribers represent the revenues of the operator/service provider, the value of the provided services in result of the production activity of the operator/provider. The revenues, in their turn, are included (part of them) in the composition of the Gross production, which forms part of the GDP (GDP calculated by the production method).

The composition of the “Internet subscribers” indicator in individual countries includes both fixed access subscribers and wireless access subscribers. The ITU synchronised system of indicators accounts for each separate group of subscribers according to the type of services which they use. In Bulgaria and the countries included in the research (with the exclusion of Turkey, Russia and Sweden), the subscribers of broadband access, which can be provided by both the fixed network and the cellular network, are counted separately. Applying the test procedure of the ADF-test, the trend of development in density of the fixed Internet-access subscribers is determined as deterministic with a stochastic component. The ADF procedure was conducted for the period from 1999 to 2015, i.e. on the grounds of information for 68 levels (three-month periods – quarters). The time series with density indicators for broadband Internet subscribers have been determined as first order integrated for all countries included in this research. The well-expressed growing trend of development, which aims is to expand the network’s scope to the remotest places and to provide the technical and economic potential needed for the providing of Internet access, complies with all plans and programmes developed at national level, at EU level and the World Bank. This growing trend is also the result of programmes concerned with overcoming of the “Digital divide” from the standpoint of access to certain regions, age groups and social groups. Similar is the situation with the series that contain the average annual number of subscribers using mobile Internet access. These series are extremely short, even when disaggregated at three-month levels. The first data for this type of subscribers in the countries from the researched group came from Denmark and Sweden in 2007, Germany, France and Great Britain – in 2008. Data about mobile Internet access for the rest of the countries included in the research are available after 2009. The brief continuity of the series is the reason for their exclusion from the analysis in this research.

The indicator that has been accepted as a factor for the increase of subscriber density is “GDP/per capita” according to the dependency derived by Jipp. Its inclusion in the composition of one or another econometric model should be done after descriptive diagnostic analysis of its trend, conducted in advance. As a result of the financial and economic crisis of 2008, the growth of GDP in the EU countries was significantly retarded and in 2009 it shrank considerably. In 2010, the levels of GDP in the European countries was restored and this trend continued (although in progressively slower rates) in the following years. The results from the descriptive analysis give reasons to conduct additional tests concerning the GDP/per capita dynamic, aimed to establish the presence of a structural discontinuity during the researched period 1990 – 2015. Within the framework of this research, a procedure for the presence of multiple structural discontinuities is initially conducted using the Bai-Perron methodology; a test for fixed (single) discontinuity is also applied. The latter is in accordance with the financial crisis period of 2008 – 2009. The conducted tests for (algorithmic data) GDP/per capita in Bulgaria, Greece, Italy, Russia and Spain give grounds to assume that the change that occurs in this indicator’s trend is statistically significant. In the individual countries, this change occurs in different periods. In Bulgaria, the tests indicate the presence of two sub-periods. The first one Q1_1990- Q4_1999 coincides with the economic and political crisis in the country of 1996-1997. In Greece, Italy and Spain, the trend changes after 2008 as a consequence of the global financial crisis. The trend of GDP development in the cited countries follows the trend in the EU Member States and the GDP levels begin to recover after 2010. In addition, the Philip-Perron test (another single-root test with embedded possibility to determine the nature of the trend before and after a possible discontinuity) as well as stationarity KPSS tests are conducted for the series with these indicators. For the rest of the countries included in the group (Denmark, France, Germany, Sweden, Switzerland, Turkey and Great Britain), the Bai-Perron test do not confirm the presence of a significant change in the direction of the trend. The tests have been conducted with varying rates of change – from 10% to 25% – but the results do not give grounds to assume that a statistically significant discontinuity exists in the overall direction of the trend, expressed as GDP/per capita. The series with GDP/per capita logarithms in Denmark, France, Sweden, Switzerland, Turkey and Great Britain have been determined as first order integrated with the presence of deterministic linear trend and a stochastic component. The preliminary analyses, aimed to determine the nature of the series with GDP/per capita indicator, do not differ from the results obtained by earlier researchers studying the variations in this indicator. In order to find periods in which change in the GDP/per capita trend has been established, additional fictitious variables have been created, which are included in the VAR-systems as an additional exogenous variable.

Determination of the order of integrity for the indicators that characterise the telecommunications infrastructure and of the indicators for economic activity is of significance for the verification of the Jipp law operation in dynamic aspect.

