Engineering and economic growth: a global view

A report by Cebr for the Royal Academy of Engineering

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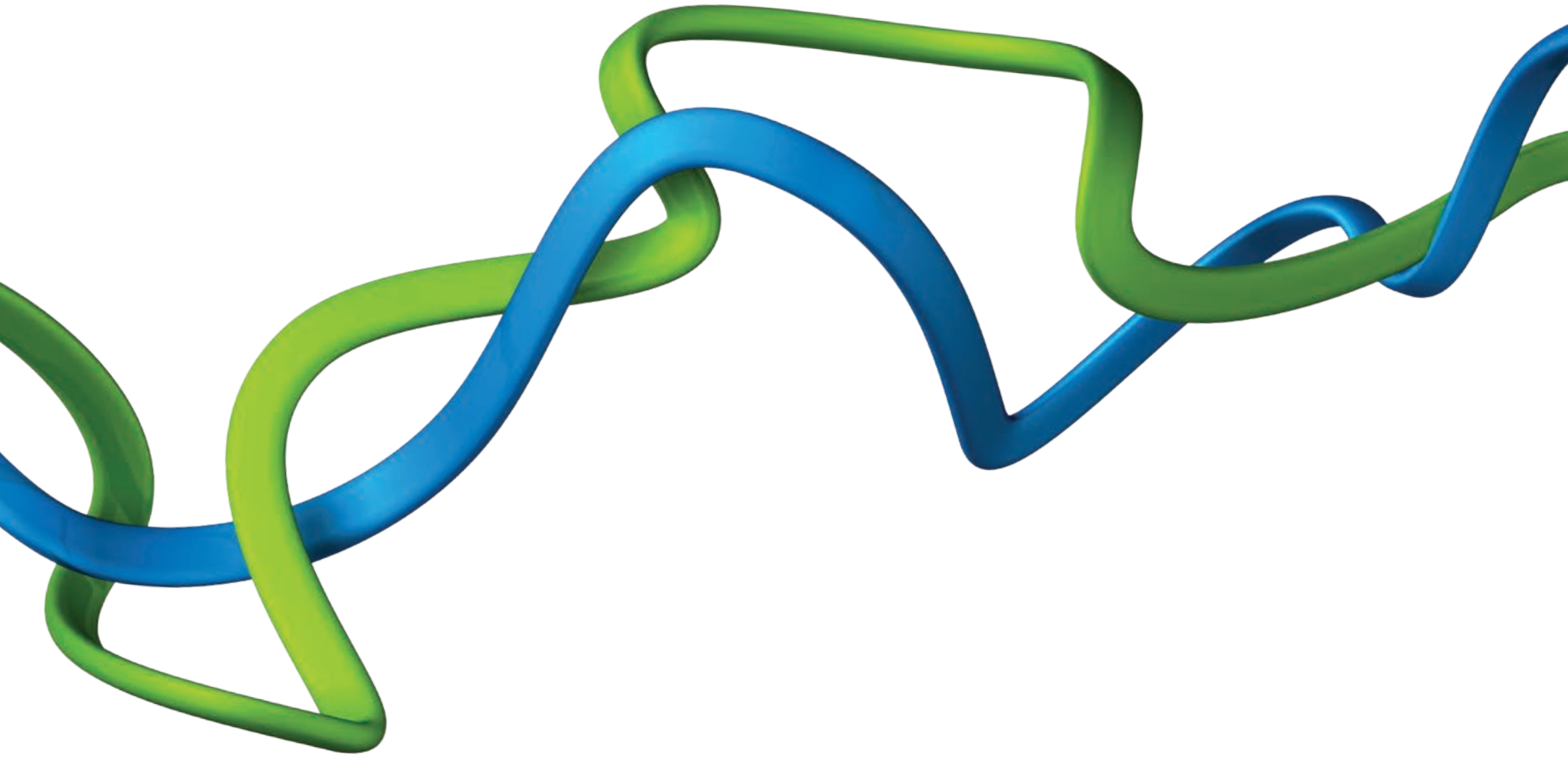

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Authorship and acknowledgements

This report has been produced by Cebr, an independent economics and business research consultancy, established in 1992. The views expressed herein are those of the authors only and are based upon independent research by them.

The report does not necessarily reflect the views of the Royal Academy of Engineering

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Executive summary

This report, by the Centre for Economics and Business Research (Cebr) commissioned by the Royal Academy of Engineering, considers the impact of engineering on economic development on a global scale. For the first time, this report brings together all available data from 99 countries (see Annex A for a full list) to paint a picture of global engineering: its workforce, output, prospective recruits, the quality of research and where its impacts are most needed. It uses a comprehensive selection of indicators to calculate a new 'Engineering Index': a measure of the engineering strength of different countries.

Engineering plays a key role in supporting the growth and development of a country's economy as well as in improving the quality of life for citizens. As such, there is an important link between a country's engineering capacity and its economic development. However, the extent to which engineering can aid development is also dependent upon governments committing finance and resources required for infrastructure projects, as well as developing a favourable business environment with good regulation and without corruption.

> Engineering plays a key role in supporting the growth and development of a country's economy as well as in improving the quality of life for citizens.

The research undertaken for this study has highlighted the lack of disaggregated data for engineering across the world, with not even an occupational breakdown for engineering as a whole in many instances, let alone across the range of engineering disciplines. This in itself is an important finding.

Measuring strength in engineering through the Engineering Index

Engineering-related data for countries across the world has enabled the creation of an 'Engineering Index'; the Engineering Index produced as part of this study directly compares 99 countries based on factors such as engineering wages, exports, employment, businesses, graduates, as well as infrastructure quality and the gender balance in engineering.

The Engineering Index produces several key findings:

- Sweden, Denmark and the Netherlands top the list of countries by engineering strength in the new Engineering Index, with high employment in engineering, the highest average engineering wages, and high-quality infrastructure.

- The United Kingdom ranks 14th in the Engineering Index, with relatively strong performance in engineering research, wages and infrastructure offset by a relatively poor gender balance among engineers and low numbers of engineering graduates within the wider population.

- Countries 'punching above their weight' – that is, with higher recorded engineering strength than their recent living standards might suggest – include Vietnam and Ukraine.

- The highest-ranking countries by Engineering Index score are located either in the regions of Europe, or Asia and Oceania. There is great potential for sub-Saharan countries in Africa to catch up with countries in other regions in their engineering strength, as shown by the Engineering Index where data is available This could be achieved through boosting the number of engineering graduates, raising the numbers of women in engineering jobs, and improving the quality of infrastructure.

The Engineering Index and economic development

We have then examined the association between the Engineering Index and two key measures of economic development: gross domestic product (GDP) per capita, and investment per capita. Despite data limitations – primarily a lack of historical data for some engineering indicators – we found the following:

- The econometric models constructed as part of this analysis provide evidence to support a strong, positive link between engineering strength and both of these indicators of economic development.
- This positive relationship remains robust when other factors influencing economic development are included in the models. Some of these 'control factors' include life expectancy, trade openness, human capital investment and changes in inventories.
- There is therefore likely to be potential for economic development for countries currently lagging in certain engineering indicators, such as employment or wages.

While the econometric models do not provide a forecast of engineering strength for the years to come, there is evidence to suggest that a country seeking to improve performance in engineering – through either increasing the number of graduates, improving infrastructure or raising employment in engineering fields – is likely to experience wider economic development as well.

Geographical asymmetries in engineering human capital

The data behind our Engineering Index highlighted asymmetries between female participation in engineering and the supply of engineering graduates.

Female participation in engineering

Myanmar (65%), Tunisia (42%) and Honduras (41%) lead the world in gender parity among engineers, according to latest data on female engineering graduates from the United Nations Educational, Scientific and Cultural Organisation (UNESCO). Of the countries where data is available, the gender gap is biggest in Ghana and Saudi Arabia. However, many richer countries such as Japan, Switzerland and the US have a poor recent record in this area. The latest UNESCO data shows that only 12.5% of Japanese engineering graduates in 2013 were women, followed by 14% in Switzerland and 18.9% in the US.

Women only make up 22% of engineering graduates in the UK. While the UK outperforms some CAETS countries in this regard, such as the US (19%), Switzerland (14%) and Japan (12%), it is behind twelve CAETS countries for which data is available, including Denmark (35%), India (30%) and Sweden (29%). Across the 99 countries considered in the study, the UK ranks 58th in gender parity, also lagging behind countries such as New Zealand, Brazil and Greece.

Supply of engineering graduates

Iran and the Republic of Korea perform strongly in terms of the number of engineering students[1] in tertiary education per capita (1.8% and 2% respectively), possibly because engineering is viewed as a prestigious field of study in these countries. The latest data shows that Russia, Iran, South Korea and the Ukraine have the highest number of engineering graduates[2] per capita (around 0.3% of the population in each country). In contrast, engineering graduates make up only around 0.1% of the UK population.

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[1] Based on UNESCO data relating to engineering, manufacturing and construction programmes.

[2] Based on UNESCO data relating to engineering, manufacturing and construction programmes.

Of the Organisation for Economic Co-operation and Development (OECD) countries[3], Mexico experienced the strongest growth in the number of engineering graduates over the period 2008-12. In per capita terms, this means that Mexico had more engineering graduates in 2012 than the US (0.06% compared with 0.04% in the US).[4] This is likely to be in part the result of government policy in Mexico, introduced by President Calderon, which aimed to attract more people towards engineering by increasing capacity and building more higher education facilities.

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[3] The OECD is comprised of the following countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Israel, Italy, Japan, Korea, Latvia, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

[4] Note that the numbers differ slightly between Figure 4 and Figure 5 due to the difference in the types of graduate being considered across the two charts.

1. Introduction

This study, by the Centre for Economics and Business Research (Cebr) on behalf of the Royal Academy of Engineering, considers the importance of the engineering sector as a vehicle for economic and social development. As part of the study, Cebr developed an Engineering Index to measure the engineering strength of different countries. This report considers a range of different indicators, some of which have fed into the overall Engineering Index. We then present the econometric analysis, which examines the link between engineering and economic development.

The study included an in-depth interview programme with engineering experts across the world. We used these interviews to ask exploratory questions about the relationship between engineering and economic development.

