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Improved Model of Global Quality Infrastructure Index (GQII) for Inclusive National Growth

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The Quality Infrastructure (QI) of a country relies on 4 major pillars i.e. metrology, standardization, accreditation, and certification. These pillars are closely associated and build a system of national and international organizations for barrier-free trade following relevant, standards, guides, rules and regulations, policies, protocols, etc. The recently developed Aswal model for the effective and robust QI system clearly explains the mechanisms wherein metrology as a core pillar and an invisible force, in association with documentary standards, accreditation, and conformity assessment facilitates the strong interactions among the Government agencies; Universities and Academic Institutions; Science and Technology Institutions; Citizens, Media and industry, for the comprehensive development and inclusive growth of the country for improved quality of life. Ulrich and Matteo proposed a Global Quality Infrastructure Index (GQII) as an indicator to measure the growth and the performance of QI of an economy. In the present paper, improved model is proposed for the GQII. A case study is presented using the improved GQII and utilizing the data available in the public domain i.e. BIPM website related to member states countries (62 countries). Further, the Global Competitiveness Index (GCI) which is used to measure the institutions, policies, and the effective use of available resources for sustainable prosperity and level of prosperity of their citizen is studied and compared with GQII for some of the leading economies. The study also depicts the export status of the leading economics with the GQII. The study clearly indicates the correlation of GQII with various influencing components i.e. calibration and measurement capabilities (CMCs), key and supplementary comparisons (K&SCs), gross domestic product (GDP) per Capita, and % expenditure of GDP incurred on education. GQII value is normally higher with higher participation in key comparisons and having a higher number of CMCs. Similarly, the same trend is obtained between GQII and GDP per capita as well as the % expenditure of GDP incurred on education. The Indian data related to these parameters is also presented and discussed. Admittedly, though utmost care is taken to accommodate the most relevant and latest information and earlier published work, some of the unnoticed discrepancies are not ruled out, which may be unintentional. The study would be very helpful for the government agencies, industry, academia, and enterprises for future decisions and policymaking related to strong and robust QI.

Keywords: Accreditation, Certification, Global Competitiveness Index, Global Quality Infrastructure Index, Metrology, Standards

Introduction

The Quality Infrastructure (QI) is defined as "the system comprising of the organizations/institutions (public & private) and citizens; their well-defined efforts, actions, and practices needed to maintain and improve the quality, safety, health, environment, services, and processes through a national quality policy, a regulatory framework, quality service providers, enterprises, customers, and consumers forums and practices.[1] The charter of the United Nations Industrial Development Organization (UNIDO) clearly stipulates that the *"QI is required for the effective operation of domestic market, and its international recognition is important to enable access to foreign markets. It is a critical element in promoting and sustaining economic development, as well as environmental and social well being. It relies on metrology, standardization, accreditation, conformity assessment, and market surveillance"*.[2–3]

In any economy, the quality guidelines make sure that institutions responsible for the implementation of metrology, standards, accreditation and certification are well established, strong and work cohesively and in synergy together.[4–7] In a specific economy, such institutions are well connected and form a network i.e. National Quality Infrastructure (NQI). This NQI is further closely linked with the international institutions/organizations and forms a network called International Quality Infrastructure (IQI) System having linkages as follows; [1,8]

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i) Metrology (Metric Convention, CIPM, BIPM, OIML, Regional cooperation bodies in the field of metrology, Legal metrology, etc.)
ii) Standards and Certification (ISO, IEC, national standard bodies, etc.)
iii) Accreditation (ILAC, IAF, RCBs, etc.).
iv) Quality management systems and conformity assessment (WTO, regional co-operation bodies, etc.)

Four main pillars of the QI of any country is shown in Fig 1.[8] Through testing, calibration, certification, verification, and inspection, these pillars ensure conformity assessment. The objective of the paper is to develop the improved model of GQII. The economies considered for the studies are the member states of BIPM. As mentioned earlier, a Global Quality Infrastructure Index (GQII) is a composite indicator that provides the ranking of different countries as per their existing QI systems. Notably, the study confirms that QI helps to reduce inferior products in the market and positively impacts the economy.

Materials and Methods

In the past, some studies were carried out on QI to understand and compare the developments and the performances of the economies. The hypothesis proposed by Ulrich and Juan Matteo consists of several composite indicators based on the data available in public domains, specially in the field of metrology; standards; certifications and accreditation.[9,10] They had proposed GQII based on a total number of Calibration and Measurement Capabilities (CMCs); total number of Key and supplementary comparisons (K&SC) carried out by the National Metrology Institutes (NMIs) and associated Designated Institutes (DIs); the total accredited bodies in the country; respective published ISO standards in the country; participation in Technical Committees (TCs) of the International Organization for Standardization (ISO) and the membership of the various international organizations backing the authority of the national QI. A more effective and robust QI system is recently published, which is now known as Aswal model for the inclusive growth of the country.[1,11] The model explains the mechanisms wherein the QI, being an invisible force, facilitates the extensive exchanges and relations among the 4 helices of a well-functioned Quadruple helix (QH) comprising of Government agencies; Universities, Science & Technology institutions; Citizen Organizations, Media & Industries for the betterment of the economic growth and high quality of life in the country. The model keeps metrology as central issue and explains its role as core of the national QI, and is applicable for all the helices for creating acquaintance & inventiveness for sustainable development and civilized society.