The relationship between telephone density and GDP represented through the model $Teledensity_i = \beta_0 + \beta_1.GDP_i + \varepsilon_i$, has been drawn and proven as a model of long-term (static) balance between the two indicators. We can talk about the presence of a long-term relationship between the variables also in cases where the trend of development in the time series follows approximately the same trajectory and the difference between the individual trends remains approximately constant. It is accepted that such time series are called co-integrated. In order to be co-integrated, the variables should have identical order of integrity or, at least, the degree of integrity of the dependant variable should be equal to the highest order (the highest degree) of integrity of the variables on the right side. In this case the variables are only two – density by subscribers and GDP/per capita, which imposes the requirement that the variables should have the same order of integrity. If the two variables have different orders of integrity, then no static long-term balance can exist between them. If different order of integrity is established for the two variables, then the variables might be causally related in short-term aspect. The results from the single-root tests conducted by different types of density by telecommunications-network subscribers and by individual countries are presented in Table 4.

Table 4.

Results from ADF-test

Countries	Density for cellular network subscribers		Density for Internet subscribers	
	Model ADF	Den_{MTS}	Model ADF	$Den_{Internet}$
Bulgaria	2	$y_t \sim I(1)$	1	$y_t \sim I(1)$
United Kingdom	2	$y_t \sim I(1)$	2	$y_t \sim I(1)$
Denmark	2	$y_t \sim I(1)$	2	$y_t \sim I(1)$
Italy	2	$y_t \sim I(1)$	1	$y_t \sim I(1)$
Switzerland	2	$y_t \sim I(1)$	2	$y_t \sim I(1)$
Spain	1	$y_t \sim I(1)$	1	$y_t \sim I(1)$
France	2	$y_t \sim I(1)$	1	$y_t \sim I(1)$
Sweden	2	$y_t \sim I(1)$	2	$y_t \sim I(1)$
Germany	2	$y_t \sim I(1)$	2	$y_t \sim I(1)$
Greece	1	$y_t \sim I(1)$	1	$y_t \sim I(1)$
Russia	1	$y_t \sim I(1)$	2	$y_t \sim I(1)$
Turkey	2	$y_t \sim I(1)$	2	$y_t \sim I(1)$

Source: Own calculations based on ITU World Database

Note. The ADF tests have been applied to log of transformed variables. *The models that meet the theoretical requirements for the individual destinations are the following:

$$(1)\quad \Delta y_t = \alpha + \varphi . y_{t-1} + \left(\sum_{j=1}^{p-1} \theta_j \Delta y_{t-j} \right) + \varepsilon_t \qquad (2)\quad \Delta y_t = \alpha + \beta t + \varphi y_{t-1} \left(+ \sum_{j=1}^{p-1} \theta_j \Delta y_{t-j} \right) + \varepsilon_t$$

The presence of the same order of integrity in the series is only a prerequisite to raise a hypothesis for the presence of a long-term relationship between the researched indicators. The same order of integrity is a necessary but not sufficient condition to assume that Jipp law operates in dynamic aspect as well. The same order of integrity between the contemporary-communication indicators and GDP/per capita is a prerequisite for further analyses in this direction.

Through Granger tests we can determine to what extent the trend in the two indicators is coordinated in short-term aspect and whether the variations in GDP/per capita can help to improve the forecast levels of subscriber density by fixed networks. The causality Granger tests for short-term periods have been conducted in both directions – from GDP/per capita to telecommunications infrastructure and vice versa. The test has been conducted for every possible pair of variables – subscriber density by types of telecommunications networks and GDP/per capita. The tested hypotheses are defined in the following way:

$H_{0(1)}$: GDP_t does not influence TI_t;

$H_{0(2)}$: TI_t does not influence GDP_t,

Where: TI_t – variable/indicators characterising the telecommunications structure in each individual country in the researched period; GDP_t – economic-activity indicator; GDP, GDP/1000 residents of the population in each country for the researched period.

In order to arrive at the conclusion that GDP influences TI, the following conditions need to be simultaneously satisfied:

- The hypothesis "GDP does not influence TI" has to be rejected.
- The hypothesis "TI does not influence GDP" has to be accepted.

If the two hypotheses are rejected, then interdependence exists between the two researched variables. In such cases, it is assumed that a third variable exists, which influences simultaneously the two initially researched variables. If both hypotheses are accepted, then no causality relationship exists between the variables in the sense of Granger. In this case, the search for a long-term relationship between them is theoretically ungrounded. Such result is taken as a proof that the law derived by Jipp cannot be accepted as an adequate reflection of the dependency between the characteristics in dynamic aspect.

