UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Measuring the Impacts of Information and Communication Technology for Development

UNCTAD Current Studies on Science, Technology and Innovation. N°3

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ABSTRACT

This paper explores why measuring the impacts of information and communication technology (ICT) is important for development – 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 section 1, 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 in section 1, and relevant statistical standards examined. The latter includes internationally agreed standards for the ICT sector, ICT products and ICT demand. The contribution of the Partnership on Measuring ICT for Development 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 2 of the paper, and empirical evidence reviewed, in section 3. 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 anecdotal 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.

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CONTENTS

1. Introduction and conceptual framework

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. This need was emphasized in the Geneva Plan of Action, paragraph 28, from the first phase of the World Summit on the Information Society (WSIS):

"A realistic international performance evaluation and benchmarking (both qualitative and quantitative), through comparable statistical indicators and research results, should be developed to follow up the implementation of the objectives, goals and targets in the Plan of Action, taking into account different national circumstances." (ITU, 2005)

While much progress has been made in measuring ICT infrastructure and use, measurement of the impacts of ICT presents a number of statistical challenges. Against this background, CSTD, at its thirteenth annual meeting in May 2010, identified measuring the impacts of ICT for development as a priority area of work and asked the UNCTAD secretariat[1] to prepare this background paper on the topic. The 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.

1.1. World Summit on the Information Society

The Tunis Commitment from the second phase of the World Summit on the Information Society expressed a strong belief in the development potential for ICT, stating:

"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 Geneva Plan of Action, paragraph 6, included 10 targets to be achieved by 2015, of which 6 were 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 world's population and a target on adapting education curricula to meet the challenges of the information society.[2] 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.

The Geneva Plan of Action, paragraphs 14–22, also suggested a number of action lines, including the promotion of ICT applications that can support sustainable development.[3] The Tunis Commitment, paragraph 2, included statements on the potential benefits of ICT to the world's population, linking them to achievement of the Millennium Development Goals (ITU, 2005).

1.2. Partnership on Measuring ICT for Development

Much of the progress in measuring ICT to date is linked to the work of the Partnership on Measuring ICT for Development and its member organizations.[4] The Geneva Plan of Action referred to the development of statistical indicators for "international performance evaluation and benchmarking" (para. 28). The Partnership was subsequently launched at UNCTAD XI in June 2004. The Tunis Agenda for the Information Society (para. 114) specifically mentioned the Partnership and its role in the measurement of ICT impacts.

The work of the Partnership is directed towards achieving internationally comparable and reliable ICT statistics which, among other things, will help countries assess ICT impacts (Partnership, 2008a). Its members are involved in various activities directed towards that goal, including developing and maintaining a core list of ICT indicators (Partnership, 2010), compiling and disseminating ICT data (Partnership, 2008b), and the provision of technical assistance to developing countries. The Partnership has several task groups, including the Task Group on Impacts, which is led by OECD and aims "… to give an overview of the economic and social impacts of ICTs, how these impacts can be measured and what the data requirements are". Its terms of reference recognize both economic and non-economic impacts and a variety of methodologies and data sources.[5]

1.3. Challenges in measuring the impacts of ICT

It may seem 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 (figure 1) 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);
- Determining causality is difficult. There may be a demonstrable relationship and a positive correlation between dependent and independent variables. However, such a relationship cannot readily be proven to be causal.

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.[6] In addition, direct impacts may be both economic and social, related through human capital, which is defined by OECD as "productive wealth embodied in labour, 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.

