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The impact of Information and Communication Technology (ICT) on economic growth

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***Abstract*---**This study gives a general overview of information and communication (ICT) – growth nexus among both developed and developing countries. It suggest that ICT is becoming a major factor in driving competitiveness, economic growth and social development. In particular, it is opening up new channels for connectivity and contributing to the free flow of ideas and opinions.

***Keywords*---**Information and communication technology, Economic growth, Developing Countries.

Introduction

Individuals living in economically underdeveloped countries have not benefited from the technological advancements achieved in developed nations, which have transformed the lives of their inhabitants for the better, particularly due to the previous technological revolutions. This does not necessarily mean that no form of technological progress has reached them—such progress has indeed occurred—but its dissemination and accessibility have remained extremely limited (Lechman, 2015). In

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reality, many developing countries have not had the opportunity to adopt and effectively utilize the benefits of past technological revolutions, leaving them "traditionally" backward in terms of adopting available "modern" technologies.

This delay has clearly hindered these countries' ability to develop rapidly or improve their overall well-being. Persistent limitations in accessing and benefiting from technological advancements have compounded the challenges and barriers to achieving development, which have only intensified over time. For some reason, underdeveloped societies never had the chance to "consume" the technological changes that emerged over the past 200 years. This means these societies have not been able to leverage technological advancements as a driving force for economic and social development. The reasons for this inability can be summarized as follows :

1- Harnessing the potential of past technological revolutions required substantial financial resources and robust infrastructure to be effectively utilized within countries.
2- It also required enhanced knowledge, skills, and absorptive capacities to disseminate technological progress, use it effectively, and trigger long-term economic benefits.

In short, economically underdeveloped countries have never been the primary beneficiaries of past technological revolutions .
Fortunately, the "Information Revolution," which began in the early 1970s, has brought about new opportunities. It can be argued that the contemporary Information Revolution is pivotal regarding the technological advancements it has introduced, as these advancements can now be accessed and adopted globally—something that was not the case with previous revolutions. According to Hannan (2010: 32), "For low-income and slow-growing economies, the Information Revolution resembles a 'tsunami' rather than merely a new technological wave." Clearly, the lack of resistance to technological change brought about by this revolution is one of its most distinctive features compared to earlier revolutions .

The Information Revolution, with its introduction of Information and Communication Technology (ICT), has brought revolutionary and fundamental changes to how individuals work, communicate, learn, spend time, and interact. ICT has also profoundly transformed the practices of the business and government sectors. In short, it has turned the world into an "information society ".

In fact, the proliferation of ICT has enhanced basic infrastructure such as fixed-line and mobile telephony and the internet. This has significantly improved resource allocation efficiency, reduced production costs, and boosted demand and investment across all economic sectors (Bahrini and Qafas, 2019.

This paper aims to highlight the importance of ICT in accelerating economic growth, particularly in developing countries. Accordingly, the paper is organized as follows :

- The first section explores the key features of the modern era and how information and information systems have shaped the world .

- The second section reviews the major waves of technological change since the Industrial Revolution, focusing on ICT's position within these waves .
- Finally, the paper examines the relationship between ICT and economic growth by presenting various viewpoints and evidence .

1- The Information Society Today

In this contemporary era, computers, mobile phone networks, smartphones, and the internet—the fundamental components of ICT systems—are nearly ubiquitous. Companies like FedEx and Amazon use these technologies to direct and track shipments, while retailers such as Walgreens and Walmart utilize ICT systems for everything from optimizing supply chains to recording purchases and analyzing customer preferences and tastes. Cities employ information and communication systems to assist in traffic control or to regulate speed limits for drivers.

Considering the environment one lives in, or even schools and universities: one can register for classes online, using email, Twitter, or Facebook to communicate with classmates and professors, freely access e-books from the library, or complete and submit assignments on online learning platforms like Blackboard, Moodle, or Sakai .

In the workplace, computers can be used for tasks such as sending emails and completing various other activities. Thanks to the internet, one can use the mobile phone to perform banking transactions on their account without physically visiting the bank. These technologies have become an essential and increasingly significant part of the social, educational, and professional life like never before .