In connection with the applying of the Granger causality test, it is necessary to observe the theoretical requirements referring to the building of autoregression models with distributed lags, i.e. requirements in respect of stationarity. The necessary number of lags that are included in the Granger test has been determined in advance through autocorrelation analysis. In each VAR-system, the maximum lag that corresponds to the last significant autocorrelation coefficient from the autocorrelation function has been included in advance. At the next stage, the significance of each lag variable has been verified through the applying of Exclusion Wald Tests for the significance of each lag, and of the values of information criteria: AIC (Akaike information criterion), SC (Schwarz information criterion), HQ (Hannan-Quinn information criterion). The obtained results, presented in Table 5, contain the maximum-possible significant lag which can be used to improve the forecast qualities of the subscriber-density indicator or GDP/per capita. The results from the conducted tests show that between the density by fixed-telecommunications network subscribers and GDP/per capita do not provide grounds to reject the hypothesis “GDP does not influence TI” (except for three of the cases, see Table 5). The second hypothesis “TI does not influence GDP” is not rejected, either. This result is yet another proof in favour of our statement that the dependency between the subscriber density and GDP/per capita cannot be researched solely and only through these two variables. By the meaning of the Granger test, a third variable exists, which influences simultaneously the former two initially researched. The role of this “third” variable can be assumed by subscriber-access prices, subscriber access to networks that are alternative to the fixed ones, other, prices of operator-provided services, prices offered by other operators and many others.

Table 5

Pairwise Granger Causality Tests
Density of fixed network subscribers and GDP per cap 1990 г. – 2015 г.

Null Hypothesis:	**Obs**	**lags**	**F-Statistic**	**Prob.**
BG_GDP does not Granger Cause BG_FTS	64	2	2,739	0,073*
BG_FTS does not Granger Cause BG_GDP			0,015	0,985
UK_GDP does not Granger Cause UK_FTS	55	3	0,548	0,652
UK_FTS does not Granger Cause UK_GD			0,690	0,562
ESP_GDP does not Granger Cause ESP_FTS	28	2	1,177	0,326
ESP_FTS does not Granger Cause ESP_GDP			0,132	0,877
FRA_GDP does not Granger Cause FRA_FTS	101	3	0,892	0,448
FRA_FTS does not Granger Cause FRA_GDP			0,922	0,433
SWE_GDP does not Granger Cause SWE_FTS	102	2	1,719	0,185
SWE_FTS does not Granger Cause SWE_GDP			0,357	0,701
DEU_GDP does not Granger Cause DEU_FTS	100	4	1,200	0,316
DEU_FTS does not Granger Cause DEU_GDP			1,094	0,364
GRC_GDP does not Granger Cause GRC_FTS	28	2	1,566	0,230
GRC_FTS does not Granger Cause GRC_GDP			0,537	0,592
RUS_GDP does not Granger Cause RUS_FTS	68	4	1,564	0,196
RUS_FTS does not Granger Cause RUS_GDP			2,690	0,040
DEN_GDP does not Granger Cause DEN_FTS	61	2	0,002	0,998
DEN_FTS does not Granger Cause DEN_GDP			0,178	0,837
CHE_GDP does not Granger Cause CHE_FTS	54	2	0,582	0,563
CHE_FTS does not Granger Cause CHE_GDP			1,161	0,322
TUR_GDP does not Granger Cause TUR_FTS	100	4	2,979	0,023
TUR_FTS does not Granger Cause TUR_GDP			0,772	0,546

Source: Own calculations based on ITU World Database
Note. FTS – subscribers of fixed telecommunications network;

* The verification has been conducted at significance level of 0.05 based on F-distribution: (through F-criterion) $F=\frac{(SSR_R-SSR_U)/h}{SSR_U/(n-k_U)}$, with degrees of freedom $\nu_1=h; \nu_2=n-k_U$, n – number of observations; k_U – number of independant variables (parameters) in unlimited Regression model; k_R – number of independant

variables (parameters) in a limited. regression model; h – number of imposed limitations $h = (k_U - k_R)$; $SSR_U ; SSR_R$ – the sum of squared residuals /the respective sums of the squares of residuals/ at unlimited and limited autoregression model.