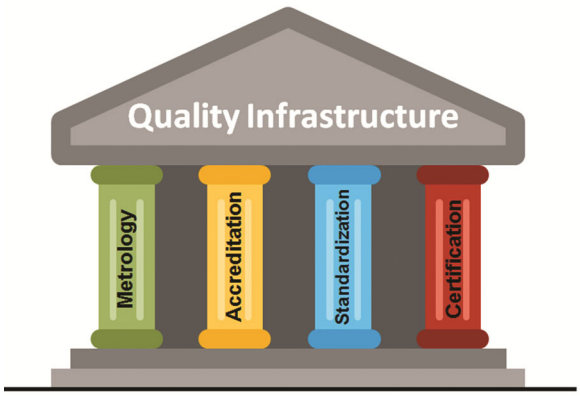

Fig. 1 — Pillars of the Quality Infrastructure

A more narrative description and analysis of Aswal model and its suggestive implementation and policy framework is included in the recently published book entitled, *"Metrology for Inclusive Growth of India"*.[11] The establishment and imposition of a vigorous national QI system ensures that the all experimental data acquired / measured are traceable to SI units, now redefined in terms of constants of nature, and therefore, have international compatibility and metrological equivalence. Aswal model envisions the necessities of competent metrological experts in each of the 4 pillars to make ensure that the metrological traceability is properly maintained in all the measurements. Implementation of metrology at the SI level is the responsibility of NMIs through a pyramid like hierarchical structure of networking of stakeholders through an unbroken chain of traceability. Standards and accreditation bodies are responsible for the accreditation, certification and conformity assessment. The government & regulators play important roles in sensitizing the stakeholders and formulation educational, industrial and science & technology policies, rules and regulations for sustainable development and proper handling of health and environmental issues. The civil society & media promote the amalgamation of local issues, varying culture and values for the advancement and suitability of the technologies for local requirements. Therefore, the absence or improper traceability in measurement results not only does it foster distrust among stakeholders, but it also has a negative influence on the financial system, economic growth, and overall quality of life.

In the present study, the authors have proposed the improved GQII. Along with other essential existing

accessible data factors, authors included the percentage of expenditure of Gross Domestic Products (GDP) on education, which is also considered as one of the crucial components of well-being and is used to assess the country's economic development and quality of life.[12–14] As per the *National Education Policy 2020*[15]; it is clearly mentioned that; an increase in public investment in education - by both the Central government and all State governments - to at least 6% of GDP and 20% of all public expenditure over a 10-year period, in order to achieve the goal of world-class education in India, and the corresponding multitude of benefits to this Nation and its economy. As on 1st November 2020, there are 62 full Member States and 40 Associate States of BIPM.[16] A brief summary of the related components and constraints considered in the improved GQII are listed in Table 1.

The major contributory factors used in our improved model are described briefly as follows;

Metrology

Metrology, according to the BIPM, is defined as the science of accurate and reliable measurements. But it is found that all countries do not have similar kinds of metrological capabilities. Some of the countries though have strong and robust metrology programs, while other countries either do not have or adequate QIs. One of the most important criteria for assessing these abilities is though not a precise exercise, but has the uppermost credibility and reliability using the published measurement capabilities i.e. CMCs. These CMCs are accorded to NMIs through the CIPM-MRA (International Committee for Weights and Measures - Mutual Recognition Arrangement) through a very stringent process.

The BIPM also provides information about the status of the comparisons in which NMIs have participated to establish the compatibility of their measurement standards and methods. Such comparisons are called Key or Supplementary Comparisons and are carried out by Consultative Committees or the Regional Metrology Organizations (RMOs). So, higher the number of participation in comparisons signify higher the credibility, compatibility of their measurement standards and more frequent interaction with other member states and the international organizations, and possibly the good metrological capabilities that could be obtained or disseminated. The GQII data are based on the information from KCDB 2.0. The KCDB is published by BIPM and its data is openly available in the public domain.

Accreditation

Accreditation is typically sought on a voluntary basis as proof of competency in a specific field. Most countries have a single national accrediting organization that is responsible for all accreditation areas. However, some of the countries do have multiple national accreditation bodies (NABs). Such NABs can be either public or private organizations. Management system certification bodies, testing and calibration laboratories, greenhouse gas validation, verification bodies, personnel certification bodies, product and service certification bodies, and inspection bodies are only a few of the sectors covered by accreditation. As a result, an increase in the number of recognized entities could lead to a spread of those bodies' competence, authority, and credibility. It is bit disappointing sometimes that IAF or ILAC has no consolidated data of NABs from each economy. Admittedly, it is constraint in the present study that accreditation data are not accessible in a consolidated form for the selected countries, may be due to confidentiality clauses or bound of disclosures.

Table 1 — Component summary of GQI index

QI index components	Summary	Remarks
Metrology	Membership of International bodies (BIPM, OIML); Calibration and measurements capabilities (CMC); Key & supplementary comparison	Data of CMCs; key and supplementary comparisons is openly available on BIPM KCDB 2.0.[17]
Standard & certification	Membership of International bodies (ISO, IEC and ITU); Technical committee participation; ISO valid certification (9001, 14001, 22000, 13485 and 27001)	Every year ISO performs a survey of the certifications for each country. The current results of the survey available for 2019 which show the number of valid certificates as on December 31 2019.[18,19]
Accreditation	Membership of International bodies (IAF, ILAC); Total accreditation bodies	Accreditation data are not accessible in a consolidated form.
Education	Government expenditure on education, total (% of GDP)	Open access data available.[20]
Trade & Commerce	Membership of International bodies (WTO)	Member states Data available on WTO website.[21]

However, leaving out such data, authors do not undermine the importance of such data and may be fairly included whenever the data is available for public use.

