

Measuring Impacts of Information and Communication Advances for Development in the 21st Century

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Abstract
This paper explores why measuring the impacts of information and communication advances is important for development in the 21st Century and why it is statistically challenging. Measuring impacts in any field is difficult, but for ICT there are added complications because of its diversity and rapidly changing nature. A number of impact areas are identified in this paper, and their relationships explored, in the context of their place in the social, economic and environmental realms. The result is a complex web of relationships between individual impact areas, such as economic growth and poverty alleviation, and background factors, such as a country's level of education and government regulation.
Existing measurement frameworks are described, and relevant statistical standards examined. The latter includes internationally agreed standards for the ICT sector, ICT products and ICT demand. The contributions on Measuring ICT for Development in the 21st Century and its member Organizations to ICT measurement, and its goals for measuring ICT impacts are outlined.
Methodologies used in the measurement of ICT are discussed and compared in section two of this paper, and empirical evidence reviewed, in section three. Most research conducted has found positive effects of ICT in the impact areas investigated. However, research has tended to focus on positive, rather than negative impacts; therefore, the latter tend to be indicated by unreliable evidence. There is relatively little evidence from developing countries and there are indications that findings in respect of developed countries may not apply to developing countries. In respect of both developed and developing countries, there are few studies that provide internationally comparable evidence.
The difficulties of ICT impact measurement, major data gaps and the lack of clear statistical standards suggest several issues for consideration. These are presented in the final section of the paper.
Keywords: ICT advances, measuring impacts, measurement frameworks, privacy, security, perceptions

1. Introduction

Information and communication technology (ICT) offers the promise of fundamentally changing the lives of much of the world's population. In its various forms, ICT affects many of the processes of business and government, how individuals live, work and interact, and the quality of the natural and built environment. The development of internationally comparable ICT statistics is essential for governments to be able to adequately design, implement, monitor and evaluate ICT policies.

While much progress has been made in measuring ICT infrastructure and use, measurement of the impacts of ICT presents a number of statistical challenges. This paper is divided into four sections. The first provides some background to why it is important to measure the impacts of ICT and the challenges involved in that measurement. It also presents frameworks for conceptualizing and measuring the impacts of ICT. The second section discusses different methodological approaches to measuring ICT impacts. The third section briefly reviews the empirical evidence in selected impact areas. The final section concludes and proposes a set of questions to consider.

The Tunis Summit represents a unique opportunity to raise awareness of the benefits that Information and Communication Technologies (ICTs) can bring to humanity and the manner in which they can transform people's activities, interaction and lives, and thus increase confidence in the future." (ITU, 2005).

The vision 2030 targets to be achieved by 2030 are to improve connectivity, for instance, between villages, educational institutions, libraries, hospitals and government organizations. There were three targets on ICT access (radio and television, other ICTs and the Internet) by the Kenya's population and a target on adapting education curricula to meet the challenges of the information society. From the targets, some important impact areas can be inferred:

- Impacts of ICT access, especially on poor and rural communities;
- Impacts of ICT use on educational outcomes and the importance of school curricula in preparing students for the information society;
- Impacts of ICT networks on health institutions and health outcomes;
- Various impacts arising from the availability of e-government services;

- Impacts of improving access to information and knowledge by suitable access to electronic content.

Global challenges in measuring the impacts of ICT

It is obvious that there are significant impacts of ICT. However, as stated succinctly by ITU (2006): "You want to know the difference information and communication technologies make? Try to live without them." Nevertheless, illustrating impacts of ICT statistically is far from simple, for several reasons:

- There are a number of different ICTs, with different impacts in different contexts and countries. They include goods, such as mobile phone handsets, and services, such as mobile telecommunications services, which change rapidly over time;
- Many ICTs are general-purpose technologies, which facilitate change and thereby have indirect impacts;
- It is difficult to determine what is meant by "impact". For example, a model proposed by OECD for ICT impacts highlights the diversity of impacts, in terms of intensity, directness, scope, stage, timeframe and characterization (economic, social or environmental, positive or negative, intended or unintended, subjective or objective);

Many studies have categorized ICT impacts as economic, social or (less frequently) environmental. However, the picture is usually more complex than this. For example, while some direct impacts of ICT use can be described as economic, there may be indirect impacts that are social or environmental. In addition, direct impacts may be both economic and social, related through human capital, which is defined by OECD as "productive wealth embodied in labor, skills and knowledge". From the perspective of the economy, human capital is a necessary condition for economic growth and competitiveness (World Bank, 2009). The use of ICT can enhance human capital in a number of ways, including through its roles in education, literacy, acquisition of knowledge and skills, and the development of human networks. Economic and social benefits will usually accrue to individuals who are gaining skills and knowledge by using ICT.