The obtained results can be perceived as proof for the inapplicability of Jipp curve in the contemporary conditions for research in dynamic. The obtained results give grounds to re-examine the Jipp curve and its application for research in dynamic aspect. When the curve was created, telecommunications were developing in a situation of state monopoly (in the larger number of ITU member states) and the investments which governments made in telecommunications infrastructure were directed to the building and maintenance of a fixed telecommunications network, including telephone and telegraph networks. This network is narrowly specialised for the transfer of voice services or text messages. At the beginning of the 1990s, a large share of the investments was directed to the building and development of a subscription network for the purpose of providing subscription access to “the last mile.” The digitalisation of the fixed telecommunications network allowed the provision of diverse services, not only voice ones. Currently, the access networks are no longer narrowly specialised; they are flexible, with a potential to provide diverse types of services, and the contemporary technologies for subscribed access offer diverse and effective solutions for such provision. In this sense, the lack of causality in the meaning of Granger is fully justified also from the perspective of technological development. The lack of dependency between the two variables has been established in a situation of limited number of observations, from the perspective of the countries included in the research. The selected methodology gives grounds for re-examination of this dependency through the prism of methods for analysis of time series and not of cross section data.

Through the researched period 1990 – 2015, the fixed-subscriber (telephone) density significantly decreased, while the subscriber density by cellular networks and the Internet expanded. For the purpose of verifying whether it is possible the subscriber density by cellular networks to be a “natural” substitute for the effect in the dependency derived by Jipp, a correlation analysis is conducted. The obtained correlation coefficients fall within a wide range (from 0.457 to 0.896). The correlation analysis cannot answer the question: what is the direction of interaction between the researched values, and, is it possible to foresee (forecast) more precisely the changes in the rate of telephone density by cellular subscribers though changing the rates of change in GDP? The results presented in Table 6 show interdependence between the subscriber density and the economic prosperity in Denmark and Sweden for the researched period. The levels with which the zero hypotheses are rejected, are considerably lower than the foreseen $\alpha=0,05$. We reject the null hypothesis at $\alpha=0,05$ or at $\alpha=0,05$ we accept the alternative.

This bilateral causality between the indicators provides grounds to state that the two indicators should not be studied through econometric models in which the variables are divided into dependent and independent. The mutual dependency between the indicators cannot be accepted as a proof that Jipp curve can be re-drawn through “mechanical” replacement of subscriber-density by fixed networks with subscriber-density by cellular networks. GDP/per capita should not be considered to be the sole factor for increase in subscriber density. In the researched countries, the growth of subscriber access to cellular networks significantly exceeds the growth of GDP/per capita. The results from the recent tests show that in the larger number of the researched countries, causality exists in the direction from subscriber density to GDP/per capita. The high subscriber density presupposes the use of contemporary-type technical means, the generation and reception of traffic composed by various types of services (video inclusive) which leads to increased revenues in the “Telecommunications” sector. The established bilateral causality between the subscriber-density by mobile networks and GDP/per capita provides grounds to research the relationship between the two groups of variables in both short-term and long-term aspect. In the research models, additional variables characterising the “Telecommunications” sector should be included, as well as variables referring to the economy as a whole.

Table 6.

Pairwise Granger Causality Tests
Density on celular network subscribers and GDP per cap 1990 – 2015

Null Hypothesis:	**Obs**	**Lag**	**F-Stat**	**Prob.**	**Conclusion**
BG_GDP does not Granger Cause BG_MTS			0,08	0,93	$(GDP \leftarrow MTS)$
BG_MTS does not Granger Cause BG_GDP	88	2	4,52	0,01	
FRA_GDP does not Granger Cause FRA_MTS			0,88	0,45	$(GDP \leftarrow MTS)$
FRA_MTS does not Granger Cause FRA_GDP	101	3	3,13	0,03	
DEN_GDP does not Granger Cause DEN_MTS			3,66	0,03	$(MTS \rightleftarrows GDP)$
DEN_MTS does not Granger Cause DEN_GDP	102	2	7,62	0,00	
DEU_GDP does not Granger Cause DEU_MTS			0,47	0,63	$(GDP \leftarrow MTS)$
DEU_MTS does not Granger Cause DEU_GDP	102	2	2,65	0,08	
GRC_GDP does not Granger Cause GRC_MTS			0,16	0,85	Both hypotheses are accepted*
GRC_MTS does not Granger Cause GRC_GDP	88	2	0,76	0,47	
SWE_GDP does not Granger Cause SWE_MTS			3,01	0,05	$(MTS \rightleftarrows GDP)$
SWE_MTS does not Granger Cause SWE_GDP	102	2	6,98	0,00	
ESP_DGP does not Granger Cause ESP_MTS			0,30	0,74	$(GDP \leftarrow MTS)$
ESP_MTS does not Granger Cause ESP_DGP	102	2	6,10	0,00	
ITA_GDP does not Granger Cause ITA_MTS			1,54	0,21	Both hypotheses are accepted*
ITA_MTS does not Granger Cause ITA_GDP	101	3	0,62	0,60	
CHE_GDP does not Granger Cause CHE_MTS			0,70	0,59	$(GDP \leftarrow MTS)$
CHE_MTS does not Granger Cause CHE_GDP	100	4	2,48	0,05	
RUS_GDP does not Granger Cause RUS_MTS			1,02	0,37	$(GDP \leftarrow MTS)$
RUS_MTS does not Granger Cause RUS_GDP	88	3	6,73	0,00	
TUR_GDP does not Granger Cause TUR_MTS			0,20	0,82	$(GDP \leftarrow MTS)$
TUR_MTS does not Granger Cause TUR_GDP	102	2	3,14	0,05	
UK_GDP does not Granger Cause UK_MTS			1,53	0,21	Both hypotheses are accepted*
UK_MTS does not Granger Cause UK_GDP	101	3	0,82	0,48	