Standardization and Certification

The ISO statistics reported in the ISO survey are utilized to determine the certification output. Every year ISO performs a survey of certifications which shows status of valid certificates issued as per ISO management standards such as ISO 9001 & ISO 14001, reported by each country. The ISO Survey considers the number of certifications granted by certification bodies that have been certified by the International Accreditation Forum's member nations (IAF). Standards data are available on the ISO website. The development of the ISO standards is carried out by its TCs.

Percentage Investment of GDP on Education

The expenditure incurred on education in % of GDP, acts as one of the crucial components of the well-being and is used in the present study as a measure of country's economic development and quality of life.

Full Membership of International Organizations

The full membshiship acquired/obtained by the economies in various International bodies such as IAF, ILAC, OIML, CIPM, IEC, ISO, ITU, WTO, etc., are important for QI and is considered as a component of the development indicator.

Improved Model proposed for GQII

In the year 2011, Ulrich and Matteo have proposed the QI measurement indicator shown in equation 1 for carrying out a comparison of QI data of different NQI.[8] In this model, authors have used open access data related to major components of QI. The index consists of total number of CMCs, the total number of ISO standards (ISO 9001 only), total Accredited Bodies (TAB) from each country, the total number of K&S Comparisons, conducted by NMIs to test the measurement capabilities of the country in particular field, number of participations as member in TCs available on the ISO website and the membership of various international bodies i.e IAF, ILAC, OIML, CIPM, IEC, ISO, ITU and WTO.

$$Index\left(\frac{QI}{Pop}\right) = \frac{Index\left(\frac{CMC}{Pop};\frac{ISO}{Pop};\frac{TAB}{Pop}\right)+Index(K\&S\ comp.;Tech.Comm.;Membership)}{2} \quad \ldots (1)$$

The indexes mentioned in the Eq. 1 are further simplified in Eqs 2 and 3.

$$Index\left(\frac{CMC}{Pop};\frac{ISO}{Pop};\frac{TAB}{Pop}\right) = \left(\frac{\frac{CMC}{Pop}}{Max.Value} + \frac{\frac{ISO}{Pop}}{Max.Value} + \frac{\frac{TAB}{Pop}}{Max.Value}\right) \times \frac{100}{3} \quad \ldots (2)$$

$$Index(K\&S\ comp.;Tech.Comm.;Membership) = \left(\frac{K\&S\ comp.}{Max.Value} + \frac{Tech.Comm.}{Max.Value} + \frac{Membership}{Max.Value}\right) \times \frac{100}{3} \quad \ldots (3)$$

In the year 2019, they have used the same databases with some of the modifications in the formula and named this index as Global Quality Infrastructure Index (GQII).[10] In the updated study authors have increased the number of countries in the data set from 53 to 70 countries related to full membership of IAF. In the modified formula mentioned in Eq. 4, they have counted the accreditation sub-components in the area of a number of Conformity Assessment Bodies in total under ISO/IEC 17025 & ISO 9001 and total number of Conformity Assessment Bodies under ISO/IEC 17025 (Testing labs only) as compared to the sum of all accredited Conformity Assessment Bodies. Although it's worth to mention here that the accreditation data which they used is either not available or available in a very complex and diversified form in the websites of various counties.

$$GQII_i = \left(\beta_1 \frac{CMC_i/Pop_i}{max.value} + \beta_2 \frac{K\&SC_i}{max.value} + \beta_3 \frac{ISO_i/Pop_i}{max.value} + \beta_4 \frac{Tech.Comm._i}{max.value} + \beta_5 \frac{CABs\ (9001)_i/Pop_i}{max.value} + \beta_6 \frac{CABs\ (17025)_i/Pop_i}{max.value} + \beta_7 \frac{Membership_i}{max.value}\right) \times \frac{100}{7} \quad \ldots (4)$$

Recently, a new model is introduced for inclusive growth of any country with the aim of more robust QI system. The model known as Aswal model connects several sectors contributing to the national economy & quality of life.[1,11] The model depicts the major role of academia in the balanced QI of any country. Further, the model connects the metrology as a major pillar and an invisible force, in association with documentary standards, accreditation and conformity assessment, facilitates strong interactions among the Government agencies; civil society; Universities, Science & Technology institutions and Media & Industries for the overall inclusive growth of any country. In the present study, authors have used % of expenditure of GDP incurred on education as one of the major component of indexation in the improved

model of GQII. This component acts as a factor of the well-being and is used as a measure of economic development and quality of life. Authors have excluded the accreditation factor due to the unavailability of reliable and comparable open access data from accreditation bodies of each country. Further research is needed in the area of accreditation data for obtaining reliable data and information before due consideration.

The improved model proposed for the GQII is depicted in the Eq 5;

$$GQII_i = (C_1 + C_2 + C_3 + C_4 + C_5 + C_6) \times \frac{100}{6} \quad \ldots (5)$$

where, C_1, C_2, C_3, C_4, C_5, C_6 are defined as follows;
$C_1 = \frac{CMC_i/P_i}{CMC_{max}}$; $C_2 = \frac{K\&SC_i}{K\&SC_{max}}$; $C_3 = \frac{ISO_i/P_i}{P_{max}}$; $C_4 = \frac{TC_{si}}{TC_{max}}$; $C_5 = \frac{E_{Edui}\,\%}{E_{max}}$; $C_6 = \frac{M_{ITCi}}{M_{max}}$

GQII = Global Quality Infastructure Index

Equal weight assumption = $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 1$

