

## DOES INFORMATION AND COMMUNICATION TECHNOLOGY LEAD TO THE WELL-BEING OF NATIONS? A COUNTRY-LEVEL EMPIRICAL INVESTIGATION<sup>1</sup>

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*This paper examines the role of information and communication technology (ICT) in enhancing the well-being of nations. Extending research on the role of ICT in the productivity of nations, we posit that the effects of ICT may not be limited to productivity (e.g., GDP), and we argue that the use of ICT can also improve the well-being of a country by helping citizens to develop their social capital and achieve social equality, enabling access to health-related information and health services, providing education to disadvantaged communities, and facilitating commerce. Using a number of empirical specifications, specifically a fixed-effects model and an instrumental variable approach, our results show that the level of ICT use (number of fixed telephones, Internet, mobile phones) in a country predict a country's well-being (despite accounting for GDP and several other control variables that also predict a country's well-being). Furthermore, by using an exploratory method (biclustering) of identifying both country-specific and ICT-specific variables simultaneously, we identify clusters of countries with similar patterns in terms of their use of ICT, and we show that not all countries increase their level of well-being by using ICT in the same manner. Interestingly, we find that less developed countries increase their level of well-being with mobile phones primarily, while more developed countries increase their level of well-being with any ICT system. Contributions and implications for enhancing the well-being of nations with ICT are discussed.*

**Keywords:** Country well-being, ICT investments, ICT policy, ICT use, ICT adoption, effects of ICT

*Everything that we choose we choose for the sake of something else—  
expect happiness which is an end.*  
—Aristotle<sup>2</sup>

### Introduction

Considerable research has focused on the effect of information and communication technology (ICT) use on the produc-

tivity of nations. Most studies have examined the role of ICT on enhancing the country's productivity, typically using a country's gross domestic product (GDP) as a metric, and they have shown that investments in ICT lead to an increase in the GDP of nations (Dedrick et al. 2011; Dewan and Kraemer 2000; Pohjola 2001; Schreyer 2000). However, the effects of ICT may not be limited to economic productivity. For example, a recent report by Deloitte (2014) for Facebook acknowledged a more comprehensive impact of ICT on both economic and social aspects of a country. The Internet allows social inclusion to groups that would otherwise would have

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<sup>2</sup>See Korsgaard (1986, p. 493).

been marginalized, facilitating the sharing of best practices in healthcare to disadvantaged communities, allowing access to education to communities that would otherwise not have had access, and facilitating commerce by allowing disadvantaged groups to access real-time market information (UNDP 2012). ICT was also shown to allow people to develop social capital that can lead to a greater sense of well-being (Bargh and McKenna 2004). Internet connectivity allowed sharing of best practices in healthcare to marginalized communities which led to a decrease in the infant mortality rates by 7 percent in developing countries (Deloitte 2014). Internet connectivity also allowed students access to learning tools that would otherwise have been difficult or even impossible. Universities are starting to offer undergraduate and graduate level classes online, often via massive open online courses (MOOCs). Research examined the effect of ICT on commerce. For example, Kumar (2004) found that the use of ICT in villages in India via eChauapals cut down on monopolistic middle men, offering competitive prices to farmers, lowering transaction costs and waste, and helping farmers benefit from a more efficient supply chain. Access to ICT has allowed a number of countries to position themselves as outsourcing hubs and offer jobs to their citizens that would otherwise not have been possible. In sum, we posit that ICT has a broader social impact on society that goes beyond productivity measures (e.g., GDP), and we seek to examine the role of ICT in the well-being of nations through a country-level empirical investigation.

The argument for moving away from a measure of the well-being of a country based purely on productivity measured by GDP is not new. For example, Robert Kennedy (1968) argued that

Our Gross National Product<sup>3</sup>...counts air pollution and cigarette advertising, and ambulances to clear our highways of carnage....It counts the destruction of the redwood and the loss of our natural wonder in chaotic sprawl....Yet the Gross National Product does not allow for the health of our children, the quality of their education or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of our public officials....It measures everything, in short, except that which makes life worthwhile.

<sup>3</sup>The difference between GDP and GNP is that GDP refers to the value of all production and services within a country defined by its geographical boundaries, and GNP refers to the value of all products and services by the nationals of a country irrespective of whether they reside in the country's boundaries.

Previous research has examined the effect of various earlier technologies on the well-being of a country. For example, Graham and Nikolova (2013) and Kavetsos and Koutroumpis (2011) studied how TV can enhance well-being. Graham and Nikolova studied technologies such as TV, while Kavetsos and Koutroumpis examined the effect of related technologies in Europe. Also, Dolan and Metcalfe (2012) studied the effect of innovation on well-being and argued that creativity and well-being are correlated. Although several studies in the economics literature have examined the effect of technologies on various metrics of well-being, to our knowledge, a country-level analysis of the impact of ICT on a nation's well-being is still an unexplored topic in the IS literature. To address this void, we examine the effect of ICT on the well-being of a nation. We specifically focus on the role of ICT in the well-established metric of the *subjective well-being* at the country level. In doing so, we argue that the effect of ICT is not limited to productivity (such as GDP), but ICT has broader effects on the well-being of the country by facilitating important aspects that help a country beyond its productivity, such as improvements in social capital, health, education, employment, and commerce.