Over the past few decades, the emergence of the internet and relatively inexpensive computers has had a significant impact on the business sector.

When pausing to think about it, the importance of ICT in business becomes obvious. In fact, increasing global competitiveness has forced companies to find the most efficient ways to operate at the lowest cost. For many businesses, the answer continues to be leveraging ICT systems to do things better, faster, and cheaper. Through global communication networks, businesses can more easily integrate their operations, access new markets for their products and services, and tap into a vast pool of skilled labor in low-wage countries .

Dramatic technological changes have also brought about new ways of working and socializing. Traditionally, individuals were tied to a stationary computer to perform basic tasks. However, with the advent of new forms of ICT such as tablets and smartphones, people can now accomplish tasks from virtually anywhere with a cellular internet signal .

On the other hand, computing has shifted from primarily automating work-related tasks to encompassing a wide range of social and informal activities. Devices like smartphones and tablets, coupled with mobile broadband networks, enable instant computing experiences wherever you are. Advances in cloud

computing (e.g., Gmail, Office Online, or Dropbox) further enhance mobility by allowing access to emails, files, and notes across various devices, providing greater portability and freedom .

It is indeed fortunate to live in a virtuous cycle where rapid and fundamental changes in technology drive social changes, and, in turn, social changes shape technological evolution .

In 1959, renowned economist Peter Drucker predicted that information and information systems would become increasingly important over time. Drucker coined the term **"knowledge workers"** to describe individuals engaged in knowledge-based work—engineers and well-educated technicians—who create, modify, and/or compile knowledge as a core part of their jobs .

Drucker's predictions about knowledge workers proved accurate. These workers generally earn higher salaries than their counterparts in agriculture or industry, rely heavily on formal education, and often possess valuable real-world skills. They are lifelong learners, continually improving their job performance, enjoying better career opportunities, and wielding significantly stronger negotiating power than ever before .

As Drucker envisioned, with the growth and increasing prominence of knowledge workers, a **"knowledge society"** has emerged. He foresaw that due to the critical role of education and learning for knowledge workers and the businesses that depend on them, education would become the cornerstone of the knowledge society .

Furthermore, he argued that owning knowledge would become as significant as, if not more important than, owning land, labor, or capital (see Figure 1).

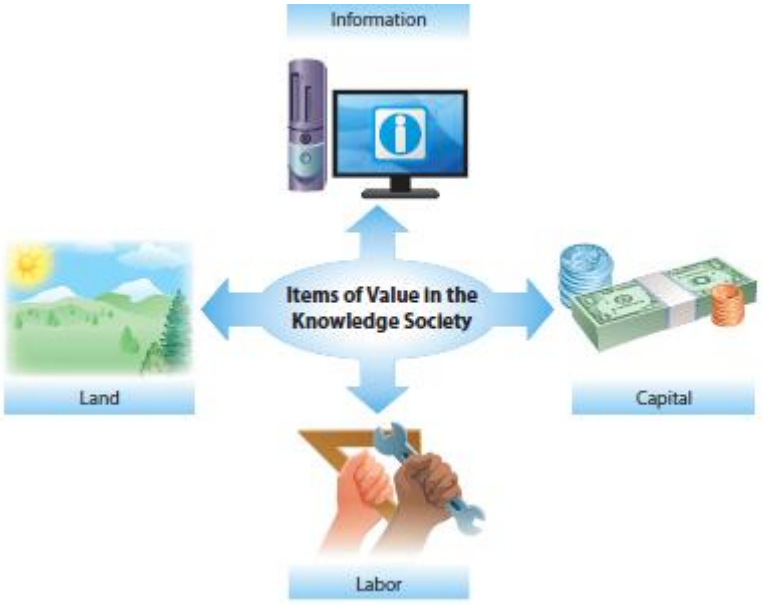

Figure (01). The importance of knowledge in the information society

Most researchers generally agree that Drucker was accurate in his predictions about knowledge workers and the evolution of society.

