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# CONTENTS

# The Future of Bangladesh: ICT Strategy and Technological Super-Convergence

Haider A. Khan

John Evans Distinguished University Professor
University of Denver
Denver, Co. 80208, USA

**Abstract**

The main purpose of this paper is to find the ICT sector strategy as an integral part of an optimal strategy for Bangladesh to become first a middle income country by 2030 and then a high income country by 2041. Formally, I argue for a Social Capabilities Enhancing National Innovation System (SCENIS) for Bangladesh to be built in the next few decades. The transition---indeed transformation--- can be realized through a process of rapid inclusive growth leading to elimination of poverty while increasing the productive capacity and building an innovating learning economy. Since ICT globally is a dynamic sector, Bangladesh will need to focus---without being exhaustive--- at least on the following areas of global ICT development: Cloud Orchestration; Distributed Storage; Alternatives to Java; Big Data Processing; Deep Learning in AI (Artificial Intelligence); the Internet of Things.

## 1 Introduction

Since its liberation, Bangladesh has gone through many ups and downs but particularly since the late 1990s the country has shown great promise by pushing ahead with its development agenda vigorously. Poverty has declined rapidly and economic growth is showing an upward trend reaching between 6 and 7 percent per annum in the second decade of this century. It is realistic to expect a growth rate of 8 percent. However, technological progress and innovation, especially in the ICT sector will be crucial in achieving rapid inclusive growth.

The country aspires to reach upper middle-income country status by 2030, and expects to become a developed economy in the 2040s decade. The transition---indeed transformation--- can be realized through a process of rapid inclusive growth leading to elimination of poverty while increasing the productive capacity and building an innovating learning economy. The cornerstone of an inclusive development strategy is a robust strategy of job creation through employment-intensive export-oriented manufacturing growth.

The ICT sector has both manufacturing and services sector characteristics and both will be discussed in this paper. With regards to the service sector aspects, it is relevant to recall Dr. Sadiq Ahmed's broader treatment of services in Bangladesh:

> A striking aspect of the development of the services sector in Bangladesh is that it not only has responded well to the growing demand emerging from the growth of manufacturing and agriculture activities, it has also positioned itself well in the global market for low-skilled workers, especially to the oil-rich middle-eastern markets. As a result, there has been a rapid inflow of worker remittances that has fueled a huge demand for construction activities and for a range of services in both urban and rural areas. This inflow of remittances has played a major role in transforming the rural economy and contributing to poverty reduction (Ahmed 2015).

While the creation of a better skill sets endowed workers is necessary for ICT, the demand side factors mentioned above also apply to the service oriented parts of the ICT sector.

Ahmed (2017) adds further:

> The services sector itself is transforming. As Bangladesh transited from a low-income developing country at the time of independence in 1972 to a lower middle-income country in 2015, the services sector has been steadily transforming from a primarily low-productivity, low-income unorganized services sector dominated by trade, transport and low-end personal services towards more organized and higher-income commercial services.

What Ahmed refers to above for a broader set including ICT, applies with particular force to the latter.

In keeping with the goals of reaching the medium income country by 2031 and high income country by 2041 to 2050 with inclusive growth, the broad objective of this study will be to explore and determine how an optimal strategy for technological adaptation, adoption, innovation and diffusion with special emphasis on the ICT sector for meeting these goals can be formulated.

Ultimately the goal of S& T---including ICT---policies and institution building must be to improve the living standards of people. For this purpose, extending Sen's capabilities approach to human well-being to S&T systems, I have coined the term *SCENIS* or Sustainable *Capabilities Enhancing National Innovation System*. Building a SCENIS is what I advocate for Bangladesh. Although the technical issues cannot be discussed here further for lack of space, I have developed two versions of a computable SCENIS model that could be implemented in Bangladesh with further appropriate data gathering and building in particular, a sequence over time of SAM-Techs or disaggregated Technology-based Social Accounting Matrices as consistent economy wide databases.

The rest of the paper is organized as follows. Section 2 analyzes the issues in the ICT sectors both intersectorally and at the firm level and introduces the key concept of an augmented equitable national innovation system for Bangladesh. Section 3 offers an analytical strategic policy space for ICT development in Bangladesh. The concluding section looks further forward to some frontier ICT sectors and how Bangladesh can catch up and reach its development targets by 2050.