In this paper, we seek to examine the relationship between the level of ICT in a country and the level of well-being in an exploratory fashion. Using a number of different empirical specifications, specifically a country fixed-effects model and an instrumental-variable approach, we show a link between ICT use and the well-being of a country (despite accounting for GDP). Also, using a novel biclustering methodology, we identify groups of countries that use ICT in a similar manner. We find that less developed countries increase their level of well-being primarily by using mobile phones, while more developed countries also use fixed-line telephones and the Internet to increase their level of well-being.

## Background

### Well-Being Measures

The argument for supporting the well-being of a nation is not a new idea and can be traced as far back as Aristotle (UNDP 1990). Aristotle argued for "seeing 'the difference between a good political arrangement and a bad one' in terms of its success and failures in facilitating people's ability to lead 'flourishing lives'" (UNDP 1990, p. 9). In order for countries to be able to measure if their citizens are leading flourishing lives, a number of different measures have been developed to measure the quality of life of citizens. One popular measure is the GDP of a country (Stiglitz et al. 2009). GDP is defined

as the sum of the value of all products and services produced within a country in a given period. However, GDP does not capture well-being dimensions such as quality of life, satisfaction, infant mortality, life expectancy and air quality as GDP only seeks to obtain the value of the goods produced in an economy. Although the GDP is not meant to estimate the well-being of a country, it has alas come to be widely used for measuring welfare (Kuznets 1934; Stiglitz et al. 2009). On the contrary, the destruction of forests and other natural habitats for the resources that they contain would lead to an increase in the level of GDP but would destroy the habitat and various nonmarket benefits that these habitats serve. To overcome this, different metrics have been developed in practice to estimate the well-being of citizens. For example, the United Nations Development Program (UNDP) publishes the Human Development Index (HDI), which uses various indicators across health, education, and living standards to estimate a country's well-being (e.g., UNDP 1990). Bhutan measures the gross national happiness of its citizens in addition to its GDP. In fact, the King of Bhutan, Jigme Singye Wangchuck, stated that he was more concerned about Bhutan's gross national happiness than its GDP (Mustafa 2005). Along the same lines, the Organization for Economic Co-operation and Development (OECD) has defined the *Your Better Life* index, which comprises of 11 factors, such as community, health, education, jobs, and work-life balance.

Although it was not developed by any particular nation, another metric that seeks to estimate the level of well-being of a population is the subjective well-being of a population. The term subjective well-being is colloquially referred to as "happiness" (Diener and Tov 2012). In one of the first such studies, Wilson (1967, p. 294) argued that a happy person was a "young, healthy, well-educated, well-paid, extroverted, optimistic, worry-free, religious, married person with high self-esteem." Since then, studies have shown that the vast majority of people believe happiness is important to them, and that happy people are more desirable than unhappy ones. Additionally, although there are a number of different factors that could affect a country's level of well-being, such as people's emotional responses, their global judgments, domain satisfaction, and global judgments of life satisfaction, studies have found a high degree of correlation between these metrics and the country's overall level of well-being (Diener et al. 1999).

Subjective well-being aims to capture the complete evaluations (both positive and negative) that people make about their lives. It includes cognitive evaluations, interest and engagement, and affective reactions to life events, joy, and sadness. The metric aims to be an umbrella term for the different valuations that people feel about their lives (Diener 2006).

Although it can be argued that the well-being measure is subjective in nature, the measure has been validated using a number of objective indicators.<sup>4</sup> Di Tella et al. (2003) showed countries with a higher well-being tend to have lower suicide rates. In a detailed review of the literature of the validity of self-reported measures of well-being, Diener and Tov (2012) argued that there is convergence between the well-being measure and biological measures of positive and negative states (such as hormone levels, immune system strength, cardiovascular system parameters), informant reports (family and friends who report on the happiness of the target), reaction time (how quickly happy people react to positive information about their lives), memory (happy people tend to remember more positive events from their lives than negative events), smiling (happy people smile more), and experience sampling.<sup>5</sup> Diener and Tov (2012) found that the correlations between self-reported scales and alternate measures of happiness range from modest to moderate and are almost always positive—but that the moderate size of correlations is to be expected due to the fact that the measures weigh different aspects of well-being. Accordingly, there is external validity for the subjective measure of well-being with objective indicators.

Finally, there is a reason for societies to want their citizens to be happy: happy citizens are more likely to be successful in their own lives, get and remain married, earn higher salaries, earn higher supervisor ratings at work. Also, they are reported to be more likely to trust others in their communities and to be involved in volunteer work, aspects that help contribute to a stable society (Diener and Tov 2012).

### **Literature on Antecedents of Well-Being**

Economists (particularly those from the neoclassical school) argue that people make decisions based on attempts to maximize their expected utility from the decisions they make. While it is often assumed that people are fully informed about the utility outcomes of their decisions, economists and psychologists have also argued that it is not always the utility that rationally guides a person to make decisions, but that a subjective sense of well-being may also guide the manner in which people make decisions (Dixon 1997).

<sup>4</sup>Appendix A presents a detailed review of the history, literature review, and description of the scales for well-being.

<sup>5</sup>People's responses to the level of happiness that they experience were checked over time, and were shown to be correlated with global responses to how happy they report to be.