$i = Country_1, Country_2, Country_3, \ldots Country_n$

P_i = Country Population

CMCs = Total number of Calibration & measurement capabilities

K&S Comp. = Total number of Key & Supplementry Comparisons

ISO = Total number of vaild ISO Standards issued (9001, 14001, 22000, 13485 & 27001)

TC_{si} = Total number of Technical Committees participations according to ISO

E_{Edui} % = % expenditure of GDP on Education

Membership (M_{ITC}) = Number of Memberships of International QI system (IAF, ILAC, OIML, CIPM, IEC, ISO, ITU, WTO)

Results and Discussion

In a QI index (comprising of accreditation, standardization and metrology), the last component represents the membership acquired/obtained by particular economy in the international organizations, responsible for IQI and percent expenditure of GDP incurred on education is included, which is regarded one of the most significant components of well-being and is used as one of the measure of economic progress & quality of life in any country. Admittedly, the inclusion of main components contributing in the GQII is also having limitation of the availability of particular data of each country studied. As an example, the data on total number of accreditation bodies in each country is not available in public domain which made us exclude the accreditation factor in the study. However, the importance and contribution of this factor is not undermined and can be included in the further research if such data is openly available.

The membership acquired/obtained in international organizations linked to IQI is also extremely important and signifies the GQII indexation. Such membership helps in improving the NQI of member states through participation in these committees, their sponsored technical sub committees and activities as well as understanding the NQIs of other advanced countries and incorporating necessary improvements in their own NQI if needed. As a result, the authors have considered including this component in the present investigation. We have considered only the internationally recognized organizations having status of signatories of Multilateral Recognition Arrangement (MLA). Consequently, eight international organizations are chosen in the improved GQII which are related to accreditation (IAF and ILAC), standardization (IEC, ISO and ITU) and metrology (BIPM/CIPM and OIML), and the World Trade Organization (WTO).

The GQII is a dimensionless indexation, so in the end, it serves to rank the countries and be able to establish the comparisons of the current status of their QI. It also helps to identify the factors and explain their contributions in the QI ranking, separately. This allowed us to analyze which component is relatively advantageously or lacking over other factors for a particular country. For example, a country distinguished by its strong metrology and accreditation programmes, could lose its position if it is not strong in the adoption of quality standards. It is found that European countries relatively have a stronger presence of QI and occupy the maximum positions in the GQII ranking.

The state of development of QI from a geographical perspective is shows in Fig. 2. It is clearly apparent from Fig. 2 that the European countries have relatively well-developed QIs. For the countries in the American continent, the United States of America (USA) is the QI leader. Many countries in South America and the Caribbean also have healthy levels of QIs. In Asia, Japan, New Zealand and South Korea are ahead in QI indexation, followed by Australia and China in a mid-range. In the Africa continent, only South Africa, Egypt, Kenya and Tunisia are the countries participating in the

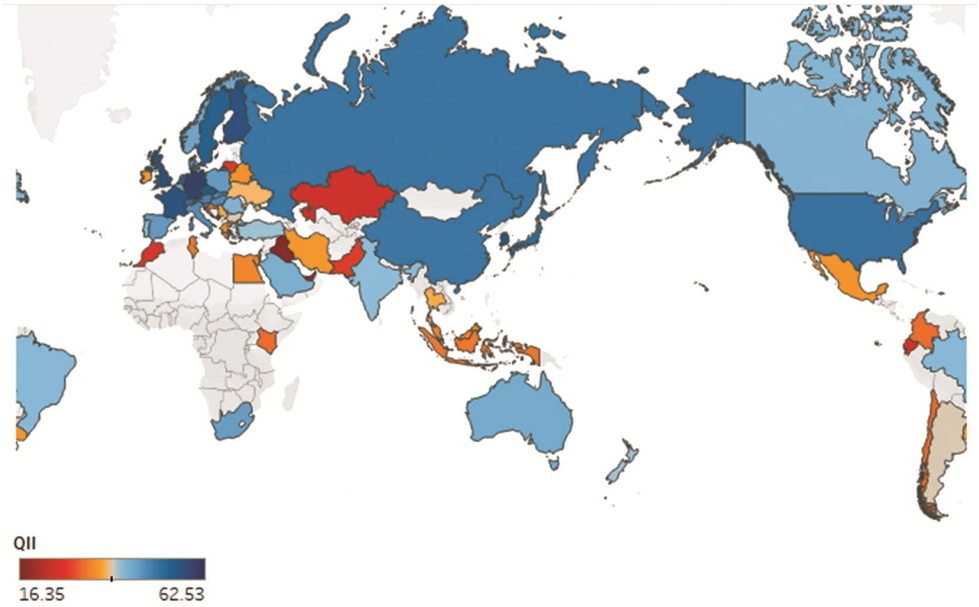

Fig. 2 — World map with GQII; the map is only for illustrative purposes and may not imply the expression of any opinion on the legal status of any country or territory