## 2 The Required Objectives of the ICT Sector for the Future

Roughly there are three broad categories of the new ICTs: (1) computing, (2) communicating, (3) Internet-enabled communication and computing. Strictly speaking, not all of ICT sectors are digital, or at least not yet. Even within the digital part, the pre- and post- internet distinction is historically important and relevant for the developing economies. This applies for example for cell phones that became smart phones with the integration of telephony and microcomputer-based internet transactions. Bangladesh has made great strides in utilizing smart phones and as recent developments show, there is still much untapped potential in the service sector use of smartphones.

We can dissect the digital economy's infrastructure into its pre-Internet and Internet eras. Before the Internet, a host of information technologies came into existence, which provided computing power on a platform-specific system, usually centralized (e.g. a central mainframe with terminals) or distributed within a local area. The advent of the Internet (and its precursors, the U.S. government-funded research networks like the defense research network - ARPANET) was a critical event because it set up the basic infrastructure, standards (e.g. protocols for communication) and technologies, that enabled large scale, distributed and platform-independent information exchange and manipulation. This "single" system allowed the introduction of literally unlimited sources of information, or access points to it, in a *scaleable* fashion, i.e., without increasing numbers of constraints or decreasing economic "returns to scale". The first computing functions consisted of basic email and file transfer capabilities like *ftp* and *gopher*, but these were soon coupled with basic "Web" technologies, like the development of the first browsers and the standards and technologies of the "World Wide Web". The "World Wide Web" further improved the remote accessing and manipulation of information, and ensured that all information could be "web-based", and therefore potentially viewable/downloadable by anyone connected to the Web. All these set the stage for electronic commerce to take place, since the connection of such large numbers of people to all the sources of information provided a potentially enormous market never possible in the history of markets.

I present below the relevant available ICT Data for Bangladesh. As mentioned earlier, it should be noted that the data for the ICT manufacturing sector is currently only available for a few years (the latest being 2012). Using the Bangladesh Survey of Manufacturing Industries, I have compiled data on establishments, gross output, total persons engaged and salaries and wages of each component. Since the report did not provide any profit calculation, I have instead included data of Gross Value Added (Gross Output-Input Cost) and Value Added at Factor Cost (Gross Value Added- Indirect Cost).

In tables below and the corresponding graphs, we note that much of the earlier growth occurred between the mid 1990s and 2000. The growth under the second BNP regime was particularly slow. For sectors 3836 and 3000 (Computing & Accounting Machineries), 3841 (electronics) and 3839 (other general-purpose machinery), there was negative growth in number of establishments. Fortunately, gross output continued to show increases, as shown in Table 2. Table 3 shows slow growth in gross input cost implying perhaps stagnant wages and some mismeasurement of capital cost. Table 4 on Value Added at Factor Cost registers growth in several ICT sectors but shows little progress in computing machinery. I will discuss this on the basis of extensive interviews with some industry leaders.

**ICT Classification Under BSIC Rev-2 and 3**

**Table 1:** Number of Establishments

| BSIC Rev-2 (as used in MIS) and Rev 3.1 for 2005-06 | Year/Description | 1992-93 | 1995-96 | 1997-98 | 1999-2000 | 2005-2006 |
|---|---|---|---|---|---|---|
| 3836 & 3000 | Computing & Accounting Machineries | | 3 | 3 | 3 | 2 |
| 3839 | Other General-Purpose Machinery | 49 | 61 | 93 | 64 | |
| 3841 | Electronics Including Machinery Appliances | 14 | 28 | 14 | 7 | |
| 3842 & 3220 | Radio and Television | 23 | 32 | 38 | 31 | 36 |
| 3843 | Electrical Appliances | 13 | | 18 | 12 | |
| 3844 & 3130 | Insulated Wires & Cables | 12 | 12 | 12 | 11 | 44 |
| 3845 & 3210 | Electric Bulbs and Tubes | 8 | 8 | 16 | 18 | 22 |
| 3847 & 3120 | Electronic Components | 4 | | | 1 | 30 |
| 3849 | Electrical Apparatus | 134 | 143 | 122 | 121 | |