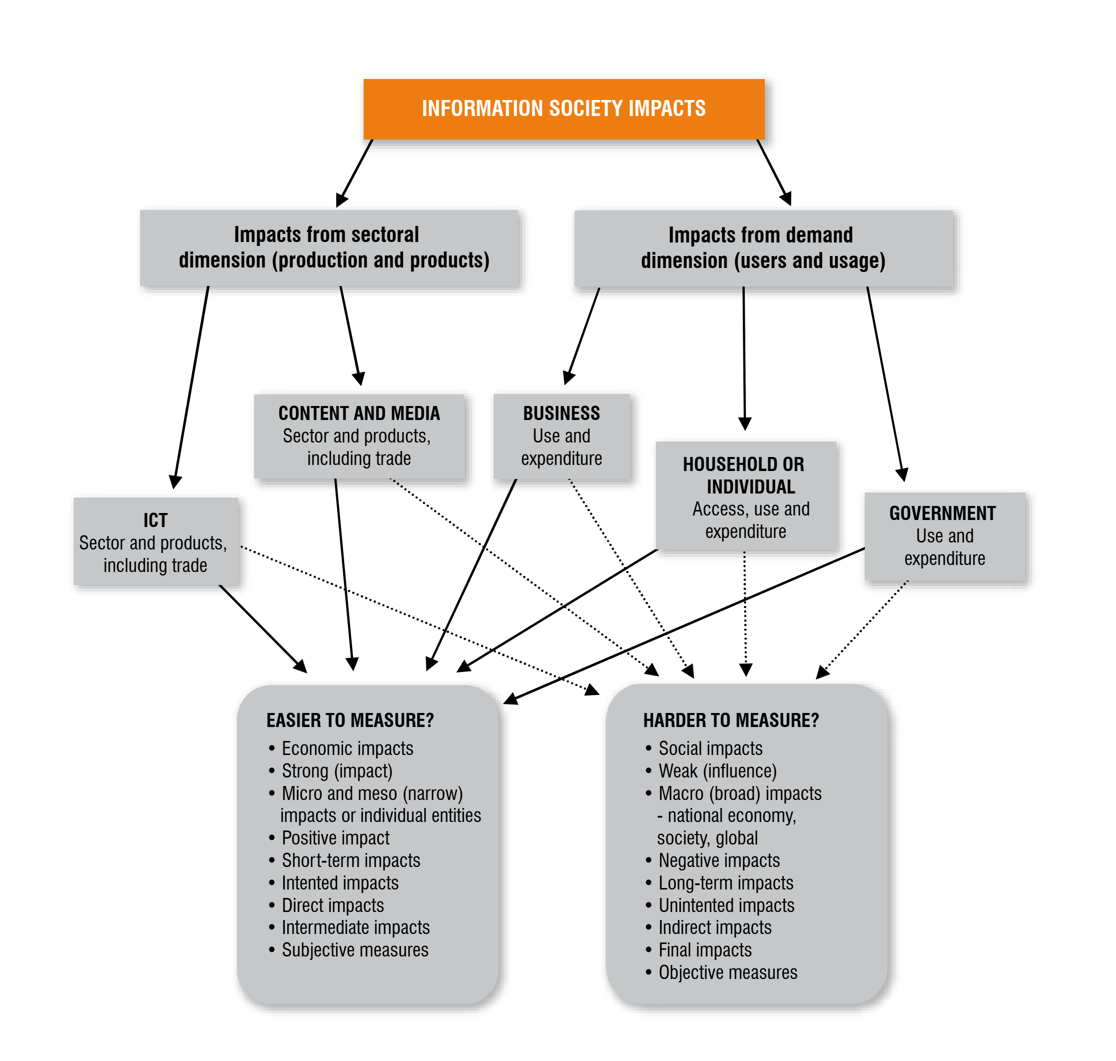
1.4. Measurement frameworks

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.

Further, OECD (2007) discussed the impacts components of the conceptual model as follows:[7]

- 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.

Figure 1. Information society impacts measurement model



Source: OECD, 2007.

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. The authors consider the last three to be impacts and distinguishes them as follows:

- Outputs are the micro-level behavioural 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 behaviour 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.[8]

An important aspect of measurement frameworks are definitions and classifications applying to its separate elements. The following paragraphs provide a brief overview of key international standards that define ICT products and the ICT sector, as well as the concept of ICT demand applied in this paper.

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 have most recently been classified by OECD in terms of the United Nations Central Product Classification (CPC) Version 2 and 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.[9] Components of ICT are also present in a variety of non-ICT products, such as scientific and medical equipment, motor vehicles and manufacturing equipment.[10] 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 most recent version is based on the international standard for classifying industries, the United Nations ISIC[11] Rev. 4.[12]

The concept of ICT demand for the purposes of this paper is broad and follows OECD (2009a).[13] 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. The Partnership's work on 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.

1.5. A note on the digital divide

An area that has received significant attention from policymakers is the question of a digital divide between individuals, organizations and countries. A major preoccupation of WSIS was 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.

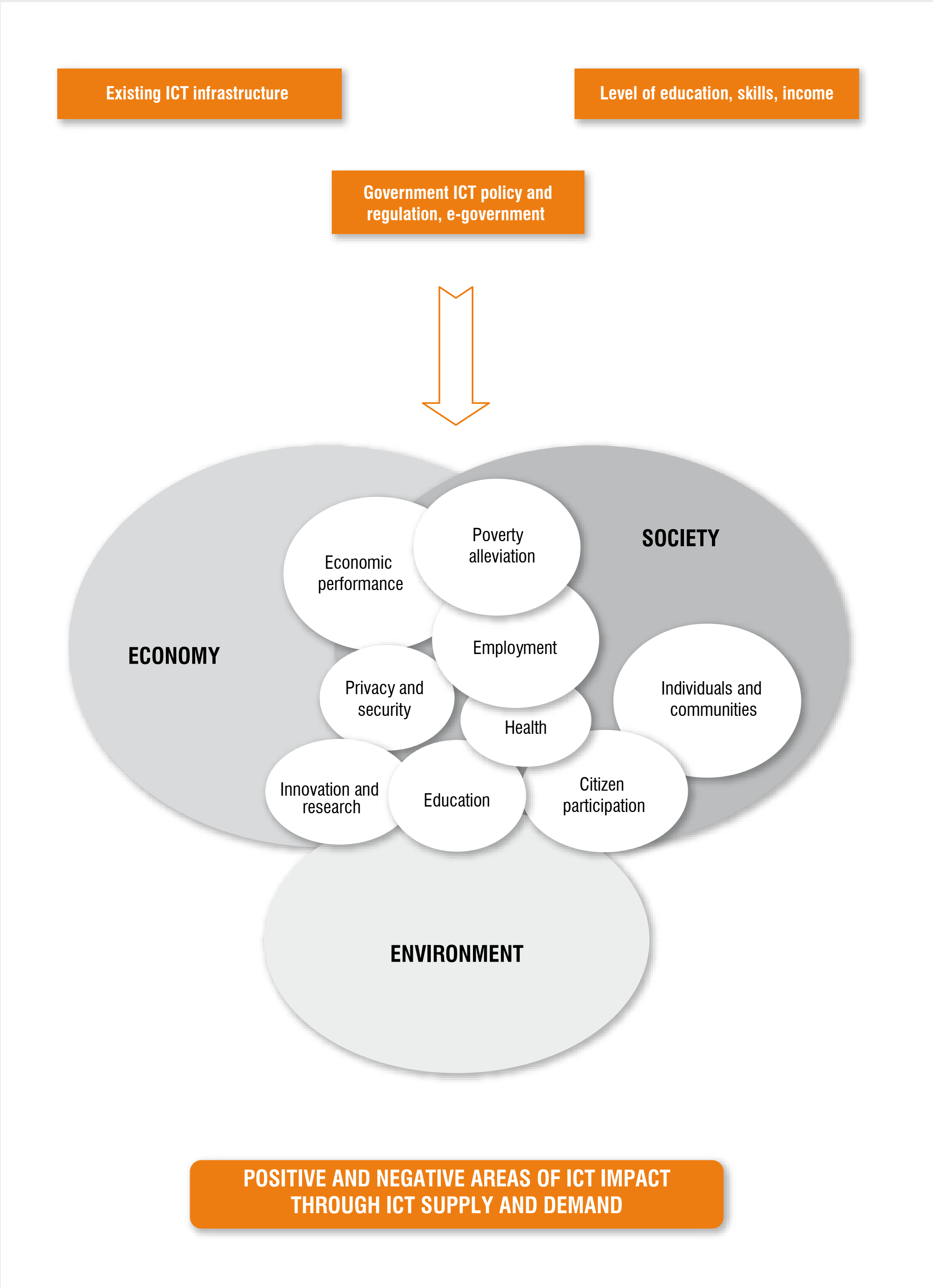
While this paper does not discuss studies on the digital divide, it recognizes its resolution as underlying much of the impetus for measuring the impacts of ICT.

