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Revisiting Digital Inclusion: A Survey of Theory, Measurement and Recent Research

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Abstract

As it becomes increasingly clear how central digital transformation is to development, the need for accurately measuring digital inclusion and understanding its relationship to socio-economic factors, becomes more urgent. Focusing on the internet as a foundational technology, this paper begins by summarising recent developments in digital inclusion theory, particularly as this relates to developing countries. It sets out a framework of core components of digital inclusion - including access/use, quality of access/use, affordability, and digital skills - and briefly considers policy implications. The paper then surveys the ways these components are currently measured in household and firm surveys and by international organisations, highlighting some of the often-overlooked weaknesses of current measures, and suggesting possible improvements. The paper also reflects on potential applications of (and risks associated with) new ways of measuring digital inclusion using big data. Lastly, building on the framework developed, the paper reviews the empirical literature on 'digital divides' in developing countries, and makes suggestions for how future research could become more rigorous and useful.

A. Introduction

Digital transformation - across trade, production, labour and service delivery - is occurring at a rapid pace, and is increasingly being recognised as central to development (World Bank, 2016). A critical question has been how to achieve digital inclusion - that is, how to ensure that everyone can benefit from digital technologies in a substantive way. The long-standing literature on digital inclusion has undergone two important shifts: First, while the initial focus was on differential access/usage rates, this has widened to include quality of access/use, affordability and digital skills; second, while much of the earlier emphasis, at least in the case of developing countries, was on mobile phones, the focus has shifted to the internet, which has been called 'the single most important general purpose technology of recent times' (Bauer and Latzer, 2016).[1]

There has been much speculation in recent decades about the potential benefits of the internet for development. Only recently, however, have credible estimates of the causal impacts of internet connectivity in developing countries emerged in the economics literature. Recent studies on developing countries have demonstrated significant positive effects on labour markets, democracy, education, financial inclusion, poverty reduction, public service delivery and health (see reviews in Hjort and Tian, 2021; Zhuravskaya et al.,2020). It has also become increasingly clear that reliable and fast access to the internet is a prerequisite for developing countries to take advantage of digital technologies, trade in services and to be able to transition to knowledge-based economies. China and India are pursuing industrial policies involving the promotion of their digital economies, and many other developing countries are looking to follow suit. The World Bank's World Development Report 2016 'Digital Dividends' concludes that improving digital inclusion is one of the primary global policy priorities (World Bank, 2016).

The International Telecommunications Union (ITU) of the United Nations, the most highly-cited source on internet statistics, estimates that, as of 2021, 63% of the world's population uses the internet (ITU, 2021). However, data on internet access at the country level for developing countries are often of low quality. Moreover, disaggregated data on internet access within countries (for example, for different demographic groups or regions) is often non-existent. Much less is known about the other aspects of digital inclusion related to the internet in developing countries. Yet, as will be argued in this paper, having accurate and detailed data on digital inclusion is critical for informing government policy, for goal-setting and for being able to monitor and evaluate the internet's impacts on development.

[1] A general purpose technology is a technology that is pervasive, improves over time, and inspires innovation (Bresnahan and Trajtenberg, 1995).

This paper critically examines how digital inclusion related to the internet in developing countries is measured in household and specialised surveys and with indicators designed by international organisations. The paper finds that when it comes to currently available data on digital inclusion, measurement issues - related to reliability and validity - are pervasive. It also argues that, while (imperfect) efforts have been made to measure internet access/use and affordability, other core components of digital inclusion - including quality of access/use and digital skills - have not received the attention they deserve. Another central argument is that while important attempts have been made to standardise questions related to digital inclusion to be used in representative surveys in developing countries, survey designers should be aware that the internet may be used in particular ways in developing countries which are not captured well in questions directly taken from high-income country surveys. Finally, the paper contends that measurement efforts and progress goals related to digital inclusion should do more to consider within-country inequalities in addition to cross-country inequalities.

The paper then assesses the empirical academic literature on 'digital divides' between and within developing countries. It shows, that despite advances in theory related to digital inclusion, these studies have tended to narrowly focus, for the most part, on access. It also argues that much of the statistical research suffers from endogeneity issues, such that it provides an unreliable picture of how socio-economic factors like gender, education, income and location affect digital inclusion. The paper recommends a number of steps to improve on and extend this research, providing relevant empirical examples.

To date, there has been no survey of measurement issues related to digital inclusion nor has there been a survey of quantitative research on this topic. Moreover, recent surveys of the relationship between the internet and development outcomes (Hjort and Tian, 2021; Zhuravskaya et al., 2020) have focused exclusively on internet access and have not considered other aspects of digital inclusion. This paper aims to fill these gaps. Though digital inclusion is occasionally thought of in the context of firms (e.g. OECD, 2001), the focus is usually individuals, households and countries, and will remain as such in this paper. Section 2 considers key theoretical dimensions of digital inclusion and reflects on the need for government intervention in the digital inclusion space. Section 3 analyses the ways digital inclusion is currently measured in developing countries, highlighting some of the often-overlooked weaknesses of current measures and suggesting possible ways to improve on workable, standardisable measures. This section also reflects on potential applications of new ways of measuring digital inclusion using 'big data', as well as some of the safeguards that need to be in place to mitigate risks around data protection and privacy. Section 4 surveys the recent literature on digital inclusion and 'digital divides' in developing countries, and makes suggestions for future work.

B. Background

B.1 Digital inclusion and digital divides theory

What is often referred to as the 'digital revolution' began with the automation and computerisation of manufacturing, and was followed by the widespread use of personal computers, mobile phones and the internet, all of which are constantly being improved, with new devices being added (Cruz-Jesus et al., 2016). Because they are related to the diffusion of innovations, digital divides - or digital inequalities - are often seen soon after a technology is developed (Rogers, 2010). Innovations do not penetrate society in a uniform and immediate fashion but diffuse over social networks with time, which inevitably creates divides between different parties. Digital inclusion received much attention in the late 1990s and early 2000s with extensive discussion on the digital divides between countries (the so-called 'global digital divide'), and within countries between demographic groups and places. As well as the internet, the discussion also considered mobile phones and digital television.

In the early years of its theorisation, the concept of a digital divide was commonly understood as the gap between those who have access to an information and communications technology (ICT) and those who do not (Dewan and Riggins, 2005; Van Dijk, 2005). It was implicit that digital inclusion could be achieved by simply providing access to ICTs (DiMaggio et al., 2004; Hsieh et al., 2008). Most of the quantitative research on inequalities associated with digital development has focused on access, exploring how access divides are measured and studying the determinants of ICT penetration and diffusion at micro, regional, and macro levels (Billon et al., 2021). The more qualitative sociological literature has claimed that this focus is too narrow. It has argued that the digital divide is 'a multidimensional phenomenon that includes a set of complex divides...caused by a variety of factors' (Bruno et al., 2011, p. 27), and that attention should be paid to how different social groups access and use technologies and how this contributes to offline advantages and disadvantages (Witte and Mannon, 2010; Helsper, 2012; Van Deursen et al., 2017). This literature has argued that even if access divides are closed, there are concerning second-level divides in skills and usage patterns (DiMaggio and Hargittai, 2001; Hargittai, 1999; Van Deursen and Van Dijk, 2011; Helsper and Eynon, 2013). Other authors then suggested that attention be paid to differential impacts of technologies (Helsper et al., 2016; Wei et al., 2011). It is now common practice among theorists to distinguish between (1) access, (2) effective usage, and (3) tangible impact of digital technologies. This framing has also been adopted, at least notionally, in the reports of some international organisations (e.g. ITU, 2006; World Bank, 2016; UNCTAD, 2017).

While these distinctions are important, they have also created confusion about which digital inclusion metrics to adopt. This has led to influential academics arguing that there is no point in standardising measures of digital inclusion (Hilbert, 2011b; Galperin, 2010). They argue that measures are inherently 'subjective' and should be conditional on the desired impact. They also contend that 'since there are no common ends in the deployment of ICT, it is counterproductive to pursue common means' (Hilbert, 2011b, p. 733).

This paper argues that embracing a multifaceted conception of digital inclusion does not mean giving up on high-level indicators related to the fundamental components of digital inclusion and that much could be done to improve their accuracy and sophistication.

B.2 Digital inclusion related to the internet and development

There has been much debate about how much of a priority digital inclusion should be for developing countries. While a theoretical case for the value of the internet for development is straightforward, until recently there has been a lack of good evidence and many commentators have questioned this view.

The theoretical benefits of the internet and related technologies are well-established in the economics literature. Most importantly, these technologies reduce the time and money involved in accessing and exchanging information – that is, they reduce transaction costs (Coase, 1937). The internet has made many types of transactions much easier, faster and cheaper - for example, those related to searching and exchanging information, enforcement, bargaining and decision-making. Due to the magnitude of the improvement over previous communications tools, the adoption of the internet could lead to a significant impact on economic growth through better functioning of markets and firms. These effects may be enhanced by network externalities, where the value of a connection to a network rises as more people join. Through similar mechanisms, the internet is expected to lead to improved public service delivery, political participation and financial inclusion.

While the theoretical case was solid, empirical evidence based on careful identification of impacts on development (or socioeconomic) outcomes was hard to come by (Deichmann et al., 2016). There have been many claims of immediate and sizeable effects, particularly from technology evangelists in industry and politicians. However, even if positive effects were anticipated in high-income countries, developing countries have poorly functioning institutions and markets and lower levels of skills, which could nullify these effects (Chen et al., 2020). Given this uncertainty, many commentators questioned whether providing internet access to all citizens of developing countries would reap any real benefits (e.g. Kenny, 2002; Fink and Kenny, 2003). Others claimed that scholars emphasising the digital divide as a major social problem were most often driven by a kind of misplaced technological determinism (Van Dijk, 2002). Fink and Kenny (2003) contended that to worry about the digital divide, we must believe that the unequal availability of ICTs leads to systematic divergence in the growth trajectories of rich and poor countries, and that there was insufficient evidence of this. They also argued that, even if ICT access gaps increased in the short term, the comparative patterns of ICT diffusion since the early 1990s suggested that poor countries experience faster growth in ICT access, pointing the way to convergence in access over the long term.

Now there is much better evidence on the gains from the extension of the internet in developing countries (see Section 4). Moreover, academics have pointed out that, just because there is saturation of devices at the top of the market, which makes it inevitable that access gaps, narrowly construed, will close, does not mean we should stop worrying about digital gaps (Van Dijk and Hacker, 2003; Hilbert, 2014) (see also Section 4). The widely-reported success of other digital technologies – for example, mobile phones, particularly as these have enabled mobile money applications – has brought awareness to the development potential of the internet and other digital technologies in policy-making circles.

B.3 Extending digital inclusion theory

It is clear now that policymakers and academics should be focusing on a richer, multifaceted definition of digital inclusion. Figure 1 shows reasons people give for not using the internet in a sample of countries in Sub-Saharan Africa, broken down by gender and reported income quartile. Not having access to devices is not the only reason people give for not being connected: many people do not use the internet because they simply do not know about the technology or how to use it. Affordability also emerges as a major obstacle. It is also noticeable that the relative importance of barriers may be different for men and women even within the same income group.

Figure 2 shows what this paper considers to be the key theoretical dimensions of digital inclusion. The relevant background information and theory related to each are considered below. Of course, there are many other possible dimensions of digital inclusion. While not generally considered a component of digital inclusion per se, access to electricity is an important constraint to using the internet in developing countries (Houngbonon et al., 2021). Online trust and safety could also be viewed as elements of digital inclusion (ITU, 2019b). Also, relevance of content can be seen as a constraint to digital inclusion in developing countries, as most application and website developers are based in high-income countries and make products aimed at users in their own countries. Language also poses a challenge for potential users in the developing world (World Economic Forum, 2016). Yet, it is fair to assume that the internet, in its current form, has the potential to provide substantial benefits to everyone with at least basic literacy in developing countries. This paper focuses on the foundational dimensions of digital inclusion related directly to the internet and ICTs, which are judged to come before online safety and trust, and empowerment.