*Source:* Report of Bangladesh Census/Survey of Manufacturing Industries

**Table 2:** Gross Output

| BSIC Rev-2 (as used in MIS) and Rev 3.1 for 2005-06 | Year/Description | 1992-93 | 1995-96 | 1997-98 | 1999-2000 | 2005-2006 |
|---|---|---|---|---|---|---|
| 3836 & 3000 | Computing & Accounting Machineries | | 7800 | 7800 | 7816 | 49755 |
| 3839 | Other General-Purpose Machinery | 247389 | 164899 | 187397 | 1170832 | |
| 3841 | Electronics Including Machinery Appliances | 94910 | 81560 | 5537 | 498181 | |
| 3842 & 3220 | Radio and Television | 914578 | 1282061 | 2023611 | 2217112 | 2501656 |
| 3843 | Electrical Appliances | 174201 | | 624736 | 398396 | |
| 3844 & 3130 | Insulated Wires & Cables | 724697 | 1669315 | 11062226 | 9090272 | 2089148 |
| 3845 & 3210 | Electric Bulbs and Tubes | 842202 | 1170748 | 2942578 | 4567064 | 1363209 |
| 3847 & 3120 | Electronic Components | 59351 | | | 27859 | 115276 |
| 3849 | Electrical Apparatus | 699624 | 6732789 | 4208753 | 3817188 | |

*Source:* Report of Bangladesh Census/Survey of Manufacturing Industries

Table 2 shows moderate growth that will need to be accelerated consistent with the plan vision for 2041. Although production in most categories shows healthy growth trajectories, two basic areas --- Insulated Wires & Cables and Electric Bulbs and Tubes---show a decline. Since electrical goods sector as a whole did not shrink and electronic components part kept growing, most probably, the gap was made up for by imports. Without a sufficiently detailed imports map year by year, it was not possible to check this conjecture directly. It could in part be also accounted for by price inflation in these sectors. A comparison with VA at factor costs in table 12 suggests that this may have happened.

**Table 3:** Gross Value Added (Gross Input Cost) (in '000 Tk.)

| BSIC Rev-2 (as used in MIS) and Rev 3.1 for 2005-06 | Year/Description | 1992-93 | 1995-96 | 1997-98 | 1999-2000 | 2005-2006 |
|---|---|---|---|---|---|---|
| 3836 & 3000 | Computing & Accounting Machineries | | 4403 | 4403 | 4418 | 10488 |
| 3839 | Other General-Purpose Machinery | 89488 | 41742 | 84160 | 417734 | |
| 3841 | Electronics Including Machinery Appliances | 25963 | 35058 | 5033 | 208295 | |
| 3842 & 3220 | Radio and Television | 368725 | 447897 | 807918 | 1229290 | 1129338 |
| 3843 | Electrical Appliances | 54914 | | 240107 | 154901 | |
| 3844 & 3130 | Insulated Wires & Cables | 308903 | 1112185 | 10070519 | 8149383 | 592751 |
| 3845 & 3210 | Electric Bulbs and Tubes | 366936 | 560194 | 1155655 | 2345189 | 1119374 |
| 3847 & 3120 | Electronic Components | 26483 | | | 7674 | 82830 |
| 3849 | Electrical Apparatus | 441453 | 2273814 | 2052942 | 1863695 | |

*Source:* Report of Bangladesh Census/Survey of Manufacturing Industries

**Table 4:** Value Added at factor cost (in '000 Tk.)

| BSIC Rev-2 (as used in MIS) and Rev 3.1 for 2005-06 | Year/Description | 1992-93 | 1995-96 | 1997-98 | 1999-2000 | 2005-2006 |
|---|---|---|---|---|---|---|
| 3836 & 3000 | Computing & Accounting Machineries | | 2981 | 2981 | 2996 | 4887 |
| 3839 | Other General-Purpose Machinery | 65035 | 31000 | 76124 | 292088 | |
| 3841 | Electronics Including Machinery Appliances | 10843 | 28344 | 3328 | 106700 | |
| 3842 & 3220 | Radio and Television | 165306 | 245769 | 373777 | 905778 | 1106904 |
| 3843 | Electrical Appliances | 34152 | | 128863 | 82838 | |
| 3844 & 3130 | Insulated Wires & Cables | 196292 | 743376 | 9836455 | 7930171 | 550082 |
| 3845 & 3210 | Electric Bulbs and Tubes | 207235 | 328266 | 363106 | 660490 | 931726 |
| 3847 & 3120 | Electronic Components | 18852 | | | 6187 | 80275 |
| 3849 | Electrical Apparatus | 398335 | 1615071 | 1636018 | 1453892 | |