At the time the term "knowledge workers" was adopted, other researchers referred to this phenomenon using terms such as the knowledge economy, the new economy, the digital society, the network era, the internet age, and others. Despite the different terminology, all these concepts share the fundamental premise that information, technologies, and related systems have become indispensable, and that knowledge workers are an essential and vital component of society .

In the emergence of the Information Age, Alvin Toffler, in his book The Third Wave, describes three distinct phases or "waves of change" that have occurred in the past and are currently shaping civilizations worldwide -see Figure 2.

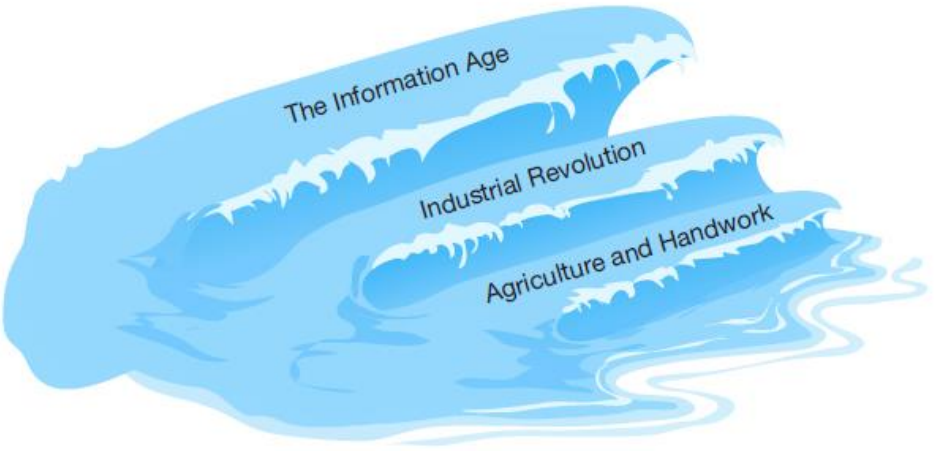

Figure (02). Waves of development throughout history
Source : Adapted from Toffler.(2013).

The first wave: a civilization based on agriculture and manual labor—was a relatively primitive stage that replaced the hunter-gatherer culture and lasted for thousands of years. The second wave of change—the Industrial Revolution—overlapped with the first. Beginning in late 18th-century Great Britain, the Industrial Revolution spanned the next 150 years, transforming society from its then-dominant agricultural culture into a mechanized age of industrial civilization .

During the agricultural era, families sustained themselves by working the land or crafting handmade goods for trade. However, the rise of steel mills, textile factories, and automobile assembly lines eventually supplanted farming and manual labor as the primary sources of family income .

As the Industrial Revolution progressed, professions adapted to fit the mechanized society, and changes extended beyond the workplace. Educational, business, social, and religious institutions also evolved. At an individual level, schools instilled values and traits such as punctuality, obedience, and the ability to perform repetitive tasks in children, preparing them to become workers in a mechanized system .

In a much shorter span of time than it took for civilization to advance after the first wave, societies around the globe transitioned from the Machine Age to the Information Age—a period Alvin Toffler referred to as the "third wave ".

With the third wave came the advantage of speed, and today, knowledge has become the currency of the world we live in. For thousands of years—from primitive times through the Middle Ages—information, or the "bundle of knowledge" of the era, was limited. It was transmitted orally within families, clans, and villages, from person to person and generation to generation .

The invention of Johannes Gutenberg's movable-type printing press in the mid-15th century marked a monumental acceleration in the quantity and diversity of information available to people. With the printing press, knowledge could be disseminated in written form, sometimes originating from distant places. Information could now be preserved, absorbed, debated, published, and aggregated into massive data hubs, setting the stage for the modern knowledge-driven world .

2. ICT and Waves of Technological Change

Numerous theories address waves of technological change, but without a doubt, the most influential in economic history is the theory proposed by the Russian economist **Nikolai Kondratiev**. Working during the Russian Revolution, Kondratiev developed his seminal work, *Major Economic Cycles*, published in 1925.

