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SPECIAL ISSUE: ICT AND SOCIAL CHALLENGES

DOES INFORMATION AND COMMUNICATION TECHNOLOGY LEAD TO THE WELL-BEING OF NATIONS? A COUNTRY-LEVEL EMPIRICAL INVESTIGATION

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Appendix A

Overview of the Well-Being Metric

Background

The idea of well-being was first mentioned by philosophers, such as Aristotle, who discussed this in Nicomachean and Eudemian ethics. Aristotle (along with other Greek philosophers) pointed out a consensus on the fact that the attainment of *eudemonia*, or well-being, is central to people's endeavors.

Since then, there has been a rich history of philosophers who argued that the attainment of well-being is what drives human endeavor. John Stuart Mill argued that happiness is a central good and other utilitarians have built theories based on the idea of the maximization of subjective well-being (Diener et al. 1998). Economists, particularly from the neoclassical school, have argued that it is the pursuit of utility that drives human endeavor, although there are a number of issues with the measurement of utility. Ideas of the attainment of well-being can also be found in Csikszentmihalyi (1975) who argued that individuals feel the happiest when they are challenged at their level of skill and then enter a state of mind called "flow."

In modern research, the study of the antecedents and consequences of the attainment of well-being has been looked at by a number of different researchers. Dolan et al. (2008), Frey and Stutzer (2002), and Diener et al. (1999) review the extensive well-being literature, which has used an empirical framework to assess the antecedents and consequences of the attainment of well-being by individuals, groups, and societies. Rather than relying on philosophical arguments for the attainment of well-being, the majority of these studies have used empirical data to support their arguments.

Overall, the idea of the attainment of well-being by man goes back to the time of the Greek philosophers and the study of this has continued through the centuries. In the last few decades, there has been a large body of research that has examined well-being in the psychology and economics literatures. However, although research in other disciplines into the study of well-being has been thriving, it has received limited attention by IS researchers. We hope that, as the attainment of well-being is also central to IS research, given the potential role of ICT, IS scholars will seek to explore how the adoption and use of ICT could play a part in the attainment of well-being. The next section describes what the subjective well-being measure seeks to capture. The third section of this appendix expands on the scales that can be used to measure the level of well-being.

Section 2: What Does Well-Being Capture?

Subjective well-being refers to all the evaluations (both positive and negative) that people make about their lives (Diener 2006). The term refers to a category of phenomenon that includes peoples' emotional responses, domain satisfactions, and global judgments about life satisfaction (Diener et al. 1999). Additionally, although these different terms may denote different aspects, they often correlate significantly and hence are often studied under the umbrella term of *well-being*.

The term *subjective well-being* is often referred to simply as well-being to restrict the negative implication that the term *subjective* may carry. Although the term implies that the level of well-being represents a measure that is not objective, there have been a number of methods that have been used to assess the validity of the measure of well-being.

On the other hand, the term *happiness* is usually used to represent the positive feelings that an individual may experience. However, happiness can mean a number of different things to different people with interpretations of the term referring to a global evaluation of life satisfaction, the causes that make people happy, if they are living a good life (with the manner in which the term happiness is used being useful to understand the context). Hence, scholars tend to avoid using the term happiness, and instead focus on using the term well-being. Nonetheless, it is important to note that well-being or subjective well-being is colloquially referred to as happiness (Diener 2006).

Additionally, studies have found that the correlation between well-being that respondents report in social situations and when left alone is correlated to 0.92 (Diener et al. 2009), their level of well-being at work is correlated with the level of well-being when at home to 0.74, and Magnus and Diener (1991) found that, across a 4-year time period, the level of life satisfaction measure was correlated to 0.58. These studies show that there is an inherent factor that the measure of well-being captures. This has lead researchers to identify traits that would make some people naturally happy and some naturally unhappy. One study examined twins to assess if this difference in the level of happiness is genetic, or if it is due to the environment and life situations. Tellegen et al. (1988) assessed twins that were reared apart and those that were reared together and found that between 40 and 50 percent of variation in the level of happiness could be explained by genetic variations. The remaining differences could be due to environmental factors.

Section 3: Scales to Measure Well-Being

There are a number of scales to measure the level of well-being. Although individual researchers may prefer different scales, these have been shown to have a high degree of correlation between the results that different scales provide. Broadly there are two classes of scales. One class is sets of scales that are single-item measures scales, which include the Cantril Scale used in this study. The other class of scales includes a multi-item scale that includes the satisfaction with life scale. Overall, there are more than 10 scales that have been used to measure the level of well-being. Some of these are summarized below.