There are other economic benefits of ICT resulting from its use by households and individuals, described by OECD (2009a) as follows:

- Final demand for ICT goods and services by households is an important component of overall demand, which may stimulate the growth of the ICT sector and industries that rely heavily on ICT, for example, media and entertainment;
- The diffusion of ICTs among households may create a critical mass allowing firms to realize the full benefits of switching to ICT, for example, in the delivery of products;
- Use of various ICTs at home may allow firms to introduce teleworking, which potentially brings economic, social and environmental benefits.

Measurement frameworks

It is useful to consider where impacts lie in a broader information society conceptual model. The model used by OECD to illustrate the information society (OECD, 2009a) identifies the following inter-related segments: ICT demand (use and users), ICT supply (the ICT sector), ICT infrastructure, ICT products, information and electronic content and ICT in a wider social and political context. OECD (2007) discussed the impacts components of the conceptual model as follows:

- Impacts of ICT access and use on individuals, organizations, the economy, society and environment;
- Impacts of ICT production and trade on ICT producers, the economy, society and environment;
- Impacts of use and production of content (in particular, electronic or digital content, which only exists because of ICT) on the economy, society and environment;
- Influence of other factors on ICT impacts, for example, skills, innovation, government policy and regulation, and existing level of ICT infrastructure.

In reference to projects relating to information and communication technologies for development (ICT4D), an ICT4D value chain has been proposed as a basis for impact assessments (Heeks and Molla, 2009). It starts with precursors and proceeds to inputs, deliverables, outputs, outcomes and development impacts. We consider the last three to be impacts and distinguishes them as follows:

- Outputs are the micro-level behavioral changes associated with the ICT4D project;
- Outcomes are the specific costs and benefits associated with the project;
- Development impacts are the contribution of the project to broader development goals.

Assessment frameworks relating to ICT4D project impacts often include (Heeks and Molla, 2009) cost-benefit analysis, assessment against project goals, assessment of the effectiveness of communications (on changing behavior or attitudes), assessment of the impact of ICT on livelihoods, assessment of whether ICT is meeting information requirements, cultural-institutional impacts and impacts on enterprise performance, relations and value chain.

An important aspect of measurement frameworks are definitions and classifications applying to its separate elements.

The term "ICT" covers a diversity of ICT products – goods and services – that are primarily intended to fulfil or enable the function of information processing and communication by electronic means, including transmission and display (OECD, 2009a). These products can be broadly grouped into ICT equipment, such as computers and peripherals, communication equipment, consumer electronics and components; manufacturing services for ICT equipment; business and productivity software and licensing services; information technology consultancy and services; telecommunication services; and other ICT services. Components of ICT are also present in a variety of non-ICT products, such as scientific and medical equipment, motor vehicles and manufacturing equipment. The manufacture and use of such products is not usually captured in ICT impact studies.

The ICT sector includes industries in ICT manufacturing and ICT services, including wholesaling of ICT products. The concept of ICT demand for the purposes of this paper is broad and follows OECD (2009a). It includes the following:

- Use of various ICTs at different levels of intensity and for various purposes;
- Use of, and access to, ICT by individuals, households, businesses, government and other organizations
- Financial aspects, such as ICT asset value of, and investment by, individuals, businesses, government and other organizations;
- Use of ICT components as intermediate inputs to production by the ICT and non-ICT sectors (for instance, electronic components embodied in domestic appliances).

It is useful to distinguish the incidence of use (for example, the proportion of individuals using the Internet) and the intensity of use. While investment in ICT is an indicator of intensity, there are a number of measurement issues that make international comparison problematic at both the micro and macro levels. Developing core ICT indicators has resulted in policy-relevant and comparable indicators of ICT use by businesses and individuals. While they are of the incidence type, they range from simple indicators, for example, use of computers, to more sophisticated applications, such as receiving orders via the Internet.