1.1 What is engineering?

Engineering covers many different types of activity. Engineers make things, make things work and make things work better. They also use their creativity to design solutions to the world's problems and help build the future. Engineering has previously been defined by the Royal Academy of Engineering as the 'creative application of scientific principles', principles that are put in practice to invent, design, build, maintain and improve structures, machines, devices, systems, materials and processes. This definition of engineering is broad, intended to account for the fact that the scope of engineering is continually evolving because of the dynamic nature of engineering-related industries.[5]

There is a diverse range of specialised engineering disciplines or fields of application, including (but not limited to):

- aerospace
- chemical and process
- civil and environmental
- computing and communication
- electrical and electronics
- energy and power
- materials and mining
- manufacturing and design
- medical and bioengineering
- transport and mechanical.

Engineers are responsible for some of the most important advances in biomedicine, and they have played a key role in building the infrastructure around us – from roads to utility networks. Engineers also play a role in the development of the food we eat and the development of new materials, such as cutting-edge foams and coatings to be used in manufacturing. With half the world living in poverty and millions of people without sufficient food or sanitation[6], engineering continues to have a key role to play in helping countries to progress across the world.

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[5] **http://www.raeng.org.uk/publications/reports/assessing-the-economic-returns-of-engineering-rese**

[6] UN Development Programme, 2014. *Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience.*

1.2 What is economic development?

Economic theory suggests that growth in the economy, which is the only means of increasing the prosperity of a country, depends on the quantities of the factors of production employed – labour and capital – and the efficiency with which those quantities are utilised. Growth is sustained by increasing the amounts of labour and/or capital that are used and by increasing the efficiency with which they are used individually and in combination to produce output.

Countries in the economic development phase must focus on improving the efficiency of utilisation of labour and capital. For example, reducing the price of capital utilisation to encourage greater utilisation to better 'sweat' the assets, or through transport infrastructure improvements that shrink geographies, making labour more mobile and flexible. This increases the likelihood of finding a job in which they can maximise their potential, while reducing search costs for companies that can access a wider labour market. Economic development is crucial in creating the conditions necessary to achieve long run growth, particularly in developing nations.

"...Economic development preserves and raises the community's standard of living through a process of human and physical infrastructure development..."[7]

The more mature, developed nations must cope with the fact that as each additional unit of the factors of production (labour and capital) are added, the resulting amount of additional output tends to diminish. Only increases in the level of technological progress can offset this decline in growth that occurs as diminishing returns to labour and capital set in. Growth over the long run is sustained by increasing the efficiency with which these factors are combined to produce output. This is known as total factor productivity (TFP). Improvements in TFP are driven by a number of variables including the depth and breadth of technical knowledge – as reflected in things like standards, patents and licenses (permissions to use, produce or resell). Other drivers include the quality of education, the average number of years of education among the wider population, or investment in Research and Development (R&D).

Therefore, economic development, while difficult to precisely define, results from investment in the generation of new ideas through innovation and the creation of new goods and services, the transfer of knowledge and the development of viable infrastructure. Examples of economic development include the creation of infrastructure, not just roads and bridges, but also digital and communications infrastructure, and the creation of knowledge through education and training, which can be utilised by businesses to create new goods and services. Investment in research and development and support for entrepreneurship and innovation make a significant contribution to economic development, as they identify new opportunities and then bring them to market to realise value, which will in turn lead to increased productivity within an economy.[8]

By investing in infrastructure, such as transport, bridges, dams, communication, waste management, water supply and sanitation as well as energy and digital infrastructure, countries can raise their productivity and enhance other economic variables. By having a well-developed transport and communications infrastructure for example, countries are better able to get goods and services to market and move workers to jobs. A strong communications network allows a rapid and free flow of information, helping to ensure businesses can communicate and make timely decisions. All of these infrastructure projects require engineers.

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[7] Fitzgerald, J., & Leigh, N.G., 2002. *Economic revitalisation: Cases and Strategies for city and suburb.* Sage Publications.

[8] Feldman, M., Hadjimichael, T., Kemeny, T., Lanahan, L., 2014. *Economic Development: A definition and model for investment.*

However, the ability of a country to develop economically is also partly dependent upon government, its policies and the way in which it interacts with private enterprises. Governments need to encourage private companies to take on projects that can lead to economic development by providing ground rules and incentives for good performance. Governments are also more likely than private businesses to take a long-term view of what can help the country, enabling them to make investments in projects that can result in development and growth. The investment made by government also needs to keep up with the scale and pace of the demand for infrastructure growth. In economic terms, in some situations there will be market failures in the absence of government investment in certain economic activities. These market failures can lead to sub-optimal outcomes for society and the inefficient use of resources.

1.3 Focal countries

Throughout this report, we endeavour to consider engineering across the world. However, in many instances we were constrained by a lack of data, as detailed later in this section. Where detailed information was not available globally, we focused on obtaining relevant data for the countries within the International Council of Academies of Engineering and Technological Sciences (CAETS).

CAETS countries

CAETS is an independent, non-political, non-governmental international organisation of 26 national engineering academies,[9] with one member per country.

CAETS has the following objectives:

- Advise governments and international organisations on technical and policy issues related to its areas of expertise.
- Contribute to the strengthening of engineering and technological activities to promote sustainable economic growth and social welfare throughout the world.
- Foster a balanced understanding of the applications of engineering and technology by the public.
- Provide an international forum for discussion and communication of engineering and technological issues of common concern.
- Foster cooperative international engineering and technological efforts through meaningful contacts for development of programmes of bilateral and multilateral interest.
- Encourage improvement of engineering education and practice internationally.
- Foster establishment of additional engineering academies in countries where none exist.

1.4 Purpose and objectives of the research

This study aims to highlight and explore the relationship between engineering and development, and how engineering can be used as a vehicle for development.

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[9] The CAETS members are: Argentina, Australia, Belgium, Canada, China, Croatia, Czech Republic, Denmark, Finland, France, Germany, Hungary, India, Japan, Korea, Mexico, Netherlands, Norway, Slovenia, South Africa, Spain, Sweden, Switzerland, United Kingdom, Uruguay and USA.

Engineers have historically played a very important role in the process of global economic development and the eradication of poverty. The improvement of infrastructure often acts as a catalyst for reducing the significance of factors inhibiting development, such as the spread of waterborne and other contagious diseases. At the same time, it strengthens the impact of those factors that can speed up the development process, such as improved transport links that in turn contribute to growth in trade, enhance the prospects for access to schooling and encourage labour mobility. Investment in communications networks, enabling access to information, the internet and mobile telephony also plays a key role in economic development and growth.

Research by the OECD deemed broadband networks as 'fundamental for economic and social development'. It highlighted the link between telecommunications infrastructure and productivity as well as the importance of communications infrastructure alongside other infrastructure investments in buildings, roads, health and energy. By linking communications, specifically broadband, to other infrastructure networks, 'smart' networks can be established, which can help save energy and improve safety, among other things.[10]

Since Adam Smith (1724-1790)[11], economists have viewed infrastructure as a key element in productivity and economic growth. Bom and Lightheart[12] find that a doubling of infrastructure capital[13] raises GDP by around 10%, while The World Bank reports that a majority of studies find a significant positive effect of infrastructure on output, productivity and growth.[14] Linked to this, large scale engineering projects such as dams, power stations and built assets can also be expected to have helped to promote development. However, it is not just about the quantity but also the quality of the infrastructure, meaning that the exact contribution of infrastructure to economic growth and development will vary across countries.

1.5 Data constraints

The research undertaken for this study has highlighted the lack of disaggregated data for engineering across the world, with not even an occupational breakdown for engineering as a whole in many instances, let alone across the range of engineering disciplines. This in itself is an important finding. Without the necessary data to understand how 'well-stocked' a country is with engineers of a sufficient quality, it is more difficult to ensure that sufficient numbers of well-qualified engineers are emerging to meet the growth in demand for them that is inevitable as economies develop and mature and seek new ways of achieving economic growth.

Alongside significant discrepancies in the engineering-related data coverage across countries, there is also the difficulty of defining engineering in itself.

Alongside significant discrepancies in the engineering-related data coverage across countries, there is also the difficulty of defining engineering in itself. There is no obvious definition of engineering that is applied across countries, and it is often unclear within datasets what is specifically encompassed within the definition of engineering, or how an engineer is classified. For example, whether the definition of an engineer includes technicians or those that do not have a university education.

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[10] Reynolds, T., 2009. *The Role of Communication Infrastructure Investment in Economic Recovery*. OECD Digital Economy Papers, No. 154, OECD Publishing. **http://dx.doi.org/10.1787/222432403368**.

[11] Adam Smith explained how rational self-interest in a free-market economy leads to economic well-being. In his book, *The Wealth of Nations*, he sought to reveal the nature and cause of a nation's prosperity

[12] Bom, P. and J. Lighthart., 2009. *How productive is public capital? A meta-regression analysis*. Andrew Young School International Studies Program Working Paper 09-12.

[13] Public and private capital investments in infrastructure. Thought to be a valuable form of capital as it provides indirect support to other factors of production. [Baldwin, J. and Dixon,J., *Infrastructure Capital: What is it? Where is it? How much of it is there?]*

[14] **http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:22629797~pagePK:64165401~piPK:64165026~theSitePK:469382~isCURL:Y,00.html**

In addition, in our calculation of the number of employees in engineering enterprises in European countries, we include data classified by the UN as 'architectural and engineering activities and related technical consultancy' along with data classified as 'research and experimental development on natural sciences and engineering'.[15] We include both classifications for completeness but note that the numbers employed in the 'research and experimental development on natural sciences and engineering' are small. On average, for the European countries for which data was available, this category accounted for 13% of our total estimate of the number of employees in engineering enterprises.

However, we have been able to use data from sources such as UNESCO, rather than attempting to use different country specific datasets. This has helped to ensure a consistent measure across countries. UNESCO's definition of engineering encompasses a range of different engineering fields, but is consistently aggregated with manufacturing and construction across its datasets.[16] We also note that in many other cases, engineering data is combined with other areas, such as construction or technology, rather than just providing a purely engineering-based statistic. We have also endeavoured to include computer science within our consideration of engineering wherever possible.

Therefore, this study has also served to highlight the shortage of statistics and indicators relating to engineering. While systemic data shortages largely affect developing countries, there are isolated examples of missing information for developed countries as well. Annex C details the full set of data availability components used in the Engineering Index.

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[15] The class of 'research and experimental development on natural sciences and engineering' includes: research and development on natural sciences, research and development on engineering and technology, research and development on medical sciences, research and development on biotechnology, research and development on agricultural sciences, interdisciplinary research and development, predominantly on natural sciences and engineering. .