Cantril Scale: The Cantril scale (Cantril 1965) has been used to measure the level of well-being by asking respondents to image a ladder with one end of the ladder representing a "best life for you" and the other end representing the "worst life for you." The respondent is then asked to identify where on the ladder they would stand. Although the initial scale used 11 steps, the ladder is occasionally described with nine or sometimes ten steps. The scale was proposed by Henry Cantril and has found success with the results being "theoretically convincing and politically interesting" (Glatzer and Gulyas 2014, p. 510). In a study of the Cantril scale, researchers found that people in two developed countries (the Untied States and Germany) perceived their position on the scale above the half way mark and people in two developing countries (India and Nigeria) perceive themselves to be below the half-way mark. However, in general, people perceive their future expectations to be higher than their current state (Glatzer and Gulyas 2014).

Satisfaction with Life Scale: The satisfaction with life scale was proposed by Diener et al. (1985) and focuses exclusively on measuring life satisfaction as a measure of people's overall assessment of their satisfaction with their lives. The five items that respondents have to answer are: In most ways my life is close to my ideal; The conditionals of my life are excellent; I am satisfied with my life, so far I have gotten the important things I want in my life; If I could live my life over, I would change almost nothing. Pavot et al. (1991) use a seven-point scale for the different items on the satisfaction with life scale.

Other single item scales to measure the level of well-being include the D-T scale, which asks about how happy you are, the Fordyce scale which is based upon how happy or unhappy you feel, another scale that was proposed by Fordyce that asks the respondents about the percentage of the time that they feel happy and the percentage of the time they feel unhappy, and a scale that was proposed by Gurin et al. (1960) that asks respondents to assess how they feel they are these days and select if they are "very happy," "pretty happy," or "not too happy." Multi-item scales to measure the level of well-being include one proposed by Bradburn and Caplovitz (1965) that uses a 10-item scale that yields a positive affect score and a negative affect score. Campbell et al. (1976) used an eight-item scale to assess the level of life for a respondent along a number of different dimensions. In a review of the literature, Dolan et al. (2008) found that the majority of data sets that measure the level of well-being use one (and sometimes two) single-item measures.

A limited set of studies have compared the different scales. Diener et al. (1985) assessed the correlation between the satisfaction with life scale and other scales and found moderately strong correlations between the scale being assessed and other subjective well-being scales. Pavot et al. (1991) examined issues surrounding the satisfaction with life scale (SWLS) and found that the there is "considerable evidence for the reliability, unitary structure and convergent validity of the SWLS scale" (p. 158).

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Appendix B

Additional Analyses

Table B1. Descriptive Statistics

	Observations	Mean	St Deviation	Min	Max
Proportion of population thriving	717	.2739	.2005	0.01	0.83
Number of telephone lines (Per 100 people)	717	20.6086	18.5749	.0449	67.2403
Number of mobile phones (Per 100 people)	717	88.6790	41.5098	3.2522	214.75
Number of internet users (Per 100 people)	717	36.1625	29.8041	0	96.9993
Total ICT	717	145.45	79.8017	3.4997	292.28
Expenditure side real GDP (per capita) PPP adjusted (in '000s)	717	13.7029	14.3854	.2456	81.6825
Health	717	1.7797	.1993	1.24	2.29
Gini	717	38.7160	9.2336	18.9833	67.4
Primary School Enrollment	717	104.7043	13.0878	50.6276	164.8584
Importance of Religion	717	.6830	.2703	0.11	1.2
Volunteered Time	717	.2107	0 .1104	0	0.52
Quality of Air and Water	717	1.4602	.2476	0.51	1.9
GFCF (% of GDP)	717	23.8692	7.2046	1.6197	63.9402

Primary school enrollment can exceed 100% due to over-enrollment (of over aged and under aged children).

