ADOPTION AND ADAPTATION OF INNOVATIONS. RE-INVENTION AS A CAPABILITY IN THE DIGITAL ERA

Alberto Medina

INTRODUCTION

The growing capabilities and rising affordability of digital technologies (DTs) might be opening new opportunities to address both contemporary and long-standing global challenges. However, considering that current digital technological development is highly concentrated in a small number of countries and companies (UNCTAD 2019: 1), how can those who do not actively engage in their development leverage from them in a sustainable way and without compromising their technological self-reliance? This paper examines 're-invention', a concept developed within the realm of diffusion of innovation studies, to discuss the potential and implications when besides using a technology, adopters also modify it and adapt it. The paper is divided into four sections. The first section reviews the challenges and opportunities for developing countries amidst the so-called digital revolution. Section II conceptualises 're-invention' and examines its occurrence and potential in the adoption and diffusion of innovations. By analysing earlier policy-related responses, Section III discusses the challenges for developing countries brought by DTs and the possibilities and implications of 're-invention' in the digital era. Section IV explores the way forward and proposes a series of policy recommendations.

CHALLENGES AND OPPORTUNITIES OF THE DIGITAL REVOLUTION

Certainly, the challenges and opportunities stemming from the digital revolution vary considerably depending on the overall level of development and digital readiness of each country (UNCTAD 2019: 103). Without disregarding the above, this section provides an examination of the implications of current digital trends for developing countries.[1]

Ciuriak and Ptashkina (2019: 103) maintain that the digital revolution presents developing countries considerable opportunities for convergence. The above, the argument goes, is enabled by the possibilities to circumvent industrial-age infrastructure investments; leverage from online knowledge spillovers; benefit from digitally enabled market opportunities (e-commerce) and to take advantage of more cost-effective and environmentally friendly production processes (ibid.: 1).

The opportunities of DTs seem to extend across almost every economic sector, from agriculture and education to manufacturing and communication. A growing number of studies concur that DTs – including Artificial Intelligence (AI), blockchain, Big Data, the Internet of Things (IoT) cloud computing – have an enormous potential to advance the United Nations' Sustainable Development Goals (SDGs) in particular and support international development efforts in general.[2]

The potential benefits of DTs can be divided into two categories: First-order benefits, that result directly from the use of DTs, such as greater productivity and improved efficiency. Second-order benefits, on the other hand, relate to the development, management and distribution of DTs. These provide greater opportunities for positive and long-lasting impacts on competitiveness and growth (UNCTAD 2019: 105).

Notwithstanding, developing countries must overcome many challenges if they are to capture the benefits posed by the digital revolution. Some of the most frequently cited in the literature can be classified into the following categories:

1. *Infrastructure:* The overall capacity increase of DTs leads to a corresponding increase in hardware and infrastructure requirements. Many, though not all, DTs require not only an internet connection but also a minimum bandwidth and computational power for ensuring their smooth operation. This challenge becomes even more daunting if one considers that some 850 million people worldwide still lack access to electricity and that only 47 % of people in developing countries have access to the internet

(IEA 2019: 4; ITU 2019: 2).[3] Therefore, developing countries are compelled to make investments in infrastructure, particularly in remote areas, to enable the broad adoption of DTs (Dahlman/Mealy/Wermelinger 2016: 26).

2. *Skills:* The complexity of some technologies demands a set of new technical skills and an overall higher level of technological savviness. Moreover, digitalization and cost-effective improvements in automation could not only lead to domestic job displacement but also encourage multinational companies to relocate production back to high-income countries (back shoring). In doing so, they jeopardise low-wage labour as a competitive advantage for many developing countries (Rodrik 2018: 14-15).[4] Amidst this scenario, developing countries will need to implement upskilling programs for their workforce and increase the IT literacy across all population segments (Dahlman/Mealy/Wermelinger 2016: 26-27).
3. *Regulation and policies:* The pace in which technological change occurs tends to outpace regulations and policy formulation (ibid.: 55). Also, the incipient stage of standardisation of many DTs may further limit the ability of governments to both design and enforce policies and regulations. Both are key to addressing the growing concerns about DTs, such as privacy and data protection, cybersecurity, surveillance, sovereignty, and cross-border data flows. Furthermore, policymaking related to digital governance, standardisation and regulation is mainly dominated by developed countries (ibid.: 28).