1.6. Impact areas of ICT and their relationships

The ICT impact areas discussed in this paper and their relationships are shown in the simplified model below (figure 2). The model indicates the web of relationships between impact areas and with the broader economy, society and environment. Impacts of ICT arise through ICT supply and ICT demand and, at a country level, are likely to be influenced by the following factors:

- Existing ICT infrastructure, which enables an ICT critical mass that can amplify impacts;
- Country level of education, skills and income;
- Government ICT policy and regulation, and the level of e-government.[14]

Figure 2. ICT impact relationships



Source: UNCTAD.

2. How the impacts of ICT are measured

This section looks at the methodologies and data sources used in measurement of ICT impacts. It concludes with some 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.

2.1. Analytical techniques

Various analytical techniques have been used to measure the economic impacts of ICT at the macroeconomic, sectoral and microeconomic (firm) level. The main techniques 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 outcomes (see section 3).

The usual objective of an ICT impact analysis is to examine the relationship[15] between ICT and productivity, economic growth or employment. The analysis usually includes other determinants such as labour, 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 growth in GDP to increases in physical inputs, such as capital and labour, 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.[16]

Many ICT impact studies examine labour productivity, that is, how productively labour is used to generate output (gross output or value added). While relatively easy to measure, it captures the joint influence of a number of factors and change cannot be attributed to any one factor (such as technological change or productivity of individual workers) (OECD, 2001).

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 advanced e-business applications), firm size and age, skill level, organizational factors and other forms of innovation.[17] In some countries, these data are brought together in longitudinal databases, which provide data over different points in time. Economic impacts studied include labour productivity, multifactor productivity and value added.

2.2. Case studies

Much of the work on 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 can be used to explore causation within their scope. At the same time, case study findings are bound by the context in which they are conducted. While their results will not usually be generalizable beyond their context, they may indicate hypotheses or topics that could be assessed more broadly.

2.3. Statistical surveys

Data needed to measure ICT impacts can come from various statistical surveys, including the following:

- Household surveys[18] 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;

Box 1. Use of surveys to measure perceived impacts of ICT

Surveys can be used to directly measure impact by collecting self-reported perception data on the benefits and disadvantages of ICT. The 2005 OECD Model Survey of ICT Use by Businesses includes a question on the benefits of selling over the Internet. Response categories include reduced transaction time, increased quality of customer service and lower business costs (OECD, 2009a). Eurostat's 2008 model questionnaire for the *Community Survey on ICT Usage and E-commerce in Enterprises* included a module on perceived benefits of new ICT projects (Eurostat, 2010).

Some official household surveys have asked individuals about their perceptions of the impact of ICT. An interesting example is a set of questions in the international Adult Literacy and Life Skills surveys of 2003 and 2006 that probed respondents' attitudes to computers.[19] The surveys are run periodically by several countries in conjunction with Statistics Canada and OECD (OECD, 2007).

The *2009 Survey on the Internet Usage* conducted by the Korea Internet & Security Agency collected data on individual Internet users' perceptions of the Internet by asking whether they agreed or disagreed with several positive and negative propositions about the Internet, including "Internet is important to daily life", "Information on the Internet is reliable" and "Groundless rumours are easily created and spread through the Internet" (Korea Internet & Security Agency, 2009).

- 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 (see box 1). However, in respect of individuals' perceptions, it has been argued that without subjective indicators, measurement efforts are bound to be inadequate (ESCWA, 2009).

2.4. Panel studies

Panel studies are longitudinal and may be 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. Such studies can be useful in examining impacts, as they can provide good baseline data and account for time lags.