Table B2. Control Variables

Metric	Control Variable	Literature	Data Source	Question Asked
Income	GDP PPP	Easterlin (1974)	Penn World Tables	Expenditure Side Real GDP at chained PPPs (in million 2005 USD)/Population in Millions
Education	Primary school enrollment	Blanchflower and Oswald (2004)	World Bank	School enrollment, primary (% gross)
Inequality	Gini	Fahey and Smyth (2004)	World Bank	
Health	Health	Shields and Price (2005)	Gallup Database	• In the area you live, are you satisfied or dissatisfied with the availability of quality healthcare • Did you experience physical pain yesterday • Did you feel well-rested yesterday • Do you have any health problems that prevent you from doing anything that people your age normally do?
Importance of Religion	Importance of Religion	Helliwell (2006)	Gallup Database	Is religion an important part of your daily life?
Volunteered Time	Volunteered Time	Greenfield and Marks (2004)	Gallup Database	Have you volunteered in the last month?
Quality of Air & Water	Quality of Air and Water	Welsch (2002)	Gallup Database	Are you satisfied with the quality of air and the quality of water?
GFCF	Gross capital formation (% of GDP)		World Bank	

Table B3. List of All Countries in Our Sample

Angola	Central African Republic	Germany	Liberia	Niger	Sri Lanka
Argentina	Chad	Ghana	Lithuania	Nigeria	Swaziland
Armenia	Chile	Greece	Luxembourg	Norway	Sweden
Australia	China	Guatemala	Madagascar	Pakistan	Switzerland
Austria	Colombia	Guinea	Malawi	Panama	Tajikistan
Azerbaijan	Comoros	Honduras	Mali	Paraguay	Tanzania
Bangladesh	Costa Rica	Hungary	Mauritania	Peru	Thailand
Belgium	Croatia	India	Mexico	Philippines	Togo
Belize	Czech Republic	Indonesia	Moldova	Portugal	Tunisia
Benin	Denmark	Ireland	Mongolia	Romania	Turkey
Botswana	Dominican Republic	Israel	Montenegro	Rwanda	Uganda
Bulgaria	Ecuador	Italy	Morocco	Senegal	United Kingdom
Burkina Faso	El Salvador	Japan	Mozambique	Serbia	Uruguay
Burundi	Estonia	Jordan	Namibia	Sierra Leone	Uzbekistan
Cambodia	Finland	Kazakhstan	Nepal	Slovenia	Vietnam
Cameroon	France	Kenya	Netherlands	South Africa	
Canada	Gabon	Latvia	New Zealand	Spain	

Table B4. List of High-Income Countries

Australia	Croatia	France	Italy	Netherlands	Spain
Austria	Czech Republic	Germany	Japan	New Zealand	Sweden
Belgium	Denmark	Greece	Latvia	Norway	Switzerland
Canada	Estonia	Ireland	Lithuania	Portugal	United Kingdom
Chile	Finland	Israel	Luxembourg	Slovenia	Uruguay

Table B5. Countries in Layer 1

Angola	Colombia	India	Nepal	Senegal	Uganda
Armenia	Comoros	Jordan	Niger	Serbia	Uzbekistan
Azerbaijan	Congo, Dem. Rep.	Kenya	Nigeria	Slovak Republic	
Bangladesh	Costa Rica	Lithuania	Pakistan	South Africa	
Burkina Faso	Czech Republic	Madagascar	Panama	Sri Lanka	
Cameroon	Dominican Republic	Malawi	Paraguay	Tajikistan	
Chad	Finland	Mexico	Philippines	Tanzania	
Chile	Guinea	Moldova	Romania	Tunisia	
China	Honduras	Morocco	Rwanda	Turkey	

Table B6. Countries in Layer 2

Benin	El Salvador	Indonesia	Peru
Botswana	Gabon	Mali	Thailand
Cambodia	Ghana	Mauritania	Vietnam
Ecuador	Guatemala	Mongolia	

Table B7. Countries in Layer 3

Argentina	Estonia	Japan	Portugal
Australia	France	Kazakhstan	Slovenia
Austria	Germany	Latvia	Spain
Belgium	Greece	Luxembourg	Sweden
Bulgaria	Hungary	Montenegro	Switzerland
Canada	Ireland	Netherlands	United Kingdom
Croatia	Israel	New Zealand	United States
Denmark	Italy	Norway	Uruguay

