FINAL PROJECT

CSSM 502 - Advanced Data Analysis for Social Sciences

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THE EFFECT OF TELECOMMUNICATION SPENDING ON HUMAN DEVELOPMENT INDEX

Objective: This study investigates the effects of telecommunication spending in the development of ICT (Information and Communications Technologies) on human development index.

1. Introduction

Telecommunication is one of the most competitive and fast-growing sectors in the world. Due to the rapid changes in technology and the requirement of renovation in the existing infrastructure, telecommunication companies have to spend a lot of money to improve their infrastructure and to be able to catch up the latest developments in the sector as well as in the world. It is quite expensive to build and maintain their networks. Further innovation requires further spending with the additional cost of devices and equipment.

Global Telco capital expenditure (CAPEX) is at its highest in more than ten years, according to research by MTN Consulting. As of June 2022, Telco capex was announced to reach $329.5 billion within the last 12 months.[1] On the Graph 1, CAPEX per revenue ratios of the operators is presented by years. It can be stated that operators should spend almost 15-20% of their annual revenue on capital expenditure which is a huge ratio compared with the other

[1] https://inform.tmforum.org/features-and-opinion/telco-capex-rises-sharply-amid-5g-and-fiber-investment

sectors. This graph indicates that the decline in the fiber investments is expected to go on, however there will be increase in mobile investments probably due to the transition of 5G in most of the countries in the world. The sharp increase in fixed network capex during 2018–2020 temporarily resulted in a ratio as high as 27%, though this will quickly return to previous levels by 2023 (14%). It will then drop further in 2025. Expenditure on fiber networks will drop as major projects come to an end. However, as it is now the time of 5G, there will be an increase in 5G investments. And also, since there will be no requirement of 3G anymore, mobile will require some more investment in order to close the spectrum allocations for 3G and use them in 4G frequency levels, all of those will require more investment.

Graph 1

Source: *Analysys Mason, Telecoms capex: worldwide trends and forecast 2017–2026*

There is a huge spending and capital expenditure on telecommunication. Telecom companies and governments spend a lot of money on the improvement of existing infrastructure with the newly updated technologies. Although all of these are done with total development of the countries and societies, and for the future of humankind, there are some

debates regarding the money spent on some further developments. For instance, billions of dollars have been spent on 5G Spectrum Licences and their infrastructures with equipment and hardware. Although it brings its own ecosystem with new economic environment, there is an ongoing debate whether these investments are useful for further development of humanity. Instead of these huge investments, would it be better to invest in education, health, medicine, transportation, etc. Is there any effect of further investment on technology? Wouldn't be our existing technology sufficient for us?

Information and communication technology (ICT) investments have grown substantially in both developed and developing countries starting through the end of 1990s. The development of ICT has also quickened up the pace of economic growth and also contributed to the country GDP. The increase in the production of smartphones with the improvements in the use of mobile broadband, the requirement of investment in fiber infrastructure due to the increase in the requirement of higher fixed broadband speeds, the use of Internet-of-Things almost everywhere in the industrial production, the invention of smart-cars, smart-buildings, smart-homes, smart-education, all of these have brought the requirement of new investment, new technology with also the requirement of more infrastructure investment with higher R&D spending.

The ICTs do not only effective on economic growth but also human development both in developed and developing countries (Iqbal and Hassan, 2019). Human development index can be considered to be used in order understand the nature of development and its indicators. Human Development Index (HDI) is a nice tool developed by the United Nations to measure and rank countries' levels of social and economic development. It was constituted in 1990 by the United Nations Development Program (UNDP) to evaluate people's capabilities instead of the economic resources in a territory. It has three dimensions:

health, education and economic dimension. The health dimension focuses on whether a population has a long and healthy life. Education signifies their being knowledgeable, and the economic dimension is directly related to their ability to lead a decent human life. The resulting indicator is the average value of these three parameters.[2] The final ultimate is for human development to be ultimately more equitable and sustainable.

To understand this, the study aims to utilize cross-sectional data for 20 countries between 2003 and 2022.