*Source:* Report of Bangladesh Census/Survey of Manufacturing Industries

**Table 5:** Total Number Persons Engaged

| BSIC Rev-2 (as used in MIS) and Rev 3.1 for 2005-06 | Year/Description | 1992-93 | 1995-96 | 1997-98 | 1999-2000 | 2005-2006 |
|---|---|---|---|---|---|---|
| 3836 & 3000 | Computing & Accounting Machineries | | 36 | 36 | 36 | 58 |
| 3839 | Other General-Purpose Machinery | 1510 | 1253 | 2562 | 6099 | |
| 3841 | Electronics Including Machinery Appliances | 395 | 490 | 182 | 895 | |
| 3842 & 3220 | Radio and Television | 1938 | 1971 | 2669 | 1549 | 10480 |
| 3843 | Electrical Appliances | 929 | | 3499 | 2136 | |
| 3844 & 3130 | Insulated Wires & Cables | 1749 | 2396 | 2316 | 2185 | 2537 |
| 3845 & 3210 | Electric Bulbs and Tubes | 730 | 764 | 1588 | 2036 | 1285 |
| 3847 & 3120 | Electronic Components | 172 | | | 795 | 420 |
| 3849 | Electrical Apparatus | 5870 | 27129 | 20654 | 18829 | |

*Source:* Report of Bangladesh Census/Survey of Manufacturing Industries

Table 5 is an important indicator of the contribution of the ICT sectors to people's well-being via employment generation. Again, the record of BSIC 3836 and 3000 is weak, and Electric Bulbs and Tubes and Electronic Components show declining employment from 2000 to 2006. More recent data for these sectors are not available; but the healthier overall growth figures for more recent years suggest a possible recovery and expansion.

The conclusion that can be drawn provisionally is that on the whole ICT sectors generate relatively decent number of jobs at relatively decent pay and benefits; but there is much room for increasing the scale and scope, generating more output and employment. My field work observations also indicate large variances both within and between firms. The potential for both quantitative and qualitative improvements by 2041 is enormous in this area.

BASIS SOFT EXPO 2017 document states that there are now more than 4500 enterprises with 56 per cent of the total revenue coming from software related firms and 44 per cent from ITES related firms. According to BASIS research, exports from 382 BASIS companies in 2015 was US $594.73 million. There is also *an upper bound estimate* of US $ 761.5 million. But this is based a generous assumption that 25 per cent of the IT and ITES sector firms are exporters.

One area of success is the extension of ITES through smart mobile telephony. In my view, more important than the success of just selling mobile phones are the creative ways firms like bKash are starting to provide important services to the people.

Bangladesh is progressing towards the broad goal of building an innovation system. Even where the country is dependent of import items, the goal is to build and train and skilled labor forces for meeting Bangladesh's needs in software development, management and administration. My case study of one leading company shows it to be committed to capturing its niche in the world market in providing state of art technology and services at a fraction of global average cost. The company's goal---stated concretely--- is to manufacture the computer hardware and provide IT enable services. It is planning to build on its existing expertise in Software/Hardware, and IOT Design and Development. It already provides enterprise level software and hardware, along with IT services across the global market. The concrete objectives are to eventually capture the niche in the world market in providing state of art technology in IOT, VDI, Virtual Reality, Drone and other related items in a cost-effective manner---manufactured and assembled in Bangladesh at the Hi-Tech Park in KaliaKhor.

Bangladesh requires desktop level computing power on each person's desktop, which can be a laptop and/or a desktop and/or Virtual Desktop Infrastructure (VDI) product uses a Private cloud technology in such a way that each person will be using a small device called A1 with a Keyboard, and a Mouse to experience a full desktop computing environment without having to have a traditional laptop or a desktop. A1 is a platform independent software that will run on Windows7, Windows10, Androids and Linux desktop environment, where a person can use Microsoft Office product, Adobe Illustrator/Photoshop for Graphic Design and any applications, able to surf the Internet. This technology has already reduced the cost of owning desktop exponentially and is closing the gap of Digital Divide for Bangladesh market.

A1 can coexist with existing environment or can function independently. With the rise of cloud computing in the world and the IT changes that are taking place in Bangladesh for digitization, within offices and institutes, by having A1 produced in Bangladesh, the local firms can provide an inexpensive desktop to address the IT challenges.

I now turn to a brief discussion of my extensions of the idea of National Innovation System(NIS) in order to pose the problems of and prospects for an appropriate NIS for Bangladesh or BNIS between 2041 and 2050.