[16] 'Engineering and Engineering trades' and 'architecture and construction' includes: chemical engineering and process; environmental protection technology; electricity and energy; electronics and automation; mechanics and metal trades; motor vehicles, ships and aircraft; and building and civil engineering.

2. Macroeconomic context for engineering as a source of economic development

Engineering plays a key role in ensuring the growth and development of a country's economy as well as in improving the quality of life for citizens within the country. Its remit is far wider than just buildings and bridges, spanning improvements in renewable energy technologies and solutions through to global health challenges. As such, there is an important link between a country's engineering capacity and its economic development.

In this section of the report, we set the scene at a broad macroeconomic level, highlighting the ways in which engineering can contribute to economic development before considering the specific indicators that contribute to the Engineering Index in the remaining sections.

2.1 Ways in which engineering contributes to economic development

> **"I see engineering as a fundamental driver for many parts of the economy"**[17]

Economic literature has highlighted a number of 'waves of innovation', or so called 'Kondratieff waves', that have acted as game-changers in the history of economic development. The current fifth wave is associated with the development and uptake of information and digital technologies. However, according to some literature there are indications that the sixth wave of innovation has already begun, with this wave associated with the development of sustainable technologies.[18] [19] In contrast to the other technological waves, the sixth wave moves away from resource dependency and towards resource efficiency and sustainability. This has been attributed to the fact that natural resources are under threat as a result of over-use by humans, thereby encouraging people to come up with sustainable solutions.[20]

Empirical literature supports the position that infrastructure acts to promote growth, such as Easterly and Rebelo (1993)[21]. In 1994, The World Bank[22] considered the importance of infrastructure on productivity and deemed that it could impact economic development through economic growth, alleviating poverty and the enabling environmental sustainability. In 1998, Canning[23] found that telephones and paved roads had a significant impact on growth.

Engineering is a broad field that can contribute to economic development through many different channels. By investing in infrastructure, such as transport, bridges, dams, communication, waste management, water supply and sanitation, energy and

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[17] Mike McWilliams, Global Head of Hydropower, Mott McDonald

[18] Silva, G., and Di Serio, L., 2016. *The sixth wave of innovation: are we ready?*

[19] Hargroves, K., and Smith, M.H, 2005. *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*. Earthscan, London.

[20] Moody, J. and Nogrady, B., 2010. *The Sixth Wave: How to succeed in a Resource Limited World.*

[21] Easterly, W., and S Rebelo, 1993. *Fiscal Policy and Economic Growth: An Empirical Investigation*. Journal of Monetary Economics 32: 417: 458.

[22] World Bank, 1994. *World Development Report: Infrastructure for Development*. Washington, DC.

[23] Canning, D., 1999. *A Database of World Infrastructure Stocks, 1950- 1955.* World Bank Economic Review 12: 529-547.

“you cannot have an economy without engineering...”

digital infrastructure, countries can raise their productivity and enhance other economic variables. Through having a well-developed transport and communications infrastructure for example, countries are better able to get goods and services to market and move workers to jobs. A strong communications network allows a rapid and free flow of information, helping to ensure businesses can communicate and make timely decisions.

This view was supported by Professor Calestous Juma HonFREng FRS of the Harvard Kennedy School,[24] who contributed to our interview programme. He highlighted that “you cannot have an economy without engineering. This is because engineering plays a crucial role in the production of goods and services, through creating new knowledge and ensuring there is the capacity in place to produce and move goods and services – infrastructure, transportation networks and logistical arrangements.”

Engineering can also help address challenges that will help countries to meet the United Nations Sustainable Development Goals (SDGs), as listed in Table 1. The set of 17 SDGs are aimed at ending poverty, fighting inequality and injustice, and tackling climate change by 2030. They are the successors to the eight Millennium Development Goals (MDGs) that were agreed by governments in 2001 and expired in 2015.

President of the World Council of Civil Engineers, Tomas Sancho, told delegates at the UNESCO Africa Engineering Week in 2016 that, “as engineers we have a big role in helping Africa to attain its 17 development pillars under the Sustainable Development Goals…We want better infrastructure to improve the life of people.”[25]

Table 1: The United Nations Sustainable Development Goals

	Sustainable Development Goal
1	End poverty in all its forms everywhere
2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
3	Ensure healthy lives and promote well-being for all at all ages
4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
5	Achieve gender equality and empower all women and girls
6	Ensure availability and sustainable management of water and sanitation for all
7	Ensure access to affordable, reliable, sustainable and modern energy for all
8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
9	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation
10	Reduce inequality within and among countries
11	Make cities and human settlements inclusive, safe, resilient and sustainable
12	Ensure sustainable consumption and production patterns
13	Take urgent action to combat climate change and its impacts
14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development

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[24] Professor Calestous Juma HonFREng FRS is Professor of the Practice of International Development at Harvard Kennedy School and Director of the Science, Technology and Globalisation Project at the Belfer Center for Science and International Affairs

[25] **http://southernafrican.news/2016/06/15/african-engineers-must-promote-sdgs/**

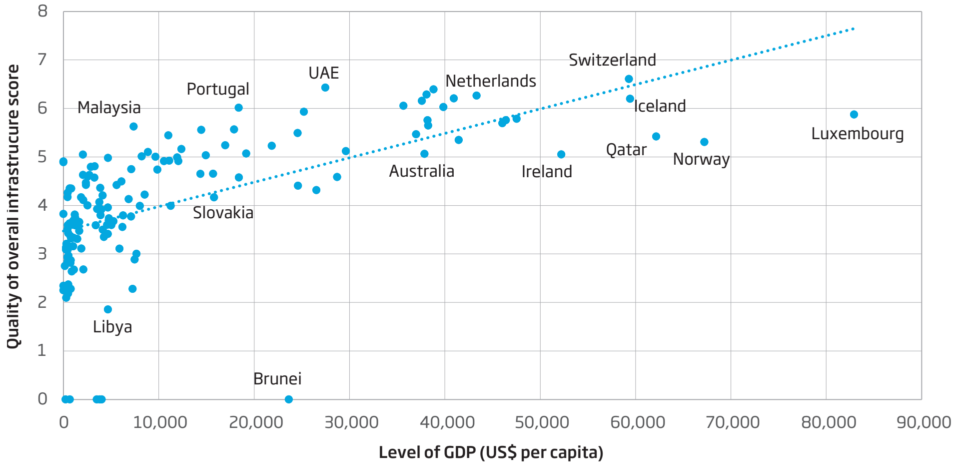
	Sustainable Development Goal
15	Protect, restore and promote sustainable use of terrestrial eco-systems, sustainably manage forests, combat desertification and halt reverse land degradation and biodiversity loss
16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
17	Strengthen the means of implementation and revitalise the global partnership for sustainable development

Source: United Nations

Engineers help countries by developing infrastructure that provides basic services such as energy; water and food security; transport and infrastructure; communication; and access to education and healthcare. Linked to these goals, engineering should also have a positive impact on factors such as life expectancy that over time can be expected to aid economic development through improvements to productivity, which in turn results in increased GDP. However, the extent to which engineers can aid development is also dependent upon governments committing finance and resources to infrastructure projects, as well as developing a favourable business environment with good regulation and without corruption.

Figure 1 clearly illustrates the strong relationship between the quality of infrastructure in a country and the level of economic development achieved across the world. This supports the assertion that engineering contributes to economic development as it has a key role to play in ensuring countries have a strong infrastructure.

Figure 1: Score on WEF GCI 'quality overall infrastructure' metric (1= extremely underdeveloped, 7=well developed) and the level of GDP (US$ per capita); 2014 country level data, 135 countries



Source: World Bank World Development Indicators, World Economic Forum Global Competitiveness Index, Cebr analysis

2.2 Macroeconomic variables

When we consider macroeconomic measures other than GDP per capita[26], developing countries[27] invariably lag behind the average across the OECD. In 2014, life expectancy at birth in the OECD countries was 80 years. This compared to 61 years in low-income countries. The OECD countries also had a higher literacy rate, which in 2010 was 98%. Meanwhile, in low-income countries in the same year, the literacy rate was 57%, increasing to 61% in 2011. Low-income countries also fared poorly relative to the OECD countries in terms of access to electricity, with just 25% of the population having access, compared to 100% across the OECD.

Engineering is crucial in helping these countries to 'catch up' with the high-income countries through the channel of improved infrastructure. This in turn can lead to more households with electricity, improved life expectancy, and higher literacy rates, which impact upon economic growth and the quality of life. Engineering has been instrumental in the technological development that has helped create modern society. It has helped to create infrastructure and transportation systems, enabled industrial production, and played a key role in technological innovations such as computers and communication systems, as well as the internet. Economic literature has highlighted a number of 'waves of innovation', or so called Kondratieff waves, which have acted as game-changers in the history of economic development, each of which has clear links to engineering. To date, five initial major economic cycles have been identified as:

- The Industrial Revolution (1771)
- The Age of Steam and Railways (1829)
- The Age of Steel and Heavy Engineering (1875)
- The Age of Oil, Electricity, the Automobile and Mass Production (1908)
- The Age of Information and Telecommunications (1971)

As part of this move towards sustainability there is predicted to be development of new forms of technology, such as green chemistry[28], renewable energy and nanotechnology.[29][30]

2.3 Large-scale engineering projects

Empirical literature, such as Easterly and Rebelo (1993)[31], supports the position that infrastructure acts to promote growth. In 1994, The World Bank[32] considered the importance of infrastructure on productivity and deemed that it could affect economic development through economic growth, alleviating poverty and improving environmental conditions and sustainability. In 1998, Canning[33] found that telephones and paved roads had a significant impact on growth.

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[26] GDP stands for Gross Domestic Product, which is a measure of the total output of a country. GDP per capita takes GDP and divides it by the number of people in the country. It is particularly useful in illustrating the relative performance of countries.

[27] The UN classifies all countries into one of three broad categories: developed economies, economies in transition and developing countries. The geographical regions for developing countries are Africa, East Asia, South Asia, Western Asia, Latin America and the Caribbean. An exhaustive list is available through the UN: **http://www.un.org/en/development/desa/policy/wesp/wesp_current/2012country_class.pdf**

[28] Green chemistry is the design of chemical products and processes that reduce the generation of hazardous substances.

[29] Marinova, D., 2009. *Global Green System of Innovation: Technological Wave or Policy?*

[30] Nanotechnology is the branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules.

[31] Easterly, W., and S Rebelo, 1993. *Fiscal Policy and Economic Growth: An Empirical Investigation.* Journal of Monetary Economics 32: 417: 458.