However, the underlying challenge of the digital revolution is that the development and production of DTs are exceedingly concentrated in a reduced number of companies, countries and cities. Ten countries – United States, Japan, Germany, China, Taiwan Province of China, France, Switzerland, the United Kingdom, the Republic of Korea and the Netherlands – are accountable for 91 % of global patent activity and about 70 % of total exports related to advanced digital production technologies (ADP) (UNIDO 2019: 48-49).[5] Table A provides a more detailed overview of the current global trends.

Table A: Global Trends in Digital Technologies

Technology	Main players	Global contribution
Blockchain	US and China	Represent more than 75 % of the total patent applications.
AI	China, US and Japan	Account for 78 % of the total patent applications.
3D-printing	US, China, Japan, Germany and the UK	Represent approximately 70 % of the total global capacity.
IoT	US, China, Japan, Germany, Republic of Korea, France and the UK	Contribute to nearly 75 % of total spending on IoT.
Cloud computing	US and China	Account for more than 75 % of the global cloud infrastructure services market.
Robotics	China, Japan, Republic of Korea, US and Germany	Represent around 73 %of the total sales volume of robots

Note: The major global players are listed in descending order of importance.

Source: Author's compilation based on (UNCTAD 2019: 2-21).

A closer analysis of the data reveals further distribution asymmetries hidden behind country aggregates. For example, a study on 30 OECD countries, including seven of the ten global leaders in DTs mentioned above, shows that the 64 % of total patenting activity is concentrated in 10 % of the cities surveyed (Paunov et al. 2019: 15). At the corporate level, the International Business Machines Corporation (IBM) has the world's most extensive portfolio of AI patent applications and is a world l leader in patent filings related to blockchain, cloud and quantum computing (Benchaita 2020; WIPO 2019: 15).

Patenting trends can only provide a partial depiction of the global concentration dynamics. Nevertheless, other indicators, such as market capitalisation of technology companies, market share proportion of digital services, global web traffic volume, e-commerce sales, the geographical distribution of data centres and geographical distribution of leading digital platforms point to similar trends.[6] Given the above, how can developing countries leverage from a data-driven and unevenly distributed digital era?

As with previous technological revolutions, the benefits will initially tend to be captured by the front-runners (Ciuriak/Ptashkina 2019: 2). By being at the forefront of the latest technological developments, the latter can benefit from a significant competitive advantage that is well protected by intellectual property rights. Although developing countries will tend to be marginalised as producers for many DTs, they could still benefit from the digital revolution, but mainly as adopters and not as rent earners (ibid.: 1).[7]

RE-INVENTION AND THE DIFFUSION OF INNOVATIONS

Developing countries are compelled to promote the adoption of DTs to leverage from their opportunities. Nonetheless, it is generally not clear how, by doing so, developing countries could counter the effects of entering an enormously concentrated market. This section introduces the concept of re-invention and argues that, besides promoting the widespread adoption of DTs, developing countries should make proportionate efforts to improve adopters' capacities to modify and adapt them to match their conditions and needs.

THE POTENTIAL OF RE-INVENTION

Adoption is the "decision to make full use of an innovation as the best course of action available" (Rogers 1983: 36).[8] Nonetheless, this decision is rather nuanced, as individuals (or other decision-making units) can only choose to adopt (or reject) some elements of the innovation, alter them, or even modify the purpose for which it was initially intended. Especially during the implementation phase, it is very likely that the innovation will experiment changes. The extent to which an innovation is changed or modified by an adopter is known in diffusion studies as re-invention (ibid.: 175).[9]

The occurrence of re-invention can help to address challenges related to the implementation of an innovation across different contexts. Several studies have shown that the adoption of an innovation by an individual (or an organisation) is unlikely to have similar characteristics when it is replicated elsewhere.[10] Therefore, the prospect that potential adopters in developing countries can re-invent or, stated differently, re-interpret, adapt or modify an innovation – an idea, practice, or object that is perceived as new – to meet their needs and conditions better endows with greater flexibility the diffusion process (ibid.: 178).[11]

Within the context of the digital revolution, the occurrence of re-invention could not only make the implementation process of DTs more resilient to unexpected problems but also make them more suitable for addressing potential adopter's problems (ibid.: 179). Similarly, a higher degree of re-invention of DTs could lead to both a faster adoption rate and a higher probability that DTs will be used over a more extended period (ibid.: 208).