***** We have no enough evidence to reject the null hypothesis at α =0.10; 0.05; 0.01

Source: Own calculations based on ITU World Database **Note**. MTS – Mobile cellular subscriptions (per 100 people)

The other pair of variables to which our attention is directed, is Internet-network subscribers and GDP/per capita. The subscriber density by this network has been researched for the period 1999 – 2015 because no reliable information is available and the subscriber reports lack synchronisation. The number of Internet subscribers in individual countries is the most dynamically growing number of telecommunications-network subscribers. The expansion of the network is stimulated by the investments made for modernising the national infrastructure and by the liberalised market of electronic-communication services. Built initially upon the modernised fixed network, the Internet network turned into the “only” network for access of voice, data and video, while significantly simplifying the network architecture. At the same time, the network infrastructure that is built, serves traffic of high level of ambiguity from the standpoint of the needs for new services, traffic volume and new technologies. Through the constructed network infrastructure, technological potential for the introduction of new services has been provided. The building of simplified architecture for the network infrastructure allows for cost reduction in the servicing and management of the network itself.

Table 7.

Pairwise Granger Causality Tests
Density on Internet subscribers and GDP per cap 1990 г. – 2015 г.

Null Hypothesis:	**Obs**	**Lag**	**F-Stat**	**Prob.**	**Conclusion**
BG_FBS does not Granger Cause BG_GDP	66	2	2,685	0,076	$(FBS \rightleftarrows GDP)$
BG_GDP does not Granger Cause BG_FBS			3,708	0,030	
CHE_GDP does not Granger Cause CHE_FBS	66	2	3,720	0,030	$(FBS \rightleftarrows GDP)$
CHE_FBS does not Granger Cause CHE_GDP			2,949	0,060	
DEN_GDP does not Granger Cause DEN_FBS	66	2	1,809	0,172	$(FBS \rightarrow GDP)$
DEN_FBS does not Granger Cause DEN_GDP			5,623	0,006	
DEU_GDP does not Granger Cause DEU_FBS	67	1	8,491	0,005	$(FBS \rightleftarrows GDP)$
DEU_FBS does not Granger Cause DEU_GDP			8,668	0,005	
ESP_GDP does not Granger Cause ESP_FBS	66	2	1,739	0,184	$(FBS \rightarrow GDP)$
ESP_FBS does not Granger Cause ESP_GDP			2,565	0,085	
FRA_GDP does not Granger Cause FRA_FBS	66	2	1,525	0,226	$(FBS \rightarrow GDP)$
FRA_FBS does not Granger Cause FRA_GDP			7,378	0,001	
GRC_GDP does not Granger Cause GRC_FBS	66	2	4,320	0,018	$(FBS \rightleftarrows GDP)$
GRC_FBS does not Granger Cause GRC_GDP			3,045	0,055	
ITA_GDP does not Granger Cause ITA_FBS	67	1	3,343	0,072	$(FBS \rightleftarrows GDP)$
ITA_FBS does not Granger Cause ITA_GDP			8,616	0,005	
RUS_GDP does not Granger Cause RUS_FBS	65	3	0,656	0,583	$(FBS \rightarrow GDP)$
RUS_FBS does not Granger Cause RUS_GDP			2,529	0,066	
SWE_GDP does not Granger Cause SWE_FBS	67	1	0,783	0,380	$(FBS \rightarrow GDP)$
SWE_FBS does not Granger Cause SWE_GDP			5,280	0,025	
TUR_GDP does not Granger Cause TUR_FBS	66	2	0,455	0,637	$(FBS \rightarrow GDP)$
TUR_FBS does not Granger Cause TUR_GDP			3,238	0,046	
UK_GDP does not Granger Cause UK_FBS	66	2	0,561	0,574	$(FBS \rightarrow GDP)$
UK_FBS does not Granger Cause UK_GDP			3,886	0,026	

Source: Own calculations based on ITU World Database
Note: FBS – Internet subscribers - including broadband and standard.