[32] World Bank, 1994. *World Development Report: Infrastructure for Development.* Washington, DC.

[33] Canning, D., 1999. *A Database of World Infrastructure Stocks, 1950- 1955.* World Bank Economic Review 12: 529-547.

In developing economies, the completion of large-scale engineering projects plays an important role in ensuring the countries' development. For example, in Africa, the Lamu Port Southern Sudan-Ethiopia Transport (LAPSSET) Corridor project is a significant transport infrastructure project underway in Kenya that when finished will be the country's second transport corridor. The rationale behind this project is to strengthen Kenya's position as a gateway and transport and logistics hub. This project is expected to facilitate trade as well as strengthen regional integration and connectivity, which in turn should help to encourage economic growth within the region. Feasibility statistics estimate that it will add at least 2-3% to Kenyan GDP.[34]

Other large-scale engineering projects were highlighted by our interview respondents, such as the Dubai Metro, which was the first underground railway in the Gulf countries. Tim Askew FREng, Managing Director of ATS Management,[35] stressed that this engineering project has been transformational as now "all the other major cities [in the area] are building their own". He gave the example of people now being able to get to the office in 20 minutes instead of taking the one hour fifteen minute journey that they would have had to take in the past. Therefore, the metro allowed people to live in cheaper areas and travel into work more easily. The ability of new infrastructure to enable people to partake in economic activity was also emphasised by Vice President of World Federation of Engineering Organisations (WFEO) Martin Manuhwa.[36] He pointed out that "energy efficient buildings around the world are a great example of how engineers contribute to the economy". These buildings not only allow people to come together to partake in economic activity, but also make the world more sustainable and improve people's quality of life into the future.

However, our interviews highlighted the difficulty in attributing a specific value, in terms of development and economic growth, to large-scale engineering projects, as the impacts are so wide reaching. In the majority of cases however, it is not difficult to see how these projects will have changed the lives of people, and the future prospects of these countries. There are so many large-scale engineering projects underway across the world, so in this section we focus on the views collected as part of our interview programme. We note that the quality of large-scale engineering projects is as important as the quantity. Countries with inadequate or poorly performing infrastructure may find this to be an obstacle to the economy meeting its full growth potential.

Mike McWilliams, Head of Hydropower for consultancy Mott MacDonald and a Cebr board member, explained in our interviews that he believed that the Kenyan hydroelectric development in the 1970s played a key role in driving the Kenyan economy as it provided virtually unlimited, free electricity. Through guaranteed access to electricity, businesses will have been able to produce more goods. It may also have improved people's quality of life, by enabling access to education and other public services. Another example of a large-scale engineering project given by one of our respondents was a water supply pipeline, also in Kenya, which took water from the base of Kilimanjaro 250 kilometres to Nairobi. This automatically benefited all of Nairobi and the surrounding areas, which now have access to clean water.

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[34] **http://www.president.go.ke/projects/lappset-projects/**

[35] Tim Askew FREng – Managing Director of ATS Management and Fellow of the Royal Academy of Engineering in recognition of his 'outstanding contributions in contracting and consulting engineering'.

[36] Martin Manuhwa, Vice President of World Federation of Engineering Organisations (WFEO) and Chair of the Committee on Anti-Corruption. President of the Southern African Federation of Engineering organisations (SAFEO)

2.4 Future regional prospects for infrastructure

There is a consensus that a key country for future construction and infrastructure development, both closely linked to engineering, is India. India's economy, currently much poorer and far less developed than China, is expected to grow at a high average annual rate of 7.4% between 2016 and 2021, in comparison to the Chinese average of 5.3% per annum.[37] As China's economy matures and moves from being a manufacturing and export-based economy to a consumption and services-led one, there is therefore huge scope for India to assume the title of the 'workshop of the world', previously used to describe Britain in the 19th century.

India is now expected to go through its own version of the infrastructure and construction boom that ramped up for two decades and is now gradually easing in its neighbour [China].

With strong economic growth forecasted, India is now expected to go through its own version of the infrastructure and construction boom that ramped up for two decades and is now gradually easing in its neighbour. Cebr's recent work on the Arcadis Global Built Asset Wealth Index 2015[38] showed that as part of a massive shift of physical built asset wealth (in other words, the value of buildings and infrastructure) from west to east, built asset wealth in India is forecast to grow from $15 trillion in 2015 to $23 billion by 2025. India will rise from 4th to 3rd in the ranking of countries by total built asset wealth, climbing above Japan and being behind only China ($97 billion) and the US ($45 trillion). As a rare bright spot in a slowing world economy, record volumes of foreign direct investment (FDI) are pouring into Indian development. Private capital follows government policy, which has pledged to put billions of dollars into easing bottlenecks in areas of infrastructure such as energy, rail, ports, airports, roads and housing under the leadership of Narendra Modi, elected Prime Minister in 2014.

India is not the only Asian-Pacific market expected to see major infrastructure work. China, despite rebalancing its economy towards services, will continue to play a crucial role in infrastructure development in the region. The largest Asian economy is expecting to invest part of its hefty savings in countries throughout Asia, enhancing its own trade links as well as soft power. The 'One Belt, One Road' (OBOR) policy – for which cumulative investment will be deployed over a currently indefinite timescale – will build land and sea routes across Asia to Europe, increasing trade and in turn raising GDP across several nations. It is expected to consist of:

- The 'Silk Road Economic Belt' – a land route connecting China with Central Asia, Eastern and Western Europe. It will link China with the Mediterranean Sea, the Persian Gulf, the Middle East, South Asia and South-East Asia.

- The 'Maritime Silk Road' – a sea route rather than a road – runs west from China's east coast to Europe through the South China Sea and the Indian Ocean, and east into the South Pacific. The aim of the sea route is to build efficient transport routes between major ports in various countries, including the development of an economic corridor through the Indian Ocean, better connecting China with South Asia, the Middle East, Africa and the Mediterranean.

It is anticipated that the OBOR policy will benefit 60 economies, with the largest volumes of investment flowing to Central and South East Asia. Indonesia, a major economy in Asia whose dearth of infrastructure stymies growth[39], will be a significant beneficiary.

Growth in infrastructure has plateaued at more modest levels elsewhere in the world, but infrastructure spending is still at a sufficient level to be causing skills shortages. Certain developed markets are likely to see rises in infrastructure spending, the US and United

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[37] Cebr real GDP growth forecast

[38] Source: **https://www.arcadis.com/en/global/our-perspectives/global-built-asset-wealth-index/**

[39] "How to solve Indonesia's infrastructure crisis", East Asia Forum. **http://www.eastasiaforum.org/2015/06/10/how-to-solve-indonesias-infrastructure-crisis/**

Kingdom being two examples. Spending on United Kingdom infrastructure is forecast to increase to £110 billion by 2025, driven by increased investment in transportation, such as Crossrail, and utilities infrastructure.[40]

Much of Europe, however, is likely to see lacklustre economic growth continuing, and a fixation on deficit reduction and fiscal austerity in several economies will hold back infrastructure spending. In emerging markets, the pace of development has generally slowed outside of Asia as many countries have seen buoyant recent expansion hit by the rout in commodities markets. This applies to Russia, South Africa and much of South America. In the long-term however, beyond short-term difficulties associated with low commodity prices and geopolitics, a wide range of emerging markets are likely to see strong growth in infrastructure spending as they continue their ascent up the economy ladder. By 2030, Belarus, Ethiopia, Kenya and Sri Lanka are expected to enter the top 60 world economies for the first time in the modern era, for example.[41]

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40 PwC 'Capital project and infrastructure spending: Outlook to 2025'.

41 Cebr World Economic League Table, 2016. **https://www.cebr.com/reports/welt-2016/**

3. Geographical asymmetries in engineering human capital

Globally, engineering skills are in high demand, and not just for engineering-specific roles. Engineers' problem-solving skills are highly prized by other industries, such as financial services. In this section of the report, we look at the existing levels of engineering human capital as well as the number of people studying and graduating in engineering.

> **"Engineering is a key ingredient to economic development, therefore we need to prioritise and encourage young people into the field of science so that they have the tools to help their countries develop" [42]**

The data presented on engineering students and graduates in this section subsequently feed into our Engineering Index, which is discussed later in Section 7. We consider that the number of engineering graduates and students is an important dataset to include in the Engineering Index, given that the ability of the engineering sector to act as a positive force for the economic development of different countries will depend on the quantity and quality of the talent pool in the sector. In the Engineering Index, we account for the varying size of populations across countries by using data on engineering graduates per capita.

Dr Allyson Lawless FREng[43] highlighted that there are likely to be differences in the way in which engineers contribute to the economy, depending on the specifics of their education and experience. Those with a four- or five-year professional degree will have covered more mathematical theory and problem solving than those training as technicians. As a result, those with a professional qualification are more likely to add value through breakthroughs in research, development and innovation, helping economies to grow and develop, while technicians are relied upon to faithfully keep systems and processes running, thus literally keeping the wheels of their nation rolling. Furthermore, engineering teaching is not standardised across countries so the quality of engineers can vary, even for those with a university degree.

It is both the number and quality of engineers that will be crucial to the performance of a country. Martin Manuhwa highlighted that "the economic development of that country will also affect the sort of projects those engineers are exposed to". As such, the experience that engineers gain is also important in terms of their ability to take on projects that are more complex in future. In addition, having exposure to new developments in the industry and access to the right resources to do the job is essential for high-quality engineering. This implies a virtuous cycle: engineering can help a country with large infrastructure projects and economic development, while exposing participating engineers to greater experience to draw upon in future projects.

In addition, our Engineering Index also takes into account the gender balance in engineering, by incorporating the percentage of graduates from engineering programmes in tertiary education who are females across countries. There is a body of evidence

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[42] Martin Manuhwa, Vice President of the World Federation of Engineering Organizations (WFEO) and Chair of the Committee on Anti-Corruption

[43] Dr Allyson Lawless FREng is a structural engineer, researcher and businesswoman. She holds a BSc in Civil Engineering from the University of Natal and an MSc, DIC in Structural Engineering from Imperial College, London. In the year 2000, she became the first female president of the then 97-year-old South African Institution of Civil Engineering (SAICE). She is the MD of SAICE Professional Developments and Projects, a non-profit company set up to address civil engineering skills development.

supporting a business case for equality and diversity in all workforces, as identified by the former Department for Business, Innovation and Skills.[44] In summary, some of the benefits of diversity identified by the Royal Academy of Engineering[45] include:

- Profit: as supported by a 2007 report by McKinsey[46], companies with more diverse workforces are more profitable; companies with three or more women in senior management functions reported significantly higher levels of employee satisfaction with work environment and values, direction, coordination and control, and leadership, than those with no women.