Considering the points above, building the capacity among potential adopters of DTs to re-interpret, adapt and modify them could facilitate a more resilient, more sustainable and more swiftly diffusion of DTs, particularly among developing countries that do not have a significant role in their development. In diffusion studies, re-invention is considered as an unexpected outcome during the innovation-decision process.[12] In this paper, re-invention is instead discussed as a capability; one that could be encouraged and systematically strengthened.

It is worth noting that re-invention can also be restricted or even intentionally avoided. DTs can be designed in such a way that they are difficult to modify, or they can

be configured to allow changes only in their secondary or non-essential elements.[13] Consequently, depending on the point of view and objective pursued, re-invention may be considered desirable and systematically strengthened or unintended and deliberately prevented.

RE-INVENTION AND DEVELOPMENT IN THE DIGITAL ERA

This section discusses in-depth the challenges presented in section I related to skills and infrastructure constraints that developing countries face amidst the digital revolution. It examines two critical policy-related responses that emerged in the 1970s: the Sussex Manifesto (SM) and the appropriate technology (AT) movement. It argues that while the digital revolution might be leading to an unprecedented period of technological development, in essence, some of the reflections and recommendations for developing countries made nearly 50 years ago remain of significant value in the ongoing debate. The objective is two-fold. First, to challenge the discourse of newness that often surrounds the challenges discussed in section I. Second, to highlight elements of both policy-responses that either directly or indirectly endorse re-invention.

SUSSEX MANIFESTO

In the early 1970s, the Sussex Manifesto (SM)[14] drew attention to the fact that technology (and knowledge) was becoming less and less suitable to be used in developing countries as it increasingly required conditions and resources that are not often found in developing countries, such as abundant capital and skills (Singer et al. 1970: para 43). The SM also affirmed that modern technologies and scientific efforts were disproportionally oriented to the needs and economic objectives of developed countries (ibid.: para 2).

The existing imbalance, the argument goes, must go beyond facilitating technology transfer (TT) to developing countries and allow a drastic reorientation of international efforts so that these countries can instead develop their own scientific and technological capabilities (ibid.: para 1).[15] The latter would be crucial to support the process of selecting, using, adapting, repairing and maintaining technologies developed elsewhere (ibid.: para 19). According to this view, the ability of TT to be the basis of further innovation in developing countries depended on the national scientific and technological capabilities of those countries (ibid.: para 20).

The arguments and policy recommendations presented in the SM made it relevant in three main accounts. First, it moved away from discussions that focused on TT problems and the prevailing discourses on catching-up with developed countries (Cherlet 2014: 15). Second, it suggested that developing countries should become technological adaptors, improvers and creators, rather than passive choosers and users of ready-made solutions developed elsewhere (Ely/Bell 2009: 6). Third, it deemed essential that developing countries develop their technological capabilities based on deliberated actions rooted within the global political-economic system (Kaplinsky 2011: 195).[16]

SCHUMACHER AND THE AT MOVEMENT

In the 1970s, E. F. Schumacher, too, considered essential to adopt alternative economic development strategies that were more appropriate to the recipient's desires, beliefs, and priorities (Seely 2003: 19).[17] In line with this view, Schumacher endorsed the development of intermediate technologies (IT), that is, technologies that would be cheaper to produce than the more sophisticated and capital-intensive modern industry technologies, but at the same time more productive than existing domestic technologies and well-suited to local conditions (Schumacher 1973: 131-132). It was based on the idea that by having access to technologies shaped by their context, developing countries could advance their development more effectively (ibid. 1973: 139).