The network for subscriber access to the Internet is flexible, with various types of services, offering diverse and effective solutions for the individual subscribers depending on their concrete conditions and needs. The fastest developing service is the high-speed access to the Internet; this creates conditions for manifold increase of the volume of information received/sent by the users while shortening the time necessary for the providing of large quantities of information. This is only a small portion of the reasons that stimulate new subscribers to join the network.

The wide popularity of Jipp’s curve prompts many researchers to mechanically replace the “subscriber density by fixed networks” indicator with the “subscriber density by Internet” indicator. The purpose of this replacement is to find the potential impact, which the “wealth of the nation” can have on the subscriber density by the Internet, creating in this way a new curve after the pattern of Jipp.

Strong positive correlation coefficients have been drawn, again for a group of countries, following the logic of the relationship /dependency/ $IT_t = f(GDP_t, \varepsilon_t)$. In this research, by using the Granger test we are trying to verify: can it be assumed that “subscriber density by the Internet” and “GDP” are causally related? If they are related, what is the direction of their interaction?

The results from the research of the twelve countries confirm the presence of a causality relationship between the indicators by the meaning of Granger. In Bulgaria, Switzerland, Germany, Greece and Italy, subscriber density by Internet and the economic activity are mutually dependent. The indicators have to be considered as cause and effect in respect of each other. In the rest of the countries, the direction of influence is from subscriber access, but not in reverse to GDP.

This is a proof for the inapplicability of the Jipp curve in its pure form, both for analysis in dynamic and in respect of the replacement of one indicator with another. The one-way causality which has been established in this research $(FBS \rightarrow GDP)$, we can assume that in a concrete country for the researched period, returnability of the investments made in the building and development of the network occurs. The development (technical and technological) of the Internet, together with the cellular networks, supports the communication between the individual network subscribers in both personal and business (economic) aspect.

When researching the relationship between telecommunications and economic development through the econometric model of growth, one of the participating variables to be included in the model is an indicator that characterises telecommunications infrastructure.

This concrete research does not deal with the question of proving the direct and indirect influence of the Internet on the economic sectors. In this work, the approach to establishing the relationship between telecommunications infrastructure and GDP is methodological, related to the definition of the place which every single variable has in an econometric model which is constructed of time series.

The Granger tests, together with the Wald exogenity tests, are a good helping tool in this direction. The results from Granger tests are good grounds to research the dependencies from the standpoint of their dynamic in both short-term and long-term aspect.

6. Conclusion

Telecommunications include a broad range of economic and social activities on both national and international scale, and they cover all strata of society. Telecommunications are directly related to societal development and their main purpose is to connect the individuals and the business.

This research accentuates methodological issues that accompany the study of the relationship between subscriber density by telecommunications networks and economic prosperity measured as GDP/per capita. The relationship between the indicators is correlational and this has been proven in numerous scientific researches, but only a small number of those pay special attention to the place of variables in an econometric model from the standpoint of dependent and independent.

In connection with the set objective and studied literature, existence of methodological inaccuracies in the research of this relationship has been established.

The Jipp's law, which is in the basis of numerous scientific researches in this subject matter, suffers from drawbacks resulting, on the one hand, from the strong heterogeneity of the units (countries) in the aggregates from which it has been derived. On the other hand, no answer can be given to the question, which is the cause and which is the effect in the correlation dependency derived through this law. The law is inapplicable in situations of dynamic, if the specifics of the time series that accompany them are not accounted for.

This work touches on a small part of the issues that accompany the research of the relationship in dynamic aspect, in an individual country. Special attention has been paid to the characterisation of the time series prior to their inclusion in econometric models for analysis of the dependency between telecommunications infrastructure and economic prosperity, the purpose being to improve the qualities of the results obtained from them.

In result of applying the dynamic econometric models, a conclusion has been reached that the Jipp law in the form in which it was derived, cannot be accepted as operative to-date. There are no grounds to accept that GDP/per capita is the one and only main factor, which influences subscriber density by individual telecommunications networks. The models which are suitable for researching the dependency between telecommunications infrastructure and economic development should go beyond the frame of the single linear regression, and the selection of the variables in them should be made upon strict control on the part of the economic theory and econometric methodology.