2.5. Controlled experiments

Controlled experiments can establish causality by controlling all the independent variables. Therefore, the experimenter can alter 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. However, where the conditions are limited, a controlled experiment may be possible.

2.6. Administrative data

An important data source in the field of ICT statistics is 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 ITU from member Governments, merchandise trade data compiled by the United Nations Statistics Division and ICT-in-education data compiled by UNESCO's Institute for Statistics. 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, through the efforts of organizations such as ITU, the United Nations Statistics Division and the Institute for Statistics, classifications and definitions can be applied to administrative data collection to enable statistical output.[20]

2.7. Other methodologies and data sources

Other methodologies and data sources include the use of focus groups, direct observation and document examination (Heeks and Molla, 2009). Scenarios may be used to establish impacts in different situations, using different sets of assumptions. Forecasting may be used to estimate the future impacts of ICT and can involve a number of techniques, data sources and assumptions.

2.8. Strengths and weaknesses of the different approaches and data sources

It is clear that there are a number of different methodological approaches and data sources used in the measurement of the impacts of ICT. Each has strengths and weaknesses, as described below.

The main analytical techniques used to measure the impacts of ICT are econometric regression techniques, growth accounting and input-output analysis. They use existing data and are therefore likely to be inexpensive, compared with other approaches. However, they will be limited to the extent that models are imprecise or input data are inconsistent, inaccurate or lacking in availability. A number of data problems relating to use of analytical techniques for measuring ICT impacts should be noted (OECD, 2001, 2004):

- Measurement of hours worked for productivity measures, especially by industry;
- Data from input-output tables may be missing, dated or not integrated with national accounts;
- Lack of comparable data on ICT investment, especially those on software,[21] and deflators adjusted for quality change (hedonic price deflators);[22]
- A number of assumptions are required to estimate the services from ICT capital;[23]
- In studies of the ICT sector, lack of value added and/or production data and hedonic deflators of output for industries in the ICT sector;
- In respect of some ICT-using services sectors, productivity growth is difficult to show because of weaknesses in measures of output, for example, banking, insurance and health;
- In respect of firm-level studies, comparability between countries is challenging because of the diversity of input data and methodologies used. A number of problems arise from the use of unit record data, including confidentiality constraints, difficulties linking records from different data sources, and small and possibly biased samples because of the limited overlap between sources.

Case studies can be flexible and shed light on particular situations. They may be used to explore causation within their scope applying a variety of data sources, including perceptions surveys conducted as part of the study. While their results will not usually be generalizable outside their context, they may indicate other avenues of enquiry. The cost of case studies is highly variable; they may be expensive if additional data collection is required.

Well-conducted statistical surveys can provide representative data about the population being measured. Their output can be cross-classified by a number of characteristics such as age of individuals, or industry of a business. While surveys are generally expensive to conduct, their results are essential inputs to many of the analyses discussed in this section. Survey results are subject to a number of sources of sampling and non-sampling errors, and a high degree of harmonization of statistical standards is required to enable international comparison of survey output. National statistical surveys of households and businesses are the basis for the Partnership's core indicators on ICT use. [24]

Panel studies can be very useful in following change over time in individual units, for example, people or businesses. One of their advantages is that such data enable investigation of causality where the phenomena being investigated are subject to time lags. However, panel studies can be expensive, especially if the panel is large, and suffer from attrition, that is, loss of units over time. For example, individuals may wish to withdraw from the study, businesses may cease to exist.

Controlled experiments are problematic for this topic, as the number of factors involved in an ICT impact can be very large, and some unknown. However, a couple of examples are presented in this paper and their results are interesting. Like case studies, results are likely to be limited in scope but may indicate areas that could be explored more broadly.

Administrative data on ICT form the basis of many of the Partnership's core indicators. Telecommunication or ICT indicators from ITU and goods trade data from the United Nations Statistics Division are available for many countries, are readily accessible and have long time series of data. They are not indicators of impact but may be used as inputs in analyses or case studies. Their usefulness may be limited because their primary purpose is not statistical. For example, subscriber data from ITU's telecommunications/ICT indicators are often used to measure the penetration of ICT. However, subscribers are not equivalent to users[25] and impacts will arise from the use of ICT, not through subscription to ICT services per se.

3. Empirical evidence

This section reviews empirical evidence on the impacts of ICT, with particular emphasis on developing countries and the alleviation of poverty. The structure of the section follows figure 2 and includes a number of 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.

3.1. Impacts of ICT on economic performance

This section discusses the impact of ICT on economic growth and productivity at the macro, sectoral 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, the 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 labour productivity;
- Multifactor productivity growth across the economy, which arises from the role of ICT in helping firms innovate and improve their overall efficiency.

A growing ICT sector can contribute to aggregate increases in productivity, GDP and trade. An OECD study (2004) reported increases in aggregate labour productivity (value added per person employed) attributable to a strong ICT sector in some OECD countries between 1990 and 2002. For example, Finland's contribution of ICT manufacturing industries was 0.2 percentage points during 1990–1995 and 0.8 percentage points during 1990–1995. The relative figures for the Republic of Korea were 0.8 and 1.0 percentage points. The contribution of ICT services industries to aggregate labour productivity growth was typically less than for ICT manufacturing in the same periods.

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,[26] 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 low-income countries. Much of this activity is in the informal sector and, while the activities are not well measured,[27] anecdotally they provide benefits for proprietors and customers and occupy niches in which larger formal businesses are not interested (UNCTAD, 2010).