Schumacher's work laid the ground for the so-called appropriate technology (AT) movement, which found acceptance and support in both developed and developing countries (Seely 2003: 19). In general, the term AT refers to technologies intended to be more suitable for conditions in low-income countries in that they are labour-intensive, low-scale, easy to run and repair, oriented to produce goods for low-income consumers and have negligible negative environmental impacts (Cherlet 2014: 13; Kaplinsky 2011: 195).

RE-INVENTION AND THE SHIFTING CAUSALITY OF ADAPTATION

Although within different conceptual frameworks and to varying extents, both Schumacher and the SM argue for re-invention as a way to make technology not only appropriate but also meaningful for developing countries. Considering the perspectives proposed by both works, re-invention can be interpreted in at least two ways. On the one hand, an innovation can be adapted to the needs and context of a given potential adopter. The focus of the re-invention is on the innovation. On the other, the conditions can be adapted to the needs of a particular innovation, such as ensuring the availability of electricity and internet access to guarantee its operation. In this case, the focus is oriented on the conditions under which an innovation is implemented.

In the context of the digital revolution, developing countries are often compelled to create suitable conditions for the adoption of DTs (Benini 2016; Larsson et al. 2006; Pueyo et al. 2012). Coincidentally, the SM considers it necessary to carry out institutional changes, conduct policy reforms, and create the conditions for the application of modern technologies (i.e. capital inputs, skilled technicians and workers) (Singer et al. 1970: para 17-19). However, Schumacher (1973: 143) suggests that by doing so, developing countries either fall or are pushed to an adaptation process that ultimately destroys their possibilities of self-reliance and self-help.

Given the challenges brought by the digital revolution, should developing countries favour the adoption of DTs suitable for their conditions (adapt the technology), as the AT movement proposed, or instead make the necessary adjustments to create a favourable environment for the application of DTs, (adapt themselves to the technology) as the SM suggested?

Its critics consider the AT movement as a backward approach that is likely leading to stagnation (Lorentzen 1990: 205). Especially the professional elite from developing countries regarded AT as an attempt to condemn their countries to a perpetual state of inefficiency and low productivity (Eckaus 1955; Emmanuel/Furtado/Elsenhans 1982). The arguments commonly hinge on the assumption that shaping technology according to the often less competitive conditions of developing countries, and not on the contrary, can lead to little or no investments in infrastructure. Hence, contributing to preserving the current technological level of developing countries.

Instead, it is probably also problematic to adapt local conditions to the infrastructure and skills required by DTs, as it seems to be reminiscent of controversial ideas about the catching-up process.[18] All points considered, neither of both approaches is flawless. Therefore, the causality of adaptation cannot be fixed. In other words, not only would developing countries have to adapt to the new requirements of DTs, as is commonly implied in the literature, but developing countries would also have to adapt these technologies to meet their circumstances and needs better.[19]

The above requires careful assessment and selection of DTs and other technologies available that can be relevant to meet the interests and objectives of individual countries, regions or communities. It should be emphasised that the discussion and arguments put forward in both SM and Schumacher's work, although critical, are very much focused on increasing productivity and efficiency. As it turns out, when innovations are diffused, they carry out an implicit purpose and intention.[20] Nevertheless, by re-inventing – re-interpreting ideas, modifying artefacts and adapting innovation practices – adopters can also assign DTs a different meaning and purpose. The above opens up new opportunities for developing countries to build competitive advantages and to strengthen their technological self-reliance (explained in further detail in the following sub-section).

Development interventions and all initiatives aimed at promoting the adoption of DTs should be accompanied by a systematic increase in the re-inventing capabilities of potential adopters. To this end, advancing local scientific and technological capacity in developing countries, as proposed by the SM nearly 50 years ago, remains essential to support re-invention capabilities. Moreover, in the context of the digital revolution, the latter can play a central role countering the prevailing asymmetries in the production and development of DTs.