Access/use

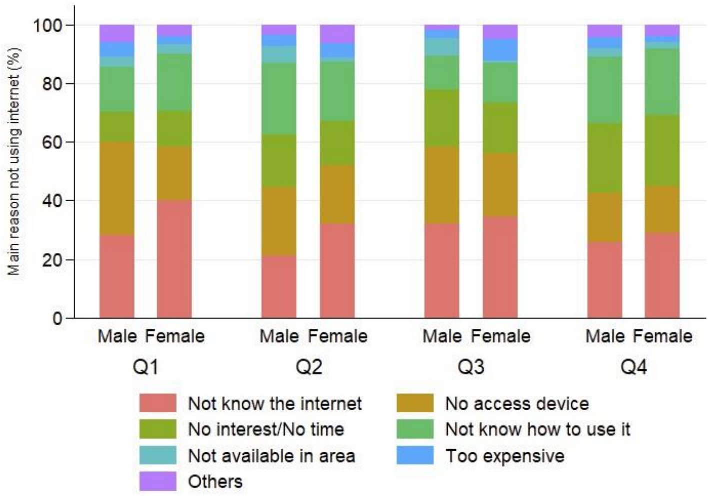
The most basic dimension of digital inclusion is access/use, which simply considers whether a person has access to or uses a technology like the internet.

Quality of access/use

Even if two people have access to or use the internet, the quality of their internet access/use may be very different. There are a few ways to think about this. First, there is the issue of how a person is accessing the internet: whether they are doing so on a computer or on a basic feature phone or a smartphone; whether they have a fixed broadband connection at home, a mobile broadband connection or are connecting in a public library or internet café. Second, there are varying technological capabilities or constraints related to bandwidth and caps on usage. The interaction between how someone connects to the internet and the technical quality of the connection will determine what they could potentially use it for: ranging from making a simple phone call or sending a message, to watching educational videos or carrying out complicated financial transactions.

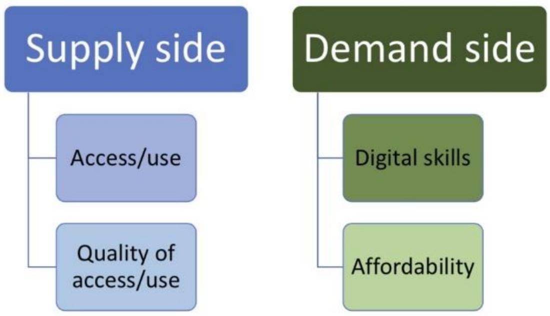
In low- and middle-income countries, handheld wireless mobile devices are the primary means of internet access: according to the GSMA (2019), in these countries, 57% of those who had used the internet in the previous three months accessed it exclusively via a handheld mobile device. It is also very common for people in developing countries to access the internet via internet cafes, which are now not very common in high-income countries. As for technical quality, speeds are on average much slower in developing countries. When commentators reflect on the dramatic uptake of the internet in low-income countries, it is important to specify that 2G mobile networks are still the most widely used in these countries, which only offer very limited narrowband speeds of less than 256 kbps. While these have enabled voice communications and triggered the development of applications such as mobile money and agricultural and health text messaging services, 2G connections support only very basic internet. In recognition of the drawbacks of measuring internet connectivity simply in terms of having an internet connection or not, in 2020 the Alliance for Affordable Internet called for a new focus on ‘meaningful connectivity’, a condition which is met when a person has daily use of their own smartphone with (at least) a 4G internet connection and the have an unlimited broadband connection at home or at a place of work or study (Alliance for Affordable Internet, 2021b).

Figure 1: Main reasons for not using the internet in selected low- and middle-income African countries



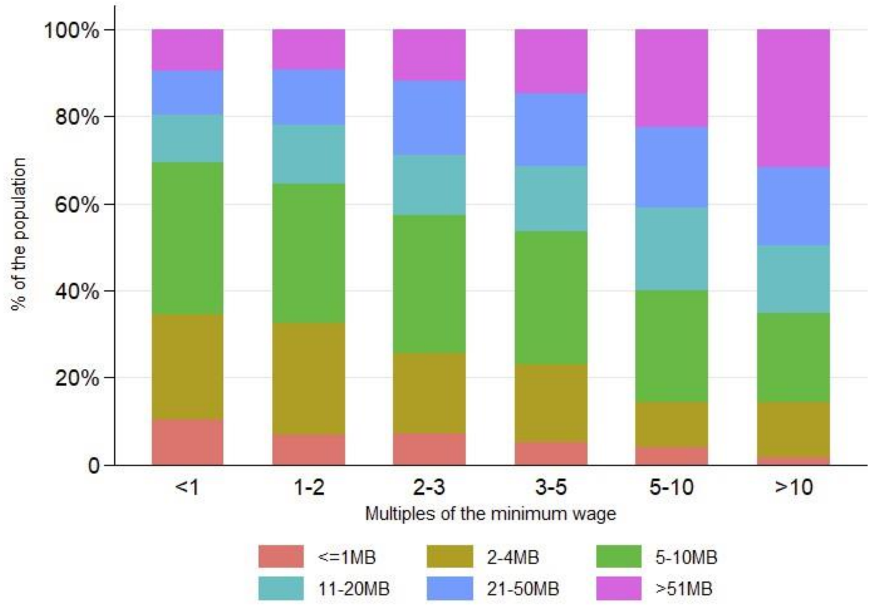
Data from AfterAccess Surveys 2017/2018 undertaken by Research ICT Africa, broken down by gender and disposable income quartile. Individuals without disposable income excluded. Countries include Ghana, Kenya, Mozambique, Nigeria, Rwanda, South Africa, Senegal, Tanzania and Uganda.

Figure 2: Fundamental supply and demand components of digital inclusion related to the internet



To show the wide variation in internet speeds across income groups in a middle-income country, Figure 3 shows the breakdown of internet speeds of home connections for people earning income of different multiples of the minimum wage in Brazil in 2017/2018. Almost 60% of people in the highest income group report accessing the internet at speeds greater than 10 mbps (which is fast enough for most common internet use cases for 1-2 people), whereas only 30% of people in the lowest income bracket do.

Figure 3: Reported internet speeds for people of different income groups in Brazil



Data from CETIC 2017/2018 on reported internet speeds, broken down by income (different multiples of the minimum wage).

Affordability

While the access and quality aspects of digital inclusion are supply-side factors, the affordability of the internet is a demand-side constraint. Internet use can be expensive relative to household income, particularly in developing countries. Often affordability measures only consider the cost of recurring data plan purchases, but the cost of buying a device to access the internet is also very important. If data or prices are high relative to income, then many people will be conservative with their mobile internet use, even if access is technically available in their region. Therefore, affordability is an important factor along both the extensive and intensive margins of internet use (Bessone et al., 2020). While the ITU reports that fixed and mobile broadband costs have decreased globally over the last ten years (Adam and Minges, 2018), they remain out of reach for many at the lowest end of the income distribution.

Digital skills

Many internet uses require basic literacy to be able to participate online. Skills required to make use of the internet can be classified in a number of ways. An important distinction has been made between technical/operational skills - that is, the skills needed to operate hardware and software - and information literacy - that is, the ability to recognise when information can solve a problem or fill a need and to effectively employ information resources (Mossberger et al., 2003; Bawden, 2008).[2] Operational digital skills are commonly divided into different categories - basic, intermediate and advanced - although there is often disagreement on how these categories are defined. Basic skills make it easier for people to communicate with others and to access and use services (ITU, 2018a) - for example, completing basic online transactions or using software to download applications. Intermediate skills enable people to use digital technology in 'meaningful and beneficial ways' (Broadband Commission for Sustainable Development, 2017). Advanced skills are those highly specialised skills used by ICT specialists.

As the internet and other digital technologies develop, the list of activities under each category tends to get longer. The level of skill applied in using the internet also may be limited by the quality of access to the internet.

B.4 Government intervention related to digital inclusion

A multi-factorial view of digital inclusion has potential implications for policy-making. This paper does not attempt to review in detail all the types of interventions that government should consider, but this section briefly reviews some of the possible market failures that may warrant government action.

[2] Within information literacy, broadly defined, it is possible to distinguish 'information navigation skills' (the ability to find, select, and evaluate sources of information on the internet), 'social skills' (the ability to use online communication and interactions to understand and exchange meaning and acquire social capital) and 'creative skills' (needed to create different types of quality content and to publish or share this with others on the internet) (Van Deursen et al., 2016).

Regulation of infrastructure and services

Building on research related to industrial organisation and the economics of networks, large economies of scale and high fixed costs in telecommunications markets complicate the roll out of networks in regions where a critical mass of users is missing, such as in rural areas (Hilbert, 2015; Greenstein, 2020; Oughton et al., 2022). This may justify the involvement of government, since the private sector may not be willing to provide last-mile infrastructure - whether mobile broadband, fixed broadband or even low-earth orbit (LEO) satellites or high-altitude balloons - on its own accord, unless costs fall dramatically or companies see the value of providing almost- free services to consumers in exchange for their data.[3] Governments can intervene in a range of ways: they can try to increase competition in the telecommunications sector via actions such as selling (parts of) state-owned monopolies, infrastructure sharing, open and cost-based access to wholesale facilities and a liberal spectrum policy (Marino Garcia and Kelly, 2015); they can require that telecommunications companies cover underserved areas in order to win contracts (e.g. Rosston and Wallsten, 2020); or they can provide subsidies to companies.

One important regulatory area related to the telecommunications sector in developing countries is over-the-top (OTT) services and zero-rated services, where mobile web content is offered to consumers by mobile internet service providers without counting against their data allowance (Hoskins, 2019). These services are very important for low-income consumers to access the internet, but they can result in loss of revenues for telecommunications providers, which can in turn lead to reduced investment in fibre-based infrastructure and new mobile access technologies. Therefore, there is an important question about whether, and to what extent, these services should be regulated. Regulation is very challenging given that most of the main OTT players - for example, Facebook, WhatsApp and Skype - are multinational companies without a presence in developing countries (Dairo and Szűcs, 2021).

Taxation in the telecommunications sector is a balancing act: taxes on consumers or providers create revenue - and may be justified to subsidise the cost of providing public infrastructure related to the internet - but can also hamper adoption, given that affordability is a key barrier to access and substantive use. Taxes can be applied to: telecommunication bills; handsets or other telecommunication devices; the spectrum; social

[3] As costs of providing access hardware decrease, some private sector companies are shifting their business models to target under-served regions - for example, Mojo Networks venture with Reliance Jia, a wireless telecom provider, in India.

media (ITU, 2013); or to mobile financial services (Ndung'u, 2019)[4], all of which may affect internet access and use.

Provision of digital skills education

Related to a long-standing debate in economics about whether education can be considered a public good (e.g. Hüfner, 2003), a case can be made that governments should be involved in ensuring that the general population attains a certain level of digital skills. One rationale could be that network effects are very important for take-up of the internet: people may be more likely to use the internet if their peers do (see Goolsbee and Klenow, 2002), which requires that their peers have some level of digital skills. If using the internet has important development impacts, there may also be externalities to its take-up and use, which the market undervalues.

C. Measurement of digital inclusion

C.1 Why standardised and sophisticated measures of digital inclusion are important

Contrary to arguments in Hilbert (2011b) and Galperin (2010) that digital inclusion is so complex as to make standardised measurement unworkable, it is very important that we can measure digital inclusion consistently and in a way such that we are able to disaggregate the data. Of course there is a trade-off between complexity and standardisability: it may be difficult to capture all possible aspects of digital inclusion related to the internet in a set of measures that can be widely applied to developing countries, but this paper aims to put forward some ideas for improving the measurement of core facets of digital inclusion. There are several reasons why this is important, including goal-setting, policy design and evaluation.