The National Innovation System or NIS--- also abbreviated as NSI or National System of Innovation---- can be broadly defined as the intersectoral flow of technology and information in the economy including households and individuals, productive enterprises and various institutions including both public and private educational and R& D institutions. All these can form a network which under appropriate circumstances can generate a self-sustaining innovative process on the national level.(Freeman 1987,1995; Nelson 1992, 1993a, b, 1994, 1995; Lundvall 1992; Edquist 1997; Kim 2000; Kim and Nelson 2000; Lee 2006,2008; Lee and Lim 2001; Lee and Kim 2009; Khan 1998, 2002, 2004 a, b, 2011, 2012,2013, 2017; Khan and Matin 2011) . According to this approach, which I generally follow with some modifications described later, technological development requires a system of well-functioning institutional networks and such development when it occurs results from this complex system of relationships among different groups of actors who respond to appropriate policies in the socio-economic system. Most advanced countries are already societies with highly evolved NIS and SISS. Some NIEs in the Asia-Pacific region like China, India, Korea and Taiwan are developing such NIS and SISS with various degrees of success. Many poor countries are far behind. This is an example of what I mean by the unevenness of the global economy and globalization as a process.

My previous work on NIS and RIS (Khan 2002 and 2004 a,b in particular) of the requirements of technical progress shows that we need both a deeper understanding of the disequilibrium processes at work leading towards multiple equilibria, and the economic implications of the complexities of the production and distribution aspects of new technologies. It is with a view towards capturing these complexities leading towards multiple equilibria that an alternative conceptualization of technology systems transition in terms of an *Augmented* NIS (ANIS) has been formulated by some economists (Khan 1993; James and Khan 1997; Khan 1998, 2001 a,b; 2002, 2004 a,b; Gabriele and Khan 2010). In addition to capturing both equilibrium and disequilibrium features of technological transitions, this broad approach can illuminate *distributional* issues as well. Since poverty alleviation remains on the agenda of the national governments of Bangladesh, it can be argued that from this perspective at least the new approach has obvious relevance for Bangladesh. From here on, I wish to highlight the fact that my framework can be viewed as simply a variety of Augmented NIS (ANIS) and its various subsystems and therefore, I will be using the more general term from now on which also has the virtue of maintaining intellectual continuity with NIS and at the same time augment the range of the concept. One important extension captured in my formulation is the explicit consideration of *both factorial and household income distributions* which interact in a causally reciprocal way with the technology systems including the ICT subsystem.

While Bangladesh is far from the technological frontier in 2017, an optimal strategy for catching up through Original Design and finally original equipment manufacturing in various areas including ICT software and hardware can be formulated and thus a BANIS or Bangladesh Augmented National Innovation System can be launched to yield some fruits by 2030s.

# 3 Strategic Policy Space: Optimal ICT Sectoral Policies for Investment and Institutional Development

There are some crucial problems in the ICT sector in particular if Bangladesh is to meet its ambitious targets for the Perspective Plan by 2041.

The past experience suggests a number of factors that constrain the growth of ICT exports. First, although a significant number of educated and qualified entrepreneurs have started ICT ventures during the last couple of decades, most are trapped in the 'small size-low growth' situation because of funding constraints. Second, there are severe gaps in both quantity and quality of human resources for the software industry. This is due to institutional deficiency of the tertiary ICT-related educational institutions (lack of industry orientation of teaching resources, slowness of curriculum modernization etc.) as well as inadequate quality input from the higher secondary education system to the tertiary level. Third, high cost of bandwidth deters growth of domestic market for ICT. Fourth, the absence of IT park/software Technology Park, high internet cost, no redundant submarine cable, and power shortages are some of the common infrastructural problems for most of the IT enterprises. … Finally, the growth of export of ICT industry is below the expected level due to inadequacy in entrepreneurial dynamism, limited overseas marketing budget and absence of government level initiatives in promoting country brand. Policies and facilities are not friendly for value added service providers in the mobile phone industry.

One of the most important operational questions for planning adequately for S and T in Bangladesh---ICT in particular---is regarding the impact of technical progress including ICT on output, employment, incomes of households and their wellbeing. Although a Social Accounting Matrix based formal CGE model is necessary for answering this question technically and carrying out a number of relevant counterfactual policy experiments[1], it can be inferred from the existing models and data that on the whole there are great gains in these areas to be made from investments in R and D and production in innovative technologies.

# 4 Strategic Policy priorities---future developments in internet architecture, big data and AI

In the broadest terms, there are two complementary sets of strategic S&T package of policies for the ICT sector, both of which can be advocated in various degrees of mixtures:

1. Supporting (via preferential fiscal, financial and other policies, subsidies, investment and capital goods support) existing S&T private firms and promote startups etc. This would be a directly market-oriented, private sector centered strategy based on a sector-specific industrial policy aimed primarily at medium-term goals such as growth and technological upgrading of manufacturing output and exports and GDP growth. Yet, it would only indirectly be conducive to the establishment of an (augmented) National Innovation System.