The literature has tried to establish the effect of various factors on people's well-being. Differences in the level of subjective well-being were linked to demographics, such as age, race, income, or unemployment (Dolan et al. 2008). Studies (e.g., Blanchflower and Oswald 2004) have shown a nonlinear relationship between age and well-being, specifically that people reach their lowest level of well-being between 32 and 50 years of age (Dolan et al. 2008). It was argued that well-being is "high among those who are married, on high income, women, whites, the well-educated, the self-employed, the retired, and those looking after the home" (Oswald 1997, p. 1823). Another stream of research is the relationship between income and well-being. Studies found that within countries, wealthier people reported a higher level of well-being than poorer people, but that this effect may be significantly weaker when doing a within-country analysis (for example, Japan is not much happier than India, while Latin American countries are happier than European countries). Similarly, although the income in the United States grew dramatically between 1946 and 1978, there was no apparent change in the level of subjective well-being (Campbell 1981; Diener 1984; Easterlin 1974, 1995).<sup>6</sup> Overall, self-reported well-being is often modeled as the sum of several factors. Specifically, a person's level of well-being can be modeled empirically by an additive function (Dolan et al. 2008):

$$SWB_{it} = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \dots + \varepsilon_{it} \quad [1]$$

In Equation 1, the dependent variable, SWB (subjective well-being), is the level of self-reported well-being, and  $X$  represents the number of different covariates that predict an individual's level of well-being. These variables include social, economic, or environmental variables (besides age, income, and ethnicity). Also,  $\varepsilon$  represents individual differences that may be present in how a covariate affects the dependent variable.

In sum, the literature on subjective well-being argues that measures of utility do not always fully capture the manner in which people make decisions, and that a metric based on subjective well-being may be a more appropriate measure. Although this metric may be subjective, studies have confirmed its external validity, as reviewed above. Thus, it is important to understand the role that the actual use of ICT by a nation can have for countries to appropriately leverage ICT to increase their overall level of well-being.

<sup>6</sup>Among the numerous reviews of the factors that affect subjective well-being, readers are referred to Dolan et al. (2008), Diener (1984) and Frey and Stutzer (2002).

## Role of ICT in a Nation's Well-Being

Previous research has studied the effect of ICT on the productivity of nations. Dewan and Kraemer (2000) found that for the period 1985–1993, there was a corresponding increase in productivity (measured with GDP) of developed nations with an increase in ICT. However, the study did not find similar results for developing countries, which Dewan and Kraemer argued could perhaps be due to a lack of complementary technologies in those countries. In a follow-up study, Dedrick et al. (2011) showed an increase in productivity with investments in ICT in both developing and developed countries over the 1994–2004 period, possibly due to the availability of complementary technologies in developing countries in the more recent period. However, as noted above, the effects of the use of ICT are not limited to changes in productivity, such as GDP. ICT has a number of uses that could further increase the well-being of citizens beyond GDP, and we articulate the role of ICT in a country's well-being in terms of (1) social capital and social equality, (2) health, (3) education, and (4) commerce, as we theorize in detail below.

**Social Capital and Social Equality:** Research has argued that ICT allows individuals to develop their social capital, and that ICT increases a person's level of well-being, self-esteem, and sense of satisfaction (Bargh and McKenna 2004; Helliwell and Putnam 2004). Ellison et al. (2007) showed that a person's "Facebook intensity" (or how much a person uses Facebook) allows people to keep in touch with others who have moved away and increase their social capital. In addition, Internet connectivity can lower social inequality by allowing citizens who did not have a voice to demand their rights. Notably, ICT is increasingly being used in innovative ways to allow women to report incidents of harassment and domestic violence. For example, in the Democratic Republic of Congo, ICT is being used to collect evidence and information from women who have faced abuse and to transfer money to these women (UNDP 2012). The ability of ICT to allow citizens to report abuse, connect with loved ones and develop social capital is proposed to affect the level of well-being of citizens, albeit that would not be captured by the country's GDP.

**Health:** The ability to use ICT technologies to transfer information to disadvantaged communities can provide health information to these communities. Studies have argued that ICT can have an effect on the level of health in underdeveloped countries. Deloitte (2014) argue that providing Internet access in developing countries could reduce child mortality by 7 percent, potentially saving 50,000 children by extending information about best practices during pregnancy.

The use of telephones as health care interventions was shown to lead to increased attendance rates at clinics (O'Brien and Lazebnik 1998) and lower rates of depression (Simon et al. 2004). Other studies found that the use of telephones was a most effective method to increase immunization rates (Kaplan 2006; Szilagyi et al. 2002), thus enhancing people's health by using ICT.

**Education:** The use of ICT enables the transfer of information to communities that may not have access to education. For example, MOOCs are now allowing students to get access to materials that would otherwise be difficult. Cooper and Sahami (2013) report the case of students who do not have computer science courses at high schools being able to study for and pass advanced placement classes through online videos. MOOCs enabled a 15-year-old Mongolian boy to achieve a perfect score on the Circuits and Electronics MIT MOOC (that was tailored to college sophomores) and learn scientific techniques that are not normally taught in high schools in Mongolia (Pappano 2013). In macro-level estimates, Deloitte (2014) argued that by facilitating the transfer of knowledge, 640 million children could gain access to cost effective learning tools and educational resources as a result of extended Internet connectivity.

**Commerce:** A number of studies have also examined how ICT is changing the manner in which commerce is being enacted. Examples include the eChoupal platform in India (Kumar 2004; Upton and Fuller 2003), which gives farmers up-to-date information and connects them directly to customers and online cooperatives of traders to directly sell products to end consumers (Romero 2000). Others showed that after the introduction of ICT, growers were able to get better prices for their produce (Banker and Mitra 2007; Banker et al. 2011; Bayes 2001). These studies argued that it is possible to create an environment where producers can use ICT to get more competitive prices for their produce and improve their standard of living. Access to connectivity could lead to the creation of 140 million new jobs and lift 160 million people out of poverty (Deloitte 2014). Also, citizens of "outsourcing hubs" have the ability to trade services that are enabled by ICT (Sako 2005).