The digital divide for ICT development for the 21st Century

An area that has received significant attention from policymakers is the question of a digital divide between individuals, organizations and countries. A major preoccupation for Kenya now is to narrow the digital divide. For instance, the Geneva Declaration of Principles referred to the goal of the Declaration as "… bridging the digital divide and ensuring harmonious, fair and equitable development for all…" Concern over digital divides is based on the assumption that ICT is, on balance, beneficial and that those without access to it are relatively disadvantaged. For individuals, negative impacts may range from inconvenience to more serious outcomes, such as employment disadvantage due to lack of familiarity with ICT. For economies, the lack of ICT access may make existing country divides greater, as the global economy relies increasingly on ICT to function efficiently and effectively.

Impact areas of ICT for development and their relationships

Impacts of ICT arise through ICT supply and ICT demand and, in Kenya, are influenced by the following factors:

- Existing ICT infrastructure, which enables an ICT critical mass that can amplify impacts;
- Kenya's population level of education, skills and income;
- Government ICT policy and regulation, and the level of e-government

Methodology

The study looked at the methodologies and data sources used in measurement of ICT, comments on strengths and weaknesses of the different approaches. The approaches considered are not mutually exclusive. For example, analytical techniques will generally use existing survey or administrative data and case studies may use data from several sources.

Analytical techniques

Various analytical techniques have been used to measure the economic impacts of ICT at the macroeconomic, sectorial and microeconomic (firm) level. The main techniques used in this study are econometric modelling using regression, growth accounting and input output analysis. Econometric regression models have also been used in other areas of measurement, for example, to measure the impacts of ICT use on educational outcome

The usual objective of an ICT impact analysis is to examine the relationship between ICT and productivity, economic growth or employment. The analysis usually includes other determinants such as labor, non-ICT capital and, for firm-level studies, factors such as firm characteristics, skills and innovation. Included in ICT are the ICT-producing sector, often split into manufacturing and services, and ICT diffusion, measured by ICT investment and/ or use. Productivity measures relate a measure of output (gross output or value added) to one or more inputs. Economic growth is usually defined in terms of change in gross domestic product (GDP) or

value added. Employment refers to jobs generated through the direct and indirect impacts of ICT.

The methodological approaches to measuring productivity can be categorized as parametric (such as econometric techniques) and non-parametric (such as growth accounting) (OECD, 2001). Econometric techniques estimate parameters of a production function using a regression model. Growth accounting attributes to growth in GDP to increase in inputs, such as capital and labor, and advances or improvements in production technology (ITU, 2006). It measures multi-factor productivity growth residually (OECD, 2001). Input-output matrices can be used to calculate the multiplier effects of ICT. Many ICT impact studies examine labor productivity, that is, how productively labor is used to generate output (gross output or value added).

In recent years, much attention has been paid to firm-level studies of ICT impacts. Such studies can provide insights not available from macro-level data, for example, the complementary roles of skills and organizational change (OECD, 2004). Firm level studies are based on analysis (usually based on econometric regression models) of data at the individual firm level. Data often come from different statistical sources and are linked at the firm level. They include firm performance, ICT investment, ICT use (varying from use of computers to advance e-business applications), firm size and age, skill level, organizational factors and other forms of innovation. In some countries, these data are brought together in longitudinal databases, which provide data over different points in time. Economic impacts studied include labor productivity, multifactor productivity and value added.

Case studies

Measuring ICT impacts is based on case studies, often small scale and project based. They may be longitudinal, examining changes over time. They are generally very detailed and can involve a number of qualitative and/or quantitative data sources. They can take advantage of a number of existing, as well as new, data sources. Case studies were used to explore causation within their scope. The case study findings in this study are bound by the context in which they were conducted. While their results will not usually be generalizable beyond their context, they may indicate hypotheses or topics that could be assessed more broadly.

Statistical surveys

Data needed to measure ICT impacts can come from various statistical surveys, this study employed the following;

- Household surveys that collect information about the household entity, including its characteristics, income, expenditure, and access to ICT;
- Household surveys that collect information from individuals, including their characteristics, income, expenditure, how they spend their time, how they use ICT and their perceptions of particular ICTs;
- Surveys of businesses, including those in the ICT sector, that collect information such as employment, economic performance, innovation, expenditure on ICT, use of ICT and perceptions of ICT impacts;
- Surveys of other entities such as government organizations that gather information such as employment details, economic performance, expenditure on ICT, use of ICT and electronic services offered.

Perception questions provide causal information on the impacts of ICT, but lack objectiveness. However, in respect of individuals' perceptions, it has been argued that without subjective indicators, measurement efforts are bound to be inadequate (ESCWA, 2009).