Economic impacts of ICT diffusion have been assessed in a variety of studies at the macroeconomic, sectoral and firm levels. The diffusion of ICT includes use, access and financial aspects. It may be measured directly through surveys[28] 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,[29] 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.

Macro-level research has generally shown a positive link between ICT investment and growth in GDP. Data for several developing countries on the contribution of ICT capital to GDP growth over the period 1990–2003 suggested that, in all cases, the impact was modest relative to the contribution from other capital and labour (UNCTAD, 2007). In part, that result may have been due to relatively low levels of ICT penetration in the countries investigated.

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 particular challenge of firm-level studies is measuring the effect of intangibles, such as good management and marketing (UNCTAD, 2007). 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). Box 2 describes a study of firm impacts in a number of European countries.

The results from developed-country firm-level studies may not always be generalizable to developing countries. 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). For an example of a firm-level study in a developing country, see box 3.

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).[30] 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,

Box 2. Firm level impacts in European countries

The most ambitious firm-level study to date was conducted from 2006 to 2008 and was led by the Office for National Statistics of the United Kingdom of Great Britain and Northern Ireland. The project included data from 13 European Union countries and variables on ICT use and relevant non-ICT factors. For each country, firm-level data were drawn from three basic data sources: ICT usage (from the harmonized European Union community survey on ICT use), economic characteristics and firm performance (from structural business surveys) and firm population information from business registers. The productivity measures were labour productivity and multifactor productivity. Metrics using ICT were computer use, e-sales, e-purchases, fast Internet-enabled and Internet-using employees. Data were compiled by each country using common methodologies and computer codes to run regressions. Countries that had additional data collaborated in topic groups; for instance, the Nordic countries worked together on skills.

The results showed that ICT use had reasonably consistent and positive labour productivity effects for manufacturing firms. For services firms, ICT use had mixed productivity impacts. Finally, industry analysis by country indicated that high-speed Internet use by employees was positively correlated with productivity in countries where ICT adoption is highest, but negatively related to labour productivity in three other countries. The authors suggest that returns depend on critical mass network effects.

Source: Franklin et al. (2009).

Box 3. Firm-level impacts in Thailand

A 2007 study by UNCTAD and the Thai National Statistical Office analysed the impact of ICT on labour productivity in urban firms with 10 or more employees in the Thai manufacturing sector. A simple comparison showed that firms with greater ICT use had higher sales per employee and that sales increased with use of more sophisticated ICT (computer to Internet to Web presence). An econometric analysis, controlling for non-ICT factors, showed that firms with a combined use of computers, the Internet and the Web had on average 21 per cent higher sales per employee than firms without any of these ICTs. The greatest increase was noted for firms with computers. The study also found that the link with ICT is strongest in large firms, though Internet access had the most effect on small firms, and the link with computers was greatest in young firms.

Source: UNCTAD (2008).

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.

Different ICTs will have different impacts, depending on a number of factors, including the development level of a country. Several studies have indicated that under the right conditions, more advanced ICTs, such as broadband, can have a greater economic impact than simpler technologies. At the same time, many low-income countries still have very limited access to the Internet, especially at broadband speed (ITU, 2010b). Thus, in these cases, more widely diffused ICTs, such as radios and mobile phones, may offer the greatest scope to contribute to poverty alleviation in the short term, including in combination with other ICTs (UNCTAD, 2010). The mobile phone can be seen as a leapfrogging tool, with particularly important impacts in rural areas – home to three quarters of the world's poor (World Bank, 2009). In addition, in contrast with ICTs such as computers and the Internet, mobile phone use does not require basic literacy skills or a high income.

In 2008, the World Bank conducted an econometric analysis across 120 countries to investigate the impact of higher penetration of broadband and other ICTs on economic growth (the average growth rate of per capita GDP) between 1980 and 2006 (World Bank, 2009).[31] It estimated that impacts were somewhat greater in developing countries than in developed countries. 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. The author made the point 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 2004 (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). Case-study evidence confirms that broadband use in developing countries has had positive economic impacts (World Bank, 2009). For instance, a 2005 study on broadband use by 1,200 companies in six Latin American countries showed an association with considerable improvements in e-business processes, such as process automation through network integration, better data processing and information diffusion.

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.[32]

Negative economic impacts associated with ICT diffusion have received relatively little attention from statisticians. They include a range of privacy and security impacts (see below), 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.

3.2. Impacts of ICT on employment

Information and communication technology has roles in the creation of employment and self-employment opportunities. Impacts can be direct, through growth of the ICT sector[33] and ICT-using industries,[34] 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 might offer the greatest opportunities for employment creation (UNCTAD, 2010). Only a small number of developing countries have a well-developed ICT sector. For those that do, ICT manufacturing can be significant in employment terms, sometimes involving the poor. 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 (for example, see 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 labour force skills (Pyramid Research, 2010).

Broadband penetration can increase employment in at least three ways (Katz, 2009). The first is the direct effect of jobs created in order to develop broadband infrastructure, the 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 second two ways can be expressed, through an input-output model, as multiplier effects. 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. Data are presented for Argentina and Chile comparing regional broadband penetration and employment growth that show a moderately positive linear relationship.