In sum, ICT allows people to communicate and increase their social capital, allows disadvantaged groups to report crimes against them to achieve social justice, transfer health information to disadvantaged groups without healthcare, allows students and teachers access to educational materials, helps eliminate inefficiencies from supply chains, and allows farmers to get better rates for their produce. Taken together, ICT use is proposed to have an impact on the overall level of well-being for the country beyond GDP.

## Data

### Well-Being

To measure the country level well-being, we used the Gallup World Poll which was conducted in more than 160 countries during 2006–2014. The target sample is the entire civilian, noninstitutionalized population of a country that is at least 15 years old. The sampling uses a probability-based mechanism and aims to be nationally representative. A standard set of core questions is used around the world, although in some areas, supplemental questions are asked about local issues. The questionnaire is translated into the major languages of each country. The interviews take place by telephone where there is telephone coverage of 80 percent the population, or where telephone surveys are the customary approach. This is the dominant methodology of performing surveys in countries such as the United States, Canada, Western Europe, Japan, Australia, and other developed countries. In less developed countries, the primary method of collecting data is face-to-face interviews. In most countries, the sample size was about 1,000.

To measure well-being, the World Poll uses a single response question based on the Cantril scale.<sup>7</sup> The scale, developed by Hardley Cantril, asks respondents to imagine a ladder with the top of the ladder representing the best possible life for them and the bottom of the ladder representing the worst possible life (Cantril 1965). The data then divides the population into three categories based on the scores obtained: percentage of the population that is thriving (that is, the percentage of the population with responses at the highest end of the Cantril scale), the percentage of the population that is struggling (percentage of the population with well-being that is moderate or inconsistent), and the percentage of the population that is suffering (that is, the percentage of the population where the level of well-being is the lowest).

Previous research has examined the effect of using the Cantril scale, reviewed in Appendix A. Notably, Diener et al. (2009) found that the use of the Cantril ladder of life scale is associated with a judgment about one's overall life situation (as opposed to a transient daily happiness level evaluation).

Although an argument can be made against the subjective well-being literature that it is a single-item construct, this is relatively standard in the subjective well-being literature.

<sup>7</sup>In a review of the literature, Dolan et al. (2008, p. 97) note "the review strategy revealed 19 major national and cross-national data sets that included measures of subjective well-being. Many of these used only one, or sometimes two, single item measures."

Additionally, the Cantril scale has a high correlation with well-being that was determined using the multi-item satisfaction of life scale (Diener et al. 1985). Additionally, the two-year reliability in the Cantril scale was found to be .65 (Palmore and Kivett 1977). Although the data has only been captured for the last five years or so, the database has been used for several peer-reviewed studies (Deaton 2008; Diener et al. 2010).

### Actual ICT Use

We matched the well-being data for nations to data on the level of actual use of ICT from the World Bank database. We restricted ourselves to data on the three major variables that capture the level of ICT: (1) *fixed telephone lines*, (2) *Internet users*, and (3) *mobile phones* (per 100 people) in a country. These variables were then aggregated to get the total level of ICT in a country. These variables were not averaged (or the highest value taken for any single variable) since the level of ICT would be substitutable across variables, that is, a country that has an extensive mobile phone penetration but a lower number of Internet users will be able to use mobile phones to carry out its communication. However, our results would not differ between aggregating and averaging these variables in our econometric specification (because the aggregate would be the average divided by three, and hence would not make a difference). The data was then merged with data on the level of well-being, while missing ICT values were imputed.<sup>8</sup>

### Control Variables

In addition, we collected data on a number of control variables. This is because that there may be a number of factors that could be correlated with the level of ICT and well-being, and thus bias our results. Table B1 in Appendix B presents the descriptive statistics. Table B2 in Appendix B overviews the control variables that are used as well as their justification on their effect on well-being from previous literature.

## Model and Results

This section outlines the econometric specifications that we have used to test the relationship between ICT use and the level of well-being in a country. Overall, our identification

strategy used fixed effects to account for country-specific variation, accounted for potential omitted variable bias with control variables, and controlled for potential endogeneity using instrumental variables. Moreover, we used a number of alternative empirical specifications to show that the results are robust to these alternative models.

**Fixed Effects Regression:** One concern that an analysis of the effect of the level of ICT can have on a country's well-being is that we are unable to control for all variables that may contribute to well-being (e.g., Dolan et al. 2008). In order to overcome this concern, we adopted a two-pronged strategy. First, we used country fixed-effects to control for all country-level variables that do not vary over time. A fixed-effects model allows us to account for country-specific time invariant characteristics that may influence the results. The second strategy was to introduce multiple control variables, such as the level of inequality in the country, education level, and religiosity (Dolan et al. 2008) in our model (Table B2 in Appendix B). This would enable us to control for factors that vary over time and whose effect has been observed in the literature. A fixed-effects model that consists of introducing time invariant dummies into the model can control for country level effects that we may not be able to observe. This representation of the model allows for controlling factors that stay constant and may influence the results. This model is as follows:

$$y_{ij} = \beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \vartheta_i + \gamma_j + \varepsilon_{ij} \quad [2]$$

In the above model,  $y_{ij}$  represents the level of well-being of a country  $i$  in year  $j$ .  $x_{1ij}$  represents the use of the total ICT and  $x_{2ij}$  represents the GDP PPP (per capita) of country  $i$  at time  $j$ .  $\vartheta_i$  are time invariant country fixed-effects that are used to capture unobserved country-specific effects whereas  $\gamma_j$  are year fixed-effects that are used to capture time invariant fixed-effects. Since the dependent variable is a proportion, its values are bounded by 0 and 1. Therefore, we use a logit transformation of the percentage of population that is thriving.<sup>9</sup> Table 1 shows that under a number of different specifications, the level of total ICT has a positive effect on the percentage of the population in a country that is thriving.