ACCOUNTABILITY OF RE-INVENTION

The development of IT could be achieved by adapting traditional techniques and methods by using knowledge of advanced techniques; by modifying the most advanced

technology to the existing circumstances or through dedicated experimentation and research (Schumacher 1973: 138-139). Similarly, producing AT entails a process of "adapting a technology in order to configure it with an operational form or design that fits the new […] environment" (UNCTAD 2014: 39). In both cases, it is not easy to determine who is responsible for performing such adjustments or adaptations.

Schumacher problematises that the accountability could lie with the developer of the technology or with the sender (in TT jargon). He questions the capacity of the latter to accurately identify the needs and methods that will allow the recipient to construct his development. As he annotates: "As long as we think we know, when in fact we do not, we shall continue to go to the poor and demonstrate to them all the marvellous things they could do […]" (Schumacher 1973: 146). Moreover, the accountability for the adaptation is then with the sender, and the recipient could also become dependent on the technology provider for future adaptations, repairs and even maintenance.[21] As Schumacher (1973: 145) summarises it:

> *"Supply [a man] with a fishing tackle; this will cost you a good deal of money, and the result remains doubtful; but even if fruitful, the man's continuing livelihood will still be dependent upon you for replacements. But teach him to make his own fishing tackle, and you have helped him to become not only self-supporting, but also self-reliant and independent."*

In line with the above, the SM deems it necessary that developing countries not only acquire the ability to use technology but also to re-invent, repair and maintain it. This is particularly true when one considers that the degree of complexity of many DTs may be unknown to a large proportion of potential adopters. Furthermore, the resulting adaptations and modifications could also serve as a basis for the development of further innovations (Singer et al. 1970: para 20). Notwithstanding, creative efforts still tend to favour the developer's accountability to provide the recipient with adequate technology.

A case in point is the living lab – user-centred, open-innovation and multi-stakeholders laboratories – which tend to emphasise the importance of the potential adopter in the process of selecting, developing, testing and evaluating technologies (Smit et al. 2011: 2-4). Perhaps this approach can partly address the availability of better-suited conditions, as the AT movement sought to do, but it does not lead to meaningful changes in the technological capabilities of the adopter, as the SM advocates. By making the potential adopter a co-participant in the process, it is likely that the resulting technology will better fit its context and requirements. Nevertheless, although the potential adopter plays a more participatory role in the process, its independence and technological self-reliance are far from guaranteed.[22]

TOWARDS TECHNOLOGICAL SELF-RELIANCE

1. The diffusion of DTs in developing countries should be accompanied by proportional efforts to develop and strengthen the capacity of potential adopters to re-invent them.

   Developing countries could also benefit from the digital revolution as consumers and users (Ciuriak/Ptashkina 2019: 3). However, by doing so, the global concentration in the development and production of DTs is unlikely to change significantly. Therefore, besides promoting the use of DTs, developing countries should seek to develop the technical capacities of potential adopters to re-interpret, adapt and modify them. A proportionate and systemic investment in the re-invention capacities could facilitate a more resilient, more sustainable and faster diffusion of DTs, particularly among developing countries that do not currently play a significant role in their development.

2. Developing countries should strike a balance between developing the infrastructure and building the skills among potential adopters to meet the requirements of DTs (adaptation to technology) and re-inventing DTs to meet their current conditions and needs (adaptation of technology).

   Both approaches have crucial implications. By attempting to create a conducive environment for the adoption of DTs, development countries can enter into an endless catch-up process that may occasionally result in them losing their opportunities of self-reliance (Schumacher 1973: 143). Conversely, shaping DTs and other technologies according to the existing conditions of developing countries can lead to little or no investments in infrastructure and help to preserve their current technological level (Emmanuel/Furtado/Elsenhans 1982; Eckaus 1955). Thus,

the causality of adaptation should also shift continually based on the needs, goals and conditions of individual countries, regions and communities.

3. Developing countries should favour the adoption of DTs that are easier to re-invent and avoid variations of DTs that are either difficult to modify or only allow changes in their secondary or non-essential components.

   To secure their competitive advantages or ensure capital returns via rents, some developers and producers of DTs would shape them in a way that is very difficult to re-invent. This limitation could increase the dependency of potential adopters on technology providers for future adjustments and changes. Contrarily, innovations that facilitate their re-invention have greater potential to lead to both a faster adoption rate and a higher probability that they will be used over a more extended period (Rogers 1983: 208). For instance, several currently available blockchain platforms are open source.[23] Access to the source code makes it easier for potential adopters to re-invent it, thus increasing their chances of self-reliance.