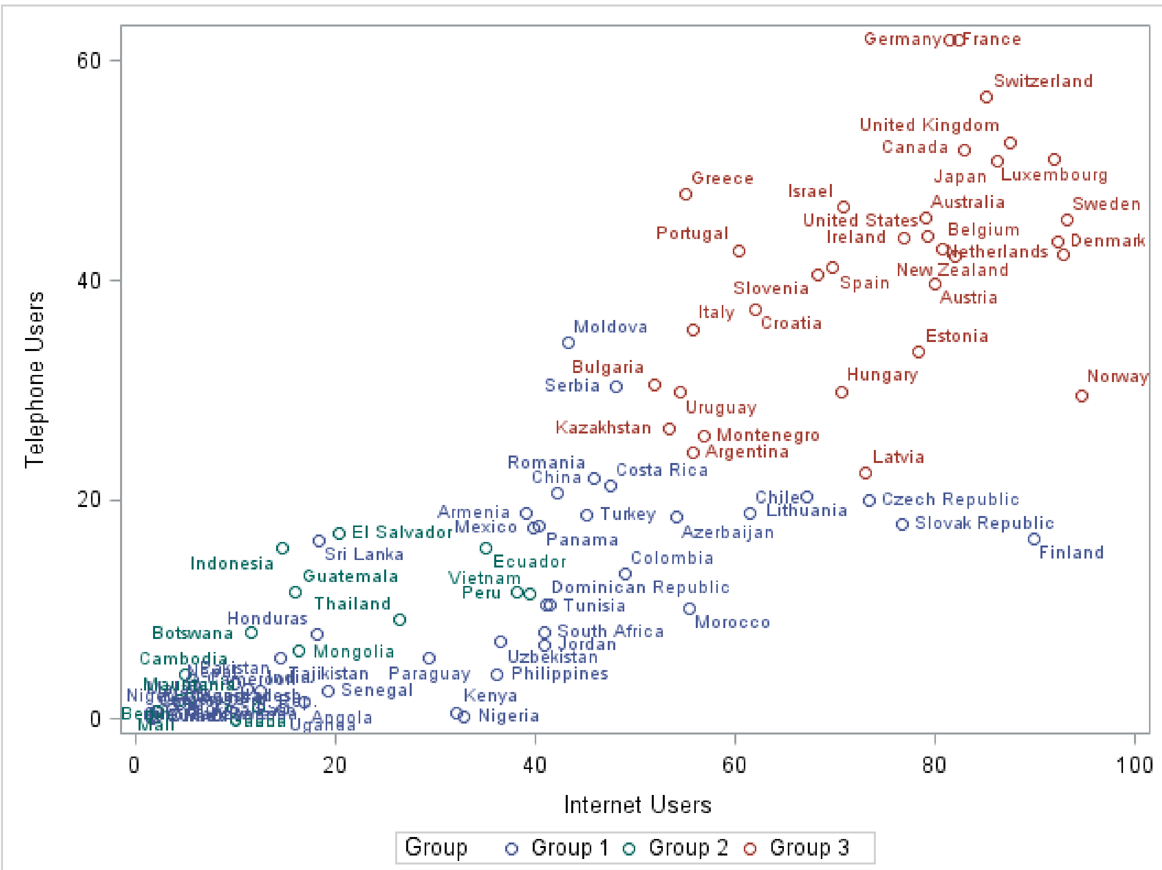

Figure B1. Groupings of Countries and Variables in Different Layers

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Appendix C

Instrumental Variable Analysis

In order to examine the effect that the level of ICT has on the level of a country's well-being, we performed an instrumental variable analysis to control for possible endogeneity that is driving both the level of ICT in a country and the level of well-being in that country.

To control for an endogenous factor that may be driving the results, we use an instrumental variable that is correlated with the dependent variable, but not correlated with the independent variable apart from through the possible correlation between x and y. For example, "cost-shifters" (Nevo 2000), characteristics of competing products and characteristics of different products manufactured by the same firm (Berry et al. 1995) can be used as possible instrumental variables. In this study, we made use of an instrument that is similar to the cost-shifter approach.

One factor that has caught the attention of researchers in recent years is the average slope of the terrain. Researchers have argued that the slope of the terrain is correlated with the cost in rolling out broadband Internet (Kolko 2012), in addition to traditional fixed-line telephones and towers for mobile phones. There is perhaps no driving factor behind the slope of the terrain and its corresponding relationship with the level of ICT in a country. We use this variable as an instrument to control for the ease in providing ICT services to citizens.