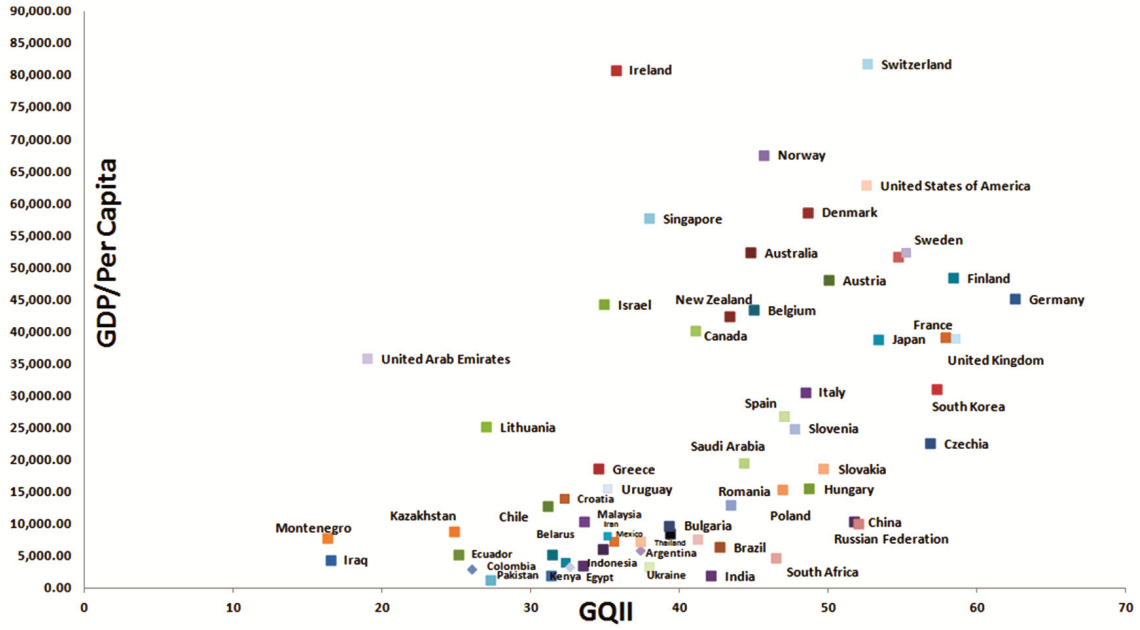

Fig. 3 — GDP per capita with GQII

key comparisons and other international QI activities and are the member states of BIPM. Furthermore, a number of African countries have limited advanced metrological capabilities and are working to expand scientific and industrial metrological capacities. Most of the African countries rely on the metrological support of NMI of South Africa i.e. NMISA, South Africa.

The comparative position in the GQII ranking with the positions taken by countries in GDP per capita is depicted in Fig. 3.[18] The GDP per capita is considering as a global measure for gauging the affluence of any country. At its most basic interpretation, GDP per capita shows how much economic production value can be attributed to each citizen in the country. It also helps to understand how the economy is growing with its population.

In order to understand the correlation of GQII with various influencing components i.e. CMCs, K&SCs,