2. Literature Review

There have been various researches in the ICT development, the effect of technology on growth with a focus of mobile communication and broadband development. However, there is a limited research analyzing the impact of information and communication technology on human development. The role of ICTs on human development and their importance for long-term economic growth (Hou et al. 2015; Ogundari and Awokuse 2018) have been studied by many researchers.

Iqbal and Hassan (2019) examines the role of ICT and economic growth on human development for five selected South Asian countries over 1990-2016 through mobile phone and internet penetration. Asongu and Nwachukwu (2018) use 49 sub-Saharan African countries' data and finds a positive marginal effect between ICTs and education quality through e-education. Although ICTs raise capital efficiency and promote sustainable economic growth (Gupta et al., 2019), researchers do not agree on how deeply ICTs penetrate the social development of the world's population (Ferrer, 2009).

[2] https://hdr.undp.org/data-center/human-development-index

Hettiarachchi (2019) claims that ICTs contribute to human development when they are used effectively with the promotion of governmental policies, active participation of population. Ngwenyama et al. (2006) investigate the effects of ICT investments on human development, find a positive relationship between ICT and human development. Westerlund and Edgerton (2007) find a positive impact of Internet usage and mobile cellular subscription on human development at the country and panel level. Asoungu and Le Roux (2017) investigated the effect ICT on human development in Sub-Saharan Africa, i.e., developing countries, and find that policies to increase ICT levels are also effective on human development.

3. Data

The data is carried out for the analysis of comparing 10 Western European countries and 10 Central Eastern European countries, and the USA to compare with them for an overall analysis and extensive evaluation.

The GSMA Intelligence: Data is extracted for telecommunication metrics and penetration levels via the following link: https://www.gsmaintelligence.com/.

World Bank, World Development Indicators Database: The data on economic growth, mobile, internet, fixed broadband, investment, and labor force is obtained from this database.

A cross-country analysis is aimed to be conducted by using the data mentioned above by also evaluating the Central Eastern European and Western European countries separately. The Western European countries include Austria, Belgium, Denmark, France, Germany, Italy, Spain, Sweden, Finland, and Norway. The Central Eastern European countries include Bulgaria, Poland, Ukraine, Lithuania, Romania, Slovakia, Slovenia, Croatia, Estonia, and

Latvia. For a healthy comparison and analysis of the data, the USA was also used to compare these countries with a high-tech dependent country which is one of the ICT-leading democratic countries in the world, however also have a different mindset from the EU countries.

The Human Development Index data was provided from the United Nations Development Programme.[3] The GDP per capita and GDP growth rates, population numbers are collected from the World Bank database.

Python programing language was used to conduct data analysis and to summarize the results. All of these models and specifications were determined by using the Python.

4. Descriptive Statistics

The following table is presented in order to give a summary regarding the data used in this analysis. The data is classified as the Western European and Eastern European countries and compared with the USA as shown in the table. The related data is presented as the mean of the related cluster for the regarding year. According to the table, it can be stated that Western European countries spend four times higher in capital per capita compared with the Eastern European countries. Based on these higher expenditures, we can see higher fixed broadband penetration levels in the USA. The Eastern European countries have lower fixed broadband penetration levels compared with the Western European countries. The table also indicates that having higher fixed broadband penetration levels and GDP per capita levels, Western European countries have higher human development index compared with the Eastern European countries. However, to compare with the USA, although the USA has much higher telecom capital expenditure per capita compared with the Western European

[3] https://hdr.undp.org/data-center/human-development-index#/indicies/HDI

countries as seen below (almost 2.5 times higher), the USA and the Western European countries have similar Human Development Index in years, there is no much difference among them. This could be a significant indicator of a very hot debate. Even though the USA spends higher money per their citizens on infrastructure compared with the Western European countries, it has similar outcome in the development index, same output levels in terms of human development, education, well-being, knowledge, and life-quality. This is mainly due to the inequalities in the services provided each citizen in the USA compared to the Western Europe. European citizens receive more equal services, equal income distribution compared with the USA. Blanchet et al. (2022) states that Europe has been much more successful than the United States at ensuring that its low-income groups benefit from relatively good-paying jobs. They claim that redistribution in the Western Europe is critical to explain why Europe is less unequal than the United States, it contributes to reducing the inequality gap among the regions.