Kondratiev's central idea was that economic development is driven by large waves of significant technological change, dating back to the Industrial Revolution. He viewed these long waves of technological change as one of the primary engines of technological progress and, paradoxically, as a source of economic crises. These crises occur when the growth dynamics of one business cycle reach their limit before the next technological wave gains momentum.

Today, proponents of Kondratiev's theory typically identify between four and six long waves of technological change. One such wave is illustrated in Figure The divergence among researchers regarding Kondratiev's predictions often stems from differences in timing and the naming of these technological waves.

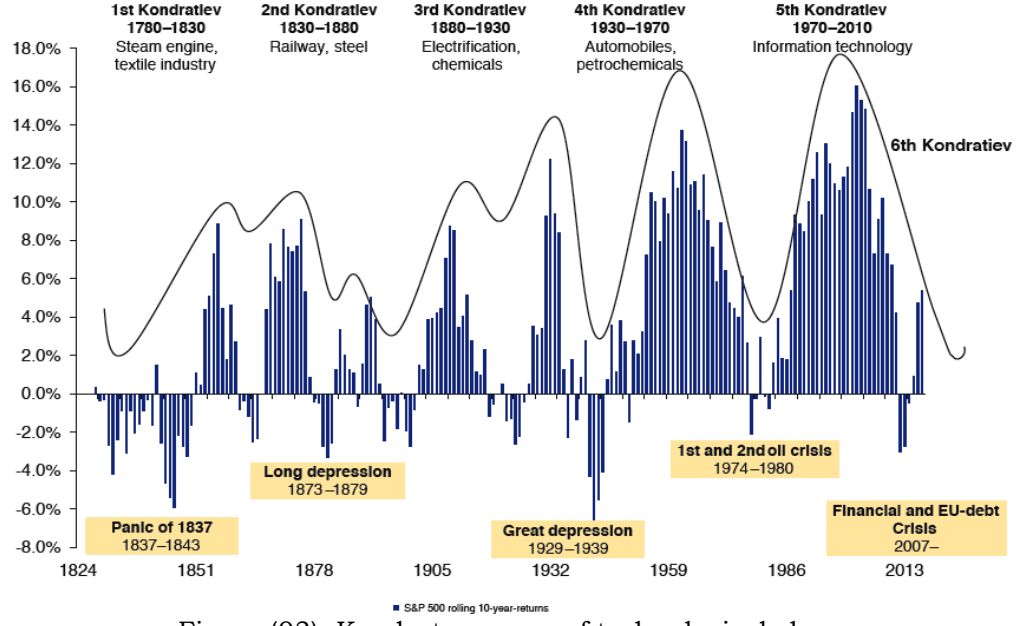

Figure (03). Kondratev waves of technological change
Source: Allianz Global Investors Capital Market Analysis

The first wave identified by Kondratiev corresponds to the invention and widespread use of the steam engine between 1780 and 1830. There is little debate regarding this classification, as the steam engine is undeniably the first significant advancement driving modern economic growth .

The second wave of technological change is marked by the explosive growth of railway construction and steel production, dating back to approximately 1830. These transformative applications were primarily built upon the steam engine, the expanding metallurgy industry, and advances in precision engineering .
In reality, these technologies revolutionized national economies and the global economy by dramatically reducing transportation costs, enabling the connection of distant markets. For the first time, it became profitable to ship raw materials (such as coal supplies, grain production, and timber) across seas and trade them in international markets (Hawas & Zerwat, 2018)

The third wave of technology is the age of electricity, which itself underwent several sub-stages. From the key discoveries in the physics of electricity in the late 18th and early 19th centuries by **Benjamin Franklin** and Michael Faraday to the initial understanding of electromagnetic principles, this period laid the groundwork for profound change. Subsequently, inventors like Thomas Edison, George Westinghouse, and others applied this growing scientific knowledge in the field of electricity, introducing us to electric lighting and incandescent bulbs in city streets, followed by electricity in homes and factories. The generation of electricity through coal-fired steam turbines and hydropower created a new industry for energy production.