2. Supporting primarily public S&T centers, institutions and infrastructure. This would be a public sector-centered strategy with a more long-term horizon, that might imply a lower GDP growth in the short and medium term. Yet, it would be the most clearly focused on the goal of creating an (augmented) National Innovation System.

Quantitatively, from the strategic planning perspective, policy makers must find targets for each year starting in 2018 to increase R&D expenditures so that by 2041 it reaches 2 per cent or more of GDP. Tables 19 and 20 below give the available R&D /GDP ratio for recent years, and the R&D-intensive export sectors. Bangladesh needs to increase the R&D /GDP ratio to at least 1% by 2025 and then gradually to 2% by the 2040s. Exports from R&D-intensive sectors should also be increased by 10% a year and by a higher percentage than that from the 2030s onwards perhaps by 2 per cent a year reaching the 25 to 30 per cent range eventually. This will be crucial for increasing productivity in the ICT sector and total factor productivity (TFP) overall.

Specific studies using the input-output structure and social accounting matrices can be undertaken for this purpose in order to come up with specific targeted R&D program within the ICT sector and other high technology sectors.

The investment through PPP in the ICT sector should specifically do the following:

- Plan to install the second submarine cable connection for expanding high speed internet facilities as soon as feasible.
- Plan to finish Phase II of implementation of broadband internet connectivity under the South Asia Sub-Regional Cooperation (SASEC) initiative.
- Within the Research and Development budget earmark 25% for ICT from 2020 to 2030, and as the absorptive capacity of the ICT sector increases, then in keeping with the goal of increasing TFP further between 30 and 40 per cent from 2031 to 2041.
- Study the examples of Korea and Taiwan carefully and build ICT parks through PPP initiative for developing capacity, attracting expatriate scientists and technicians and train the future ICT-capable workforce.

# 5 Incentive Policies for ICT Facilitation

Bangladesh can improve its scores on doing business by deregulating procedural aspects. It can improve the drive to motivate greater private provision of ICT services by appropriate substantive deregulation of ICT sector activities promoting ease of entry and expansion of capacity. The government should ensure that the line Ministries related to ICT engage in constructive dialogue with ICT manufacturers and service providers. *Inter alia*, these can be facilitated through public meetings with business chambers and conducting special purpose surveys as necessary to obtain specific feedback on regulatory burden or other constraints faced by the producers and suppliers.

In addition, domestically the Government should invite private sector and non-profit sector for increasing broadband connectivity in rural area. The local entrepreneurs should be incentivized to cooperate in extending internet service to every local community. Tax incentives may be necessary for this.

In order to encourage the different actors in the R&D scene, the government needs to earmark an increasing volume of funds to elite universities, mainly through the Ministry of Education (MOE). Elite universities should be expected to lead in national R&D programs and projects, facilitate technology diffusion and pullovers, promote spin-off companies, incubation centres, and open laboratories for R&D sharing, to bridge-in foreign technology and partners.

A short run action program can be launched within the next 3 years to promote specifically university-industry links for R&D. A policy action group with scientists, engineers, economists and entrepreneurs can be set up for this purpose. The goal of this group should be to set up state technology transfer centres in four to six leading universities, with adequate funding and the most competent leadership that can be recruited nationally and internationally. It is vital strategically, to promote the commercialization of viable technological achievements. Bangladesh should also undertake tax write offs and incentivized subsidies policies for university-based start-up companies. As in China, these start-ups should be seen as crucial channels through which universities can contribute to national and local economies. For a country like Bangladesh emphasis on distributed computing such as the cloud computing mentioned will be strategically rewarding.

Policy makers also need to keep in mind some other key sources of production improvement and innovation growth such as each firm's absorptive capacity, the production network, openness, and managers' education. Market-oriented, competition-enhancing innovation system reforms can indeed improve the effectiveness of the incentive structure and foster the right set of S&T linkage activities, in the ICT sector specifically.

The influence of the two main stakeholders (government and end-users) can lead to a creative synergy when the incentives are transparent and

impartially imposed by the government. Hence specific areas of good governance are relevant to S&T and R&D intensive firms. Business laws and corporate governance should be transparent and enforced. While facilitating business and reducing bottlenecks, the state should not be captured by special interests. A responsive and responsible bureaucracy is part of this picture. Therefore, administrative reforms in the government and within the larger private sector firms need to be at the top of good governance priority list.