- Skills and talent: in engineering, the Royal Academy of Engineering argues that it makes no commercial sense for companies to draw their workforce in such large numbers from only half of the population (the male half), and that the gender disparity in engineering is the starkest aspect of lack of diversity that needs attention.

- The nature of future engineering: the future success of the engineering sector will come from addressing complex and multi-layered global challenges. Without a diverse set of skills to call on, new solutions and innovation will be hard to come by.

3.1 Engineering students in tertiary education

In this sub-section, we present our findings relating to the number of engineering students in tertiary education across different countries. There are several routes into a career in engineering; through work-based learning (apprenticeships), university (degrees) or through vocational qualifications (college courses). However, the quality of training varies between countries. Dr Allyson Lawless emphasised the fact that while some countries had seen an increase in the number of engineering students, they had not increased spending on university engineering departments to the same extent.

Data from UNESCO illustrates that emerging economies lead the way in terms of the proportion of students in tertiary education that are enrolled in engineering, manufacturing and construction programmes.[47] In Iran, 37% of students in tertiary education are enrolled in such programmes, which compares with 9% in the United Kingdom and 7% in the US. Ethiopia, the Republic of Korea and Mexico also perform strongly in terms of the proportion of engineering, manufacturing and construction students in tertiary education, as illustrated in Figure 2. These findings are particularly interesting for Ethiopia and Mexico as they have both introduced policies at government level aimed at increasing the number of engineering students and graduates compared to other subjects.

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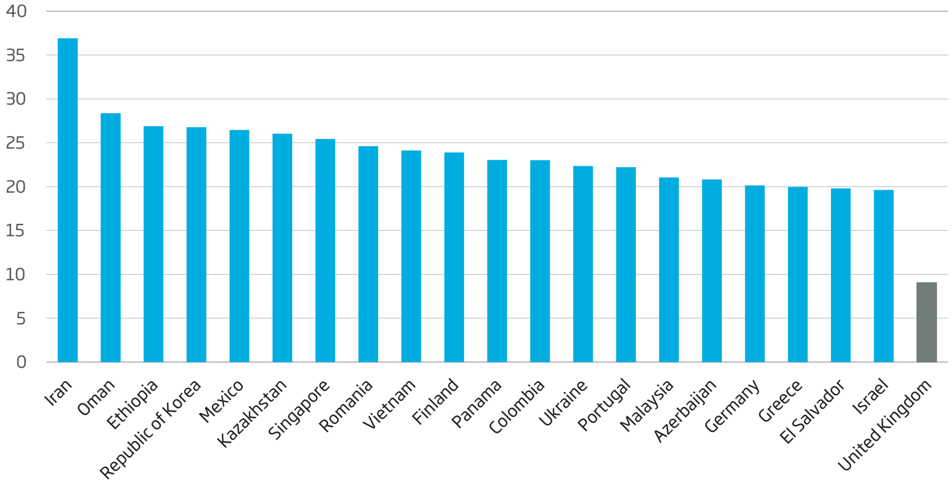
[44] BIS, 2013. *The Business Case for Equality and Diversity*

[45] Royal Academy of Engineering, the business case for diversity.
http://www.raeng.org.United Kingdom/policy/diversity-in-engineering/why-is-diversity-important

[46] McKinsey & Company (2007). *Women Matter: Gender diversity, a corporate performance driver*

[47] Engineering, manufacturing and construction encompasses engineering and engineering trades (chemical engineering and processes, environmental protection technology, electricity and energy, electronics and automation, mechanics and metal trades, motor vehicles, ships and aircraft, inter-disciplinary programmes and qualifications involving engineering and engineering trades, engineering and engineering trades not elsewhere classified), manufacturing and processing (food processing, materials, textiles, mining and extraction, inter-disciplinary programmes and qualifications involving manufacturing and processing), architecture and construction (architecture and town planning, building and civil engineering, inter-disciplinary programmes and qualifications involving architecture and construction). More disaggregated data was not available.

Figure 2: Top 20 countries by the percentage of students in tertiary education enrolled in engineering, manufacturing and construction programmes, United Kingdom included for comparison, latest year[48]



Source: UNESCO World Economic Forum, Cebr analysis

In Ethiopia, there is a strong demand for engineers in renewable energy, and the transportation and information and communications technology sectors are rapidly evolving.[49] The Ethiopian government requires universities to have 70% of students studying engineering and natural science courses, with the aim of having a significant intake of engineering students each academic year.[50] However, while there are, as a result, a high number of engineering students, it is necessary to consider whether the quality of teaching has kept pace with the rapid expansion in student numbers. This was one of the components of the Engineering Capacity Building Programme (ECBP) launched in 2005 in Ethiopia. By 2007, the programme had developed new engineering courses, occupational standards and training for teachers at engineering faculties. However, one review of the ECBP found that the lack of Ethiopian experts has made progress on university reform to date unsatisfactory.[51]

Mexico has also implemented policies with the aim of increasing the number of engineers, to help the economy create more high-wage jobs. Former President, Felipe Calderon, envisaged Mexico as a 'country of engineers'. During Calderon's time as President (2006-2012), the government built 140 new schools of higher learning (universities), with 120 of them dedicated to science and engineering. In addition, capacity was expanded at 96 other public campuses. Alongside this expansion in engineering schools, there was also an increase in the number of college engineering scholarships offered to students. This increased engineering talent is required by Mexico as it seeks to make significant investment across its infrastructure, from transport systems to waste management.[52]

However, the extent to which there are a high number of engineering students enrolled in tertiary education, while partly driven by government, is also likely to be the product of societal factors, such as how engineers are perceived and valued. For example, if people do not fully understand the role of an engineer then they will be less inclined to

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[48] By this, we mean that the majority of data is from 2013 or 2014, with some exceptions depending on data availability.

[49] US Embassy Ethiopia. **http://ethiopia.usembassy.gov/business-faq.html**

[50] Kahsay, M.N, 2012. *Quality and Quality Assurance in Ethiopian Higher Education: Critical Issues and Practical Implications.*

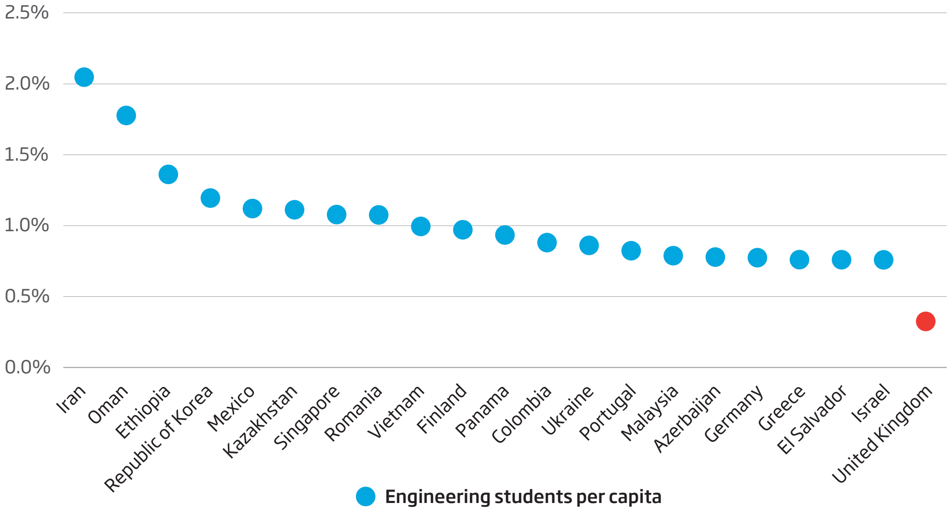
[51] Federal Ministry for Economic Cooperation and Development, 2008. *The Engineering Capacity Building Program in Ethiopia.* Evaluation reports 039.

[52] PwC, 2012. *Gridlines: Closing the talent gap in the emerging world.*

pursue a career in that field. Tim Askew explained that there is a significant difference in how engineering is perceived across Europe: in France, Germany and Italy, engineering is generally perceived as an elite profession, compared with the perception in the United Kingdom. In addition, professional engineers in the United Kingdom who move to other sectors do not generally take their engineering title with them. Instead, if they move into banking for example, they prefer to be seen as bankers and not as engineers. This supports the idea that engineering is often not valued as highly as other professions.

Poor perceptions of engineers more widely were also highlighted by Professor Calestous Juma. He commented that the lack of appreciation and misrepresentation of engineering affects the choices of young people, a systemic problem that needs to change. The extent to which these engineering students and graduates can then find work as engineers depends on a number of factors that differ by country. Those countries investing in infrastructure and having the right conditions to encourage investment from private businesses will have greater demand for engineers. However, in some countries, engineers may be constrained by a lack of resources, unfavourable policies, and corruption, which make it more difficult to find work in the industry.

Figure 3: Top 20 countries by engineering, manufacturing and construction students enrolled in tertiary education per capita, United Kingdom included for comparison[53]*, latest year*[54]



Note: Data availability highlighted in Annex C . Source: World Economic Forum, UNESCO, Cebr analysis

Figure 3 illustrates the top 20 countries by the number of engineering, manufacturing and construction students enrolled in tertiary education, per capita. This shows Iran and the Republic of Korea perform strongly in terms of the number of engineering, manufacturing and construction students in tertiary education per capita, likely to be because engineering is viewed as a prestigious field of study in these countries.

Furthermore, the Republic of Korea has been reforming its engineering education, as well as trying to attract more women to engineering through establishing colleges of engineering education for women.[55] These two countries have the highest per capita ratio of engineering, manufacturing and construction students in tertiary education of all the countries we analysed, at 1.8% and 2% respectively. Finland comes in third place in terms of engineering, manufacturing and construction students in tertiary education per capita at 1.4%.

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[53] The United Kingdom ranks 56th based on the number of engineering students per capita.

[54] By this, we mean that the majority of data is from 2013, with some exceptions depending on data availability.