One drawback of using the slope of the terrain is that the instrument in static in nature as opposed to the longitudinal panel structure of our data. To overcome this, we used two instruments. The first instrument, provided by Nunn and Puga (2012), is cross-sectional in nature and is the slope of the terrain weighted by the country's population. This is computed by calculating the Terrain Ruggedness Index for a country and weighting it by the proportion of the country's population that lives in that area. In addition, to overcome the static nature of the instrumental variable, we multiplied the slope of the terrain with the population density of the country. Since we have information on the population density across the panel for our data, we are able to construct a dynamic instrument to use with our panel data. The advantage of using such a dynamic instrumental variable is the ability to control for endogeneity that may be present in the analysis.

Additional Instrumental Variable Analysis

The tables presented below provide detailed test results for the instrumental variable analysis already presented in Table 2, Panel A in the main text of the paper. Specifically, we conducted tests for overidentification, underidentification, weakness of the instrument, and the endogenity of the instrument using a number of statistical tests. However, due to the upper bound of the number of countries that we were able to include in the analysis, we are limited by the sample size that we are able to have for these tests. The exogeneity test was not conducted for the panel data due to clustering of errors that was done for the model.

The results that have been provided in Table 2, Panel A (and the corresponding tests that have been provided in Table C1) are for a larger set of countries than have been included in Table 1. However, we document that our results (as shown in Table C2 and C3) are robust to the smaller set of countries presented in Table B3.

Table C1. Additional Tests for Instrumental Variable

	2011	2012	Complete Data Set
Correlation with ICT - First Stage test	Supported	Supported	Supported
p-value	.000	.000	.000
Underidentification (Kleibergen-Paap rk LM statistic)	Supported	Not Supported	Not supported
p-value	0.031	.1140	.1474
Weak IV (Cragg Donald F Statistic)	Partially Supported (maximal size: 20-25%)	Not Supported (Maximal size greater than 25%)	Supported (Close to 10%)
Exogenous to well-being (Wu-Hausman test)	Variable is Exogenous	Variable is Exogenous	
p-value	.7928	.3627	

Table C2. Instrumental Variable Regression

Year	2011	2012	Complete Data Set
Total ICT	.0142***	.0203***	.0139*
	(.0046)	(.0073)	(.0077)
Constant	-3.4991***	-4.7024***	-3.2871***
	(.7110)	(1.2347)	(1.1654)
Number of Observations	94	91	699
First Stage Regression			
Instrumental Variable	30.3128**	-20.5516	-15.0497**
	(12.5978)	(15.6210)	(6.4434)
Constant	173.6306***	182.9437***	154.6849***
	(12.7280)	(13.1291)	(5.3699)
Number of Observations	94	91	699

Table C3. Additional Tests for Instrumental Variable

	2011	2012	Complete Data Set
Correlation with ICT–First Stage Test	Supported	Not statistically Supported	Supported
p-value	.000	.000	.000
Underidentification (Kleibergen-Paap rk LM statistic)	Supported	Not Supported	Not supported
p-value	0.0940	0.2970	.39
Weak IV	Not Supported	Not Supported	Not Supported
	Maximal IV size >25%	Maximal IV size > 25%	Maximal IV size > 25%
Exogenous to well-being	Variable is Exogenous	Variable is Exogenous	
p-value	.4453	.4400	

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Appendix D

Biclustering

One of the general methods that has received attention in the field of biclustering is the plaid algorithm (Lazzeroni and Owen 2002). The plaid algorithm works by attempting to fit the data in to layers (or clusters) that contain a combination of similar variables and observations to maximize the variance explained by the model. In our case, a layer would contain a collection of countries that use the three metrics of ICT (fixed line telephone, Internet, and mobile phones) in a similar manner.

The plaid algorithm adjusts the loadings onto the different layers to minimize the difference between the sum of squares between the actual data and the fitted data. In addition, the user specifies parameters that include the row release value and the column release value which are based on telling the algorithm to drop a row/column based on how heterogeneous we would like the layers to be. Additionally, the algorithm often picks up "noise" layers that have to be dropped from the model. Suppose we represent the data as

$$x_{ij} \approx \mu_0 + \sum_{k=1}^{K} \mu_k \rho_{ik} k_{jk}$$

Where x_{ij} represents the data point for the i^{th} country (i = 1, 2, …, r) with the j^{th} ICT variable (j = 1, 2, …, n). In addition, m_0 represents the expression layer or the background later and m_k represents the expression on the k^{th} layer (k = 1, 2, …, K) and ρ_{ik} and k_{jk} are indicator variables taking either the values of 0 or 1. ρ_{ik} takes the value of 1 when the i^{th} country is in the k^{th} layer and otherwise takes a value of 0 when it is not. On the other hand, k_{jk} takes a value of 1 when the j^{th} ICT variable is in the k^{th} layer (and 0 otherwise).