As new product output is an important indicator of R&D intensive firm performance, high technology firms in Bangladesh should be incentivized to operate at the frontier of new product development ---at first slowly but in an accelerated pace from the 2030s. There are sometimes static inefficiencies in R&D and these should be minimized as soon as possible without losing much time; but the main focus should be on dynamic advantages in terms of innovative capacity and technological progress, with major spillovers benefiting the national economy as a whole.

A dualistic pattern in Bangladesh's technological development, with the export-oriented segments of the economy being relatively isolated from those producing mainly for the domestic market can also develop. While some of these are inevitable and beneficial with proper reinvestment and distribution of benefits, care must be taken not to become exclusively export dependence for the innovative sectors to be innovative. This is where ANIS in Bangladesh can come into its own in the 2040s. The weight of constraints such as an insufficiently developed institutional framework, relatively low overall educational attainments, the lack of a large pool of world-class talents, the embryonic stage of indigenous innovation capacity, and insufficiently developed linkages between R&D and industrial enterprises can and should be overcome to a large extent by the 2040s and 2050s.

It is clear from both the empirical evidence and the institutional analysis above that the governmental bodies set up to administer the R&D can pursue the goal of building a BANIS with emphasis on ICT more vigorously in the coming years. A well-funded PPP institutional mechanism will need competent technical and managerial talent for functioning properly. A better mechanism for monitoring and timely action and agenda formulation is needed. Instead of relying on multiple, overlapping and sometimes dysfunctional bureaucratic formations, it may be possible to set up a relatively autonomous functional body of experts by careful selection from within the government and from the civil society.

For the ICT sector, this could be an ICT Monitoring Board (ICTMB) of experts by drawing upon both local and international pool of competent scientists and managers. The ICTMB should have the authority to get information from all the divisions and districts. It should also have the authority to design a flexible and pragmatic ICT inputs pricing policy where such a policy is needed. Through its professional cadres it could monitor more effectively the supply and demand conditions in a rapidly changing market by developing a Geographically Decentralized ICT Monitoring System (GDICTMB). The GDICTMB will also keep track of import levels and future import needs.

The GDICTMB should have the authority to take steps to promote both market competition and good corporate governance (Khan, 1999, 2004). It should also have the authority to set up laboratories and mechanisms for detecting the quality of ICT products manufactured and services delivered, and supply public prosecutors with the needed information so that the guilty parties who abuse government support can be brought to justice swiftly. Needless to say, there are many organizational and other details that will need to be worked out. But such institutional reforms if carried out competently, will enhance the prospect for stabilizing the ICT markets and lead to further innovation. If and when institutional reforms in ICT sector take hold, producing desirable results, then such boards could be set up for other R&D intensive markets. Further coordination problems will doubtless emerge and have to be tackled. Indeed, the capacity to coordinate effectively is the hallmark of good governance.

Finally, without being exhaustive, some operationally relevant areas of future research should also be mentioned.

First, is an integrated survey of ICT needs and ICT resources and the shortfalls in the latter. This in itself could be a PPP project.

Second, an ICT oriented SAM should be built for both creating a consistent economy wide technical data base and for future modeling for counterfactual policy experiments. Relevant CGE models by technically competent teams of researchers will be a necessary tool for rigorous policy analysis. Such a multistep project---creation of SAM, formulation of model and implementation, training Bangladeshi technical personnel and carrying out policy experiments can be done in 2 to 3 years with provisions for updating every 3 years or so. Though costly in terms of time and money, the payoff will be substantial with future self-sufficiency and learning mechanisms and facilities for Bangladeshi professionals in Bangladesh as part of the value added.

Third, the other alternative is to have modern time-series based models such as VECM that are informed by the advances in time-series analysis of non-stationarities and spurious regression problems among other pertinent

econometric issues. These models should allow us to identify clearly the causal links if any, between variables in the long run. Since we are looking up to and beyond 2041, this is an important consideration.

It should be emphasized that the two technical approaches are not mutually exclusive. Actually, my recommendation is to build and make operational both types of models if time and resources allow.

Fourth, some intellectual resources can be devoted to political and social economic analyses. An economic system has complex connections with political and social systems. A complex system of political and social economic analyses will uncover many hitherto unseen linkages revealing both future problems and possibilities for progress.

Fifth, with the help of the above data collection, data integration and rigorous modeling focused studies regarding ICT sector industrial policies including the role of credit and subsidies will need to be carried out.