4. Developing countries should strive to assign DTs with different meanings, uses and purposes than those to which they are initially assigned.

   By re-inventing them, an adopter can also assign DTs with a different meaning and purpose than those to which they were initially given. The significance is two-sided. On the one hand, enhancing the technical capacity to modify DTs to assign them with new meanings and purposes can strengthen the technological self-reliance of developing countries. On the other hand, assigning uses to which DTs have not previously been thought of, especially within the specific context of developing countries, can help to develop new competitive advantages. In combination, they could form a counterweight to the global concentration dynamics.

5. In building and strengthening re-invent capabilities, developing countries should ensure that this ability lies chiefly on potential adopters.

   User-centred approaches, such as the so-called living labs, can play an essential role in reducing the differences between the designer's perception and potential adopter's experience. However, they can ensure neither the technological self-reliance of the potential adopters nor the overall sustainability of a particular project. It should therefore be ensured that the responsibility for re-inventing DTs to adapt them to the local context and to address existing problems better lies mainly with the adopters and not with the developers and producers of DTs.

6. Developing countries should play an increasingly active role in the development of policies for standardisation and regulation of DTs

   There are forums where developing countries can contribute to the global regime of digital policies. While the road ahead for developing countries to be at the edge of the technological frontier is still distant, in the short-term developing countries could considerably improve the extent to which they benefit from the dividends of the digital revolution.

CONCLUSIONS

Mühleisen (2018: 6) notes that "many benefits come not simply from adopting the technology, but from adapting to the technology". Some challenges posed by the digital revolution seem to require developing countries to adapt to DTs, for example, by meeting their new infrastructure and skills requirements. Without neglecting that, as Mühleisen suggests, some degree of adaptation to DTs may be needed, this paper argues for re-invention, as a way to shift the causality of adaptation.

Re-invention, as a capability of potential adopters, is essential for transforming and assigning DTs with different purposes to better fit to the contexts and needs of developing countries. However, potential adopters should be accountable for re-inventing if their self-reliance is to be assured. Moreover, re-invention should not be incidental but actively promoted and systematically strengthened. Considering the high concentration in the production and development of DTs, enhancing the scientific and technological capabilities of developing countries should remain as the utmost priority.

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1 There are important differences between the level of digitalization of developed and developing countries. On the one hand, China, which is considered a developing country, is a global leader in digitalization and automation (UNCTAD 2019: 103). In contrast, many developing countries in Africa have some of the lowest levels of digital readiness (Banga/te Velde 2018: 56-57). Clearly, it is difficult to make accurate statements without discussing the challenges and opportunities in the context of a specific country. The references made in this paper about developing countries relate to those countries that are at or below average level of global technological readiness.

2 For a detailed analysis see: blockchain (Adams/Kewell/Parry 2018; Hughes et al. 2019); Big Data (Hilbert 2016); Artificial Intelligence (Goralski/Tan 2020; Mann/Hilbert 2018) and IoT (López-Vargas/Fuentes/Vivar 2020; Renda/Laurer 2020).

3 The existing gap between population groups with access to information and communication technologies (ICT) is usually referred to as the digital divide. This divide is not only evident between countries, but also within countries and particularly evident between urban and rural areas.

4 Some studies suggest that improved labour costs are not the main driver of back shoring. Greater flexibility in logistics appears to have a greater influence on the decision of both emerging and high-income companies to engage in back shoring (IDR 2020: 108). The discussion still remains in its early stages and more empirical data is needed, especially to assess the impact of the COVID-19 pandemic towards increased automation.

5 Advance Digital Technologies include AI, Big Data, cloud computing, IoT, advanced robotics, additive manufacturing (3D printing), among others.

6 For a more comprehensive analysis of the concentration trends of the digital revolution, see the Digital Economy Report 2019 (UNCTAD 2019).