To interpret the coefficient of Model 4, we took the exponential of the coefficient to get an effect size of .0029. This indicates that when a representative member of a country adopts any of the three ICT metrics, the proportion of the population that is thriving increases by 0.29 percent. This implies that, on average, the adoption of ICT by individuals has notable effects on the well-being of a population.

<sup>8</sup>Our results are robust to dropping the observations that have missing data.

<sup>9</sup>The regressed value is  $\log(p/(1-p))$  where  $p$  is the proportion.

**Table 1. Role of ICT on Well-Being**

Variables	(1) Thriving	(2) Thriving	(3) Logit(Thriving)	(4) Logit(Thriving)
Total ICT	0.0007*** (0.0001)	0.0006*** (0.0002)	0.0067*** (0.0007)	0.0029** (0.0012)
GDP per capita	0.0054*** (0.0011)	0.0085** (0.0037)	0.0191*** (0.0053)	0.0357* (0.0204)
Gini coefficient	0.0034*** (0.0006)	0.0011 (0.0012)	0.0226*** (0.0041)	0.0041 (0.0092)
Primary School Enrollment (%)	-0.0003 (0.0003)	0.0000 (0.0005)	-0.0015 (0.0024)	0.0010 (0.0040)
Health Control	0.1032*** (0.0271)	-0.0027 (0.0289)	0.7595*** (0.1831)	0.0198 (0.2020)
Importance of Religion	-0.0685** (0.0283)	0.0020 (0.0620)	-0.4001** (0.1597)	-0.0995 (0.3923)
Volunteered Time	0.1969*** (0.0482)	0.0438 (0.0725)	1.0103*** (0.3048)	0.1273 (0.6489)
Quality of Air and Water	0.0980*** (0.0245)	-0.0159 (0.0274)	0.5904*** (0.1631)	0.1094 (0.1993)
GFCF	-0.0008 (0.0006)	0.0012* (0.0007)	-0.0016 (0.0040)	0.0067 (0.0055)
Constant	-0.3025*** (0.0552)	0.0456 (0.1137)	-5.3341*** (0.4029)	-2.6519*** (0.8571)
Fixed Effects	No	Yes	No	Yes
Observations	717	717	717	717
R <sup>2</sup>	0.6677	0.0921	0.6565	0.0543

Robust Standard Errors in parentheses

\*\*\*p &lt; 0.01, \*\*p &lt; 0.05, \*p &lt; 0.1

### Instrumental Variable Analysis

A number of country-level studies have proposed different country characteristics as instruments.<sup>10</sup> Previous studies have argued that the roll-out of Internet services is more difficult in areas that are more rugged (Kolko 2012).<sup>11</sup> A hilly terrain, it has been argued, reduces the broadcasting range of mobile technologies (e.g., Arokiamary 2009). Additionally, it is more expensive to roll out fixed line telephones in hilly

terrain due to the additional cost incurred in laying the telephone lines.<sup>12</sup>

We argue that a higher slope of terrain in areas will make it more difficult to provide ICT services in such areas, but that there is no *ex ante* reason to assume that the slope is correlated with the level of well-being in a country. We obtain ruggedness data from Nunn and Puga (2012). Table 2 shows that, with the inclusion of this instrument, the results are robust to a two-staged least squares (2SLS) model.

$$y_1 = \beta_0 + \beta_1 y_2 + u_1 \quad [3]$$

$$y_2 = \pi_0 + \pi_1 z_1 + v \quad [4]$$

<sup>10</sup>An ideal instrument is one where the instrument is correlated with the independent variable  $x$  and thus to the dependent variable  $y$ , but the instrument is not directed correlated with the independent variable  $y$  (Appendix C). The instrumental variable needs to be uncorrelated with the error term  $u$  but should be correlated with regressor  $x$ .

<sup>11</sup>Similarly, a hilly terrain limits how far it is possible to broadcast a mobile signal with limits being roughly 5 km when the terrain is hilly versus about 50 km when the terrain is not hilly.

<sup>12</sup>Technical problems in rolling out fixed telephone lines are similar to rolling out other utilities in hilly terrains (Freeman, Sullivan & Co. 2008; Jain 2004).

**Table 2. Regressions<sup>†</sup>**

<b>A: Instrumental Variable Regression</b>			
Year	2011	2012	Complete Data Set
Total ICT	.0092** (.0038)	.01738*** (.0059)	.0120*** (.0045)
Constant	-2.7137*** (.5985)	-4.1988*** (1.0164)	-3.0097*** (.6865)
Number of Observations	120	115	859
<b>B: First Stage Regression</b>			
Year	2011	2012	Complete Data Set
Population Adjusted Slope of Terrain	-27.9788*** (8.1012)	-25.2854** (12.5016)	-21.4869*** (4.7876)
Constant	175.2672*** (9.7424)	188.1928*** (10.7430)	160.0513*** (4.3666)
Number of Observations	120	115	859

Robust Standard Errors in parentheses for cross sectional years. Clustered standard errors for complete data set.