Literature

Agiakloglou, C. and Karkalakos, S. (2009) ‘A spatial and economic analysis for telecommunications: Evidence from the European union’, Journal of Applied Economics. Universidad del CEMA, 12(1), pp. 11–32. doi: 10.1016/S1514-0326(09)60003-9.

Alleman, J. et al. (1994) ‘Telecommunications and Economic Development: Empirical Evidence from Southern Africa’, ITS Sydney, 4(2), pp. 83–91. doi: 10.1177/089124249000400201.

Bai, J. (1997) ‘Estimating Multiple Breaks’, Econometric Theory, 13(3), pp. 315–352. doi: 10.1017/S0266466600005831.

Bai, J. and Perron, P. (2006) ‘Multiple Structural Change Models: A Simulation Analysis’, Economic Theory and Practice: Frontiers of Analysis and Applied Research, pp. 212–237. doi: 10.1017/CBO9781139164863.010.

Byrne, J. P. and Perman, R. (2006) ‘Unit roots and structural breaks: a survey of the literature’, Work, pp. 43–45. doi: http://www.upo.es/economia/metodos/.

C.W.J. Granger (1980) ‘Testing for causality: A personal viewpoint’, Journal of Economic Dynamics and Control, 2(Issue C, 1980), pp. 329–352.

C.W.J. Granger (1988) ‘Some recent developments in the concept of causality’, Journal of Econometrics, Volume 39(Issues 1–2, September–October 1988), p. Pages 199-211. Available at: http://www.sciencedirect.com/science/journal/03044076/39/1.

Carlaw, K. I., Chu, N. and Oxley, L. (2005) ‘Information and Communication Technology and Economic Performance’, (1956), pp. 1–47.

Chakraborty, C. and Nandi, B. (2011) ‘“Mainline” telecommunications infrastructure, levels of development and economic growth: Evidence from a panel of developing countries’, Telecommunications Policy. Elsevier, 35(5), pp. 441–449. doi: 10.1016/j.telpol.2011.03.004.

Chen, P. F., Lee, C. C. and Zeng, J. H. (2014) ‘The relationship between spot and futures oil prices: Do structural breaks matter?’, Energy Economics, 43. doi: 10.1016/j.eneco.2014.03.006.

Chow, G. C. (1960) ‘Tests of Equality Between Sets of Coefficients in Two Linear Regressions’, Econometrica, 28(3), pp. 591–605. doi: 10.2307/1910133.

Colecchia, A. and Schreyer, P. (2002) ‘The Contribution of Information and Communication Technologies to Economic Growth in Nine OECD Countries’, OECD Economic Studies, (34), pp. 153–171.

Dolado J. J., J. T. and S.-R. S. (1990) ‘Cointegration and Unit Roots’, Journal of Economics Survey, Vol.4, pp. 249–273.

Dolado, J. J., Tim, J. and Sosvilla-rivero, S. (1990) ‘Cointegra Tion and Unit Roots’, Journal of Economic Surverys, 4(3), pp. 249–273.

Drakopoulos, S. A. and Torrance, T. S. (1994) ‘Causality and Determinism in Economics’, Scottish Journal of Political Economy, 41(2), pp. 176–93. doi: 10.1111/j.1467-9485.1994.tb01119.x.

Dutta, A. (2001) ‘Telecommunications and economic activity: An analysis of Granger causality’, Journal of Management Information Systems, 17(4), pp. 71–95. doi: 10.2307/40398505.

Fuller, D. A. D. and W. A. (1979) ‘Dickey_Fuller_Distribution of the estimators for autoregressive time series.pdf’, Journal of the American Statistical Association, Vpl.74(No 366 (Jun,1979)), pp. 427–341. Available at: http://www.deu.edu.tr/userweb/onder.hanedar/dosyalar/1979.pdf.

Glynn, J., Perera, N. and Verma, R. (2007) ‘Unit root tests and structural breaks: A survey with applications’, Revista de Metodos Cuantitativos para la Economia y la Empresa, 3(3), pp. 63–79. doi: 10.5093/cl2010v21n1a6.

Granger, C. W. J. (1969) ‘Investigating Causal Relations by Econometric Models and Cross-spectral Methods’, Econometrica, 37(3), pp. 424–438. doi: 10.2307/1912791.