Panel studies

Panel studies are longitudinal and survey based, in contrast with cross-sectional surveys, which collect data at a point in time across a population. A panel is selected at the start of the study and data are collected about its members, for example, individuals or businesses, during successive periods. This study employed panel studies in examining impacts, as they provide good baseline data and account for time lags.

Controlled experiments

This paper use controlled experiments to establish causality by controlling all the independent variables. Therefore, we altered a condition and observe the effect. In general, the types of studies of interest for ICT impact analysis cannot be controlled to the degree necessary to determine a cause-and-effect relationship.

Administrative data

This paper considered importantly administrative data source. ICT statistics use administrative data collected primarily for non-statistical purposes but used to form statistical indicators. The main examples are telecommunication or ICT infrastructure data collected by ICT authority of Kenya from merchandise trade data. All three sources are used for the Partnership's core ICT indicators (ICT infrastructure and access, trade in ICT goods and ICT in education indicators respectively). Even though these administrative data are not usually collected for statistical purposes, classifications and definitions can be applied to administrative data collection to

enable statistical output. Focus groups, direct observation and document were also used in this study. Scenarios were used to establish impacts in different situations, using different sets of assumptions. Forecasting was used to estimate the future impacts of ICT and can involve a number of techniques, data sources and assumptions.
This section reviews empirical evidence on the impacts of ICT, with particular emphasis on developing countries and the alleviation of poverty. The impact areas, covering the economic, social and environmental realms. The areas covered are the impact of ICT on economic performance, employment, innovation (including research and development), privacy and security, education, health, citizen participation, individuals and communities, and the environment. It is important to note that the coverage does not aspire to be comprehensive. Moreover, the different impact areas are not mutually exclusive. For example, innovation is an important factor in firm performance, which is described in the first impact area, and education is a key element in economic growth

Impacts of ICT on economic performance

ICT impacts on economic growth and productivity at the macro, sectorial and firm levels. Effects on poverty alleviation are also considered, although the concept of poverty extends beyond the economic dimension. Following most studies on the economic impact of ICT, this paper distinguishes economic impacts arising from an ICT sector and from ICT diffusion throughout the economy.
Positive macroeconomic impacts of ICT in terms of increases in productivity and growth can arise from the following sources (OECD 2004, 2008a):

- Increase in the size and productivity of the ICT sector, and associated effects such as growth in industries that provide inputs to ICT production;
- ICT investment across the economy, which contributes to capital deepening and leads to a rise in labor productivity;
- Multifactor productivity growth across the economy, which arises from the role of ICT in helping firms innovate and improve their overall efficiency.

A review of research on macroeconomic impacts of ICT found that productivity gains in developing countries were mainly generated by the ICT sector, rather than through ICT use. The opposite tends to apply for developed countries, however (UNCTAD, 2007).

There is some evidence that the development of a strong ICT sector has led to poverty reduction, although there are few targeted studies on this (UNCTAD, 2010). Opportunities exist, not least in ICT microenterprises, such as very small businesses providing mobile phone and Internet services, ICT repair and ICT training. While not in the ICT sector, businesses retailing ICT goods, such as used mobile phones and recharge cards, will also be created as a consequence of increased ICT penetration in society. Banking services related to ICT, such as mobile money, are also activities suited to small businesses in Kenya. Much of this activity is in the informal sector and, while the activities are not well measured, they provide benefits for proprietors and customers and occupy niches in which larger formal businesses are not interested (UNCTAD, 2010).

The diffusion of ICT includes use, access and financial aspects. It may be measured directly through surveys or indicated by the levels of ICT penetration measured by administrative data.

In macroeconomic terms, a direct link has been established for developed countries between aggregate labour productivity based on value added and income per capita, a measure of living standards (OECD, 2001). In respect of developing countries, UNCTAD (2010) notes the recent deployment of ICT networks and the lack of available data to perform extensive macro-level analysis of the impact of ICT diffusion. The critical mass effect, whereby impacts of ICT use will only be seen once a certain level of ICT penetration is reached, is likely to affect the outcome in developing countries.

Firm-level studies have been used extensively, especially in developed countries, to examine the impact of ICT on firm performance. They typically involve a number of variables covering ICT, firm performance and non-ICT factors that might affect performance. In developed countries, many firm-level studies have been conducted on the impact of ICT. They have generally found that use of computers, the Internet and broadband have a positive relationship with productivity. However, this varies among individual businesses according to other factors, such as skills and innovation. A number of studies have found that ICT has most impact when accompanied by complementary investments and changes, for example, in human capital, organizational change and other forms of innovation (OECD, 2004).