\*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1

<sup>†</sup>We have used a larger sample of countries for the instrumental variable analysis to get additional power. However, the results are robust to the sample used in Table 1. Detailed results are shown in Appendix C.

In the model presented in Equations 3 and 4,  $y_1$  represents the level of well-being of a country. We regressed well-being on the actual use of ICT in the country (represented by  $y_2$ ) and the instrument  $z_1$  which is the population adjusted slope of the terrain in the country. In order for  $z_1$  to be an appropriate instrument for the model, it should be correlated with the actual use of ICT in the country (represented by  $y_2$ ) but not correlated with  $u_1$ . Table 2 shows the instrument variable (IV) regression for the complete data set plus recent years with the highest coverage of countries. We see that the results are consistent in this empirical specification as well. Table C1 in Appendix C details the diagnostics of the various tests (correlation, overidentification, underidentification, test for weak IV) that largely support the validity of the instrument given the limited number of countries in our sample size. Overall, there is considerable evidence for the validity and appropriateness of the proposed IV.

### **Analysis by Economic Development and Geography**

Next, we analyzed the role of ICT in a country's well-being for different clusters of countries. We identified geographic and economic development characteristics that can be useful for understanding which countries may have a stronger correlation between the level of ICT and well-being. First, we clustered countries by their economic status by using the

countries that have been classified by the World Bank as high-income<sup>13</sup> (to account for level of economic development and complementary infrastructure). Second, we clustered countries by geographical location (to account for different continents).

Table 3 shows that both low and high income countries benefit from the use of ICT on their well-being, but geographical differences do exist. For example, an increase in the level of ICT in South America has a higher increase on level of well-being whereas the adoption of ICT leads to a decrease in well-being in Europe (relative to the adoption of ICT by countries in North America).

### **Biclustering**

The previous subsection did not make a distinction between the three ICT metrics used (telephone lines, Internet users, and mobile phones) across countries that differ on their economic development and geography. However, since not all countries may use these three metrics of ICT in the same manner, we used *biclustering* (also called block clustering,

<sup>13</sup>See Table B5 in Appendix B for a list of countries that have been classified as high income. We have used the list provided by the World Bank that classifies countries that have a GNI per capita of greater than \$12,746 as high income.



**Table 3. Role of ICT on Well-Being on Countries by Geography and Economic Development**

	(1) Thriving	(2) Logit(Thriving)	(3) Thriving	(4) Logit(Thriving)
Total ICT	0.0006*** (0.0002)	0.0027*** (0.0010)	0.0009*** (0.0002)	0.0035*** (0.0011)
Total ICT * Developed Dummy	-0.0005 (0.0006)	-0.0035* (0.0019)		
Total ICT * Africa Dummy			-0.0002 (0.0003)	0.0007 (0.0027)
Total ICT * Asia Dummy			-0.0005* (0.0002)	-0.0014 (0.0013)
Total ICT * Europe Dummy			-0.0009*** (0.0003)	-0.0043** (0.0018)
Total ICT * Oceania Dummy			-0.0019*** (0.0005)	-0.0095*** (0.0030)
Total ICT * S. America Dummy			0.0008** (0.0003)	0.0044** (0.0020)
GDP per capita	0.0092** (0.0039)	0.0404*** (0.0152)	0.0083** (0.0037)	0.0371* (0.0208)
Fixed Effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Constant	0.0882 (0.1162)	-2.3615*** (0.6670)	0.0233 (0.1133)	-2.6257*** (0.8946)
Observations	717	717	717	717
R <sup>2</sup>	0.0976	0.0594	0.1550	0.0862

Robust Standard Errors in parentheses

\*\*\*p &lt; 0.01, \*\*p &lt; 0.05, \*p &lt; 0.1

direct clustering, or co-clustering), a two-way clustering method that can cluster variables and observations simultaneously (Izenman 2009). Biclustering differs from conventional algorithms, such as cluster analysis (that is useful to cluster similar observations together) and principal component analysis (PCA) (which is useful for clustering similar variables together) by allowing us to identify groups of observations that may be using a subset of variables in a similar manner. The biclustering algorithm works by combining observations and variables into layers to maximize the variance explained. Based on ICT data from 2012,<sup>14</sup> the plaid algorithm<sup>15</sup> was able to identify two layers with relevant loadings of observations and variables. Both layers relied on the number of telephone lines and the number of Internet

users as variables. The countries that were not in either of the layers were assigned to their own layer. Layer 1 consists of the 47 countries with the lowest levels of total ICT. Layer 3 consists of the 32 countries with the highest levels of total ICT. Layer 2 consists of 15 countries with modest levels of total ICT. Figure B1 in Appendix B shows the different groups of countries that were identified by the algorithm, and also the two variables that have been selected for the different groups.

After running an OLS regression of the role of total ICT (all three metrics of ICT) on well-being (Table 5, Panel A), we found countries in all layers to have a positive and significant effect of their *total* level of ICT on their well-being. In contrast, an analysis of mobile phones on well-being (Table 5, Panel C) showed that for countries with low ICT (less developed countries), the use of mobile phones contributes to their well-being. The coefficients indicate that the adoption of mobile telephones by one additional person (on average) in a low ICT country will lead to an increase in the percentage of

<sup>14</sup>The biclustering methodology is currently unable to cluster panel data. In order to overcome this, we selected ICT data from 2012 that provide sufficient data to run the biclustering analysis.

<sup>15</sup>A detailed description of the plaid algorithm can be found in Appendix D.