Granger, C. W. J. and Newbold, P. (1974) ‘Spurious Regressions in Econometrics’, Journal of Econometrics, 2, pp. 111–120.

ITU (2011) ‘Handbook for the collection of administrative data on Telecommunications/ICT’, p. 152. Available at: http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-ITC_IND_HBK-2011-PDF-E.pdf.

Jeunhomme, C. (2000) ‘Measuring telecommunication infrastructure needs and demand by’.

Jipp, A. (1963) ‘Wealth of nations and telephone density’, Telecommunications Journal, July 1963, pp. 199–221.

Koutroumpis, P. (2009a) ‘The economic impact of broadband on growth: A simultaneous approach’, Telecommunications Policy, 33(9), pp. 471–485. doi: 10.1016/j.telpol.2009.07.004.

Koutroumpis, P. (2009b) ‘The economic impact of broadband on growth: A simultaneous approach’, Telecommunications Policy. Elsevier, 33(9), pp. 471–485. doi: 10.1016/j.telpol.2009.07.004.

Kunst, R. M. (2007) ‘Vector autoregressions’, 2001(September), pp. 1–37.

Kuyumdzhiev, I. (2016). The DIMBI project–innovative approaches for teaching business informatics. Economics and computer science, Volume 2, Issue 5, pp. 26-36. Available:

http://eknigibg.net/Volume2/Issue5/spisanie-br5-2016.pdf#page=26

Lars-Hendrik Röller, L. W. (1996) ‘Telecommunications Infrastructure and Economic Development : A Simultaneous Approach’, Wissenschaftszentrum Berlin für Sozialforschung, University of Toronto, FS IV 96-(0722), pp. 1–20. doi: ISSN Nr. 0722 - 6748.

Lee, S. Y. T., Gholami, R. and Tong, T. Y. (2005) ‘Time series analysis in the assessment of ICT impact at the aggregate level - Lessons and implications for the new economy’, Information and Management, 42(7), pp. 1009–1022. doi: 10.1016/j.im.2004.11.005.

Madden, G. G., Savage, S. J. and Madden, G. (2008) ‘Economic Growth Growth’, (11843).

Madden, G. and Savage, S. J. (1998) ‘CEE telecommunications investment and economic growth’, Information Economics and Policy, 10(2), pp. 173–195. doi: 10.1016/S0167-6245(97)00020-6.

Mankin N. Gregory, David Romer, D. N. W. (1997) ‘A contribution to the Empirics of Economic Growth’, The Quarterly Journal of Economics, 112(2), pp. 443–477. doi: 10.1093/wbro/lkj004.

Nosko, W. P. (2002) Econometrics, Introduction to regression analysis of time series, russian. Available at: http://economics.fizteh.ru/econom/econometrikanosko.esp.

Rodríguez-Caballero, C. V. and Ventosa-Santaulària, D. (2014) ‘Granger Causality and Unit Roots’, Journal of Statistical and Econometric Methods, 3(1), pp. 97–114.

Shannon, M. and Moazzami, B. (2014) ‘Bai-Perron Estimates of OECD Natural Rates of Unemployment 1955-2011’, (September), pp. 143–149.

Sims, C. A. (1980) ‘Macroeconomics and Reality’, Econometrica, 48(1), pp. 1–48. doi: 10.2307/1912017.

Sims, C. A. (1996) ‘Macroeconomics and methodology’, Journal of Economic Perspectives, 10(1), pp. 105–120. doi: 10.1257/jep.10.1.105.

Sridhar, K. and Sridhar, V. (2007) ‘Telecommunications infrastructure and economic growth: Evidence from developing countries’, Applied Econometrics and International Development, 7(2), pp. 37–61. Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1250082.

Stoyanova, M., & Vasilev, J. (2017). Evaluation report on intellectual output O3 (interactive books) within the DIMBI project. Economics and computer science, Varna: Knowledge and business, 3(5), 30-35. Available: http://eknigibg.net/Volume3/Issue5/spisanie-br5-2017_pp.30-35.pdf

Vasilev, J., & Stoyanova, M. (2017). Second conference on innovative teaching methods–Varna 2017. Conference summary and evaluation report. Economics and computer science, Varna: Knowledge and business, 3(4), 18-22. Available: http://eknigibg.net/Volume3/Issue4/spisanie-br4-2017_pp.18-22.pdf

Ward, M. R. and Zheng, S. (2015) ‘Mobile telecommunications service and economic growth: Evidence from China’, Telecommunications Policy. Elsevier, 40(2), pp. 89–101. doi: 10.1016/j.telpol.2015.06.005.