[55] Cheongsig, K., 2008. *Korea's Engineering Education Reform Policy and the Direction.*

3.2 Engineering graduates

After considering the number of engineering students enrolled in tertiary education, we next move on to look at the number of engineering, manufacturing and construction graduates across countries.[56] Where looking at the number of engineering students can give an indication of the future supply of engineers in a country, engineering graduates enable us to consider the current supply, and how this might influence the ability of countries to undertake engineering projects. As part of our interview programme, Dr Allyson Lawless highlighted that in South Africa, the peaks in engineering graduation tend to occur a couple of years after peaks in spending on infrastructure, as young people become interested in engineering as they see what is going on around them.

Earlier in the report, we discussed how economic development is dependent on investment in the generation of new ideas through innovation and the creation of new goods and services, the creation of knowledge through education and training, the transfer of knowledge and the development of viable infrastructure. Therefore, we expect that increasing numbers of engineering graduates across countries – added each year to existing numbers of engineers and those with engineering-related training – will add to the stock of knowledge and know-how, in time contributing to higher levels of economic development in countries where graduate numbers are increasing.

However, the economic benefit of higher numbers of engineering graduates in developing nations may not manifest immediately. Many graduates will continue to leave their country of origin to seek further education or employment in more developed countries, of which only a proportion will return (and bring their skills and experience with them). This phenomenon is particularly apparent in China, each year, it is estimated that approximately 15% of graduates from the top Chinese Universities pursue further education in overseas universities, mainly in the US and Europe.[57] A recent survey by recruitment company Hays[58] found that the provision of good job opportunities, a faster career path and a salary equal to their current earnings would motivate many returners. However, only around 5% of those surveyed want to work in engineering.

In a 2013 study, Zeithammer and Kellogg[59] surveyed Chinese PhD graduates in STEM (science, technology, engineering and mathematics) subjects – studying in three large US universities – on their job and migration preferences. They found that Chinese doctoral graduates tend to remain in the US because of a large salary disparity between the two countries rather than because of an inherent preference for being in the US. They also forecast that many more science and engineering graduates will return to China once this large salary disparity closes over time (which Cebr forecasts will happen over the coming decades).

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[56] Again, the data in this section is taken from UNESCO and we use their classification of 'engineering , manufacturing and construction' programmes.

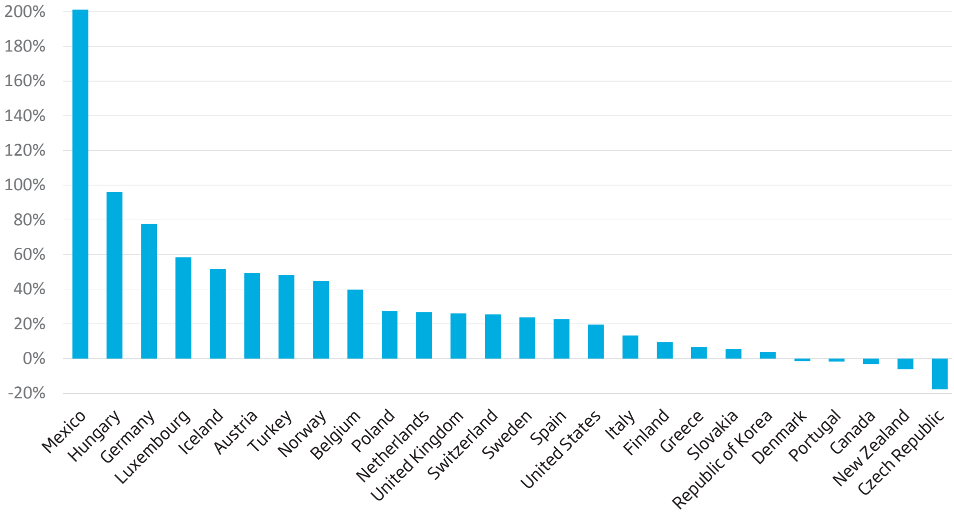
[57] **http://www.apmforum.com/columns/china19.htm**

[58] Source: h**ttp://www.hays.cn/en/press-releases/HAYS_238313**

[59] Zeithammer, Robert and Kellogg, Ryan, (2013). The Hesitant Hai Gui: Return-migration preferences of US-educated Chinese scientists and engineers *Journal of Marketing Research* 50.5: 644-663.

In Figure 4 below, we examine growth in the numbers of engineering graduates across a selection of OECD countries in recent years.

Figure 4: Percentage change in the number of 'engineering and engineering trades' graduates over the period 2008 -2012 across OECD countries



Note: Data not available for France, Australia, Ireland and Japan
Source: OECD, Cebr analysis

Specifically considering the OECD countries, Mexico experienced the strongest growth in the number of engineering, manufacturing and construction graduates over the period 2008-12, with numbers tripling to 71,300. In per capita terms, this means that Mexico had more engineering, manufacturing and construction graduates in 2012 than the US (0.06% compared with 0.04% in the US).[60] This is likely to be, at least in part, the result of government policy in Mexico, introduced by President Calderon, which aimed to attract more people towards engineering, by increasing capacity and building more higher education facilities.

Over this period, the majority of OECD countries experienced an increase in the number of engineering, manufacturing and construction graduates. However, the Czech Republic experienced a notable decline in the number of engineering graduates of 18% to 6,800. Denmark, Portugal, Canada and New Zealand also experienced slight falls in the number of engineering graduates, as illustrated in Figure 4.

We find that the per capita number of engineering, manufacturing and construction graduates is particularly high in economies such as Russia, Iran and the Republic of Korea relative to the more developed economies of the United Kingdom and France, as illustrated in Figure 5. This is consistent with the findings relating to the number of engineering students per capita in these countries.

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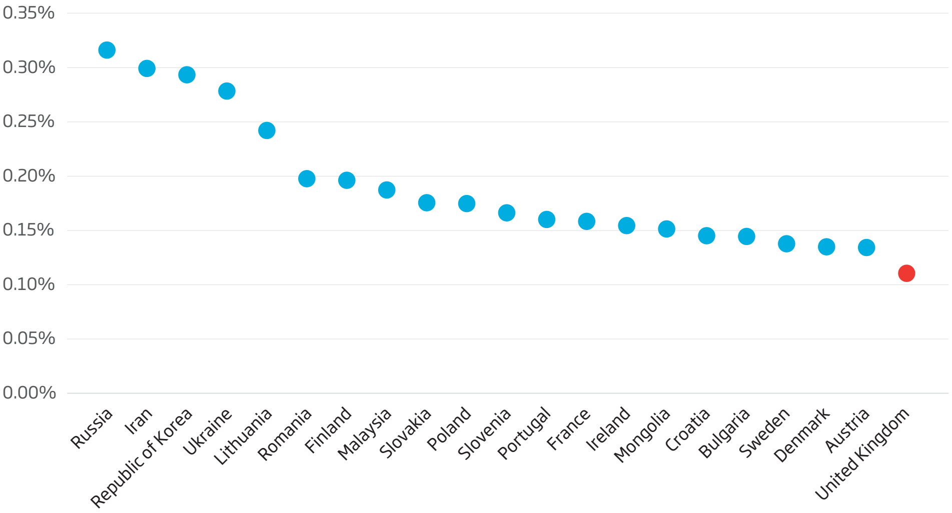
[60] Note that the numbers differ slightly between Figure 4 and Figure 5 due to the difference in the types of graduate being considered across the two charts.

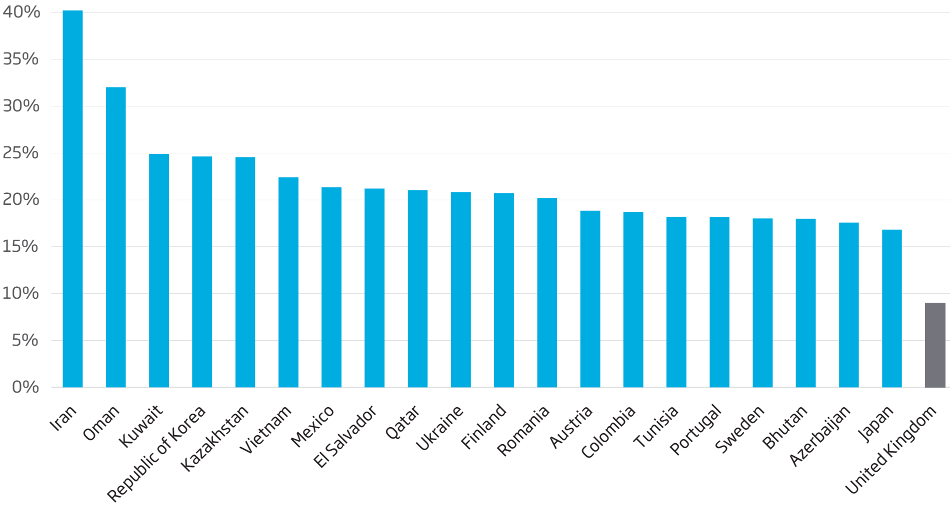
Figure 5: Top 20 countries by engineering, manufacturing and construction graduates per capita, United Kingdom included for comparison,[61] *latest year*[62]



Note: Data availability highlighted in Annex C
Source: UNESCO World Economic Forum, Cebr analysis

As illustrated in figure 6, Iran led the way in terms of the proportion of students in tertiary education that graduated[63] in engineering, manufacturing and construction programmes (40%), in the most recent year for which there are data relating to this measure. Meanwhile, for countries such as the United Kingdom, engineering, manufacturing and construction were less popular degree programmes, with 9% of students in tertiary education graduating in these fields. This divergence between countries could in part be a result of how societies view engineering relative to other subjects. Later in this section, we investigate the split between different degree subject areas across graduates in the CAETS countries.

Figure 6: Top 20 countries based on the percentage of students in tertiary education that graduated in engineering, manufacturing and construction programmes, United Kingdom included for comparison, latest year[64]



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[61] The United Kingdom ranks 31st based on the engineering graduates per capita measure.

[62] By this, we mean that the majority of data is from 2013 or 2014, with some exceptions depending on data availability.

[63] The term graduate is not defined by the World Economic Forum

[64] By this, we mean that the majority of data is from 2013 or 2014, with some exceptions depending on data availability.