7 The growing engagement of some emerging economies with DTs, particularly China, should not be underestimated. The U.S. and China alone are accountable for more than half of the global spending on IoT; more than 75 % of the cloud computing market and hold more than 90 % of the market capitalization value of the 70 largest digital platforms (UNCTAD 2019: 2). Accordingly, in China and other developing countries with advanced digital readiness such as India, the impact of the digital revolution is certainly different.

8 In this paper, innovation is understood as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (Rogers 1983: 11).

9 The concept of re-invention employed here is drawn from the Diffusion of Innovations Theory (DIT) developed by Everett Rogers.

10 See, for example, innovation research conducted on scientific instruments (Hippel 1976); mental health agencies (Larsen/Agarwala/Rogers 1977); local government agencies adoption of computer-based planning tools (Eveland et al. 1977); educational tools in schools (Emrick et al. 1977) and school-based drug abuse prevention program (Dearing/Rogers 1996).

11 Diffusion is "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 1983: 5). Therefore, it can be said that while adoption is related to the choice and extent to which an innovation is used, diffusion refers to how it spreads among population groups (Straub 2009: 626).

12 According to Rogers (1983: 181-182), it is likely that a potential adopter will re-invent an innovation when a) it lacks sufficient knowledge or training to use it; b) the innovation entails a high degree of complexity; c) the innovation aims to address a wide range of user problems and does not accurately match their perceived problems; d) the elements constituting the innovation are loosely bundled; e) there is a need for ownership or a desire to make an innovation more locally acceptable and when f) there is an external influence that encourages to perform changes to an innovation. The innovation-decision process is a five-step process that leads to the adoption or rejection of innovations (ibid.: 163-206).

13 For example, many computer software allows the user to customise its appearance and configuration, but significantly limit the user's ability to change its core elements and functions, for instance by restricting user's access or safeguarding the source-code.

14 The SM is a document originally intended to be an introductory statement to the World Plan of Action on the Application of Science and Technology to Development, commissioned by the United Nations Advisory Committee on the Application of Science and Technology to Development (ACAST) (Ely/Bell 2009: 4).

15 For the purpose of this paper, TT will be mainly used to refer to cross-national exchanges of technological innovations, particularly those between the developed and developing countries.

16 The critical views of the SM, together with its accompanying policy recommendations, were relegated to Annex II of Science and Technology for Development: Proposals for the Second Development Decade, a 1970 report to the UN's Department of Economic and Social Affairs (Ely/Bell 2009: 4).

17 E. F. Schumacher's (1973) publication "Small Is Beautiful: Economics as if People Mattered" is considered the foundation of the so-called AT movement (Seely 2003: 19).

18 Catching-up implies that by emulating the practices of developed countries, developing countries will eventually be able to catch up with its counterparts (Mies 2002: 107-109).

19 See for example (Benini 2016; Larsson et al. 2006; Pueyo et al. 2012).

20 For example, the potential of DTs described in section I is fraught with pre-conceptions or beliefs about how those technologies could or should be employed by developing countries to achieve a determined goal.

21 The different ways in which TT can lead to a dependency-path has received substantial scholarly attention, see for example (Castells/Laserna 1989; Coombs/Hull 1998; Fuchs/Shapira 2005).

22 Similarly, the principles for digital development stress that in designing with, rather than for potential adopters leads to more effective ways of developing, testing and redesigning digital tools in line with their context, culture, behaviours and expectations. See, Principles for Digital Development https://digitalprinciples.org/. The above may have an essential role in reducing the differences between the designer's perception and the potential adopters' experience, but here again Schumacher's concerns are not taken into account.

23 Free Software and open-source software are commonly used interchangeably. However, they show essential differences. For one, open-source licenses focus on the availability of the source code and allow the user to modify and share it. By contrast, Free Software places a sharper focus on the user's freedom to use the program, but also allows the user to modify and redistribute it. Specifically, Free Software gives its users four freedoms: to run a program for any purpose; to study the mechanics of the program and modify it; to distribute copies and to improve and change modified versions for public use. See, GNU. What is free software? https://www.gnu.org/philosophy/free-sw.html#f1