		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Fixed-Mobile Capital Expenditure per Capita	WE	116	141	116	138	124	135	142	146	134	179	142
	CEE	31	51	43	41	47	46	47	48	43	49	39
	USA	372	377	360	442	367	383	404	391	293	650	355
The Share of Capital Expenditure in GDP	WE	0,2%	0,3%	0,2%	0,3%	0,3%	0,3%	0,3%	0,3%	0,3%	0,3%	0,3%
	CEE	0,2%	0,4%	0,3%	0,3%	0,4%	0,3%	0,3%	0,3%	0,3%	0,3%	0,2%
	USA	0,7%	0,7%	0,7%	0,8%	0,6%	0,6%	0,6%	0,6%	0,5%	0,9%	0,5%
GDP growth (annual %)	WE	-0,3	0,0	1,3	2,0	2,0	2,5	1,6	1,5	-5,2	5,5	3,2
	CEE	1,5	0,7	1,2	1,9	2,8	4,3	4,1	3,4	-3,4	7,2	0,0
	USA	2,3	1,8	2,3	2,7	1,7	2,2	2,9	2,3	-2,8	5,9	1,9
GDP per capita (current US$)	WE	47.605	49.388	49.465	42.432	42.847	45.017	47.905	46.516	45.216	51.856	52.027
	CEE	13.258	14.048	14.475	12.557	13.000	14.327	16.141	16.366	16.422	19.168	19.634
	USA	51.784	53.291	55.124	56.763	57.867	59.908	62.823	65.120	63.529	70.219	76.330
fixed broadband – household penetration	WE	63%	65%	68%	71%	74%	77%	79%	81%	84%	86%	87%
	CEE	46%	49%	51%	53%	56%	58%	61%	62%	65%	68%	71%
	USA	70%	72%	73%	76%	77%	79%	80%	83%	86%	90%	94%
mobile - total	WE	134%	134%	132%	133%	132%	130%	130%	129%	129%	131%	132%
	CEE	126%	127%	128%	129%	129%	129%	129%	131%	130%	133%	135%
	USA	98%	101%	104%	108%	110%	110%	111%	113%	115%	119%	122%
Human Development Index	WE	90%	90%	90%	92%	92%	92%	93%	93%	93%	93%	93%
	CEE	83%	83%	83%	85%	85%	85%	86%	86%	85%	85%	86%
	USA	91%	91%	91%	92%	92%	92%	93%	93%	92%	92%	93%

5. Econometric Model and Specification

In order to make the analysis in Python, I would like to use linear regression methods which are OLS, Ridge, and Lasso. I will provide their results by comparing with their ultimate outcomes.

First, it is aimed to understand whether there is a relationship between fixed and mobile telecommunication spending, broadband penetration, mobile subscriber penetration, gdp per capita, and annual gdp growth rate have correlation with the Human Development Index, and how is their relationship between them, in what extent do these variables explain the effect on HDI?

The following equation is used:

$$HDI_{i,t} = \beta_0 + \beta_1 GDPpercapita_{i.t} + \beta_2 GDPgrowth_{i.t} + \beta_3 Telecomspending_{i,t} + \beta_4 FixedHHPenetration_{i,t} + \beta_5 MobilePenetration_{i,t} + \varepsilon_{i,t}$$

(Eq. 1)

Here, GDPpercapita denotes for GDP per capita, Telecomspending indicates total Telecommunication spending on Mobile and Fixed Capital Expenditure, FixedHHPenetration is calculated by dividing the total number of Fixed Broadband subscribers with the number of Households in order to find the number of fixed broadband connection per total number of households. Mobile penetration provides us the percentage of the mobile connection per population who are at least 9 years old. As mobile devices are widely used by those older than 9 years old, mobile penetration rates excluding the population between 0-9 years old. HDI is the dependent variable presenting the Human Development Index score of a country i in a given period of time t.