Source: UNESCO World Economic Forum, Cebr analysis

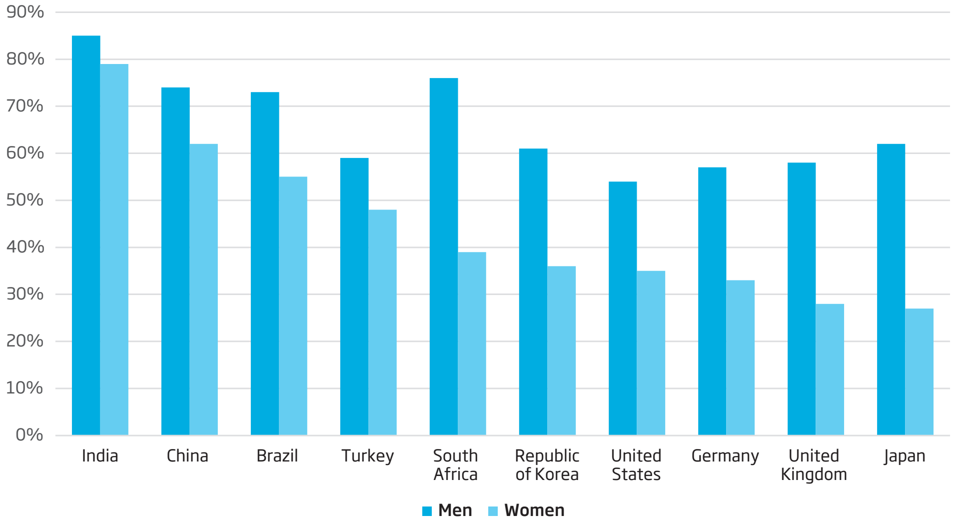
One potential explanation for the lower per capita numbers of engineering, manufacturing and construction graduates in developed countries was suggested by Mike McWilliams. He commented that, having developed a certain standard of infrastructure that benefits the majority of the population, it is possible that the demand for engineers per capita reduces. For example, it was pointed out that in past decades the US committed high levels of investment (as a share of GDP) to its infrastructure but has made very little investment since. This is supported by trends in state and local investment in infrastructure; which reached a 30-year low in 2014, having peaked at around 3% of GDP prior to 1970.[65] Federal investment in this period has also dropped by around 50% during this period, from 1% to 0.5% of total US GDP.

However, engineering goes beyond physical infrastructure, so across engineering disciplines, there is still a high demand for engineers, be it to help in the development of renewables, or further expansion of the digital economy. As we highlighted earlier, as we move into the sixth wave of innovation, engineers still have a key role to play in the development of economies.

3.3 Women in engineering

Traditionally, women have been under-represented in the field of engineering. In this sub-section, we consider the number of women studying or graduating in engineering globally. According to research undertaken by the Queen Elizabeth Prize for Engineering, women in emerging economies express a greater interest in engineering than those in developed nations, as illustrated in Figure 7 below.

Figure 7: Respondents to the Queen Elizabeth Prize for Engineering expressing an 'interest'[66] in engineering, by selected countries and gender, in 2015



Source: Queen Elizabeth Prize for Engineering report, 2015

The majority of the OECD countries have increased the number of female engineering graduates over the period 2008-12. The most notable increases were in the emerging economies of Mexico, Hungary and Turkey, as illustrated in Figure 8 below. In each of these countries, the number of female engineering graduates increased by over 150%. However, in developed countries, the increase was often less marked, with countries such as the United Kingdom and US increasing the number of female engineering graduates by 31% and 24% respectively.

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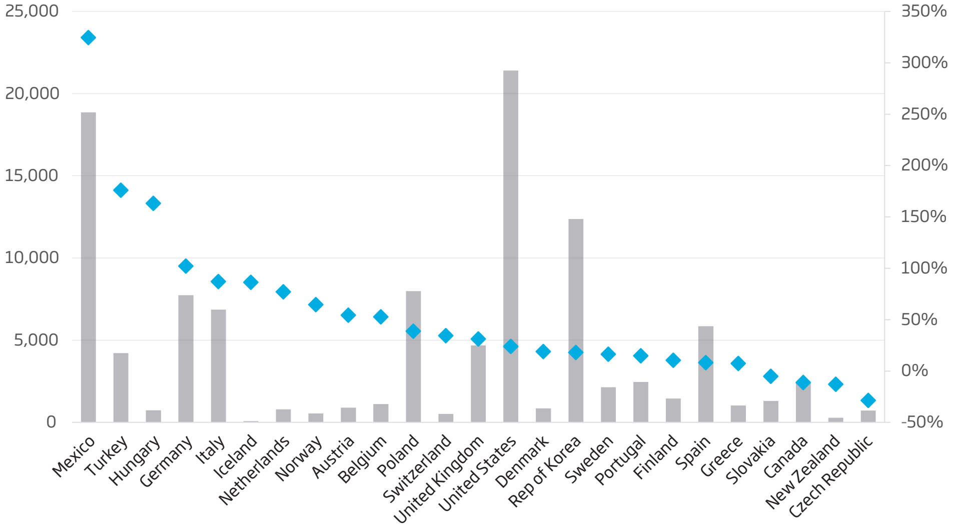
[65] US Bureau of Economic Analysis

[66] 'Interest' in engineering is not defined within the Queen Elizabeth Prize for Engineering report – the definition is determined through the judgement of the individual respondent.

Figure 8: Absolute number of female engineers in 2012 (LHS), percentage change in the number of female engineering graduates over the period 2008-12 (RHS), OECD Countries



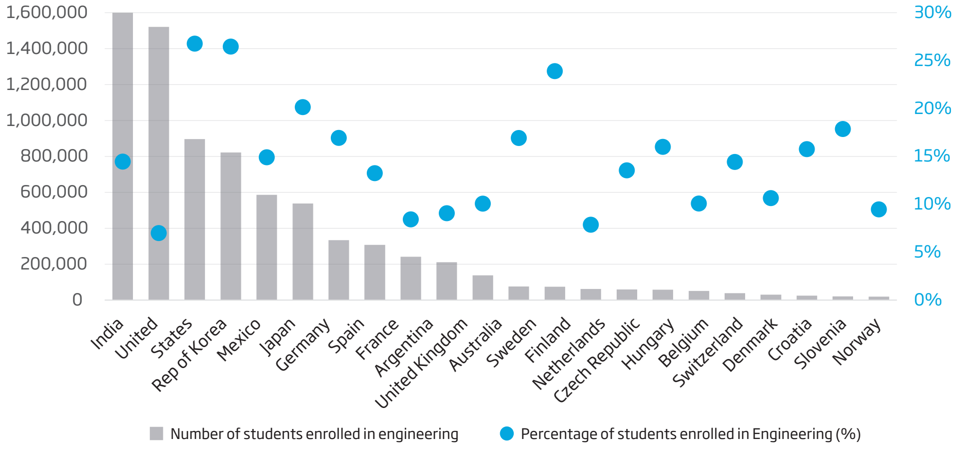
Note: Data not available for France, Australia, Ireland and Japan
Source: OECD, Cebr analysis

3.4 Focus on CAETS countries

In this sub-section, we focus on the engineering human capital of the 26 countries in the CAETS network. We find that the number of engineering students and graduates[67] varies significantly across the country grouping. The data highlights that the Republic of Korea and Mexico perform well both in terms of the absolute number of engineering students and the proportion in tertiary education enrolled in the subject, with 27% and 26% of students enrolled in these courses in each country respectively, as illustrated in Figure 9 below. Meanwhile, many of the more developed countries, such as the US and the United Kingdom, have a much lower proportion of students enrolled in engineering programmes, 7% and 9% respectively.

> ... many of the more developed countries, such as the US and the United Kingdom, have a much lower proportion of students enrolled in engineering programmes.

Figure 9: Number of students in tertiary education enrolled engineering, manufacturing and construction programmes (LHS), % of students in tertiary education enrolled in engineering, manufacturing and construction programmes (RHS), CAETS countries[68], latest year[69]



Source: UNESCO, Cebr analysis

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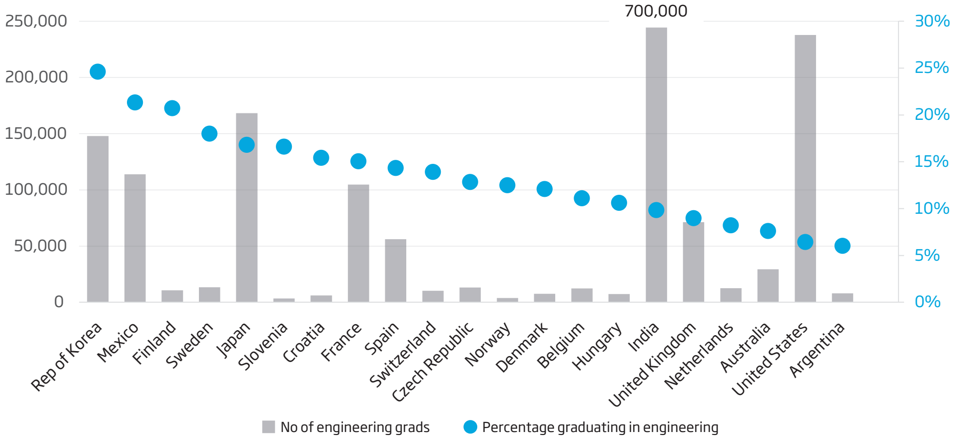
[67] Based on the UNESCO classification of engineering, manufacturing and construction programmes.

[68] Note that one or both sets of data were unavailable for Canada, China, Uruguay and South Africa.

[69] 'Interest' in engineering is not defined within the Queen Elizabeth Prize for Engineering report – the definition is determined through the judgement of the individual respondent.

In the Republic of Korea and Mexico, the proportion of engineering graduates is significantly higher than in many other CAETS countries at 25% and 21% respectively, as shown in Figure 10:

Figure 10: Number of graduates from engineering, manufacturing and construction related subjects (LHS), % of students in tertiary education graduating from engineering, manufacturing and construction programmes (RHS), CAETS countries[70]*, latest year*[71]



Source: UNESCO, Cebr analysis

Subject areas in which CAETS country students graduate

Given the small percentage of engineering graduates in many countries, it is worth considering what subjects students are graduating in. Data from UNESCO indicates that across almost all CAETS countries, the majority of students graduate in 'social sciences, business and law'. The exception to this trend is the Republic of Korea where, while 21% graduated in the social sciences, 25% graduated in engineering, as illustrated in Figure 11.

Therefore, while it is not clear precisely how many engineers a country needs (this will also vary from country to country), it is clear that the subject is struggling to attract students to the same extent as the social sciences, business and law. Given the amount of literature detailing engineer shortages, which we discuss in later sections, it is likely that the current share of engineering graduates across many countries is insufficient to meet the demand.

> Data from UNESCO indicates that across almost all CAETS countries, the majority of students graduate in 'social sciences, business and law'.