As mentioned before, these five items do not exhaust the list of future policy-relevant research tasks, but these can provide the knowledge base on which a quantitative target oriented policy platform can be built. There are many challenges for Bangladesh in its bid to meet the six goals identified clearly by the MoP. With proper planning tools, PPP institutions, R&D policies and institutions like the proposed ICTMB the ICT sector can be developed by 2041 to meet these challenges with a high degree of probability of success. The concluding section that follows presents some preliminary investment requirements estimates projections until 2041 for the ICT sector.

# 6 Conclusions: Towards the Frontier-- Making A Future Scenis for ICT in Bangladesh

With proper incentives, as discussed before, much of the investment in ICT sector, esp. from 2030s onwards will come from the private sector. The projected reforms in regulatory and incentive policies along with improved prudential regulations will result in an expansion of private domestic and foreign investment. However, as discussed above, complementary public investments in infrastructure including that in the ICT sector will be crucial for an effective expansion of private investment leading to an increase in ICT productivity and TFP .

It is crucial to increase both public and private investments quickly so that an enduring foundation for an innovation sub-system in the ICT sector can be created by 2031. Keeping all these in mind, I use estimates for the ICT sector investments that are roughly in line with the overall ICOR, TFP and other indicative macroeconomic projections of MoP.

Since ICT globally is a dynamic sector, what does Bangladesh need to do to follow the trajectories of likely future developments in ICT and realize the above targets consistent with the visions such as A2i and the perspective plan ? It is impossible to be definitive or exhaustive in the field of innovation in ICT; but to the best of our technical knowledge---without being exhaustive, the following areas will be important to catch up with in the next ten years: Cloud Orchestration; Distributed Storage; Alternatives to Java; Big Data Processing; Deep Learning in AI (Artificial Intelligence); he Internet of Things.

All these areas involve learning from frontier technological practices of today and tomorrow. We should be improving access to internet and the various areas such as e-governance, e-health, e-education etc. We need to develop the human resources and institutions of learning for this. In the next 5 years, internet of things (IoT) will become widespread. The growing adoption of intelligent agents like Amazon Alexa or Google Assistant in more and more devices will lead to new ways of interacting for both businesses and government. There will be edge IoT devices that can act locally based on data they generate, as well as utilize the cloud computing networks for security, scalability, configuration, deployment, and management. IoT will evolve rapidly to cut data ingestion costs and reduce network latency.

Likewise, adopting cloud orchestration and distributed storage will need to be top priorities for the next 10 years. Training our software developers in adopting big data programs should also be a top priority.

From 2031 onwards, the focus should be even more on Big Data. Bangladesh will need to develop technical capabilities in utilizing Deep Learning algorithms and all other areas of AI. By that time, the world will most likely move towards advanced nanotechnology, robotics and ICT-linked AI. We need to have top quality learning institutions to keep pace. Utilizing the skills of highly trained expatriates in specific technical fields should be high on our agenda by 2031.

By 2041, if the above strategy is followed, we should be near the frontiers in AI and ICT. However as Khan (2017b) and others have pointed out, by 2050 there will most likely be a “superconvergence” of ICT, Biotechnology and Nanotechnology with enormous increase in total factor productivity. Bangladesh must not be left behind in this process. The time is now to begin thinking about this prospect in connection with ICT . It is recommended that an experts group comprised of a majority of scientists in this field in Bangladesh together with a few expatriates of international standing in their respective

research communities should be set up to study the prospects of "superconvergence" of technologies in Bangladesh for 2050 and recommend specific policies for all three sectors.

A last important point is to be alert to the prospects of developing markets in Asia and beyond for ICT exports through strategic alliances with regional partners. This could be pursued in a synergistic manner by participating in a regional innovation system.

## Endnote

1. This looms as a necessary future technical project. A necessary component is to create a SAM that uses clearly distinguished technological classifications for ICTs. Following and extending the term introduced by Khan and Thorbecke (1988, 1989), we can call this kind of a SAM an ICT-SAMTech. Such a multistep project---creation of SAM, Formulation of model and implementation, training Bangladeshi technical personnel and carrying out policy experiments can be done in 2 to 3 years with provisions for updating every 3 years or so. The payoff will be substantial with future self-sufficiency and learning mechanisms and facilities for Bangladeshi professionals in Bangladesh as part of the value added. The other alternative is to have modern time-series based models such as VECM that are informed by the advances in time-series analysis of nonstationarities and spurious regression problems among other pertinent econometric issues. It should be emphasized that the two technical approaches are not mutually exclusive.

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