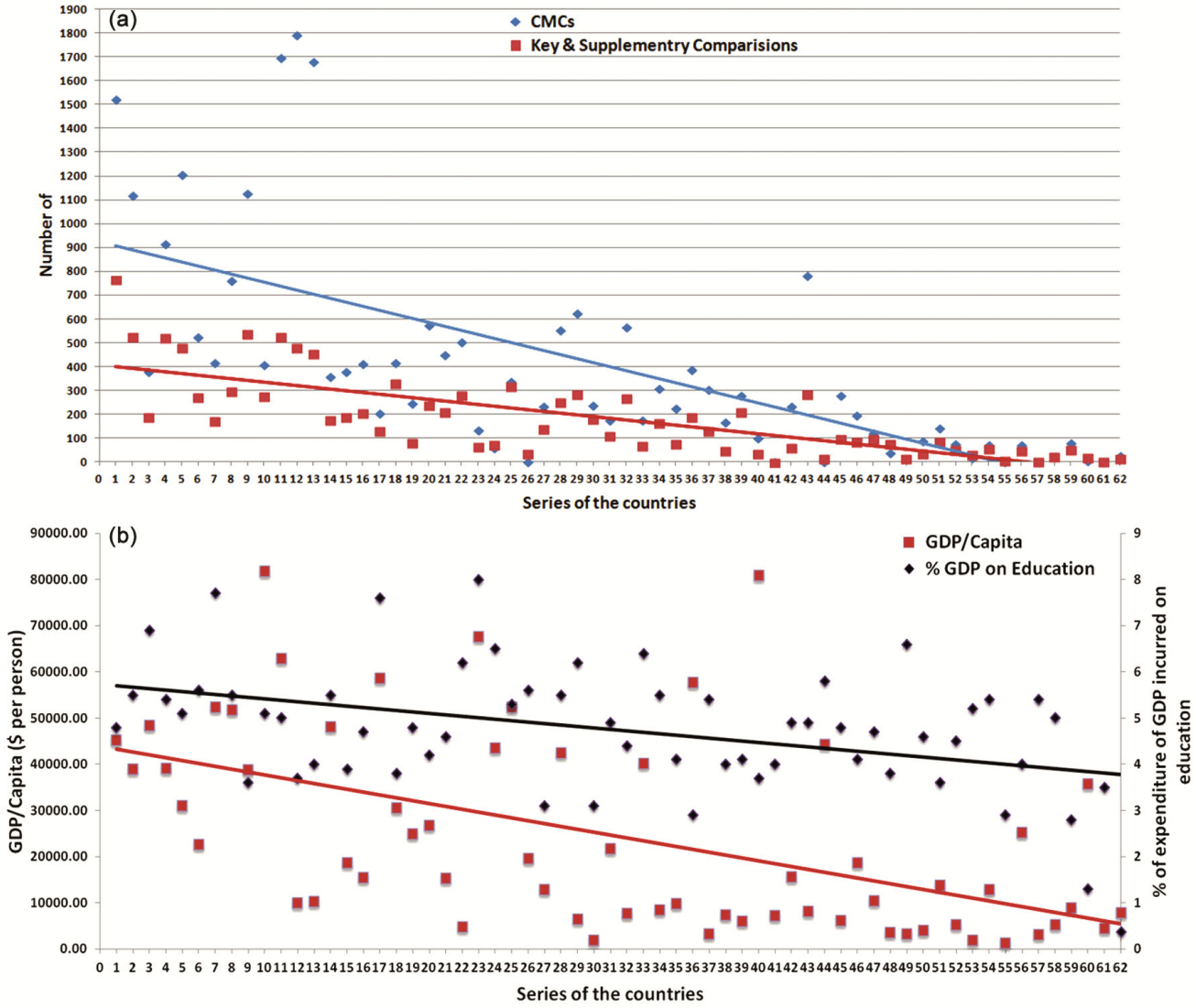

Fig. 4 — The roles of (a) CMCs and Key & supplementary comparisons (K&SCs) and (b) GDP per capita and percentage of expenditure of GDP on education, in GQII. The different countries studied and depicted as numbers on x-axis are: 1. Germany=62.5; 2. United Kingdom=58.5; 3. Finland=58.4; 4. France=57.9; 5. Korea=57.3; 6. Czechia=56.8; 7. Sweden=55.2; 8. Netherlands=54.7; 9. Japan=53.3; 10. Switzerland=52.6; 11. United States of America=52.5; 12. Russian Federation=52; 13. China=51.7; 14. Austria=50; 15. Slovakia=49.6; 16. Hungary=48.7; 17. Denmark=48.6; 18. Italy=48.4; 19. Slovenia=47.7; 20. Spain=47.1; 21. Poland=46.9; 22. South Africa=46.5; 23. Norway=45.6; 24. Belgium=45; 25. Australia=44.8; 26. Saudi Arabia=44.3; 27. Romania=43.4; 28. Canada=43.3; 29. Brazil=42.6; 30. India =42.1; 31. Portugal=41.8; 32. Turkey=41.2; 33. New Zealand=41.1; 34. Argentina=39.3; 35. Bulgaria=39.3; 36. Singapore=38; 37. Ukraine=37.9; 38. Serbia=37.4; 39. Thailand=37.4; 40. Ireland=35.7; 41. Iran=35.6; 42. Uruguay=35.2; 43. Mexico=35.1; 44. Israel=34.9; 45. Belarus=34.8; 46. Greece=34.5; 47. Malaysia=33.6; 48. Egypt=33.5; 49. Tunisia=32.6; 50. Croatia=32.3; 51. Indonesia=32.3; 52. Colombia=31.4; 53. Kenya=31.4; 54. Chile= 31.1; 55. Pakistan=27.2; 56. Lithuania=27; 57. Morocco =26; 58. Ecuador=25.1; 59. Kazakhstan=24.9; 60. United Arab Emirates=19; 61. Iraq=16.5; 62. Montenegro=16.3

GDP per Capita[22], and percent expenditure of GDP incurred on education, further various plots are shown in Fig. 4 (a) and (b). There exists a clear linear relationship between GQII and other components in decreasing orders. It is evident from Fig. 4(a) that GQII is normally higher with higher participation in K&SCs and a having higher number of CMCs. The GQII value decreases linearly with a decrease in values of these components. Similar trend is obtained between GQII and GDP per capita as well as the percent expenditure of GDP incurred on education, as shown in Fig. 4(b).

Therefore, for better GQII value, the economy and states need to improve all these components. For this

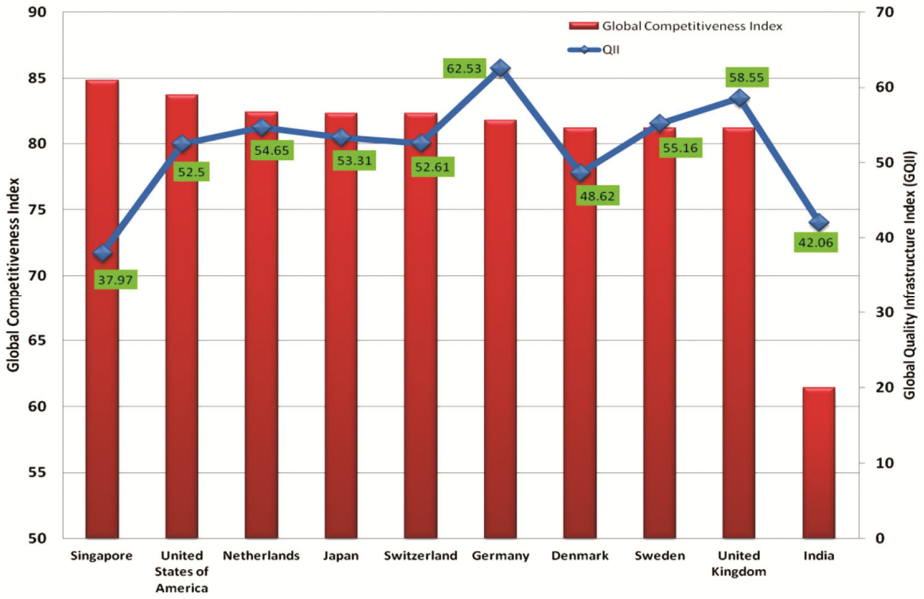

Fig. 5 — Global Competitiveness index of leading economics & India with GQII

purpose, as mentioned earlier, metrology plays a prominent role as CMCs and K&SC are the direct outcomes of metrology. Even GDP, as a function of imports and exports, depends upon metrological activities in any country. Thus, the ignorance of metrology would seriously affect the GQII. On a serious note, the countries having better position in GQII also indicate that such countries are also having well established, compatible and advanced metrological infrastructure. Similarly, the countries with higher GQII generally invest more on education which finally results in skilled manpower, expertise and strong QI.