One difference is the level of sophistication of ICT use. In developed countries, firm-level studies are increasingly focusing on higher level ICTs such as networks and broadband. In developing countries, lower level ICTs such as computers are likely to be at least as significant (UNCTAD, 2008).

Case study evidence indicates that small and microenterprises in low-income countries can benefit from mobile phone use for business purposes, including improving communication with customers and obtaining information on inputs and markets (UNCTAD, 2010). Other case studies have indicated that the provision of Internet access alone may not bring significant benefits to microenterprises; other support and tailored

information appear to be needed. The Internet is generally far less accessible to poor communities than mobile phone technology, especially in rural areas. However, the Web and Internet e-mail offer significant potential for communication and information delivery. It appears that use of the Internet by small businesses for more advanced applications, such as e-commerce in developing countries, is still rare. Several projects have successfully used combinations of technologies in agricultural areas of developing countries, for instance, using mobile phones and radio programmes to provide information and web platforms to sell produce (UNCTAD, 2010),

Larger enterprises in developing countries may benefit from the use of more sophisticated ICT applications (such as web-based e-commerce and other e-business applications). These benefits may be transferred to the poor in various ways, for example, by intermediary services for small businesses. In China, UNCTAD (2010) reported that 20,000 small businesses work through China's main e-commerce platform, Taobao.com, to advertise and sell online.

There may also be spillover benefits. For instance, in the Ugandan cut flower industry, ICT investment in a larger enterprise benefitted the whole sector, expanding employment opportunities for growers. There may furthermore be gains from ICT diffusion along the supply chain. However, suppliers who are not connected may be disadvantaged.

For developing countries, every 10 percentage point increase in the penetration of broadband services was associated with an increase in per capita GDP of 1.38 percentage points; Internet and mobile phone penetration were associated with a 1.12 and 0.81 percentage point increase, respectively. This study points that the results of such an analysis may in part be attributed to two-way causality, where demand for ICT rises with wealth, which leads to increased penetration, and in turn increases wealth.

Broadband is essential to enable enterprises to make full use of Internet-based services and applications. In the United States of America, broadband users were 20 per cent more likely to make online purchases than narrowband users in 2008 (OECD, 2008b). In Sweden, enterprises with a high-speed Internet connection made more use of the Internet, which in turn helped raise productivity (Statistics Sweden, 2008).

Broadband is also associated with ICT convergence and this has implications for ICT use. An example is the convergence of telephone networks and Internet to enable Voice over Internet Protocol (VOIP) telephone calls, significantly reducing the cost of telephone based services.

Negative economic impacts associated with ICT diffusion have received relatively little attention from statisticians. They include a range of privacy and security impacts, as well as systems failures, data loss or corruption, inadvertent disclosure of data and loss of productivity because of employees' use of ICT, particularly the Internet, during work time. A possible indirect negative impact is a productivity trap resulting from updating ICT too frequently to enable efficiency gains.

Impacts of ICT on employment

ICT has roles in the creation of employment and self-employment opportunities. Impacts can be direct, through growth of the ICT sector and ICT-using industries, and indirect through multiplier effects. In economies increasingly dependent on ICT, individuals will benefit by having requisite ICT skills, thereby enhancing their opportunities for employment. Arguably, ICT can also lead to loss of employment as tasks are automated.

In respect of the ICT sector in low-income countries, telecommunication services offers the greatest opportunities for employment creation (UNCTAD, 2010). Only a small number of developing countries have a well-developed ICT sector. In China, for example, the ICT sector provides employment to about 26 million internal migrant workers, with evidence that a large portion of their earnings is remitted to poor rural and remote areas. Mobile telephony penetration is increasing dramatically in developing countries (ITU, 2010b). In Nigeria, the positive economic impacts of a growing mobile telephony industry include growth in the industry itself and associated industries, creation of direct and indirect employment, and development of labor force skills (Pyramid Research, 2010).