In order to understand the nature of the data, following tables are deducted. First, by using the Python matplotlib, the following tables are obtained for comparison purposes for these 20 countries below. On the following tables, it can be seen that there is a positive relation between GDP per capita and Human Development Index. It may be clearly identified, there is a somehow positive correlation between fixed broadband penetration and Human Development Index on Figure 1. Note that each color in figures corresponds a country and the data span is 11 years. Thus, there are 11 same colored-dot in figures for separate years, and it can be clearly visible to understand the behavior pattern of the data.

As we have suggested above, figures indicate that fixed broadband penetration is a strong indicator of human development as a tool of education, knowledge, communication among the humans, the fixed broadband speed and its rank among the countries indicate a country's development index, and shows service quality it may provide its own citizens in order to increase their knowledge, and make them know the outside world better.

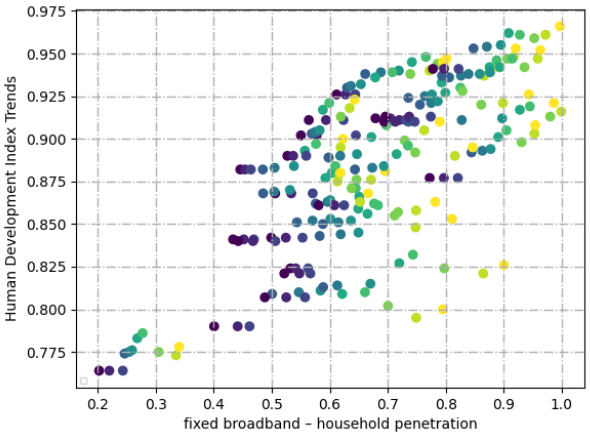

Figure 1. Fixed Broad. and House Pen. vs. HDI

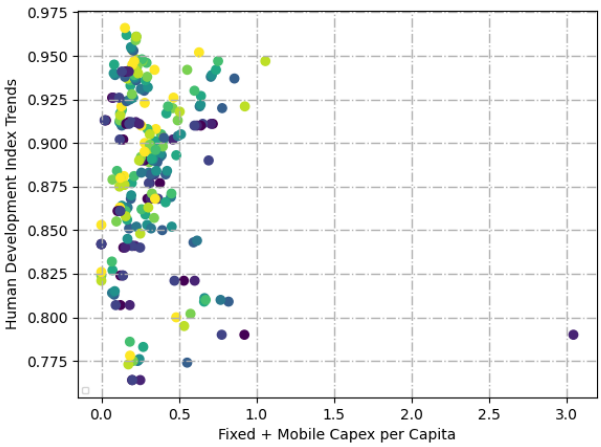

Figure 2. Fixed and Mob. Cap. vs. HDI

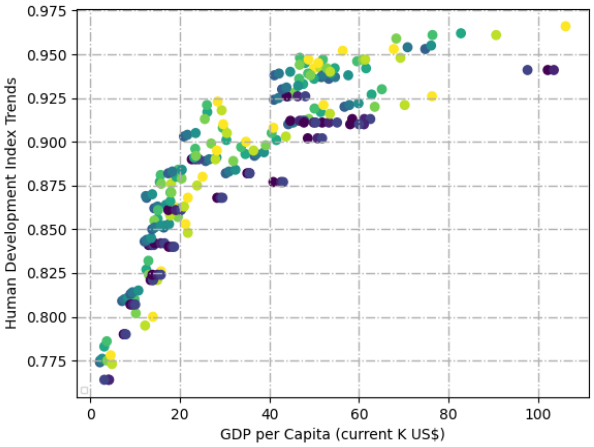

Figure 3. GDP p. Capita vs. HDI