Currently some of the most important development indicators regarding digital inclusion for development leave much to be desired. For example, the importance of the internet (and ICTs in general) is considered in Sustainable Development Goal (SDG) Target 9.c, where the international community commits to 'significantly increase access to information and

[4] Some countries have imposed taxes on social media use ostensibly to manage risk of harm, such as misinformation campaigns. This can be problematic since social media may be an important entry-point to the internet for many consumers.

communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020'.

The official indicator selected to track SDG Target 9.c is the 'proportion of population covered by a mobile network, by technology'. The indicator, which is defined as 'the percentage of inhabitants living within range of a mobile-cellular signal, irrespective of whether or not they are mobile phone subscribers or users' (ITU, 2015) measures the possibility of subscribing to and using mobile cellular services. By including the breakdown 'by technology', the indicator is flexible in terms of internet quality, so basic narrowband (2G) mobile networks are treated the same as emerging 5G networks. Moreover, this UN indicator does not seem to consider whether people are actually able to access the internet, whether it is high quality, whether it is affordable or whether they have the skills to use it. Of course, it was important for the UN to balance relevance with feasibility (Hilbert, 2016), but an indicator for the internet based only on a mobile-cellular signal is setting a low bar, and does not push governments towards meaningful digital inclusion. Likewise, standalone indicators that only reference the number of internet subscriptions are increasingly obsolete due to technology diffusion and technological progress (ibid.). Surprisingly, the World Bank has invested in measuring access to mobile money allowing for breakdowns by demographic group (with its Global Findex Survey) but it has not yet developed a global survey with standardised questions on internet access and use, which is arguably more fundamental.

Inaccurate measures or the absence of data can lead to misguided public policy including underinvestment in important infrastructure or poorly designed regulations or public-private partnerships (Aker and Mbiti, 2010). Too often, governments assess their actions and policies using systematically biased information because they lack data about people from disadvantaged groups, including the poor, elderly, rurally located, and - particularly in developing countries - women (ibid.). Only having information on internet access but not quality, for example, can lead to policymakers underestimating challenges related to digital inclusion. If detailed information is not collected, then it also becomes difficult to evaluate policies designed to improve digital inclusion. Ultimately, this limits the body of knowledge that can enhance our understanding of digital development.

C.2 Current approaches and ways to improve measuring digital inclusion

Having made the case for why the measurement of digital inclusion needs to be improved, this section discusses how each of the key components of digital inclusion are currently measured and the weaknesses thereof, suggesting potential ways to improve measures as well, in some cases, additional metrics that should be considered.

Measuring internet access and use

Traditionally the international digital divide is assessed in terms of telecommunication subscriptions (OECD, 2001; ITU, 2015). At the international level, the most commonly cited data source is the ITU. The ITU has for several decades collected supply-side data from administrative registries of national telecommunication authorities (NTAs), trying to do so in a harmonised manner (Hilbert, 2016). In some cases, public entities own records on persons and households; in other cases, they have to negotiate to gain access to these data from telecommunications service providers, which is often complicated due to the presence of legal frameworks for the protection of personal data.

These data are imperfect. One well-known drawback is that there is a difference between mobile cellular subscriptions and access to and use of the internet. A subscription can be used by more than one person in a household, and one person may have more than one subscription. In majority prepaid markets, it is difficult to track active subscriptions since maintenance of a prepaid subscription does not necessarily imply a payment (ITU, 2016). Since in many countries, individuals may have multiple sim cards or internet subscriptions, the official access statistics for these countries are well over 100%. It is also common in developing countries for people to have multiple active sim cards, which may allow them to take advantage of special offers on data rates and overcome connectivity problems related to uneven network coverage of operators across these countries. Also, private data owners may use different definitions and concepts, and it may be difficult to harmonise or adapt these for statistical production. Telecommunications authorities collect national aggregate data on telephone subscriptions, devices and connections, but data by individual attributes are not usually collected (Hafkin and Huyer, 2007).

In general, systematic and regularly available quantitative data on disaggregated ICT use have remained relatively limited (Broadband Commission for Sustainable Development, 2013; Fatehkia et al., 2018). However, in recent times, modules on ICT access and use have been added to general household surveys in developing countries. Population censuses may also provide information: many in developing countries ask basic questions related to the household availability of the internet or mobile phones. Of course, it might be useful to measure digital inclusion at the individual level since there may be considerable inequalities households. For the purpose of cross-country comparisons, it is important that measures are defined and questions are asked in a consistent way across countries, but this is often not the case. Researchers thus often turn to nationally representative multi-country surveys that collect basic information on internet access in developing countries including the Demographic and Health Surveys and Afrobarometer. Many countries - mostly high-income

- have also adopted standalone ICT surveys sometimes at the individual level. When such data are available, inconsistencies across data sources and measures make cross-national comparisons impossible (Fatehkia et al., 2018). However, some research institutions - e.g. Research ICT Africa - have conducted standardised surveys across a number of developing countries.

ITU presents statistics on individuals 'using the internet (in the last three months)' where the data sources are listed as various statistical offices, NTAs or 'estimated'. In recent years it has also started providing statistics broken down by gender, for young people (15-24 years) and by urban and rural areas (e.g. ITU, 2021). The ITU seems to rely heavily on national statistics offices filling out a detailed annual questionnaire requesting information on access rates, which they could have collected either from surveys or from NTAs or telecommunications providers (ITU, 2020a, p. 23). One obvious problem here is that national statistics offices will often not have information at hand which corresponds with the highly specific questions on the survey form. For example, even in the best case scenario where they have a nationally representative annual household survey that asks detailed questions related to internet access (which is extremely rare), they may not have information on 'the proportion of individuals, [by sex, by age group and urban/rural location] who have used the internet from any location in the last three months' (for example, they may only have information at the household level on internet access at the home for a different time period). The ITU also notes that it may draw on multi-country surveys - including UNICEF's Multiple Indicator Cluster Surveys, the Demographic and Health Surveys (DHS), and the surveys of Research ICT Africa and LIRNEAsia - for its access statistics (ITU, 2021). For many countries, no data on access are available, and so statistics have to be imputed. There is limited information on the imputation models that ITU uses, although a country's income seems to be the main predictive variable employed (ITU, 2017b, 2021). When disaggregated information is missing, ITU reports that it uses 'comparable economies for which disaggregated data are available...to estimate [data] for the country in question, filling the gap in real data' (see Appendix in ITU (2021)), but it does not explain how 'comparability' is defined.

It would be helpful if the ITU provided a detailed discussion of the challenges it faces in coming up with harmonised access data across countries. While it may provide some guidance to national statistics offices on how to fill out its annual questionnaire, it seems that, in practice, it leaves many difficult harmonisation decisions to these offices. Also useful would be a detailed description of the model it uses to predict data when these are missing.

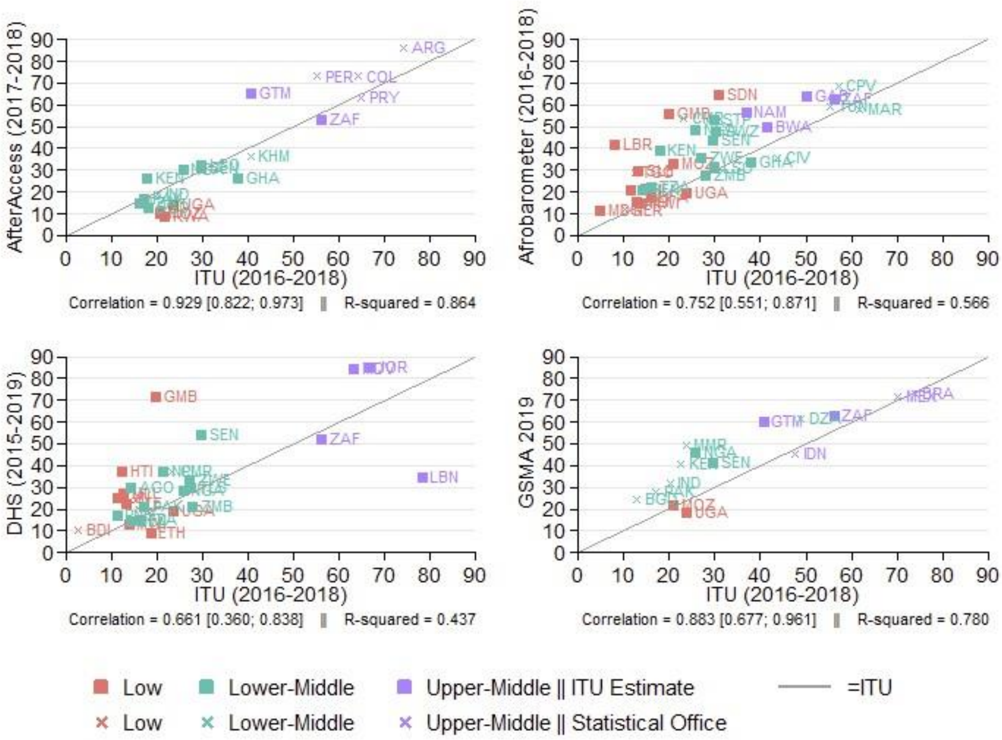
Figure 4 compares estimates of internet access for developing countries from ITU surveys to those from other often-cited sources of internet access data. There are substantial discrepancies between sources. It is likely that ITU data are highly correlated with AfterAccess data because ITU will have drawn on the latter source for many of the countries where data are available in both sources. However, though ITU also states that it sometimes draws on DHS data, the correlation between ITU and DHS access data is quite low. In general, it appears that the variation between data sources is larger the lower the country's income level.

Figure 5 depicts 'access gaps' between Afrobarometer and ITU sources and between DHS and ITU sources, showing that ITU estimates are generally lower than those from these other sources and that the gaps are indeed larger for countries on the lower end of the income spectrum.

It is not obvious why these huge discrepancies exist between ITU data and those from other sources. One possibility is that national statistical offices are under-reporting access rates in their countries to the ITU. These data should be carefully validated and cross-checked before they are presented as official statistics by the ITU.

Several organisations have begun thinking more about how to improve household survey questions related to internet access - for example, there is the OECD Model Survey on ICT Access and Usage by Households and Individuals. Core indicators are designed to monitor dimensions in usage - that is, access to the internet, frequency and intensity of usage and the types of activities performed (including e-commerce, e-government, online education, and so on). Supplementary indicators are meant to provide more in-depth information on these phenomena, including individuals' satisfaction and perception of obstacles, and to extend surveying to child online protection and to use of ICTs at school. The OECD admits that the list of questions will need to be dynamic as technological change will affect what is important to monitor (OECD, 2015).