A more general way to represent the data point is in the form of an ANOVA expression where we have the following representation:

$$x_{ij} \approx \mu_0 + \sum_{k=1}^{K} \left(\mu_k + \alpha_{ik} + \beta_{jk}\right)\rho_{ik} k_{jk}$$

Where α_{ik} and β_{jk} represent the effect of the i^{th} row and the j^{th} column respectively and ρ_{ik} and k_{jk} continue to have their indicator variable status. Now, if we represent $\theta_{ijk} = \mu_k + \alpha_{ik} + \beta_{jk}$, the problem becomes one of minimizing the equation given below based on choosing appropriate values of ρ_{ik}, k_{jk} and θ_{ijk}. The plaid algorithm is set up without enforcing any conditions on ρ_{ik} and k_{jk}. This allows countries and variables to enter multiple rows and columns and does not restrict them to a single layer. The following equation represents the squared difference between the data point and the estimated point:

$$Q = \frac{1}{2}\sum_{i=1}^{r}\sum_{j=1}^{n}\left(x_{ij} - \theta_{ij0} - \sum_{k=1}^{k}\theta_{ijk}\rho_{ik}k_{jk}\right)^2$$

However, the method to optimize the objective function given above is not trivial. To obtain a detailed description of appropriate minimization methods, we refer interested readers to Lazzeroni and Owen (2002) for a description of the methodology. In addition, the user is required to specify row release values as well as column release values. Following the developers of the algorithm, these are specified to .51 for each. Additionally, we set conditions that the row and column coefficients had to have the same sign and shuffled four times. We then repeatedly run the algorithm to obtain layers of countries and observations. To run the software, we use the Plaid software that we obtained from the developers of the algorithm.

Reference

Lazzeroni, L., and Owen, A. 2002. "Plaid Models for Gene Expression Data," *Statistica Sinica* (12:1), pp. 61-86.

Appendix E

Role of Mediating Variables Between ICT and Well-Being

To examine whether the proposed mediating variables (social capital, social equality, health, education, commerce, and employment) do explain how and why the relationship exists, using a 2SLS model[1] in an exploratory fashion using a set of proxies for the proposed mediators, we present some initial evidence on the variables that are proposed to mediate the effect of ICT on a country's well-being. Although some of the proxies that we use to capture the mediators between the use of ICT and the level of well-being in the country may not be comprehensive, we present the analysis as initial evidence of the mechanism of how the use of ICT can affect the level of well-being. The proxies used to estimate the proposed mediating variables are presented in Table B2 in Appendix B. Figure E1 illustrates that the use of ICT increases the level of social equality in the population (measured by proxy), enhances the level of health of the population (measured by proxy), and increases the level of education (measured by tertiary education) and commerce (measured with GDP). In turn, these mediators are shown to affect the level of well-being for the country, following the literature. These findings pave the way for a theory of how and why the use of ICT shapes a nation's well-being.

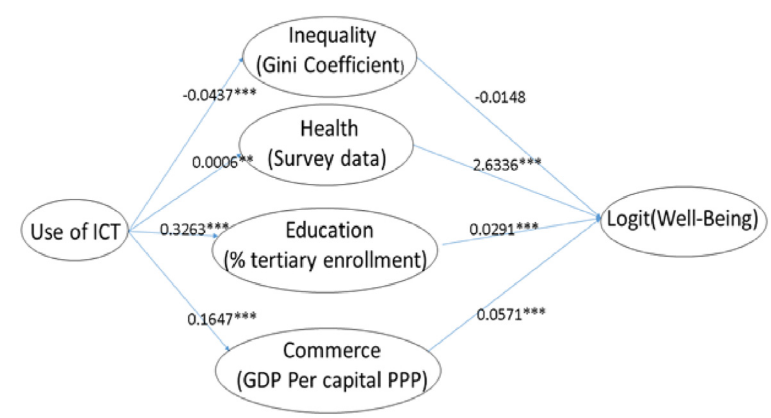

Figure E1. Proposed Mediating Variables Between ICT and Well-Being

[1]The model is a two-stage least squares (2SLS) model to control for simultaneity. The results are also robust to a seemingly unrelated regression (SUR) model (not shown for brevity).