Broadband penetration can increase employment in three ways (Katz, 2009). First is the direct effect of jobs created in order to develop broadband infrastructure, second is the indirect effects of employment creation in businesses that sell goods or services to businesses involved in creating broadband infrastructure and the third is induced effects in other areas of the economy. The relationship between broadband diffusion and employment through these mechanisms is a causal one, although the estimate of employment growth relies on a number of assumptions. The Economic and Social Commission for Western Asia examined the impact of telecentres on the economic development of poor communities (ESCWA, 2009). Many of the impacts were on employment opportunities. The potential impacts of IT services and ICT-enabled services on poverty reduction include employment and its multiplier effects. Because workers in IT services and ITES industries tend to be relatively well educated, indirect employment may be the major employment benefit for the poor (UNCTAD, 2010). According to the World Bank (2009), women in India and the Philippines benefit disproportionately from employment opportunities in IT services and ITES, with women accounting for about 65 per cent of professional

and technical workers in the Philippines, and 30 per cent in India. Both are higher participation rates than in other service industries.

Results in this study showed a positive and statistically significant effect of use only at work and this was always greater than the return to use only at other places, including home. However, use at work as well as other places displayed higher returns than use only at work. For self-employed workers, results were similar, with Internet users having higher earnings.

Relationships between ICT and innovation for development in the 21st Century

Innovation is a broad concept, defined by the *Oslo Manual* (OECD and Eurostat, 2005:46) as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations". Innovation can occur in all sectors of the economy, including government and higher education, and includes all forms of research and experimental development as defined by the *Frascati Manual* (OECD, 2002)

A key determinant of business and macro-level productivity is innovation, especially organizational change. More broadly, there is clearly a strong impact of innovation, especially research and development, on the development of ICT goods and services. A study by OECD (2010a) explored the effects of ICT use as an enabler of innovation. Business use of ICT surveys and innovation surveys were linked at the firm-level and analyzed using an econometric model. Results indicated that higher ICT use, measured as the number of web facilities, generally increases the probability of innovation, with variations on the strength of the relationship by country, industry (manufacturing or services) and the type of innovation.

The importance of ICT in research is to connect scientific and research centres with ICTs. It can be expected to have a strong impact on research and development activities in all sectors, as a general purpose technology, although there seem to be few studies in this area.

Impacts of ICT on privacy and security

This study identified a number of adverse impacts of ICT on the privacy and security of individuals and organizations. They include commercial losses from denial of service attacks, data loss through theft or corruption and disclosure of confidential data. The OECD model business and household surveys (OECD, 2009a) and Eurostat's 2010 model community surveys of enterprises and households (Eurostat, 2010) included questions on the incidence of harmful security incidents. Such questions do not quantify the extent of impact, although they are useful in measuring how widespread the problems are. Far more serious potential negative impacts could arise because of the increasing reliance of critical infrastructure on ICT and the serious consequences of failure. Such impacts can affect societies and economies, as well as individual businesses (OECD, 2008c).

Impacts of ICT on education

There is considerable policy interest in the benefits that ICT can bring to education, which is a particular focus of the Millennium Development Goals. The impact of ICT in education has been assessed in various studies, with mixed results. ICT has significant educational benefits by providing tools for the teaching and learning process and by providing the skills needed in a society that is increasingly reliant on ICT. Conversely, students who enter such a world without those skills may be unable to fully participate and suffer from a digital-divide effect. The digital divide is a greater problem for developing countries, where access to ICT is generally lower. The other benefits of ICT in education are improved attitudes to learning, development of teachers' technology skills and increased access of the community to adult education and literacy (OECD, 2010 b; Kozma, 2005).

Empirical experiments that are highly controlled can help establish causal relationships between ICT use and educational outcomes (Kozma, 2005). Controlled experiments from the United States, Kenya and Uganda showed positive impacts on student learning arising from use of computers in specific school subjects, while general availability and use of computers at school did not affect student learning (Kozma, 2005). An OECD study (2010b) reviewed empirical experiments and correlation studies. The conclusion was that results of the former indicate that ICT in the classroom improves performance "if certain pedagogical conditions are met" and the latter, that there is no demonstrated consistent relationship between ICT availability and use at school and educational attainment. It is argued that more intensive use of ICT needs to go hand in hand with an increase in the social capital of students as measured by other complementary educational assets. It is clear from our discussion that the impact of ICT on school performance is a very complex topic and is not easily measured.

This study found that for Kenya, the groups of variables that affected the science score were as follows: students' characteristics, such as science interest and motivation; parents' characteristics; household characteristics; school characteristics, not including access to ICT; and frequency of computer use at home and school.