**Table 4. Difference in Total ICT Levels Between Identified Biclusters of Countries**

	Layer 1 Countries (Low ICT)	Layer 2 Countries (Medium ICT)	Layer 3 Countries (High ICT)
GDP PPP Per Capita (Average) (\$)	6.6796	5.2827	30.5828
Telephone Lines (per 100 citizens)	9.4377	7.7241	41.2472
Internet Users (per 100 citizens)	30.469	17.073	74.5352
Mobile telephones (per 100 citizens)	87.029	122.67	125.402

**Table 5. Role of ICT on Well-Being**

<b>A. Role of Total ICT (All Three Dimensions) on Well-Being</b>			
	Low ICT	Medium ICT	High ICT
Total ICT	0.01324*** (0.00170)	0.01530* (0.00753)	0.01489** (0.00697)
Number of Countries	47	15	32
R <sup>2</sup>	0.5741	.2410	.1319
<b>B. Role of ICT (Fixed Line Telephones and Internet) on Well-Being</b>			
	Low ICT	Medium ICT	High ICT
Total ICT	0.02869*** (0.00351)	0.04538*** (0.01019)	0.02578*** (0.00613)
Number of Countries	47	15	32
R <sup>2</sup>	0.5981	0.6043	.3707
<b>C. Role of Mobile Phones on Well-Being</b>			
	Low ICT	Medium ICT	High ICT
Mobile Telephones	0.02148*** (0.00331)	0.00368 (0.01075)	-0.00782 (0.00672)
Number of Countries	47	15	32
R <sup>2</sup>	.4834	.0090	.0432

the population that is thriving by 2.1 percent. However, the adoption of mobile telephones by a representative individual in a medium ICT country will lead to an increase in the percentage of the population that is thriving by .36 percent. This corroborates with the widespread use mobile phones in developing countries, such as in Africa and South Asia and we find that this could be contributing to an increasing level of well-being for these countries. On the other hand, developed countries that have high levels of ICT increase their level of well-being due to the use of all three ICT metrics.

## Discussion

Although prior research has validated the effect of ICT on productivity (GDP), the IS literature has still not shown the broader role of ICT in the well-being of citizens at the country

level. To overcome this, we have taken some initial first steps to analyze the relationship between the level of ICT in a country and the level of its well-being. Using a number of empirical specifications, we show empirical evidence of the role of ICT on a nation's well-being. We notably find less developed countries with low levels of ICT to increase a higher level of well-being with the use of mobile phones, whereas developed countries with higher levels of ICT increase their well-being with the use of fixed telephones and the Internet as well.

Ideally, an analysis of the impact of ICT on well-being requires three aspects that need to be shown, *whether* the relationship exists, *how* the relationship exists, and *why* the relationship exists. In this paper, we have conducted an initial empirical exploration whether the relationship exists between the level of ICT and well-being at the country level. Exam-

ining a number of models, we find that the relationship does indeed exist and that this important finding is robust to a number of different empirical specifications, thus contributing to the literature by demonstrating the positive role of ICT in the well-being of a country.

## Implications

Since the golden age of Greek philosophy, the pursuit of *eudemonia* (or well-being) has been recognized as central to people's endeavor. Aristotle, Plato and, Socrates all argued that the pursuit of happiness was what human beings wanted more than anything else. Each of these philosophers argued that different factors are what matter in achieving this sense of well-being; for example, Aristotle argued that excellence in reasoning leads to the achievement of *eudemonia*. Although the pursuit of well-being has been a central tenet for philosophers for more than two millennia, the question whether ICT could be a potential factor has yet to be examined in IS research. Here, we attempt an initial exploration into the effect that the adoption of ICT has on the general sense of well-being of humans across countries.

It should be noted that not all the effects of the adoption of ICT may be positive and it is entirely possible that the adoption of ICT could have negative effects on a society as well. For example, there are concerns that the adoption of ICT may increase unemployment by automating processes and reducing the demand for low-skilled jobs (Atasoy 2013; Brynjolfsson and McAfee 2012). As communication has increasingly gone digital, governments have been able to track communications and limit the privacy of their citizens. Other research has argued that the adoption of ICT has increased wage inequality (Acemoglu 2002). Still, for the role of the adoption of ICT in well-being, we find that the adoption of ICT has a positive impact on the well-being of countries, although the mechanism of this may be different across different countries.

Similarly, although the adoption of ICT may be driven to achieve some intended outcomes, adoption of ICT may have unintended outcomes as well. Although ICT in countries was pushed to allow citizens to be more connected, we were able to find evidence that an unintended consequence of the adoption of ICT is that ICT may have led to an increase in the level of well-being of citizens. In an exploratory analysis we undertook on *how* ICT leads to an increase in the level of well-being for a country, we explored the role of our theorized variables as mediators in a model by which ICT shapes well-being (Appendix E). We found that the adoption of ICT has an impact on the well-being of a country through the

mediating role of inequality, health, education, and commerce. However, this mediated model presents exploratory results, and we hope that further research is able to refine the model as well as perhaps examine this mediating relationship for different groups of countries (similar to the biclustering approach used in this study).

Additionally, although we find that, on average, the adoption of ICT may lead to an increase in the level of well-being for a country, the results in the "Biclustering" subsection showed is that not all types of ICT would be useful in pushing the level of well-being for all countries. For example, we did not find that the adoption of mobile telephones by high ICT countries has any significant effect on the level of well-being in these countries. This finding points to the phenomenon of leapfrogging, where generally poorer countries that have underdeveloped traditional ICT services in the past seem to adopt mobile technologies straightaway (without first deploying fixed telephone lines). This implies that a "one-size-fits-all" strategy for the adoption of ICT and its effects on the well-being of a country is unlikely to generalize across all countries.