Similarly, the World Economic Forum published the Global Competitiveness Index (GCI).[23] It is used as a standard to measure country's competitiveness across the globe. This index is used to integrate the macroeconomic and the micro/business aspects of the competitiveness into a single index. Fig. 5 presents the comparative analysis of the GCI of some of the leading economies of the member states of BIPM & India along with their respective GQII. There are several important factors which significantly contribute to the higher ranking in GCI such as tele-communications, internet bandwidth speed, and high-tech exports are all part of the education system and technological infrastructure. It is found that the countries having better ranking in GCI also have better ranking in GQII.

The export status of India with other leading economics along with GQII status is shown in Fig. 6. For the modern economics, the share of exports is incredibly important because they provide consumers and businesses with a much larger market for their goods. It is crucial for boosting economic commerce, encouraging exports and imports for the benefit of all trading parties, and it serves as the major role of diplomacy and foreign policy between government agencies.[24] The statistics in exports depict that the leading countries in this area are also equally good in GQII.

These relationships are essential for analyzing the contribution of QI to a country's competitiveness and economic development. According to the GQII formula, a country with a well-developed QI is economically prosperous; and conversely, a country lacking in the development of its QI is economically less favored. The GQII indicates the status of the various economics in the area of QI. It is clearly evident from the proposed model that with higher CMCs, more Key comparisons, more technical committee's participation, high ISO certification and more economic investment on education would lead any country to attain higher position in GQII.

In the case of India, the GQII ranking is 30 out of 62 member states of BIPM studied with a GQII score of 42.1. This is reasonably good and having the potential to improve further. In case of export of goods and services, India is positioned at 20th rank with the exports of 330706 million dollar which is surely would improve in future with several positive initiatives taken by Govt. of India viz. 'Make in India', 'Vocal for Local', 'Skill India', Digital India'

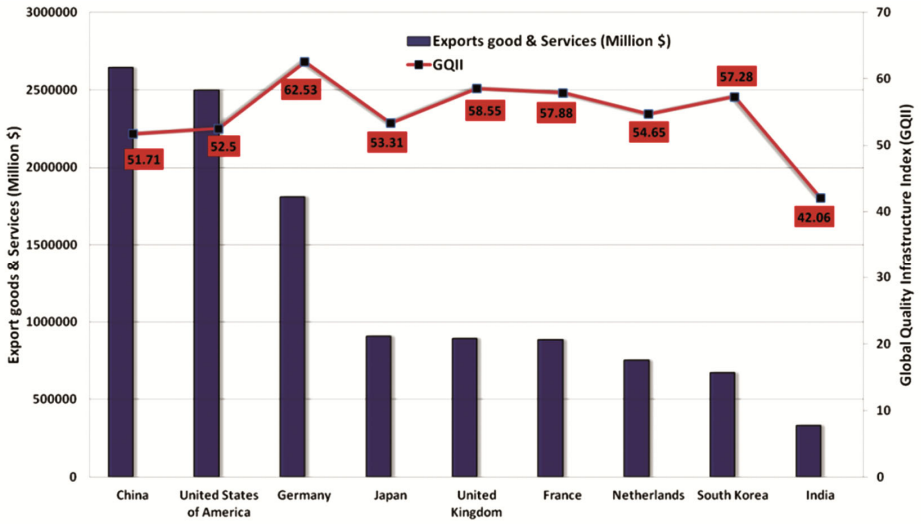

Fig. 6 — Status of leading economics in export goods and services along with India and status of GQII

and very recently 'AtmaNirbhar Bharat' i.e. 'Self Reliant India'. However, for the success of all these Govt. initiatives, metrological traceability needs to be ensured in all the measurements. Although, the existing system is working reasonably well but much more concentrated efforts are needed. On a suggestive note and as per existing system of leading NMIs, the NMI of India i.e. CSIR-NPL may be further empowered on both technically and administrative fronts. The NMI in turn has the extremely important role to play to ensure metrological traceability of all the physico-mechanical, electrical and electronics, environment monitoring and emission, health and safety measuring instruments; better synergy between all the stakeholders including international organizations; generating skilled manpower to cater the demands of more than 4 hundred thousand calibration and testing laboratories in the country to ensure inclusive growth. Further, India has got the 48th position in GCI with score of 61.4. The 2019 OECD Economic Survey of India examines strategies aimed at improving India's export competitiveness. India would gain higher market shares with better skills and capital-intensive goods with improved QI.[25] However, the performance in other areas needs to be strengthened for better economy and global ranking on various indexes. The recently released National Education Policy (NEP) 2020 has proposal of increasing the public spending on education to 6% of GDP, which will be a significantly increase.[22]

Limitations of the Study

In this study, authors have used open access available data in the area of metrology, standardization, certification and education. The major limitation is with the accreditation data which is either not available or available in a very complex and diversified form from country to country to make a comparison. The regional & international accreditation bodies such as the IAF and the ILAC may take lead to advise or ensure further transparency in the data through their respective member national accreditation bodies as in case of other international organizations like BIPM, OIML, ISO, IEC, etc. The annual data on the accreditation bodies in each county needs to be consolidated and published so that the development of QI and its components becomes traceable. Admittedly, the ranking of the countries in GQII may be different if the accreditation data is available and included.