Impacts of ICT on health

From this study health is as an area where ICT is expected to bring major benefits. According to ITU (2010a), e-health ICT applications include electronic health records, telemedicine, m-health (the use of mobile devices such as mobile phones for health purposes), decision-support systems, e-learning and e-journals. The use of ICT is also cited as enabling complex and networked medical equipment. This study points out that the Internet can be a useful source of information about health from an individual's point of view. There is no doubt that ICT can also have negative effects on health, for instance, occupational overuse injuries associated with computer use. Recycling of e-waste is a particular problem for developing countries, with adverse health impacts.

The World Health Organization (WHO, 2009:7) has a broad scope for e-health, defining it as "the use of information and communication technologies (ICT) for health" and stating that "e-Health works to improve health by enhancing patient services and health systems". Through its Global Observatory for e-Health, the Organization has plans to establish indicators for monitoring e-health and assessing its impact on health systems (WHO, 2010).

The World Bank (2009) described the impact of mobile phones on health outcomes in developing countries. It cited examples of drug inventory management and monitoring programmes, using the mobile phone as an interface. According to the World Bank, broad band enabled telemedicine is widespread in developed and developing countries, yet there are few studies on its effectiveness. The socio-economic and financial impacts of interoperable electronic health records and e-prescribing systems were investigated. Evaluation was based on cost–benefit analyses; for all cases, the socio-economic gains to society exceeded the costs.

Impacts of ICT on citizen participation, individuals and communities

ICT facilitates democratic processes and increase participation by citizens. Such impacts may occur as a result of greater communication and information dissemination offered by ICTs, through the use of social networking sites, e-mail and mobile phones. They are also frequently enabled by electronic information and services offered by government (e-government), usually via the Internet or mobile phones. Of particular interest is how e-government can improve democratic processes and encourage citizen participation in decision-making.

According to UNDESA, e-participation can change the dynamics between government and citizens. It undertakes an international survey of e-government every one to three years and collects information on channels offered for online participation of citizens in public affairs. Results from the 2010 survey show that developed countries are leading the way in e-participation, although there are a small number of developing countries in the top 20 countries. Examples of greater electronic participation are provided for Singapore and China. Many of the impacts on individuals of using ICT can be seen as intermediate, that is, they concern how ICT is directly changing activities such as shopping, banking and dealing with government; how people spend their income; how they spend their time; and how they communicate with family, friends and the broader community. These differ from ultimate or final impacts, such as cost and time savings.

It is clear that ICT use has both negative and positive social impacts on individuals and communities. On the negative side, there is increasing concern about the impact on children of Internet use, for example, exposure to undesirable content and the overuse of Internet applications such as online games, the use of the Internet to disseminate images of pornography and violence against women; Internet-based crime; copyright infringement; and security and privacy concerns.

Positive impacts are potentially numerous and include the ease and immediacy of communicating, finding information and accessing services.

In respect of perceived impacts, results from the international 2003 Adult Literacy and Life Skills surveys included a comparison of respondents' perceived usefulness of computers with their literacy, numeracy and problem-solving skill levels. A study using the survey data found a positive relationship, though there was no suggestion of causality (Statistics Canada and OECD, 2005).

The *2009 Survey on the Internet Usage* conducted by the Korea Internet & Security Agency collected information from Internet users about their perceptions of the Internet. Results showed high levels of agreement with both positive and negative propositions; 72 per cent of respondents agreed ("somewhat agree" or "agree") that the Internet is important to their daily lives. The survey also asked about complaints about using the Internet and included response categories such as leakage of personal information (31 per cent of respondents) and exposure to obscene contents' (26 per cent of respondents) (Korea Internet & Security Agency, 2009).

A perceptions survey of 1,500 mobile phone users in Kenya found that a high proportion reported savings in travel time and lower costs for travel or entertainment. Uses of mobile phones included education, health and entertainment purposes (IPSOS Research, 2010).

Impacts of ICT on the environment

Measurement of the relationship between ICT and the environment is a relatively new. In OECD (2009b),

positive and negative links between ICT and the environment are discussed. The scope of environment is limited to aspects where ICT is likely to be a strong positive or negative factor, that is, climate change, energy use and waste. The proposed conceptual model recognizes the following impacts of ICT on the environment:

- Positive impacts, such as its potential to improve the efficiency of a range of energy-using processes and equipment, facilitation of dematerialization, and ICT's role in climate change monitoring and modelling, dissemination of information, and administration of carbon-pollution-reduction schemes;
- Negative impacts from energy needs and greenhouse gas emissions arising from ICT use, the manufacturing and transport of ICT products and pollution from disposal of e-waste.