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. In Egypt, survey data from 2009 indicated positive impacts accruing to IT Club members, for example, improving ICT skills and having better job opportunities. In Jordan, a 2007 survey-based evaluation of the impact of the Knowledge Stations Initiative on community development showed positive impacts, affecting males and females almost equally, and indirect employment opportunities through better access to microloans. In the Syrian Arab Republic, cultural community centres have trained a large number of people and appear to have enhanced indirect employment opportunities.

The potential impacts of IT services and ICT-enabled services on poverty reduction include employment and its multiplier effects.[35] 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.

Evidence from six Latin American countries suggests that Internet use by individuals is associated with increased earnings (Navarro, 2010). Controlling for factors, such as education, that relate to wealth before Internet adoption, the study found significant differences between salaried and self-employed workers. For the former, there was a large and statistically significant positive return to Internet use on earnings for all countries except Paraguay, where the difference was large but not statistically significant. The earnings advantage ranged between 18 per cent in Mexico to 30 per cent in Brazil and Honduras. Results 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. Difficulties controlling for pre-existing characteristics indicate that the results show an upper bound on the impact of Internet use on earnings.

3.3. Relationships between ICT and innovation

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).[36]

There are several relationships between innovation and ICT. We saw above that 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 across nine member countries using a common methodology. Data from business use of ICT surveys and innovation surveys were linked at the firm-level and analysed using an econometric model provided by OECD. 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 reflected in WSIS target 3, which aims "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.

3.4. Impacts of ICT on privacy and security

There are 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).

3.5. 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 and WSIS outcomes. The impact of ICT in education has been assessed in various studies, with mixed results (see the discussion in Institute for Statistics, 2009).

For example, ICT may deliver 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 likely to be a greater problem for developing countries, where access to ICT is generally lower than for OECD countries. Other possible 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, 2010b; Kozma, 2005).

Empirical experiments that are highly controlled can help establish causal relationships between ICT use and educational outcomes (Kozma, 2005). In Vadodara, India, in 2000, 100 primary schools were each provided with four computers. A controlled experiment commenced in 2002–03 and ran for two years. Half the schools were randomly allocated with training and educational software. Students in those schools played educational computer games for two hours a week and scored significantly higher on mathematics tests than students in the control schools. The bottom group of students benefitted most, with girls and boys benefitting equally (Abhijit et al., 2007). Controlled experiments from the United States, Kenya and Uganda also showed positive impacts on student learning arising from some types of use of computers in specific school subjects, while more general availability and use of computers at school did not affect student learning (Kozma, 2005). An analysis of learning outcomes from the Khanya project in South Africa showed a positive relationship between use of the ICT-based Master Maths programme and mathematics scores on standardized tests (James and Miller, 2005). The analysis was controlled, with comparisons made between a random sample of experimental and control schools. The study found that scores for learners on the ICT-based mathematics programmes were significantly better than for other students.

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 OECD's discussion that the impact of ICT on school performance is a very complex topic and not easily measured.

The Programme for International Student Assessment (PISA) is a triennial study of the knowledge and skills of 15-year old children in mathematics, reading, science and general problem-solving.[37] It is possibly the best available vehicle for studying the impact of ICT on learning outcomes. Results from the 2003 PISA surveys showed that the mathematics performance of students without home access to computers was significantly below that of those with home access. The gap was significant for all countries in the study and, in 23 out of 31 countries, a performance advantage persisted even after accounting for different socio-economic backgrounds of students (OECD, 2005b). The performance difference associated with school access to computers was generally less marked, with a positive association seen in only about half the participating countries.

The intensity and type of computer use has also been found to be related to PISA scores. In the 2003 survey, the highest performances in both mathematics and reading tended to be from students with a medium level of computer use, indicating that excessive computer use could have a negative impact on school performance. The 2003 survey also measured students' confidence in using computers and the Internet. For most countries, it found a strong positive relationship between performance on the mathematics test and confidence in Internet and routine ICT tasks, such as opening and saving files. This could suggest that the quality rather than the quantity of ICT usage is a more important determinant of the contribution of ICT to student performance (OECD, 2005b).

Findings from the 2006 survey were similar and showed positive relationships between science scores and length of time using computers, frequency of computer use at different places (with a stronger relationship associated with home use), a moderate level of usage and higher levels of ICT confidence. A more detailed analysis of 2006 data found that for most countries, 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. For all countries, average science scores rose with increased frequency of computer use (OECD, 2010b).

3.6. Impacts of ICT on health

Health is mentioned in WSIS documents 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. In OECD (2007), the use of ICT was also cited as enabling complex and networked medical equipment. The 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[38] is a particular problem for some 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 "eHealth works to improve health by enhancing patient services and health systems". Through its Global Observatory for eHealth, 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, broadband-enabled telemedicine is widespread in developed and developing countries, yet there are few studies on its effectiveness. It described an eye hospital in southern India that connects rural communities using a wireless broadband network. The rural clinics screen about 1,500 patients a month using a web camera. Doctors at the hospital are able to diagnose problems and distinguish minor problems that are able to be treated locally, from more serious problems. This is of great benefit to individuals, providing rapid diagnosis and treatment, and in many cases saving the cost and inconvenience of travel.