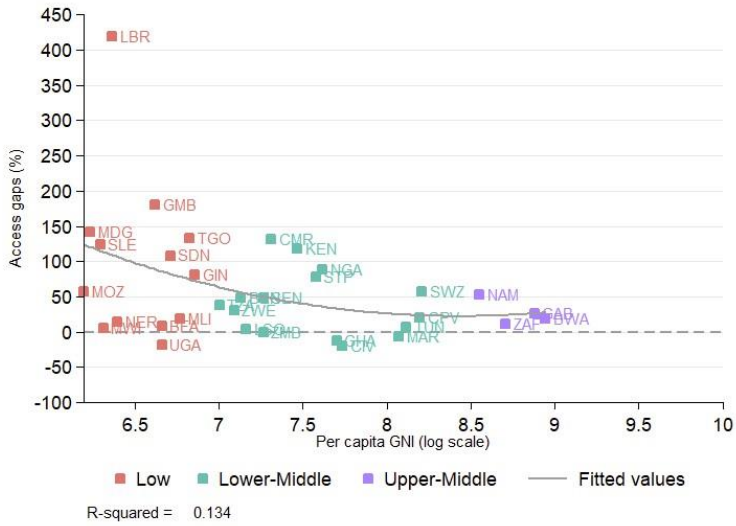
Figure 4: Comparing internet access statistics for developing countries across different data sources



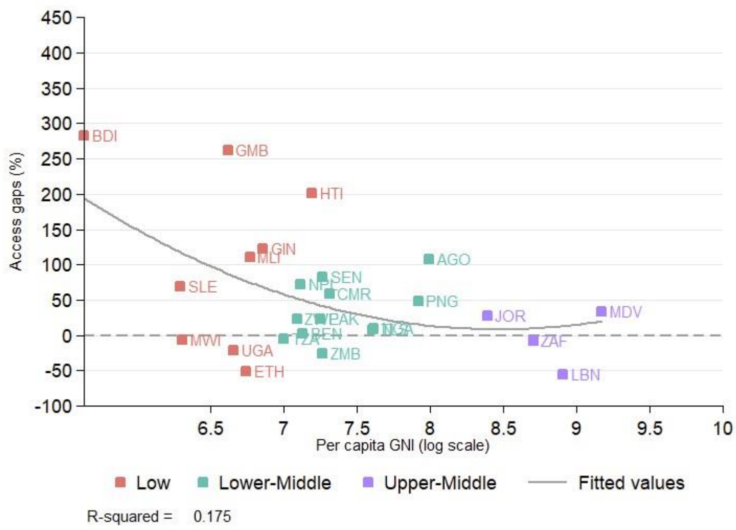
Data from International Telecommunications Union (ITU) (2016-2018), AfterAccess (2017-2018), Afrobarometer (2016-2018), Demographic and Health Surveys (DHS) (2015-2019) and GSMA (2019). Graphs indicate country income group classifications from World Bank and whether ITU data are 'from statistics offices' or 'estimated' (through cross-country imputations - see ITU (2017b). ITU reportedly measures the total population accessing the internet during the previous three months. AfterAccess Surveys measure the population aged 15-65 who have ever accessed the internet. Afrobarometer measures the voting age population (18 years and older) who have ever accessed the internet. DHS measures the population aged 15-49 who have ever accessed the internet. GSMA measures the population over 18 years who have accessed mobile internet in the last three months. To ensure maximum comparability between ITU (available for most countries for most years) and other data sources (where only one data point is available per country, but it may have taken several years to collect data across all countries in the sample) the following steps are taken: when comparing to AfterAccess data, 2018 ITU data are used if available and otherwise 2017 or 2016 data; when comparing to Afrobarometer data, 2017 ITU data are used or otherwise 2018 or 2016 data; when comparing to DHS data, 2017 ITU data are used and otherwise 2018 or 2016 data; when comparing to GSMA data, 2019 ITU data are used and otherwise 2018, 2017 or 2016 data. DHS and GSMA data are presented separately by gender so the average access rates across genders was calculated to compare with ITU data. Correlation parameters with 95% confidence intervals reported in brackets. Countries available for After- Access: ARG-Argentina, BGD-Bangladesh, KHM-Cambodia, COL-Colombia, GHA-Ghana, GTM-Guatemala, IND-India, KEN-Kenya, LSO-Lesotho, MOZ-Mozambique, NGA-Nigeria, PAK-Pakistan, PRY-Paraguay, PER-Peru, RWA-Rwanda, SEN-Senegal, ZAF-South Africa, TZA-Tanzania, UGA-Uganda. Countries available for Afrobarometer: BEN-Benin, BWA-Botswana, BFA-Burkina Faso, CPV-Cabo Verde, CMR-Cameroon, CIV-Côte d'Ivoire, SWZ-Eswatini, GAB-Gabon, GMB-Gambia, GHA-Ghana, GIN-Guinea, KEN-Kenya, LSO-Lesotho, LBR-Liberia, MDG-Madagascar, MWI-Malawi, MLI-Mali, MAR-Morocco, MOZ-Mozambique, NAM-Namibia, NER-Niger, NGA-Nigeria, SEN-Senegal, SLE-Sierra Leone, ZAF-South Africa, SDN-Sudan, STP-São Tomé and Príncipe, TZA-Tanzania, TGO-Togo, TUN-Tunisia, UGA-Uganda, ZMB-Zambia, ZWE-Zimbabwe. Countries available for DHS: AGO-Angola, BEN-Benin, BDI-Burundi, CMR-Cameroon, ETH-Ethiopia, GMB-Gambia, GIN-Guinea, HTI-Haiti, JOR-Jordan, LBN-Lebanon, MWI-Malawi, MDV-Maldives, MLI-Mali, NPL-Nepal, NGA-Nigeria, PAK-Pakistan, PNG-Papua New Guinea, SEN-Senegal, SLE-Sierra Leone, TZA-Tanzania, TLS-Timor-Leste, UGA-Uganda, ZAF-South Africa, ZMB-Zambia, ZWE-Zimbabwe. Countries available for GSMA: DZA-Algeria, BGD-Bangladesh, BRA-Brazil, GTM-Guatemala, IND-India, IDN-Indonesia, KEN-Kenya, MEX-Mexico, MOZ-Mozambique, MMR-Myanmar, NGA-Nigeria, PAK-Pakistan, SEN-Senegal, ZAF-South Africa, UGA-Uganda.

Figure 5: Gaps in access statistics for developing countries from various sources

(a) Gaps in access statistics from Afrobarometer and ITU data



(b) Gaps in access statistics from DHS and ITU data



Data sources as in Figure 4. Access gaps calculated using:

$$\text{Access gap} = \frac{\text{Non} - \text{ITU result} - \text{ITU result}}{\text{ITU result}} \times 100$$

This is a step in the right direction. However, these questions may need to be modified for the developing country context. For example, developing country surveys often include questions such as 'Do you have access to the internet in your household?'. This type of question is taken from high-income country surveys where fixed line connections at home are very common, but this is confusing in settings where most people connect to the internet via a mobile phone. It is not clear, for example, how this question should be answered if say the head of the household has a mobile phone, which other family members cannot access. Furthermore, in low-income countries, many users may access the internet through public and shared access facilities, such as internet cafes, community centres or ICT-equipped libraries; this is not captured in survey questionnaires that only ask about internet access in the household. Of course, though it would be useful to include questions on use of public facilities, it should be acknowledged that owning an internet-enabled device comes with considerably more benefits than using a public device or someone else's device. For example, owning a mobile phone may be associated with greater convenience, privacy and security for the user, and may allow for certain uses, for example, access to microfinance or a bank account (GSMA, 2015; ITU, 2016).

Measuring quality of access/use

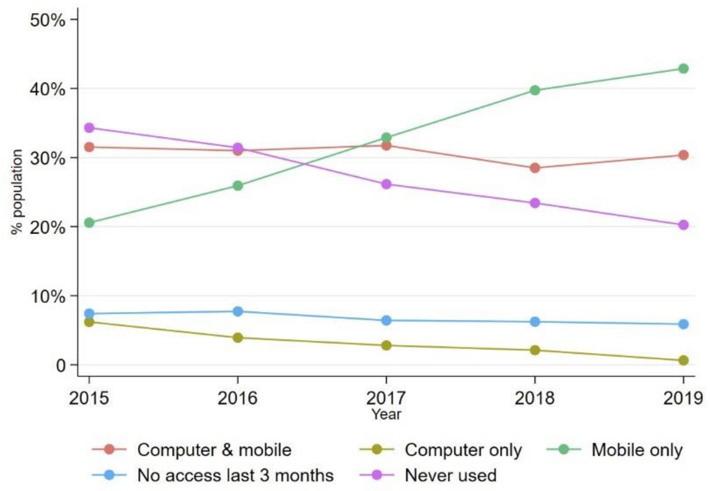
It would be very valuable to have more information on technical internet quality in developing countries, particularly since there is such wide variation and often internet speeds are inadequate for many types of uses. This would also help to focus attention of policymakers: policies in developing countries need to focus on quality assurance in addition to their conventional focus on proliferating internet access. Sometimes information on technical internet quality is available from regulators, usually just at the national level. Regulators collect information on the advertised download speed of subscriptions which can be compiled into indicators of subscriptions broken down by speed tiers to give a view of the 'theoretical' speed of subscriptions. However, measurement of broadband performance is affected by the potential gap between advertised and 'actual' speeds delivered to customers (OECD, 2019).

Very few surveys with questions about internet use in developing countries include questions on the quality of the internet connection. The Centro Regional de Estudos para o Desenvolvimento da Sociedade da Informação (CETIC) survey in Brazil collects information on this, asking respondents what speed bracket their home internet connection falls into (see Figure 3). However, it is not clear how respondents know the average speed of the internet connection in megabytes per second, short of doing a speed test on their internet-enabled devices during the interview. Questions could also be asked about data caps, as this is a major constraint to internet usage developing countries. Testing internet quality is one area where there is a clear case for the use of big data (see subsubsection 3.3.2).

It would also be useful to have more information on how people are using the internet. Aside from basic survey questions about whether a person has access to the internet, a fundamental follow-up question, which is rarely asked, is how the person has accessed the internet. In the detailed Brazilian survey undertaken by CETIC, there is a question about having a computer at home (where 'computer' could include a desktop computer, a notebook or a tablet). As shown in Figure 6, the proportion of people accessing the internet exclusively via mobile phones rose steeply from 20% in 2015 to 40% in 2019; however, the share accessing the internet via both mobile phones and computers stayed constant over this period and the share accessing the internet via computers exclusively decreased slightly. One interesting possibility is that, faced with budget constraints, Brazilians are substituting away from computer devices to smartphone devices. This may have substantial policy implications since as shown in Table 1, even after controlling for a multitude of individual attributes that could influence the likelihood of owning devices, respondents who access the internet with a computer or with both a computer and mobile phone are 10 to 20 percentage points more likely to use the internet for education or work purposes than those who only access the internet via a mobile phone. Unfortunately, the CETIC survey does not ask questions to differentiate between types of mobile phones that people own, but GSMA (2020c) estimated a smartphone penetration rate of 69% for Brazil in 2019, so it is safe to assume that most people who accessed the internet on a mobile phone did so on a smartphone (rather than on a feature phone, which may support basic internet access).

The recommendation of the Alliance for Affordable Internet to measure 'meaningful connectivity' separately from basic internet access seems to be a sensible one (see subsubsection 2.3.2). Helpfully, it has developed a draft measurement guide (Alliance for Affordable Internet, 2021a), which suggests four indicators for the four dimensions of 'meaningful connectivity' which it says should be added to ICT household surveys, and to the ITU's official manual for completing these (ITU, 2020a). Based on the analysis above, it might be useful to rethink whether smartphone access to the internet should always be held up as the standard to aspire to above all other means of access including that from computers or tablets. The analysis also suggested that it would be helpful to develop detailed guidelines for how survey administrators can record internet quality.

Figure 6: Means of accessing the internet in Brazil



Data from CETIC 2015-2019. 'Computers' include desktop computers, notebooks and tablets

Table 1: Probability of using the internet for 'empowerment'-related purposes depending on type of device used to access in Brazil

Table 1: Probability of using the internet for 'empowerment'-related purposes depending on type of device used to access in Brazil

	Uses of the internet			
	School research	Distance learning	Own learning	Work activities
Only computer/	0.177***	0.104***	0.196***	0.181***
both computer and mobile	(9.04)	(7.88)	(9.57)	(9.44)
Individual controls	Y	Y	Y	Y
Observations	12,179	12,179	12,180	12,177

Analysis at individual level using CETIC 2019 data. Conditional on having access to the internet in the household. 'Computers' include desktop computers, notebooks and tablets. Base category for dummy: Access internet via mobile only. Significance levels: *p<0.1, **p<0.05, ***p<0.01. T-stats in brackets. With individual controls for age, gender, education, sex, urban/rural, class and race. Survey weights used.