Some impacts of ICT on environmental outcomes can be easily demonstrated by using scientific knowledge and other available information. The greenhouse gas emissions attributable to power hungry data servers can be calculated if their power use and source of power are known.

For some other aspects, impacts are more difficult to measure, for example, the impact of Internet purchasing on greenhouse gas emissions. Indirect impacts are even more difficult to measure, for example, the positive role of ICT in facilitating a knowledge-based society with an awareness of environmental issues. Empirical evidence on the impact of ICT on environmental outcomes is lacking. Several analytical studies have attempted to estimate the impact, for example, the Climate Group and GeSI (2008) estimated that the ICT sector and ICT products are responsible for about 2 per cent of global greenhouse gas emissions and that this will grow unless mitigated.

Conclusion

This section summarizes the findings presented above and proposes a set of key issues for further consideration.
This study explained why measurement of the impacts of ICT is important for policymakers and why it is difficult. Reasons for the latter include the diverse and changing nature of ICT, the complexity of ICT impacts and the more general difficulties of illustrating a cause-and-effect relationship between the different variables.
These impacts are also contextual. In Kenya, determining factors include human capital, the level and availability of ICT infrastructure and government intervention. At a business level, there is significant empirical evidence that complementary factors, such as skills and innovation, are important in determining the degree, and even the direction, of the impact of ICT access and use.

Reflecting the complexity of measuring ICT impacts, there is a variety of methodological approaches, which are not mutually exclusive. Particular approaches appear to be generally suited to measuring a particular type of impact. For example, econometric regression models suit the analysis of firm-level impacts of ICT and case studies are suited to the evaluation of small-scale ICT projects.

Most of the empirical research examined in section 3 had found positive impacts – for economies, businesses, poor communities and individuals. Impacts are direct and indirect, and include impacts across the economic, social and environmental realms. There is case study that ICT may contribute to poverty alleviation. Mechanisms include trickle-down effects from overall economic growth, employment and self-employment opportunities, establishment of microbusinesses that are in the ICT sector or related to it, such as the retailing of mobile phone cards, and the use of ICTs, such as mobile phones by small businesses.

Evidence of negative impacts is more likely to be anecdotal and includes adverse economic and social impacts on individuals and organizations, and negative impacts on the environment.

Many data gaps remain in the area of ICT impacts, particularly with regard to developing countries. Much developing country evidence is provided by local case studies. Although this is useful, the extension to different situations or to a country level is challenging.

It appears that evidence from developed countries may not apply to developing countries, although the methods of investigation may. In low-income countries, access to more advanced ICTs is problematic, leaving a much greater role for ICTs, such as radio, TV and mobile phones, to have important economic and social impacts, at least in the short term. There are still significant data gaps in developing countries on the core ICT indicators, especially measures of the ICT sector, and household and business data on ICT use. While these data do not directly measure the impact of ICT, they may be used in the analysis of ICT impacts.

There are internationally agreed standards for many aspects of ICT measurement. While these are necessary for measuring the impacts of ICT, they need to be complemented by a framework and standards specifically targeted at measuring the impacts of ICT. These could include methodologies for econometric approaches and model questions for perceived impacts.

Recommendations

This paper has examined a number of impact areas in measurement of ICT. Against the discussion above, a set of questions for further consideration are proposed below.

- Given the range of ICT impacts and the fairly low availability of evidence on impacts, should the measurement of impact in certain areas be given higher priority than others in the years leading up to 2030?

This question is to be seen also in conjunction with considerations of feasible and affordable data collection work.

- This paper has emphasized the importance of producing relevant and internationally comparable data needed to conduct impact studies. What can the government, development partners and international organizations – especially on the wake of vision 2030, do to extend ICT impact indicators? Examples may include setting statistical standards, accelerating the building of capacity for the production of relevant statistics and allocating sufficient funds to undertake surveys.
- From a policy perspective, what types of impact studies are the most useful? Possibilities include the following:
    - Extending macroeconomic analysis to Kenyan counties using methodologies used in this paper;
    - Extending the measurement of firm-level impacts to more all counties;
    - Considering the use of perceptions questions on surveys of business and household use of ICT. Several survey models and further investigation could be useful in checking the validity and comparability of results;

- What can be done to raise awareness among different stakeholders about the need for the measurement of impact of ICT?

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