The socio-economic and financial impacts of interoperable electronic health records and e-prescribing systems were investigated via several case studies in Europe and the United States (European Commission, 2010). Evaluation was based on cost–benefit analyses; for all cases, the socio-economic gains to society exceeded the costs. A common feature of all the studies is that interoperability between electronic health records and other clinical and non-clinical systems is a prime driver of benefits. The benefits were found to be distributed unevenly, with health provider organizations benefitting most, with an average of 61 per cent of the benefits; patients and medical staff each gained, on average, 17 per cent of the benefits. Important observations are that benefits to providers tend to be long term – with an average seven years before a net positive benefit occurs – and that solutions are context-specific.

3.7. Impacts of ICT on citizen participation, individuals and communities

Information and communication technology can facilitate 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.[39]

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. In the latter case, senior government officials appear to be soliciting, and responding to, online suggestions posted by citizens (UNDESA, 2010).

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 (see ITU, 2010c);[40] 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. For minority groups and those who are socially disadvantaged, such impacts may be particularly beneficial. The World Bank (2009) discussed the potential empowerment of women when they are able to access public services electronically at home or in the community, and of minorities when they are able to gain electronic access to relevant public information on rights and benefits.

Using case study evidence, ESCWA (2009) summarized the positive social impacts of ICT in poor communities as improving communication, facilitating knowledge-sharing, networking within and between communities, and improving the delivery of awareness-raising activities.

Final-level impacts are generally harder to measure than intermediate impacts (OECD, 2007). However, some survey data on final impacts exist. Statistics Finland (cited by OECD, 2007) studied the links between ICT and social capital and found significant correlations between ICT use and the components of social capital, community involvement and size of the social network. An ITU study (2006) cited similar evidence from South Africa concerning the use of mobile phones to improve relationships with friends and family.

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.[41] 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; for example, 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 Nigeria 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 (Pyramid Research, 2010).

3.8. Impacts of ICT on the environment

Measurement of the relationship between ICT and the environment is a relatively new topic. 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,[42] 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. For example, 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. Some data that are relevant for measuring the potential impact of ICT on the environment through dematerialization are already included in the Partnership's core set of individual use indicators, for example, the use of the Internet for various activities. However, as mentioned above, assumptions would be required to convert that information into measures of impact.

Despite the importance of the topic, 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. They also found that the greatest potential for a positive impact of ICT is its use to increase the energy efficiency of industrial processes that are high greenhouse gas emitters: power transmission and distribution, the heating and cooling of buildings, manufacturing and transport. A 2004 report commissioned by the European Commission's Institute for Prospective Technological Studies found a greater potential for greenhouse gas reduction through dematerialization (Institute for Prospective Technological Studies, 2004).

4. Summary and issues for consideration

This concluding section summarizes the findings presented above and proposes a set of key issues for further consideration.

Section 1 explains 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. At a country level, 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 (see section 2), 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 and some macro-level evidence 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.

While ICT also produces negative impacts, there has been less research in this area. 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. Evidence for developed countries has tended to focus on macro- and micro-level analyses, usually supported by extensive statistical datasets. While the modelling required for such studies is not necessary difficult, data requirements are significant and pose barriers to such approaches for most 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.

Few studies or surveys provide internationally comparable data on the impacts of ICT. The main exceptions are macroeconomic analyses carried out by OECD and the World Bank, firm-level analyses covering mainly European countries, the OECD's PISA study (which in 2006 covered 57 countries) and ICT impact-perceptions data from some surveys that are harmonized internationally, for example, Eurostat's 2008 Community survey on ICT usage and e-commerce in enterprises and the Adult Literacy and Life Skills survey.

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. The work of the Partnership's Task Group on Impacts will be important in overcoming this deficit of measurement standards.

4.1. Key issues for consideration

This paper has examined a number of impact areas indicated by the WSIS targets. 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 2015? 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 governments, development partners and international organizations – especially those that are members of the Partnership – 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 developing countries using methodologies applied by OECD;
  - Extending the measurement of firm-level impacts to more developing countries;
  - 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;[43]
  - Extending the PISA programme to more developing countries to shed light on the impact of ICT on learning outcomes of 15-year olds.
- What can be done to raise awareness among different stakeholders about the need for the measurement of impact of ICT?

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NOTES

[1] The UNCTAD secretariat functions as the CSTD secretariat.

[2] ITU assessed progress against the targets in 2010 (ITU, 2010a).

[3] These are e-government, e-business, e-learning, e-health, e-employment (including teleworking), e-environment, e-agriculture and e-science (ITU, 2005).

[4] Eurostat, ITU, UNCTAD, UNDESA, the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics, the World Bank, OECD and four United Nations regional commissions (Economic Commission for Africa, ECLAC, Economic and Social Commission for Asia and the Pacific, and ESCWA).

[5] For further information on the Partnership's objectives and activities, see http://measuring-ict.unctad.org.

[6] ESCWA (2009) discussed the overlap between economic and social impacts, for instance, where communicating and networking for social purposes result in new business opportunities.

[7] See also ITU (2006).

[8] Each assessment framework includes information on the nature of data and the requirements of data collection. A particular framework may accommodate different analytical techniques and data sources.

[9] An earlier and broader definition of ICT goods was based on the 1996 and 2002 Harmonized System used for classifying goods trade (OECD, 2005a).

[10] The 2003 definition of ICT goods included many such products, whereas the current version does not.

[11] International Standard Industrial Classification of All Economic Activities (ISIC).

[12] An earlier version, released in 2002 and based on ISIC Rev. 3.1, was somewhat broader, including also manufacturing of some goods that use ICT products. For more information, see OECD (2009a), Partnership (2010) and UNCTAD (2009a).