Measuring affordability

There is increasing recognition of the importance of measuring affordability of accessing and using internet technologies in developing countries - for example, this was one of the major recommendations of the Broadband Commission for Sustainable Development, an initiative founded by ITU and UNESCO in 2010 (Broadband Commission, 2012).

Standard baskets of usage are often used to normalise internet technology prices so they can be compared across countries. Again, the most widely cited source is the ITU, which monitors prices from ITU member states, the results of which are disseminated in the World Telecommunication/ICT Indicators Database and the ITU's Yearbook of Statistics. Until now, the focus has been on the costs of different types of internet service (that is, the data prices of fixed and mobile connections) on personal devices rather than the cost of acquiring a device to use the internet. Data on mobile broadband prices are collected by ITU directly from operators' websites (the prices are collected for the largest mobile operator), while fixed-broadband price data are collected through the ITU ICT Price Basket Questionnaire sent to the administrations and statistical contacts of all 193 ITU member states. The mobile cellular basket is based on the most common contract modality (prepaid or postpaid) in the economy in question - that is, if more than 50% of subscriptions are prepaid, then prepaid is selected - otherwise, a postpaid plan is selected (ITU, 2020a).

The affordability of a standard basket of internet usage is measured by relating domestic basket prices to the monthly per capita gross national income and benchmarking against a set target, offering a high-level indicator of affordability for the average earner. The Broadband Commission for Sustainable Development's target for 2025 is for entry-level broadband services to be made affordable in developing countries at a level corresponding to less than 2% of monthly Gross National Income (GNI) per capita. The baskets are designed to provide a snapshot of prices at any given time rather than as a series. As such, the lowest cost plan is selected at any point in time and may have different characteristics from earlier plans - for example, a higher speed or an increased amount of data (OECD, 2019).

The ITU has made some recent progress in improving the sophistication of its affordability measures. One issue with looking at affordability through the metric of proportion of per capita income is that it does not distinguish between the effects of tariffs and incomes. In recent years, the ITU has also begun to provide relevant tariff information for countries (ITU, 2018b). This is a good move to target government action. Another issue that the ITU has paid attention to is that even where a basket appears to be affordable for the average citizen, a significant share of the population may find the price to be beyond their means due to income and consumption inequality. Helpfully, ITU (2020b) examines affordability for the poorest 40% of the population in the countries where data are available.

There may still be room for other methodological improvements. For example, the ITU's explicit methodology - if mobile cellular or broadband prices vary between different regions of the country - is to take prices that apply to those in the largest city (in terms of population) or in the capital city (ITU, 2020a). However, only reporting this information creates perverse incentives for governments to ignore prices in under-served regions. An effort should be made to collect information on prices in more remote parts of countries, which could then be used in a new measure summarising how large the price differential is between the cheapest and most expensive region.

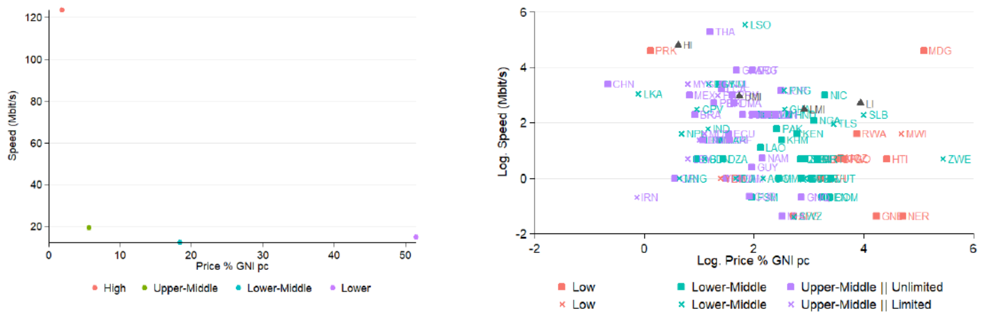
It is also worth pointing out that data packages of the same minimum size may be of very different quality across countries. Figure 7 shows the massive variation in average speed of a 5MB fixed broadband internet bundle across different country income categories based on ITU's data. It may be useful to consider minimum connection speeds in this context, presenting another sets of prices that take this into account.

The ITU relies on GNI, presumably because there is good standardised data on this but, arguably, household income may be the more relevant measure. GNI is an aggregate measure used to measure economic development by the size of the economy in the context of national accounts, and including the business sector (ITU, 2020a). Household income collected through household surveys excludes the business sector and measures all income received by members of a household less taxes and social security contributions. In developing countries, household consumption expenditure may also be used. Either household income or expenditure can then be compared to expenditure on the internet. There is huge variation in questions on expenditure on the internet in developing country surveys, which creates confusion and makes it difficult to examine disaggregated measures of internet affordability. Frequently the questions are extremely vague, for example: 'How much did you spend on the internet in the last 30 days?' or 'What was the amount of the internet bill last month?'. It is unclear if these questions refer specifically to a fixed line internet connection or if they also may refer to costs for internet accessed on a mobile device. It seems that the best approach would be to ask questions that explicitly break down internet expenses; for example: 'How much did you spend on mobile internet last month?'; 'How much did you spend on fixed line internet at home in the last month?'; and 'How much did you spend at internet cafes in the last month?'.

Figure 7: Variation in speed of cheapest 5MB fixed broadband internet bundle for countries of different income levels

(a) Average speed of 5MB fixed broadband internet bundle for countries in different income groups

(b) Average speed of 5MB fixed broadband internet bundle with logged speed and log price as a proportion of GNI per capita



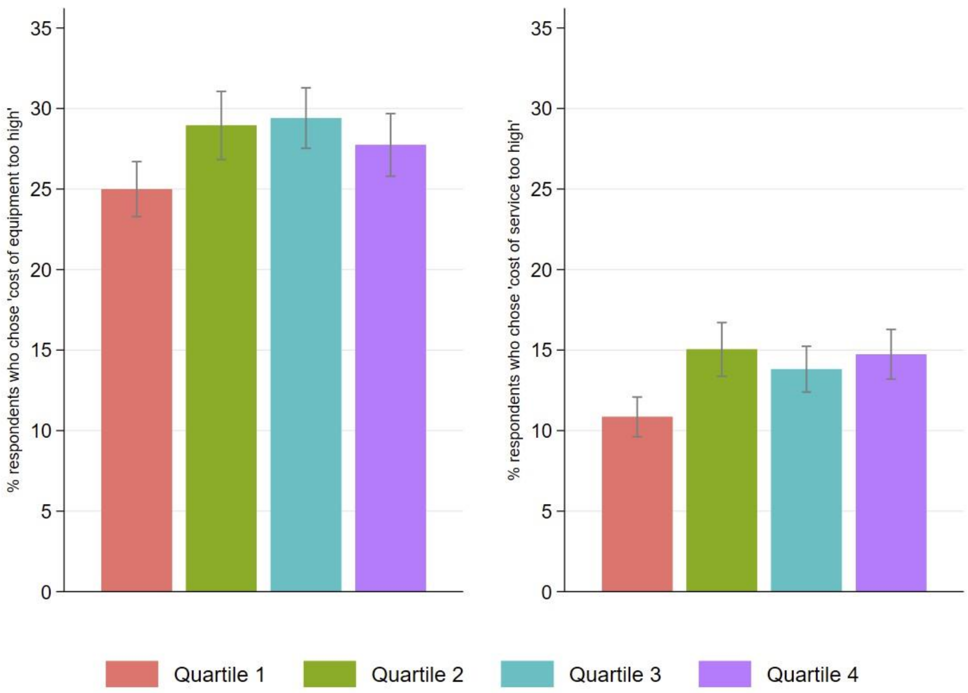
ITU price baskets underlying indicators based on ITU and A4AI. GNI p.c. and PPP$ conversion factors from the World Bank. USD exchange rates from the IMF or the UN. Lower income countries: AFG-Afghanistan, BFA-Burkina Faso, ETH-Ethiopia, GIN-Guinea, GNB-Guinea-Bissau, HTI-Haiti, PRK-Korea, Dem. People's Rep., MDG-Madagascar, MWI-Malawi, MLI-Mali, MOZ-Mozambique, NER-Niger, RWA-Rwanda, SOM-Somalia, TGO-Togo, YEM-Yemen, Rep. Lower-middle income countries: DZA-Algeria, AGO-Angola, BGD-Bangladesh, BEN-Benin, BTN-Bhutan, BOL-Bolivia, CPV-Cabo Verde, KHM-Cambodia, CMR-Cameroon, COM-Comoros, COG-Congo, Rep., CIV-Côte d'Ivoire, DJI-Djibouti, EGY-Egypt, Arab Rep., SLV-El Salvador, SWZ-Eswatini, GHA-Ghana, HND-Honduras, IND-India, KEN-Kenya, LAO-Lao PDR, LSO-Lesotho, MRT-Mauritania, FSM-Micronesia, MNG-Mongolia, MAR-Morocco, MMR-Myanmar, NPL-Nepal, NIC-Nicaragua, NGA-Nigeria, PAK-Pakistan, PNG-Papua New Guinea, PHL-Philippines, SEN-Senegal, SLB-Solomon Islands, LKA-Sri Lanka, STP-São Tomé and Principe, TZA-Tanzania, TLS-Timor-Leste, TUN-Tunisia, VUT-Vanuatu, VNM-Vietnam, ZMB-Zambia, ZWE-Zimbabwe. Upper-middle income countries: ARG-Argentina, BLZ-Belize, BWA-Botswana, BRA-Brazil, CHN-China, COL-Colombia, CRI-Costa Rica, CUB-Cuba, DMA-Dominica, DOM-Dominican Republic, ECU-Ecuador, GNQ-Equatorial Guinea, FJI-Fiji, GAB-Gabon, GRD-Grenada, GTM-Guatemala, GUY-Guyana, IDN-Indonesia, IRN-Iran, JAM-Jamaica, JOR-Jordan, LBN-Lebanon, LBY-Libya, MYS-Malaysia, MDV-Maldives, MHL-Marshall Islands, MEX-Mexico, NAM-Namibia, PRY-Paraguay, PER-Peru, WSM-Samoa, ZAF-South Africa, LCA-St. Lucia, VCT-St. Vincent and the Grenadines, SUR-Suriname, THA-Thailand, TON-Tonga.

the price of mobile phones has been dropping, the price of a device can be a barrier in many developing countries, particularly when onerous import duties and other taxes are added. According to GSMA (2020a), in Sub-Saharan Africa the median cost of an entry-level internet-enabled handset represented more than 120% of monthly income for the poorest 20% of the population in 2019.

Figure 8 shows that across all income groups in a sample of African countries, the cost of the device is rated by a much larger proportion of non-internet users as a more important barrier to access compared to the cost of the service.

A final issue to consider is that affordability of using the internet in developing countries will also depend on the availability of OTT and zero-rated services. However, there is currently a lack of clear metrics on these services (ITU, 2018b).

Figure 8: Cost of internet services versus cost of devices as the main reason for not using the internet in a sample of African countries for different income quartiles



Data from AfterAccess Surveys 2017/2018 undertaken by Research ICT Africa. 95% confidence intervals are shown. Countries include Ghana, Kenya, Mozambique, Nigeria, Rwanda, South Africa, Senegal, Tanzania and Uganda.

Measuring digital skills

Information about the level of digital skills in developing countries is very limited (Bashir and Miyamoto, 2020). Very few developing country governments collect information on digital skills using a representative sample (ITU, 2018b). There is also the issue that digital skills are difficult to measure. Even in high-income countries, digital skills are rarely measured directly and many of the existing measures are based on self-reporting of proxies of digital skills including possession of devices or tasks performed.