The fourth wave of technology occurred between 1880 and 1930, known as the age of automobiles, which greatly expanded mass transportation for individuals and facilitated the growth of major cities and chemical industries. This wave brought forth new materials, including explosives, chemical fertilizers, dyes, and plastics. Additionally, this wave included the era of modern aviation in the first half of the 20th century. While automotive technologies like the internal combustion engine began developing in the latter half of the 19th century, the significant expansion occurred in the early 20th century with the introduction of the low-cost Model T in 1908, thanks to Henry Ford's invention of the modern assembly line. This innovation enabled industries to mass-produce cars and trucks, profoundly transforming how we live, where we live, and how we produce, ship, and trade goods within the economy.

The fifth wave dates back to around 1970, with roots extending even further: it is the wave of Information and Communication Technology (ICT) brought about by the digital revolution. Essentially, the digital revolution is built on the idea that complex information can be stored as binary code (0s and 1s). This binary information can then be processed and transmitted at speeds and with precision previously unimaginable, thanks to groundbreaking inventions like transistors (for processing and storing information) and fiber optics (for transmitting vast amounts of information.

The ICT era ushered in the knowledge economy, enabling vast amounts of data to be stored, processed, and transmitted globally for use across virtually every sector

of the economy education, healthcare, finance, entertainment, production, logistics, agriculture, and more.

The invention and widespread adoption of mobile phones—now smartphones and other portable devices turned the ICT revolution into a mobile revolution , allowing information to reach virtually every corner of the planet. When combined with advancements in space sciences, particularly satellite systems, ICT has enabled significant progress in geolocation, mapping, spatial planning, and countless other geographic information applications. Moreover, the ability to transmit information via satellites, fiber optics, and microwave technology has defined our era as one of mobile information revolution.

In the 1980s, telephones were limited to fixed landlines, and most of the world's population lacked access to phones. By 1990, there were approximately 50 million mobile phone subscribers, primarily in high-income countries. By 2014, there were nearly 7 billion mobile phone subscribers and around 1 billion smartphone users, with mobile devices reaching remote villages worldwide. By 2020, it was anticipated that most of the globe would be covered by broadband wireless internet a technological marvel enabling instant information sharing, accessible to nearly every part of global society.
Here's the translation:

3-The Link Between ICT and Economic Growth

Regardless of the different definitions and the wide uses of ICT in human society, it is important to note that the development of ICT is crucial for economic growth and the development of countries for several reasons:

1. Increased Speed of Data Transfer:
ICT increases the speed of data transfer, thus enabling the wider dissemination of information among individuals. This leads to the "knowledge spillover effects," which are considered one of the key factors contributing to economic growth (**Romer, 1990).**

2. Reduction of Production Costs:
ICT reduces production costs because it allows access to generated knowledge at a lower cost. Additionally, it helps lower the costs of exchanging knowledge, thus reducing inefficiencies and unreliability.

3. Overcoming Time and Space Constraints:
ICT overcomes the limitations related to time and space, meaning it enhances the transfer of data between buyers and sellers, surpassing national boundaries. This technology enables individuals to recognize their advantages over others in the market economy, leading to the expansion of markets and greater access to global supply of goods.

4. Increased Market Transparency:
ICT increases market transparency, which in turn leads to greater individual demand due to easier access to the necessary data (Quah, 2003).

In researching the patterns of the relationship between ICT and economic growth, Figure 4 shows a strong correlation between ICT infrastructure and economic growth (and thus national wealth).