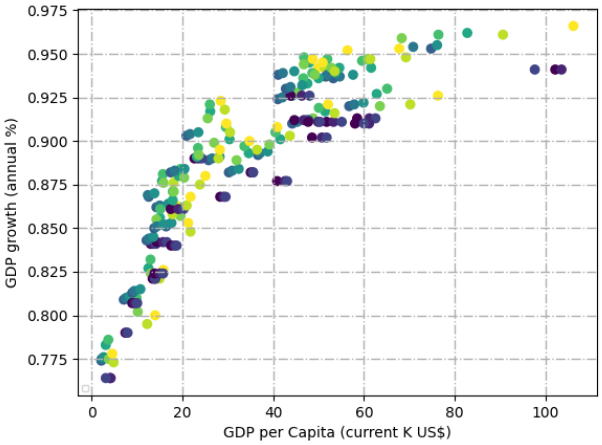

Figure 4. GDP p. Capita vs. GDP

Fixed and mobile capital expenditure ratio to GDP doesn't have a visible direct correlation to HDI for the same year (Figure 2). It is important to indicate that expenditures have delayed effect on economic status which would have effect an indirect effect.

GDP has a direct effect on HDI as expected which is also visible on Figure 3 and also on GDP growth on Figure 4.

6. Results

I used the Python **scikit-learn** (https://scikit-learn.org/) tool box to analyze the data and create regression models. In first analysis the output of the regression is considered as HDI as in Eq. 1.

The results for linear regression with ordinary least squares(OLS) and ridge are as follows:

Regression Score:0.7568427907741169
Regression Coefficients:[0.00071105 0.0015379 0.06941484 0.01524676 -0.00781812]
Regression Root Mean Squared Error: 0.0025274755360352444

Ridge Score:0.7567622834997213
Ridge Coefficients:[0.0007295 0.00155141 0.06681344 0.01470496 -0.00779999]
Ridge Root Mean Squared Error: 0.024518732382942016

The OLS method is sufficiently accurate as visible in comparison of the target and prediction of two separate points.

target:[0.911, 0.92] , **reg_pred:**[0.91412788 0.91827009]

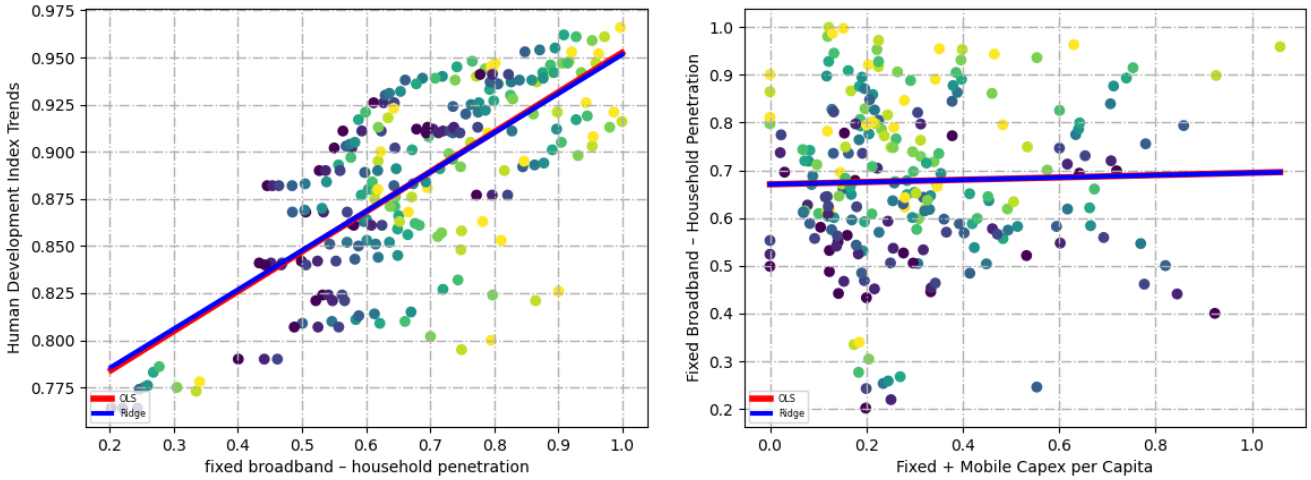

Figure 5. Two different relations and Linear Regression lines with two different approach.