[13] A note on terminology. Various terms are used in this area of measurement. ICT use refers to use of ICT by entities (except households). ICT access refers to availability of ICT and is generally used in the context of household access to ICT. A business or government organization may also have access to an ICT application (for example, an extranet), though it is generally assumed that it will also use it. ICT diffusion is generally used in a broad sense, analogous to ICT demand.

[14] E-government is not treated as a separate impact area in this paper. In terms of ICT demand, e-government can have positive impacts on the efficiency of government operations. In terms of ICT supply, government as a provider of electronic services can influence the outcome in all areas, for example, by encouraging the adoption of electronic processes and by providing information via the Web or mobile phones.

[15] Most analytical techniques are unlikely to be able to demonstrate a causal link, though they can demonstrate strong relationships, some of which may be attributed to two-way causality.

[16] Katz (2009) cited a number of studies that used input-output techniques to calculate the multiplier effects on employment of broadband diffusion through indirect and induced effects. OECD (2008a) also used them to analyse the impacts of the ICT sector on economic growth by three channels (final demand increases the output of the ICT sector, the ICT sector's intermediate demand from non-ICT industries and the supply of intermediate inputs by the ICT sector to non-ICT industries).

[17] The *Oslo Manual* (OECD and Eurostat, 2005) recognizes four types of firm-level innovation, including new organizational methods.

[18] Household surveys include population censuses, which can be a useful source of household ICT data.

[19] Questions for 2006 were a set of agree/disagree statements about computers, such as they allow the respondent to do more in less time they have made it easier to get useful information and they have helped the respondent to communicate with people (OECD, 2007).

[20] Partnership (2010) discusses statistical standards applying to core ICT indicators. The Institute for Statistics (2009) provides guidelines for collection of data on ICT in education.

[21] Chapter 4 of OECD (2004) includes a useful discussion of software measurement difficulties.

[22] These adjust for price and quality. For example, for computers, the deflator takes changes in speed and memory into account.

[23] Services from ICT capital are estimated from a number of data sources, including ICT investment. Data on the flow of capital services are used in growth accounting to measure the contribution of ICT to economic growth. OECD (2004), chapter 4, discusses the estimation of capital services.

[24] Guidance on conducting household and business ICT surveys may be found in manuals produced by ITU (2009) and UNCTAD (2009a), respectively. The ultimate aim of the manuals is to assist in the production of reliable and internationally compared ICT indicators.

[25] The differences apply in both directions; for example, there may be more than one Internet subscriber in a household or several individuals may use the same Internet access subscription. In respect of mobile phones, many users have more than one SIM (subscriber identity module) card, with each one counting as a subscription.

[26] Using the definition referred to in section 1, ICT retailing is excluded from the ICT sector.

[27] The statistics needed for capturing the informal sector are particularly difficult to collect and typically lacking.

[28] For example, surveys of ICT use by businesses, from which the Partnership's core indicators of business ICT use are sourced.

[29] This arises because of the network nature of ICT – the more people and firms using the network, the more benefits are generated (OECD, 2004).

[30] A perceptions survey of 1,500 mobile phone users in Nigeria found that, in respect of economic impacts, 80 per cent of respondents reported experiencing financial gains from using mobile services. High proportions also reported gains from better ability to find jobs and improved communication with clients (Pyramid Research, 2010).

[31] The study used ITU data on the penetration of different ICTs and controlled for other factors that could contribute to GDP growth.

[32] The World Bank (2009) suggests that convergence could have an enormous impact on economic and social development, for instance, by increasing productivity, lowering transaction costs and facilitating trade.

[33] For example, in some developing countries, such as Egypt, Malaysia and Mauritius, the ICT sector accounts for more than five per cent of the total business sector workforce (UNCTAD, 2010).

[34] Some may be new industries based on ICT-enabled business models, for example, web-based businesses.

[35] It is common to make a distinction between IT services and ICT-enabled services. The latter group covers front-office services, back-office services and various forms of knowledge process offshoring. IT services refer to programming, systems integration, application testing, IT infrastructure management and maintenance, IT consulting, software development and implementation services, data-processing and database services, IT support services, data warehousing, and content management and development (UNCTAD, 2009b).

[36] Research and development is defined as "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications".

[37] The Programme is commissioned by OECD and was conducted in 2000, 2003 and 2006. The 2006 surveys are the latest for which data are available and covered 400,000 students in 57 countries.

[38] E-waste stands for waste electrical and electronic equipment and describes old, end-of-life or discarded appliances using electricity, including computers, consumer electronics and fridges, which have been disposed of by their original users (Global Knowledge Partnerships in e-Waste Recycling, 2011).

[39] WSIS target 6 refers to the role of e-government in contributing to development by enhancing transparency and accountability and promoting good governance in the public sector.

[40] The proposed statistical framework has few impacts indicators and those are of an intermediate nature, for example, the proportion of children who have ever "ended up on a porn site accidentally when looking for something else".

[41] The 2003 survey involved Bermuda, Canada, Italy, Mexico, Norway, Switzerland and the United States.

[42] Use of the Internet as a substitute for material activities, for instance, downloading online newspapers, Internet banking and downloading digital content.

[43] In order to shed light on the impacts of the digital divide, it may be appropriate that non-users of ICT be asked about the impacts of lack of access. Both positive and negative impacts should be canvassed.


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