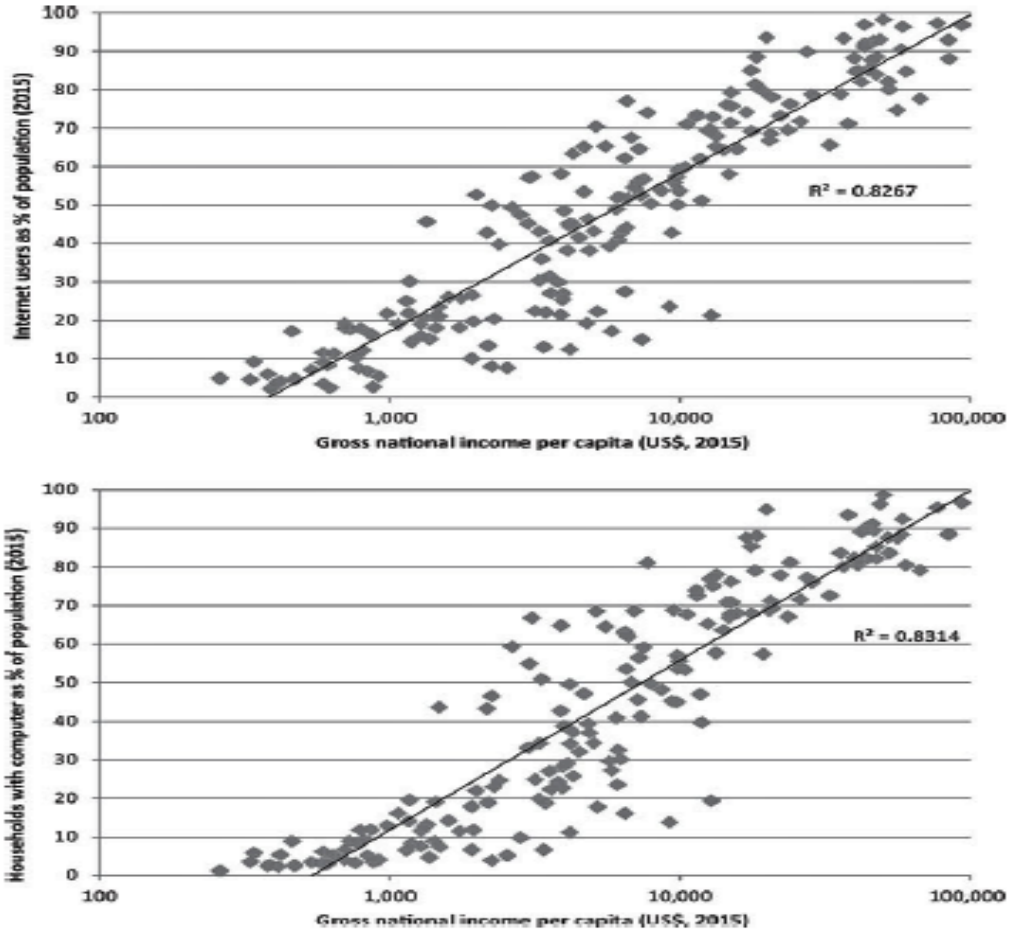

Figure (04). ICT versus economic growth

But does this mean that ICT makes countries richer? In fact, these figures show only a correlation and do not imply a causal relationship. Yes, ICT could cause an increase in the economic progress of countries, but the opposite could also be true – the more developed a country becomes, the more it spends on developing ICT infrastructure. Alternatively, other factors might contribute to this link – for instance, people in wealthier countries may tend to adopt freer and more mobile lifestyles, which drive them to buy more ICT, or perhaps this link is coincidental, This is indeed a real problem .

For example, the 2015 Global Information Technology Report (Pepper and Garrity, 2015) cites two studies that confirm a causal relationship from ICT to economic growth (Qiang et al., 2009; Scott, 2012). Upon reading both studies, neither of them can reject the reverse causality – the possibility that economic growth drives

more ICT consumption. However, there are statistical techniques to overcome this issue, such as including the lag effects of ICT on subsequent economic growth outputs. These techniques have shown causal effects in both directions and confirmed the strength of the relationship between ICT and economic growth.
- An increase of 10 mobile phones for every 100 people increases GDP growth by up to 0.6 percentage points (Deloitte, 2012: 4.(
- A 10 percentage point increase in broadband penetration increases annual per capita GDP growth by 0.9-1.5 percentage points (Czernich et al., 2011: 530.(

Many studies conducted so far have been on developed countries or a mixed sample of both developed and developing countries, but is it expected different aggregate economic effects of ICT on economic growth between developing and developed countries? In fact, there are some reasons to expect the emergence of "exclusionary effects" that increase the inequality gap between the two groups:

1-Complementary Inputs: Effective use of ICT requires various complementary inputs: data, skills, knowledge, institutions, capital, etc. knowing that these elements are severely lacking in developing countries, which will lead to a less effective transformation of ICT into economic growth.