Conclusions

The study confirms and clearly indicates the correlation of GQII with various influencing components such as CMCs, K&SCs, GDP per Capita, and % expenditure of GDP incurred on education. This paper provides terse review of the QI of 62 BIPM member states. Utmost care is taken while choosing data from international organizations freely available in the public domain. Using the inputs data of these reliable international sources, an improved model has been reported as a measure of projecting improved QI of various countries, including additionally percentage of expenditure of GDP and participation in the membership of 8 international organizations i.e. BIPM, OIML, ILAC, IAF, ISO, IEC, ITU and WTO. The strong QI is a step forward and an indicator for the good existing political framework, improved economic conditions,

as well as the rule of law. Also, it is a key to make a strong economy which finally leads to produce quality products, better environment and quality of life. With the understanding of the GQII and its role in improved QI system of any country, the policy makers would be in a better position and making their appropriate decisions for the better implementation of reforms and policy frameworks. In this perspective, the results presented are very useful to understand and implement the role of QI in the inclusive growth of any country. It is concluded from the studies that the countries with higher ranks in GCI also have equally good QI. Also, several leading countries having higher export of goods and services have higher rank in GQII. The GQII is also shown to be higher in the counties have more participants in K&SCs and a larger number of CMCs. The GQII value drops linearly as the values of these components decrease. GQII and GDP per capita, as well as the percent of GDP spent on education, show a similar pattern. Additionally, the strong GQII will support the domestic and foreign industries in complying with the requirements of standards as well as encourage their active participation in the development of new and emerging standards. The studies would also act as a reference for policymakers and stakeholders and contribute towards further development and better implementation of Govt. policies.

References

1 Aswal D K, Quality infrastructure of India and its importance for inclusive national growth, *MAPAN*, **35** (2020) 139–150.

2 *Overview of India's Quality Infrastructure*, Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, December 2018, New Delhi, India

3 UNIDO partners with technical institutions on quality infrastructure to achieve Sustainable Development Goals (SDGs), https://www.unido.org/news/unido-partners-technical-institutions-quality-infrastructure-achieve-sustainable-development-goals-sdgs, accessed on 15 October 2020

4 Kellermann M (2019), *The Importance of QI Reform and Demand Assessment*, Washington DC: The World Bank Group and PTB.

5 Rab S, Yadav S, Garg N, Rajput S & Aswal D K, Evolution of measurement system and SI units in India, *MAPAN*, (2020) 1–16.

6 Yadav S & Aswal D K, Redefined SI Units and Their Implications, *MAPAN* **35** (2020) 1–9. https://doi.org/10.1007/s12647-020-00369-2

7 Zafer A, Yadav S, Sharma N D, Kumar A & Aswal D K, *Economic Impact Studies of Pressure and Vacuum Metrology at CSIR-NPL, India*, *MAPAN* **34** (2019) 421–429.

8 Rab S, Yadav S, Jaiswal S K, Haleem A & Aswal D K, Quality Infrastructure of National Metrology Institutes: A Comparative Study, *Indian J Pure Appl Phys*, **59** (2021) 285–303.

9 Ulrich Harmes-Liedtke, Juan José Oteiza Di Matteo, Measurement of Quality Infrastructure, published by Physikalisch-Technische Bundesanstalt, Germany, 2011, https://www.ptb.de/cms/fileadmin/internet/fachabteilungen/abteilung_9/9.3_internationale_zusammenarbeit/q5_publikationen/305_Discussion_5_Measurement_QI/PTB_Q5_Discussion5_Measurement_QI_EN.pdf. Accessed on 15 March 2020

10 Ulrich Harmes-Liedtke, Juan José Oteiza Di Matteo, Measurement and Performance of Quality Infrastructure–A proposal for a Global Quality Infrastructure Index, DOI: 10.13140/RG.2.2.29254.83526, https://www.researchgate.net/publication/337840061 Accessed on 5 September 2020

11 Aswal D K (Ed.) Metrology for inclusive growth of India. Springer Nature, 2020.

12 Hanushek E A & Woessmann L, Education and economic growth, Economics of education, (2010) 60–67.

13 Denison E F, Measuring the contribution of education to economic growth, *In The Economics of Education* (1966) 202–260

14 European Commission/EACEA/Eurydice (2013), Funding of Education in Europe 2000–2012: The Impact of the Economic Crisis — Eurydice Report, Publications Office of the European Union, Luxembourg

15 The National Education Policy 2020 (NEP 2020), https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf Accessed on 15 November 2020.

16 BIPM member states; https://www.bipm.org/en/about-us/member-states/, Accessed on 1 November 2020

17 The KCDB- the BIPM key comparison data base, https://www.bipm.org/kcdb/ , Accessed on 1 November 2020

18 Technical Committees; https://www.iso.org/technical-committees. html, Accessed on 5 November 2020

19 Members; https://www.iso.org/members.html, Accessed on 5 November 2020.

20 Government expenditure on education, total (% of GDP), https://data.worldbank.org/indicator/SE.XPD.TOTL.GD.ZS, Accessed on 5 November 2020.

21 Members and Observers, https://www.wto.org/english/thewto_e/whatis_e/tif_e/org6_e.htm,

22 GDP per capita, https://data.worldbank.org/indicator/NY.GDP.PCAP.CD, Accessed on 10 November 2020.

23 Global Competitiveness Index (GCI), http://www3.weforum.org/docs/ WEF_TheGlobalCompetitivenessReport2019.pdf

24 Exports of goods and services, https://data.worldbank.org/indicator/NE.EXP.GNFS.CD, Accessed on 5 November 2020.

25 OECD's periodic surveys of the Indian economy, https://www.oecd-ilibrary.org/economics/oecd-economic-surveys-india_19990898, Accessed on 5 November 2020.