It has long been known that self-reporting of internet skills may lack validity. Self-assessments lead to overrating and underrating of the skills possessed (Hargittai, 2005; Merritt et al., 2005; Deursen and Van Dijk, 2010). In a study in the US, Hargittai and Shafer (2006) found that men and women did not differ greatly in their online abilities, but that women's self-perceived skill level was significantly lower than for men. However, self-assessments offer the chance to present a large number of questions on a wide range of skills in a relatively short time period, and they are also simple to score and fast to process (Kuhlemeier and Hemker, 2007; van Deursen and Van Diepen, 2013). Just as numeracy and literacy are not measured through proxies but directly through standardised testing, the future focus should be on measuring digital skills directly where subjects' command of internet skills are observed during particular assignments, usually in a controlled environment. Some academic studies have tested digital skills directly among populations in high-income countries through online tests that require participants to complete a range of tasks (Katz, 2007; Aesaert and Van Braak, 2015; Pagani et al., 2016). However, most of these studies have been small in scale and, in the near future, governments, particularly in low-resource settings, may need to use more traditional survey methods.

The existing task-based measures of digital skills are outdated and of limited relevance in developing countries. UNICEF-sponsored surveys using the EU's DigComp 2.1 Digital Skills Competence Framework have been completed in many developing countries. According to this framework, digital skills are measured by the extent to which a respondent can perform computer-related activities: copying or moving a file/folder; using copy and paste tools in a document; sending emails with attached files; transferring files between computers and other devices; and writing a computer programme using a specialised programming language. Asking questions only about computer-based tasks, when the vast majority of people only use mobile phones makes little sense. When considering basic digital skills in developing countries, more focus should be placed on skills related to mobile phones, as this is the entry point for most people.

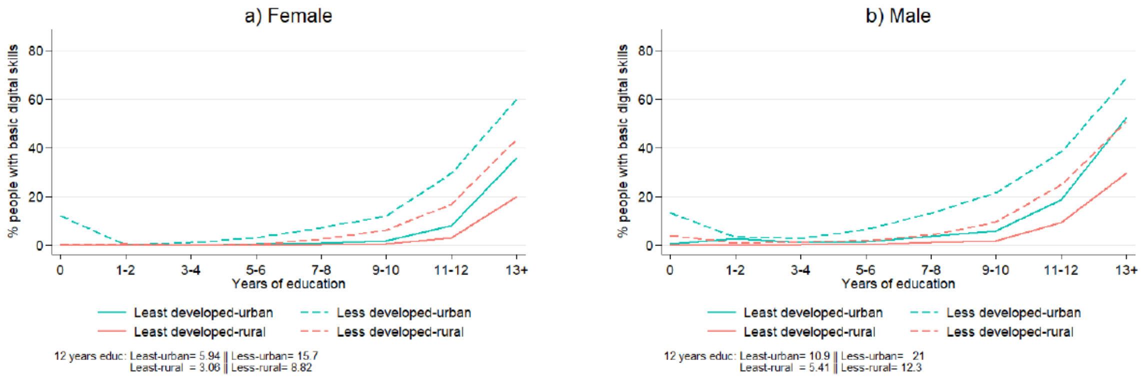
An alternative proposition to assess the supply of digital skills in developing countries is to use information on the completion of education, assuming that some form of ICT training is provided in education institutions. Bashir and Miyamoto (2020) from the World Bank suppose that students in high schools in most African countries acquire only basic digital skills (if ICT is included in the curriculum and actually delivered). Intermediate-level skills may be provided at the upper secondary level. The argument is then made that 'different levels of education and in different types of ICT-related courses could provide a rough estimate of the supply of digital skills through the formal education system' (ibid., p.19). The ITU also uses mean years of schooling and enrolment rates in secondary and tertiary education as proxies for digital skills (see ITU, 2017b).

The current data from UNICEF, albeit flawed, do not provide evidence in favour of the use of these basic proxies. Figure 9 shows that there is significant variation between countries and genders in the relationship between years of education and the attainment of basic digital skills. In a geographically broad sample of countries, on average, the proportion of men in least developed countries with basic digital skills after having completed 12 years of education was 15.7%, whereas in less developed countries it was 33.2%. For women, the corresponding numbers were much lower at 6.6% and 26.1%. Based on the proxies suggested by Bashir and Miyamoto (2020), 100% of men and women would be expected to have basic digital skills after 8 years of schooling.

Figure 9: Proportion of male and female population with basic digital skills by years of education in a geographically broad sample of less and least developed countries

(a) Proportion of female population with basic digital skills

(b) Proportion of male population with basic digital skills



Data from UNICEF-MICS surveys 2017-2019. Notes: Years of schooling computed using the highest level and grade/year of school. In the case of Nepal years of education censored at 14 years. Least developed countries: Chad, Lesotho, Nepal, and Sierra Leone. Less developed countries: Cuba, Ghana, Suriname, Tunisia, and Zimbabwe.

Digital inclusion indices

Since digital inclusion is multifaceted, it is tempting to come up with composite indices, which aggregate a plethora of indicators into one or more summary measures. In general, such policy-relevant indices are politically appealing and can focus attention (Booysen, 2002). There has been a proliferation of digital inclusion indices. For example, the ICT Development Index (IDI) published by the ITU (which has been under review since 2018) is a composite index that combines 11 indicators for ICT access, use and skills into one benchmarking measure to monitor progress for 175 economies (ITU, 2017a). Among other factors related to digital inclusion, the Inclusive Internet Index published by The Economist Intelligence Unit considers the quality and breadth of available infrastructure, the cost of access relative to income, the level of competition in the internet marketplace, the existence and extent of local language content, the prevalence of digital skills, and cultural acceptance of the internet (EIU, 2021). GSMA's Mobile Connectivity Index considers 41 indicators related to four 'enablers' including infrastructure, affordability, consumer readiness and content and services (GSMA, 2021). Some countries also have their own connectivity or digital inclusion indices (for example, Argentina).

These digital inclusion indices suffer from the same shortcomings as all other indices. Methodologies are necessarily arbitrary, particularly related to the weighting and aggregation approaches (e.g. Greco et al., 2019). Existing digital inclusion indices also try to be all-encompassing and there seems to be an emphasis on quantity over quality of data. Many indicators or sub-indicators are somewhat arbitrary or measured with error - some are estimated while others are based on rough proxies. For example, infrastructure access is often just based on data on network coverage rather than actual access data (e.g. GSMA, 2021). While the continued existence of digital inclusion indices is inevitable, efforts should be taken to improve the transparency of their composition (see Böhringer and Jochem, 2007; Jesinghaus, 1999).

C.3 The potential uses of big data

Surveys have been the preferred tool for analysing dimensions of digital inclusion and their relationship with socio-economic- and spatial factors. However, the widespread presence of mobile phones and computers connected to the internet in developing countries is generating millions of digital footprints. This offers the potential for more up-to-date and more easily comparable data across countries than those from traditional sources. This section discusses examples - mostly from academic studies - of how big data may be used, before considering some of the risks involved and how these may be mitigated.

Internet access/use

Internet search engines collect highly detailed information on internet use. In a study in the US, Weber and Jaimes (2011) analysed a large query log of 2.3 million anonymous registered users from a web search engine. They analysed basic session statistics, classified queries into types (navigational, informational, transactional) and topic categories, and clustered users based on the queries they issued. They then examined the resulting clusters in terms of search behaviour and demographics, drawing the latter from registration information provided by the users, augmented with U.S. census data. Using a similar methodology, though focused on mobile phone rather than internet use, studies have combined digital footprint mobile data with representative surveys of the population in Rwanda (Blumenstock and Eagle, 2012) or have merged (roughly) geo-located digital footprint data with census data in Spain (Frias-Martinez and Virseda, 2012).

These analyses give a detailed picture of mobile phone use by different socio-economic groups and the size of digital gaps without relying on self-reported usage. Social media platforms also constitute a valuable source of data. Fatehkia et al. (2018) use digital trace data in the form of Facebook's advertisement audience estimates to measure digital gender gaps in internet access at the country level. The high temporal resolution of these data make them particularly useful for 'nowcasting' - that is, predicting the present, the very near future, and the very recent past state of an indicator - or for measuring changes over shorter time scales. The authors test the validity of Facebook-derived data for measuring digital gender gaps against ITU data (although ITU data may not be very accurate - see subsubsection 3.2.1). A regression model based solely on Facebook's gender gap is found to explain 69% of the variance in the 'ground truth' Internet Gender Gap Index that was computed using ITU data. In two related studies, Mejova et al. (2018) investigated subnational digital gender inequality in India through gender gaps in Facebook use and Haranko et al. (2018) estimated the size of gender gaps in the U.S. labour market using LinkedIn data. These analyses using social media are useful for building models combining online and offline variables so as to be able to estimate missing data for countries where they are no data (or at least no up-to-date data) on digital gaps. However, these data may be better for tracking relative measures - for example, female-to-male ratios - rather than absolute levels of internet adoption by demographic group (Fatehkia et al., 2018).

Internet quality

Crowd-sourced internet speed test estimation data are very useful for learning about internet bandwidth (e.g. Riddlesden and Singleton, 2014). Data are usually gathered from providers of web-based applications that enable users to test their internet connection system. The benefits of this data source are that potentially large data sets can be collected at little cost and that the information reflects more than just the installed capacity, but also the effective speed (Hilbert and López, 2012; Rivera-Illingworth et al., 2020). However, since data are voluntarily provided, there is much variation in the quality of data across countries and there may be selection biases. Data on internet speed may also be collected automatically without requiring users to visit a website. For example, in one study in Sau Paulo, Brazil, open-source software was installed in public Wi-Fi access points which performed measurements every hour by sending a sequence of packets and calculating throughput, latency and packet loss (Kamienski et al., 2020).

Affordability

Information on the prices of internet services and technologies are available on websites. Alliance for Affordable Internet (2020) collected information on the cheapest available online price for a smartphone from a major mobile network operator in 70 low- and middle-income countries. They also collected some data on the prices of feature phones. This seems to be the first major effort to collect this kind of information, and, in future, it would be useful if the ITU incorporated these data into its official internet affordability estimates. Web-scraping - a technique used to automatically extract large amounts of data from websites - could potentially be used to automatically record changes in device prices over time.

Digital skills

Both the supply of and demand for digital skills can be measured using big data. Focusing on the supply side, Verkroost et al. (2020) use aggregate anonymous data from LinkedIn Campaign Manager, which gives an estimate of how many female and male LinkedIn users work in a particular industry per country, to examine the variation in supply-side gender gaps in different subdomains of the ICT sector (for example, computer hardware or software, computer and network security, and so on). However, one shortcoming, acknowledged by the authors, is that if there are systematic gender differences in internet use in a country, gender gaps on LinkedIn may reflect inequalities in internet use rather professional gender inequalities. Data from online jobs platforms are particularly well-suited to measuring demand for digital skills. Algorithms are developed by online jobs platforms to predict the most in-demand occupations at a detailed level. This is a useful alternative to traditional methods of assessing demand (employer surveys, industry consultations, focus groups), which can be cumbersome and expensive to undertake (Bashir and Miyamoto, 2020). One constraint here is that online jobs platforms often only the formal economy, whereas a large share of employment in developing countries is in the informal economy.

Discussion

Big data approaches offer the possibility of dramatically increasing the information available on digital inclusion, though there are some issues to be aware of. It is important to recognise that online populations on, for example, social media platforms may not be representative of relevant populations. Moreover, in some situations, accurate ground-level data are required to verify models. Therefore, these data cannot always replace data collected from statistically robust probability samples in household surveys and censuses, such as those completed by national and international statistics agencies, but should often be seen as a complement to them (di Bella et al., 2018).

It is also very important that safeguards are put in place to mitigate risks around data protection and privacy. Various organisations have called for a new social contract for data co-created and agreed on by governments and the people they govern (e.g. World Bank, 2021; CGD, 2021). To be effective, such a contract would need to be built on a common understanding that digital innovation will play an increasingly important role in national economies, and that the best way to build and preserve the trust needed to support that innovation is to use data in an ethical and transparent manner that protects the rights of individuals (CGD, 2021).