The coefficient of determination, R^2, measuring how well a statistical model predicts the outcome is very high all of these methods here. Both Ridge and OLS give higher than 0.756 score, Root Mean Squared Error (RMSE) of OLS is a lot smaller than Ridge (0.00252 vs 0.02451). The RMSE is a performance indicator for a regression model measuring the average difference between values predicted by a model and the actual values. It provides an estimation of how well the model is predicting the target value. In Fig.5 two cross relation of the features are investigated with linear regression methods. The linear regression is giving us an average approach but every country has their own dynamics.

Following the analysis of the data, the goal of this study is established as to create a model/method to determine how much a state should invest in telecom as Mobile and Fixed Capital Expenditure ratio with GDP (%) with the current conditions of GDPpercapita, GDPgrowth, FixedHHPenetration, MobilePenetration to achieve a desired Human Development Index.

Linear regression equation is changed to Eq. 2 where the output is Fixed Capital Expenditure ratio with GDP (%)

$$Telecomspending_{i,t} = \beta_0 + \beta_1 GDPgrowth_{i.t} + \beta_2 GDPpercapita_{i.t} + \beta_3 FixedHHPenetration_{i,t} + \beta_4 MobilePenetration_{i,t} + \beta_5 HDI_{i,t} \quad (2)$$

I aim to understand whether there is a relationship to see how much we need to spend telecommunication spending to reach a specific HDI level with current economical and infrastructural status.

First method is ordinary linear regression with the following results:

Regression Score: -0.00491
Regression Coefficients: [-4.91577995e-04, 1.92534775e-03, -5.36267985e-02, -2.18094629e-01, -5.27313271e-01]
Regression Root Mean Squared Error: 0.34484071370623853

Two target points are selected as **target**: [0.653687591, 0.779139196] and prediction achieved a quite unsuccessful result **reg_pred**: [0.38400333, 0.37281342]

Second method is Ridge regression which resulted with slightly better score but testing revealed similar results.

Ridge Score: -0.00155
Ridge Coefficients: [-0.00070525, 0.00145891, -0.06806255, -0.21658321, -0.25161631]
Ridge Root Mean Squared Error: 0.1786059014275109

Same two target points are selected as **target**: [0.653687591, 0.779139196]

and prediction achieved a better result **ridge_pred**: [0.38031437, 0.37044531]

Linear methods resulted worse in reverse problem of finding necessary Fixed Capital Expenditure ratio with GDP (%). Thus, KernelRidge Support Vector Regression is also applied to achieve a more inclusive estimation method. A third degree polynomial kernel is

used and the score= -0.019384 is attained. The two-point random test set is elected. The same target is set, **target**: [0.653687591, 0.779139196], and **kr_pred**: [0.55079372, 0.49427157] is reached.

7. Conclusion

This study indicates that there is a positive relationship between telecom spending, fixed broadband penetration and Human Development Index. Our findings are consistent with the literature and suggest that countries can gain benefits from ICTs to improve their human development. Therefore, it can be concluded that with an increase in spending in telecom and provide same service almost everywhere in the world with an equal opportunity, global human development index can be also increased to further levels.

This analysis may be extended to all countries in the world with a wider set of features. Most probably linear regression would not be enough with those features and Support Vector Regression would be the method of choice. A better nonlinear regression method with different kernels and parameters may be investigated. Clustering might be also done to group the countries for different methods of investments. In addition to the independent variables discussed in this study, broadband average speed is also a significant indicator as a development index. Based on the high relationship between HDI and telecom accessibility, further studies can be conducted to understand the possible welfare of Starlink which has the claim to increase the broadband penetration with the equal service offering almost everywhere around the world. The further impacts of this initiative can be considered with this perspective with further researches.

To summarize, I have tried to do my best in this project. However, as a Social Science student, I am totally aware that I have to spend much more time on Python to develop my

code writing skills. Thank you very much for all your efforts and materials that you have provided us.

8. References

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