## Limitations and Suggestions for Future Research

Although our results show the effect of the level of ICT on the well-being of a country, there are still a number of limitations. First, a possible drawback is that there may be unobserved variables that may be driving the results (omitted variable bias). We used a number of approaches to mitigate this bias by introducing fixed effects into the model as well as controlling for many factors that were shown to affect the level of well-being for a population (Table B2 in Appendix B), and our results are consistent. Also, our results are robust to alternative specifications, including the instrumental variable approach. Still, future research could examine additional econometric specifications.

Second, our metric of the use of ICT (telephones, Internet users, mobile phones) may not be capturing all of the different dimensions of which ICT may be comprised. For example, future research could try to include data on mobile Internet access, broadband Internet, and other cutting edge ICT technologies. Also, although we have used the slope of the terrain of a country as an instrument for ICT adoption in a country, we recognize that the instrument has drawbacks. One of its major drawbacks is the fact that terrain slope does not change over time. In addition, given the small sample size of the cross-sectional analysis given the stable nature of the instrument, future research could explore other instruments that are longitudinal in nature.

Third, although it can be argued that our dependent variable (well-being of a population) is subjective, there has been a large amount of research that has examined the correlation between this and other measures of external validity (Appendix A). Diener and Tov (2012) provide an extensive list of biological, physiological, and external reports of variables that have been found to be highly correlated with subjective well-being. Still, future research could examine additional measures to capture the well-being of a country.

Finally, although we have attempted an initial analysis into how the relationship between ICT and well-being exists through proxies for our proposed mediators (Appendix E), our access to data on social capital, social justice, health, education, and commerce is limited, and we hope that this will be an opportunity for future research to verify how and why such a mediated model works. We hope that our initial evidence of how ICT enhances a nation's well-being would entice research on the exact means by which various forms of ICT enhance well-being across nations.<sup>16</sup> Additionally, although we have studied the country-level effect of the adoption of ICT on the well-being, a similar individual-level analysis is also possible. However, due to the exorbitant cost of these databases, we did not conduct this analysis.<sup>17</sup>

## Conclusion

The question of the nature of well-being was one that Aristotle understood to be the final goal of all human action (Spencer 2007). Understanding the role of ICT in fulfilling this goal has so far been limited, and we hope to provide initial first steps in exploring this key relationship. As ICT becomes ubiquitous, it is important that we seek to explore how countries and citizens are transformed by ICT adoption and use. Interestingly, we show that more developed countries use fixed-line telephones and the Internet to increase their well-being, while less developed countries enhance their level of well-being by using mobile phones. Moreover, research on the societal impacts of the ubiquity of ICT has been largely limited to examining the role of ICT on GDP. However, ICT has a larger role to play in society by empowering disadvantaged communities, offering access to

healthcare services and information, providing opportunities for education, enhancing access to markets, and reducing unemployment. By showing that ICT use enhances a country's well-being, we hope to entice future research on the macro-level effects of ICT on metrics other than GDP. We feel that the IS community is ideally positioned and has the appropriate set of knowledge on ICT to comprehensively examine these important issues, and we hope this study entices the IS community to lead research on these fundamental questions related to the broader economic and societal effects of ICT.

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<sup>16</sup>Further highly exploratory analysis of the three biclusters showed that less developed nations tend to increase their well-being through education, health, and GDP using mostly mobile phones, while more developed nations tend to enhance their well-being only through GDP using primarily fixed telephones and the Internet.

<sup>17</sup>Micro-level data would have allowed us to conduct an analysis at the individual level. However, the cost of obtaining this data currently stands at \$145,000.

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**Paul A. Pavlou** is the Milton F. Stauffer Professor of Information Technology and Strategy at the Fox School of Business at Temple University. He is also the Fox School's Chief Research Officer and Associate Dean of Research, Doctoral Programs, and Strategic Initiatives. Paul received his Ph.D. from the University of Southern California in 2004. His research appeared in *MIS Quarterly*, *Information Systems Research*, *Journal of Marketing*, *Journal of Marketing Research*, *Journal of Management Information Systems*, *Journal of the Association of Information Systems*, *Journal of the Academy of Marketing Science*, and *Decision Sciences*, among others. His research focuses on e-commerce strategy, digital business strategy, and development of research methods.

**Rajiv D. Banker** is the Merves Chair and Director of the Center for Accounting and Information Technology at the Fox School of Business, Temple University. Rajiv received his Doctorate in Business Administration from Harvard University concentrating in Planning and Control Systems. He qualified as a Cost Accountant and as a Chartered Accountant, securing several awards including those for standing first and third respectively at national examinations of the two institutes. He has published more than 150 articles in prestigious research journals including *Management Science*, *Accounting Review*, *Journal of Accounting and Economics*, *Journal of Accounting Research*, *Operations Research*, *MIS Quarterly*, *Information Systems Research*, *Communications of ACM*, *IEEE Transactions in Software Engineering*, *Academy of Management Journal*, *Strategic Management Journal*, and *Econometrica*. Rajiv's research interests range from analytical modeling to statistical analysis of data collected from different companies to address complex or emerging problems of importance to managers. His research on information systems explores issues of technology enabled competitive strategy, investments in information technology, software productivity and quality metrics, and management of software development and maintenance.