D. Recent research on digital divides and factors affecting digital inclusion

A growing body of empirical work has investigated the association between digital inclusion and socio-economic factors - including gender, educational attainment and income - or spatial locations. In developing countries, most of the focus has been on access divides. Many studies have focused on country-level data and have used multiple regression analysis to try to work out which factors are determining access divides between countries. Studies examining the divides within countries have also used multiple regression and correlational analysis. Other studies have focused on a descriptive analysis of the unequal distribution of aspects of digital inclusion across or within countries. Generally, studies using regression or correlational analysis are plagued by endogeneity issues, particularly the cross-country studies. Moreover, since many of the socio-economic variables are correlated with one another (for example, income, education and age), it is difficult to isolate the effects of specific factors. This section reviews this literature, organising the analysis around the more important socio-economic factors that are found to affect digital inclusion.

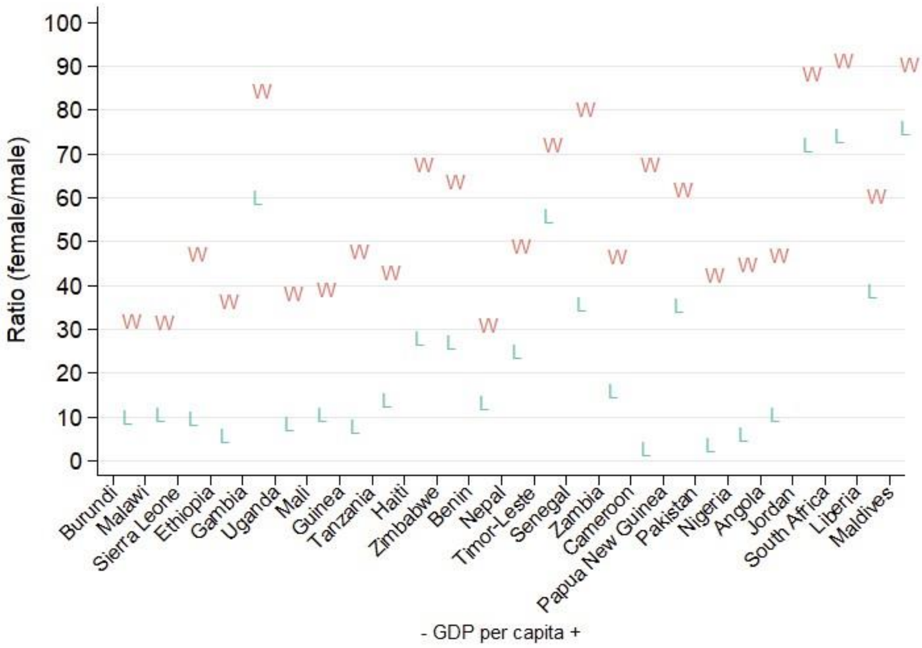
D.1 Gender

ITU (2019a) suggests that gender gaps in internet access were ‘growing fast’ between 2013 and 2019 in developing countries, particularly those in Sub-Saharan Africa and the Asia-Pacific region. A more recent report (ITU, 2021) claims that gender gaps decreased in all regions between 2018 and 2020. However, as discussed earlier, these data can be questioned as they are often not based on surveys but on the predictions of simple models (the ITU always includes a footnote under its graphs to say that access gaps between genders are ‘estimated’). There are several plausible reasons why women may have lower levels of digital inclusion than men in developing countries - including, for example, differing socio-economic status or purchasing power, social norms or uneven power relations, or differing demands in terms of domestic labour (Bimber, 2000; Ono and Zavodny, 2003) - however, very often studies are of low quality and make little effort to isolate specific factors.

Claims are often made that attitudes and cultural beliefs play a role in the gender digital divide and while this seems plausible, there is a lack of quantitative evidence. Hilbert (2011a) uses data from 25 developing countries in Africa and Latin America, and finds that women tend to use the internet more than men with the same levels of income, education and employment. He interprets this as being evidence against the widely held view that gender norms play a direct role in internet use gaps. Similarly, a study examining data from nationally representative surveys across 16 African countries (Milek et al., 2011) found that, when women had similar income, education and employment status, they had comparable access to ICTs as their male counterparts. Of course, even if the findings of these studies are interpreted as evidence against gender norms directly affecting internet or ICT use, gender norms related to other aspects of society could have an indirect effect by, for example, reducing female participation in education and the labour force. It is also possible that gender norms may play more of a direct role in other developing regions (for example, South Asia or the Middle East) where traditional patriarchal norms may be stronger (Zainudeen et al., 2010).

Since digital inclusion is often self-reported, gender gaps - particularly related to digital skills or knowledge of the internet - could be, at least in part, a function of the fact that women have a different style to men when answering survey questions about their abilities or knowledge (see subsubsection 3.2.4). Though Figure 1 shows that women across the sample of developing countries are less likely to say they ‘know’ what the internet is, this question is vague, which allows different answering styles to play a role.

Figure 10: Gender gaps in access among low-income groups do not close linearly with income level of country



$$Gender\ ratio = \frac{Female\ access\ rate}{\text{Male access rate}} \times 100$$

Indicator calculated for the total population (W) and separately for people in the lowest income quantile (L). Data on access from DHS (2015-2019). On the X-axis, countries are ordered by GDP per capita PPP according to World Bank data from 2017.

Gender gaps in internet and digital technology use rightly receive a lot of attention. While there was some speculation that gender gaps in ICT use may disappear as countries develop (see Broadband Commission for Sustainable Development, 2013), this is not the case for all socio-economic groups. Figure 10 shows the ratio of female to male access to the internet for whole populations (W) and for the lowest quartile of the population (L) for a sample of developing countries ordered by per capita GDP. While ratios for whole populations tend to increase in a linear fashion as countries get richer, this is not the case for low-income group ratios, where there is no such relationship. This is an important area for further exploration.

Further research on gender gaps could also examine detailed questions such as when, how long and for what purpose do men and women use the internet in developing countries (Hafkin and Huyer, 2007). Preliminary research suggests that women's use of the internet in developing countries may be different to men (e.g. ITU, 2021). There is also a need for more research to look into the extent of and reasons for differential participation in platform work - that is, employment facilitated by online platforms that connect individuals and organisations - and in careers involving science, technology, engineering and mathematics in developing countries (GSMA, 2020b). And, since much previous quantitative research has been cross-sectional, it would be useful to have studies that carefully examine levels of digital inclusion for men and women over time to test whether gaps are growing or closing.

D.2 Education

Disparities in education are also seen as an important barrier to digital inclusion. According to theory, better educated individuals are more likely to recognise the benefits of using the internet and other digital technologies, and can more easily develop their digital skills to gain access to jobs and resources (Van Dijk, 2020). In cross-country studies, some researchers have suggested that education seems to be more relevant to explain ICT adoption in developing countries than in developed ones (Bagchi and Udo, 2007; Kiiski and Pohjola, 2002), while others have found that there are no differences between developing and developed countries (Kottemann and Boyer-Wright, 2009; Pick and Nishida, 2015) or that education does not actually explain ICT adoption in developing countries (Baliamoune-Lutz, 2003). Several micro-level studies using national surveys have shown the positive relationship between individuals' educational level and internet use in developing countries (Zhu and Chen, 2013; Pick et al., 2013).

It is unclear from the above studies to what extent education inequalities directly affect internet or ICT use, or are just correlated with internet or ICT use. Indeed, none of these studies make a serious attempt to isolate the causal effects of educational attainment. While not a perfect solution, studies should at least control for factors like income that could bias the relationship between education and ICT use. As an example, using the nationally representative Indian Human Development Survey (IHDS) in India, Tewathia et al. (2020) use a multivariate analysis of covariance (two-way MANCOVA) model to estimate the relationship between ICT usage (proxied by ICT expenditure) and educational attainment of the most educated member of the household (among other variables), controlling for household income. One drawback of the study is that it only uses one wave of the IHDS, even though this survey is designed as a household panel and an earlier wave is available. Using both survey waves would have allowed for an analysis of changing ICT expenditure/use within households over time.

Future research focusing on the relationship between education and digital inclusion could try to make use of institutional features of the supply side of the education system as exogenous determinants of schooling outcomes (see Card, 1999). Going beyond access, it would be useful to have more descriptive studies on how people of different education levels use the internet in different ways in developing countries. It would also be interesting for studies to look more carefully at the relationship between formal education and digital skills. Are the returns to formal education in terms of digital skills different across countries (as indicated in Figure 9) or regions primarily because of different levels of ICT infrastructure in educational institutions, and to what extent do syllabi and teachers' skills also matter?

D.3 Income

Numerous cross-country studies have tried to explore the relationship between a country's income level and its internet or, more generally, ICT access (Baliamoune-Lutz, 2003; Chinn and Fairlie, 2007, 2010). Rather than focusing on the effects of absolute levels of income, some research has explored the impacts of income inequality on technology use (Fuchs, 2009; Wunnava and Leiter, 2009; Zhang, 2013). There are also many studies that have shown a positive correlation between income and internet or ICT use within countries (see examples below). None of these studies have adopted causal inference techniques to try to isolate the effects of income. Omitted variable bias is an issue because income also arguably has the strongest potential among socio-economic variables for reciprocal causation; low income leads to low internet use, which, in turn, can lead to lower income in a mutually-reinforcing way (Martin and Robinson, 2007). At the country level, income is associated with internet use due to the fact that richer countries have better developed socioeconomic infrastructures, regulatory systems and a larger population share prone to internet adoption; at the household or individual level, richer people have more disposable income to spend on technologies that improve their lives (Vincent, 2016).

One particularly interesting question related to income at the household and individual level, is whether the internet exists as 'a necessity' to serve basic communication needs among the poor, or as 'a luxury' service that people have a choice to consume or not. This can differ by country and studies on the relationship between income and ICT use typically adopt an Engel Curve analysis, which compares the amount of expenditure on an item with total household income or expenditure. If a greater share is spent on the good or service as household income or expenditure rises, then the item is considered a luxury; if the opposite, it is considered a necessity. Hilbert (2010) finds that ICTs are necessities in more developed countries, and luxury items in poorer countries in Latin America in the early 2000s. Ureta (2005) evaluated households' telecommunications expenditures in four countries - Albania, Mexico, Nepal, and South Africa - between 2000 and 2003, finding similar results.