2- Critical Threshold: The presence of network effects means there is a critical threshold of 20 to 25 percent of the population being connected to the network. Below this threshold, significant ICT effects on economic growth will not be realized. Clearly, all developed countries have reached this level in terms of mobile phones or internet and broadband usage (ITU, 2016). As for developing countries, most have reached this threshold for mobile phone networks (except for countries like Eritrea and North Korea), but only a few developing countries have reached the threshold for internet and broadband usage. For example, there are 19.4 and 15.2 users per 100 people, respectively, in the least developed countries.

3- Different Cost Equation: ICT originated in the Global North, and these digital technologies are based on a cost equation – money is saved as cheap technology replaces expensive labor, thus reducing input costs as the foundation for increased economic growth. In contrast, in the Global South, this equation might be reversed as ICT could be more expensive, unlike cheap labor.

However, there is also reason to believe in the expectation of "Northern Effects" that could limit the inequality between developed and developing countries:
-**Information Failures**: This case is more prevalent in developing countries than in the Global North. For example, mobile phones have a weak or modest impact in the Global North, where there is already a reasonable infrastructure for fixed-line phones. In the Global South, mobile phones are mostly not a complement or substitute for fixed lines but rather the primary means of communication.

In fact, evidence can be found for all the ideas mentioned above:
1- Countries with : larger stocks of human capital, greater openness to business and foreign activities, and strong institutions" will benefit economically more from ICT** (Seck, 2012: 437; Derich et al., 2013.(
2- An influential study found that threshold effects exist only in OECD countries (Roller and Waverman, 2001), but other works revealed threshold effects for a

sample that includes developing countries (Sassi and Goaied, 2013). Some argue that developing countries benefit less from ICT than developed countries as a result (Cruber and Koutroupis, 2011.(

3- Due to high infrastructure costs and taxes, the cost of ICT in developing countries tends to be somewhat higher compared to developed countries (WB, 2016). In contrast, labor costs are much lower – on average, three times lower (ILO, 2016). However, there is little evidence of operational effects of ICT on developing countries (Vivarelli, 2014). As mentioned earlier, the demand for ICT so far has been more focused on communication services rather than replacing labor in operational processes, with the limited scope for automation constrained by the technology/labor cost equation and the effectiveness of automation processes hindered by the severe lack of complementary inputs.

4- There is evidence of greater benefits from ICT for developing countries due to "information failures". For example, there are larger gains from mobile phones where fixed-line phones are "limited" (Lee et al., 2012: 461). It has been revealed that developing countries benefit more from ICT than developed countries in terms of ICT's impact on economic growth (Deloitte, 2012). "Inclusion effects" have been observed at different levels: "It appears that broadband productivity gains in Brazil are higher in the less developed regions of the country" **(Jung, 2015: 107).**

Whatever the relative impact of ICT on economic growth and its contribution to inequality between countries, it should not obscure the largely accepted basis for its absolute impact: ICT causes economic growth in developing countries. There is growing evidence of this: alongside the study by Czernich et al. (2011) and Deloitte (2012), a study by Cleeve and Yiheyis (2014: 556) shows that "an increase of about 0.3 percent in real GDP growth for a 10 percent increase in mobile phone penetration". A study by Katz and Collorda (2013: 15) in Ecuador suggests that "a 1 percent increase in broadband penetration increases GDP growth by 0.052 percent". While the numbers vary widely, the overall conclusion is that the return on investment in ICT is typically higher when compared to investments in energy, water, or transport (Estache and Garsous, 2012). However, ICT's effect on growth is still "modest" at present (Stanley et al., 2015.

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