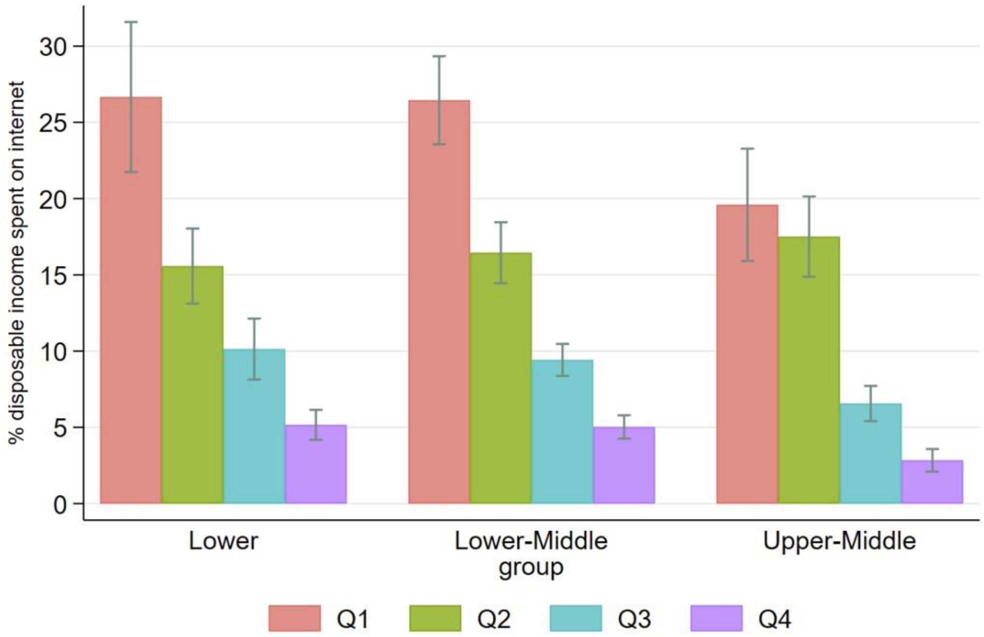
Often ignored in these Engel Curve analyses is the fact that, when thinking about expenditure on internet or other telecommunications services accessed through a personal device, it is important to consider the cost of the device, ideally coming up with a monthly rental amount. This requires having data on the cost of devices, which is often not collected in household surveys. In the absence of this information, the statistical analysis should condition on the ownership of internet-enabled device, which does not seem to have been done in previous studies. It would also be preferable to complete the analysis at the individual level, since income or expenditure may increase with household size and yet internet access may be shared (or at least its cost may not increase in direct proportion to household size). Figure 11 shows monthly expenditure on internet services as a share of individual disposable income, conditioning on the ownership of mobile phone devices, for different income quartiles for countries in the AfterAccess Survey categorised into low, lower-middle and upper-middle income groups. Internet services emerge as a necessity across countries of all three income groups.

The ITU builds its model to predict internet use for countries primarily based on per capita income data (ITU, 2017b, 2021). There is a strong correlation between per capita income and internet access but it will be important for future research to investigate this relationship more thoroughly, identifying cases where per capita income does not predict internet use well, and finding other variables and data sources that could be included in predictive models to improve their accuracy.

D.4 Location

The most basic study of the effects of location on digital inclusion simply describes spatial disparities between rural and urban areas or different sub-regions of a country using cross-sectional data. In one recent example, Brito et al. (2016) carry out a study on ICT access concentration in Brazil. The authors find a substantial spatial disparity between the (rural) municipalities of the Amazon and other regions in terms of ICT infrastructure concentration at the household level. In addition, the results demonstrate that rural households are more likely to lack any kind of ICT service than urban households. In a related but deeper study, Sujarwoto and Tampubolon (2016) undertake a detailed descriptive analysis of geographic gaps in Indonesia, finding that inequality of internet access widens between urban and rural areas and between remote islands and mainland island areas over the period 2010-2012.

Figure 11: Share of monthly individual disposable income spent on internet services

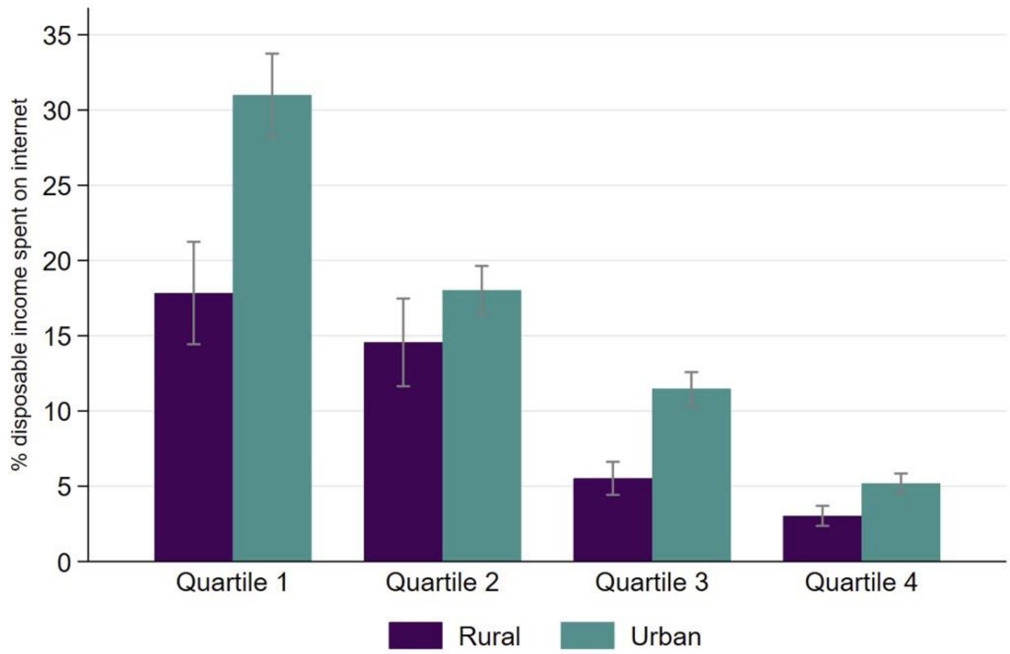


Data from AfterAccess Surveys 2017-2018 undertaken by Research ICT Africa. Conditioning on ownership of a feature phone or smartphone. Disposable income data imputed when missing (for 529 out of 3,842 observations). 95% confidence intervals are shown. Group of countries defined following World Bank criteria. Lower-income countries: Mozambique, Rwanda, Uganda. Lower-middle income countries: Kenya, Ghana, Nigeria, Tanzania, Senegal. Upper-middle income countries: South Africa.

The authors suggest that this is linked to disparities in telecommunications infrastructure and education. The study provides a more interesting analysis than the standard descriptive analysis because it exploits panel data and looks at the interaction between location and socio-demographic variables. However, one issue with both studies described above is that they are limited by the questions asked in household surveys, which typically only ask about personal internet connections and ignore access to the internet via communal or public facilities. While using a much smaller data set, Otioma et al. (2019) conducts a spatial analysis of internet access in Kigali, distinguishing between home or office/school access and internet café access. Outside of the core of Kigali, internet cafes are found to be much more important for people gaining access to the internet.

It would be useful if studies examining the association between digital technologies and space went beyond mere access and looked into skills, affordability and the quality of internet access. Related to spatial gaps in affordability, Figure 12 examines the proportion of total disposable income spent on the internet across a range of developing countries for people in urban versus rural areas (distinguished according to the census definitions used in each country) and in different quartiles of the income distribution. In urban and rural areas, the share of income going to the internet is larger for poorer groups, suggesting that the internet is a necessity in both areas. However, across the income distribution, urban households spend more of their income on the internet than rural households.

Figure 12: Income expenditure as a proportion of disposable income for income quartiles and rural vs urban areas



Data from AfterAccess Surveys 2017-2018 undertaken by Research ICT Africa. Urban includes both urban and peri-urban regions. Conditioning on ownership of a feature phone or smart phone. Disposable income data imputed when missing (for 529 out of 3,842 observations). 95% confidence intervals are shown. Countries include Ghana, Kenya, Mozambique, Nigeria, Rwanda, South Africa, Senegal, Tanzania and Uganda.

D.5 Discussion

This section has cast doubt on studies that have attempted to find the most important factors behind digital inclusion using aggregate data at the cross country level. There are simple ways of improving descriptive studies of digital gaps including using panel data and examining the interaction of different factors to get a richer picture of digital exclusion. Often studies have focused on gaps in internet access, but it is important to go beyond this in empirical studies, which need to catch up to theory. Some studies focused on high-income countries have looked at divides in skills (Deursen and Van Dijk, 2010) and divides in the ways different socio-economic groups spend their time online (Van Deursen et al., 2015; Blank and Groselj, 2014), and these should be replicated in developing countries. It should also be pointed out that, if dimensions of digital inclusion are poorly measured, this will undermine efforts to improve the sophistication of studies that analyse gaps.

An obvious direction for future research is to examine divides in internet quality. Studies have tried to go beyond measuring differences in access to devices and have attempted to take into account the capacity of the devices/quality of the internet connection. Hilbert and López (2011) and Hilbert (2016) try to arrive at a measure of 'total technological capacity' taking into account the number of telecommunication subscriptions (fixed and mobile); the kind of access technology per subscription (such as Digital Subscriber Line (DSL), second-generation Global System for Mobile Services (GSM), and so on); and the corresponding bandwidth per access technology. The findings of these papers are interpreted as providing evidence that, while the digital divide in terms of access between countries is getting smaller, the bandwidth divide continues to be dynamic. The authors provide disclaimers that these studies are intended to be 'exploratory' and make the important point that indicators need to be developed to track the digital divide in terms of bandwidth. However, there are also numerous issues with the methodology adopted. Strangely, these studies multiply all devices by any kind of bandwidth: as the sum of the products of the number of installed devices and their respective performances as yearly averages. This is not very well thought out - in fact, it would probably be more useful just to compare some aggregate measures of average bandwidth experienced by households of different income levels across countries. There is still a significant lack of internationally harmonised statistics that consider access to bandwidth, and more studies are needed on digital divides related to internet quality.

E. Conclusion

Clearly, thinking of digital inclusion only in terms of access is insufficient, and important theoretical contributions have been made to extend this concept to consider additional barriers to meaningful usage, and outcomes as well as opportunities. For the purposes of goal-setting and policy-making to tackle digital divides, it is necessary to focus on certain core indicators of digital inclusion, and efforts should be made to improve their sophistication and reliability, and to disaggregate them. While there have been many commentators who have questioned the importance of the internet in developing countries, there is now wide acceptance of the internet being a key enabler for development, which has been aided by recent robust economics research on the topic.

This paper has set out a framework for defining digital inclusion via the internet that focused on key components: access/use; quality of access/use; affordability; and digital skills. It has reviewed how a broader definition might have implications for government policy-making and regulation, considering potential market failures related to infrastructure roll-out and digital skills education. The paper has undertaken a wide-ranging evaluation of how the key components of digital inclusion it identified are currently measured, drawing attention to some weaknesses in current metrics and making constructive suggestions for improvements and additional metrics.

There are significant discrepancies between major data sources on internet access/use, which are not easily explained. International organisations should be more candid about how they combine and compare data sources to arrive at official estimates and should more clearly explain modelling approaches that are used when data are missing. There is also a need for more investment in household and individual-level surveys, with carefully-constructed questions that take into account how the internet is used in developing countries. These questionnaires should include questions related to the quality of access/use, considering both technical quality and how people access the internet, which can affect what they can use it for.

Related to digital skills, current measurement efforts take an outdated approach that focuses on computer skills, which is not suitable for measuring digital skills in developing countries. Also questionable is the usefulness of basic proxies that equate attainment of education with attainment of digital skills. International organisations should develop survey questions which focus on digital skills related to mobile phones, and reassess their proxy measures.

Related to measuring affordability, there is a need to develop additional metrics beyond those that consider internet service bundles as a proportion of per capita GNI. It is important to also consider the cost of devices, and it may be useful to develop additional metrics that focus on internet service bundles that provide certain minimum speeds and summarise information about cost differences within countries and between different regions. Questions in household and individual-level surveys related to internet expenditure also need to be improved and standardised.

Digital inclusion indices, which sacrifice important detail for arbitrarily defined summary measures, are of limited value. Digital inclusion is multi-faceted, and a plethora of indicators cannot be aggregated to form a clear conclusion. On the contrary, there is much potential in using big data methods to measure digital inclusion. Already, researchers can draw on internet speed estimation data and online jobs platform data to examine the technical quality of internet connections and the demand/supply of digital skills, respectively. In the future, it may be possible to exploit new data sources such as internet search engines. There are, however, important concerns around data protection and privacy associated with the use of big data that policymakers should pay close attention to.

Lastly, this paper has reviewed the relevant literature on digital inclusion and digital gaps related to the internet and ICTs. Most relevant studies focus on socio-economic factors that affect basic internet access and many suffer from serious endogeneity issues. Future research should make use of panel data, where available, and examine how socio-economic factors interact. The research should also consider other dimensions of digital inclusion besides access: there is still a very limited understanding of gaps in internet quality, digital skills and internet affordability.

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