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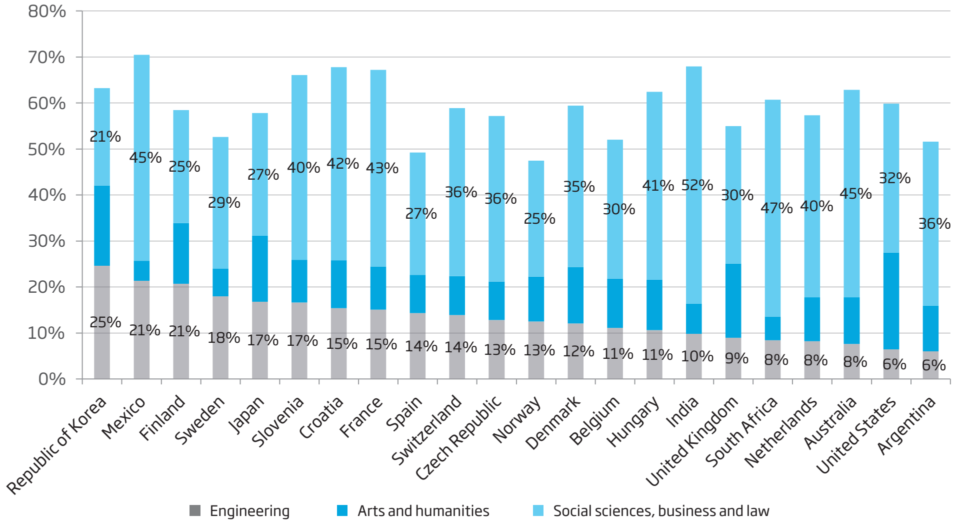
[70] Note that one or both sets of data were unavailable for Canada, China, Germany, Uruguay and South Africa.

[71] By this, we mean that the majority of data is from 2013 or 2014, with some exceptions depending on data availability.

Figure 11: Percentage of students graduating in engineering, manufacturing and construction; arts and humanities; and, social sciences, business and law, CAETS countries,[72]*, latest year*[73]



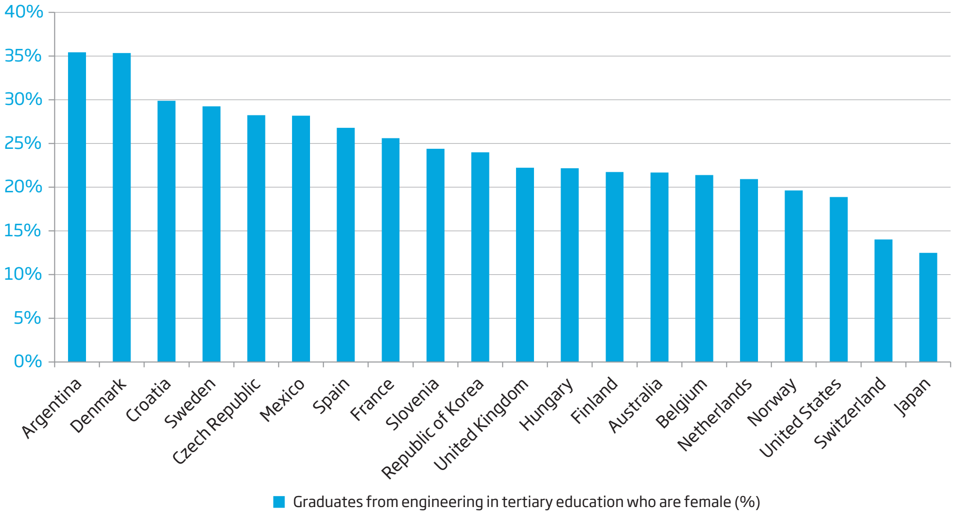
Source: UNESCO, Cebr analysis

Engineering gender split in CAETS countries

The number of women in engineering is an important issue, with many countries endeavouring to increase their numbers of female engineers and make greater use of this under-utilised share of the workforce. In terms of the absolute number of female engineering, manufacturing and construction graduates, the Republic of Korea and Mexico again perform well with an estimated 35,400 and 32,100 female graduates in the field respectively. This puts them just behind the US with approximately 44,900 female engineering, manufacturing and construction graduates. Argentina and Denmark lead the way at approximately 35%, as shown in Figure 12.

India and South Africa also perform well based on this measure, with around 30% of engineering, manufacturing and construction graduates being female. Yet, a number of developed countries perform particularly poorly, such as Japan, where although it has a relatively high number of engineering graduates (168,200), only 12% are female.

Figure 12: Percentage of graduates from engineering, manufacturing and construction programmes in tertiary education who are female (RHS), CAETS countries[74]*, latest year*[75]



Source: UNESCO, Cebr analysis

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[72] Note that there is no data available for Canada, China, Germany or Uruguay.

[73] By this, we mean that the majority of data is from 2013 or 2014, with some exceptions depending on data availability.

[74] Note that one or both sets of data were unavailable for Canada, China, Germany, Uruguay and South Africa.

[75] By this, we mean that the majority of data is from 2013 or 2014, with some exceptions depending on data availability.

4. Future engineering: emerging and growing engineering sectors

In this section of the study, we consider factors that may affect the need for different types of engineering in coming years and decades, as well as those that could affect future engineering capacity and the supply of engineering skills. Those engineering sectors that will be in high demand in the future are likely to be closely aligned to the demands of countries with high infrastructure growth, which are discussed in Section 5.

4.1 Emerging areas of engineering

In this sub-section, we consider the potential for different engineering disciplines to grow in importance over the coming years. We begin by looking at the role that engineering has played to date in aiding development and consider how these existing roles may change. We then look at increasing urbanisation across the globe and the impact this will have. We include the views of engineering experts on what they perceive to be the emerging areas of engineering.

The current and future role of engineering

According to UNESCO, engineering has been, and will continue to be, challenged with designing systems that facilitate education and healthcare, enhance quality of life, and help to eliminate global poverty. It considers that the development of technological approaches that can help prevent or mitigate hostile acts[76], reduce the impact of natural disasters, and motivate humans to reduce their use of the earth's valuable resources, will be key challenges for engineering in the coming years. Alongside these, we can expect that engineering will continue to play a key role in helping to avert environmental crises, as well as helping to reduce poverty – for example through engineers providing community infrastructure.[77]

Engineering already plays an important role in managing and conserving resources, from water to food, energy and materials. For example, engineering skills have been essential in ensuring the development of systems relating to water and wastewater treatment. Given that some parts of the world still lack access to water, engineering skills will remain essential to ensure universal access to clean water and sanitation. Engineering has also been extensively involved in finding solutions to reducing carbon emissions alongside ensuring increased portions of the world's population have access to sustainable power. Engineering's role in this area is likely to continue to be important in the coming years, especially as in 2015 it was estimated that 2.8 billion people still did not have access to modern energy services, and that over 1.1 billion people were without electricity.[78]

In addition, with the global population expected to grow to 9.7 billion by 2050[79], engineering will become increasingly important in ensuring future food security. For example, by ensuring that there are sustainable food production systems in place that maintain ecosystems, and by helping to improve land and soil quality. Over and above

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[76] A hostile act is an attack or other use of force.

[77] Singleton, D. Arup. Brunel International Lecture 2002-2003. *Poverty Alleviation – the role of the Engineer*

[78] **https://sustainabledevelopment.un.org/topics/energy/** accessed on 22 June 2016.

[79] UN world population projections (2015), **http://www.un.org/en/development/desa/news/population/2015-report.html**

these growth areas, UNESCO envisages new challenges for engineering across four key areas: materials, energy, information and systems and bioengineering. Each of these fields will require engineers across a range of disciplines to ensure future innovations and success. Therefore, having sufficient numbers of engineering graduates and professionals focusing on engineering for development in these areas will be essential both now and in the future.

Urbanisation

According to the UN, in 2014 54% of the world's population lived in urban areas. This is expected to increase to 66% by 2050, with the majority of the increase concentrated in Asia and Africa. In absolute terms, the urban population of the world grew from 746 million in 1950 to 3.9 billion in 2014. This figure is expected to surpass six billion by 2045.

This urbanisation will come with its own challenges and engineers will be involved in meeting the needs of growing urban areas, such as ensuring that there is adequate housing, water, sanitation, electricity and telecommunications. Engineers can also help to ensure that those living in urban areas have a good quality of life, for example by reducing congestion and pollution. According to the UN, "managing urban areas has become one of the most important development challenges of the 21st century." [80]

Key findings from expert interviews

We asked engineering experts as part of our interview programme where they thought the demand for specific engineering fields would lie in the coming years. Each respondent gave a different answer, highlighting not only the breadth of engineering but also how, globally, there is a requirement for engineers across a variety of fields.

"The world is going digital, which will require a breed of engineers who are more literate in high-tech areas like nanotechnology, materials engineering, ICT"

Thinking globally, and linked to the next wave of innovation, Martin Manuhwa stressed that: "The world is going digital, which will require a breed of engineers who are more literate in high-tech areas like nanotechnology, materials engineering, ICT." [81] Closely related to this, he predicted that engineers in the field of sustainability and renewables will be in high demand in order to meet the future needs of the world.

Mike McWilliams explained that environmental engineering[82] is a growing area, a field that was practically non-existent 20 years ago. This may have been driven by increased technological development and population growth, which are both putting greater demands on the environment. More environmental engineers will be required to help deal with ecological damage and climate change. Furthermore, climate resilience engineering (a strand of engineering closely linked to civil engineering), is expected to become important in coming years, with greater climate change and a growing population demanding more reliable infrastructure.

Considering Africa specifically, Dr Allyson Lawless emphasised the important role of agricultural engineering, which needs to be expanded to improve productivity and address poverty. Furthermore, Professor Calestous Juma considered that civil engineering will play an important role in Africa in the future because of growth in the transportation and housing sectors. He also predicted that there will be demand for mechanical engineers and electronic engineers due to increasing transportation and Africa's emphasis on IT and communications technology.

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[80] John Wilmoth, Director of UN DESA's Population Division.
http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html

[81] Ibid

[82] Environmental engineering is the branch of engineering concerned with the application of scientific and engineering principles for the protection of human populations from the effects of adverse environmental factors.

Across the world, automation is likely to play a key role in shaping the future of engineering, for example, some activity of electrical engineers can be automated and completed within a fraction of a second by computers. The journal *Computers and Electrical Engineering* highlights the significant impact that computers have had on the field of electrical engineering, with the design, analysis and operation of electrical and electronic systems now dominated by computers.[83]

4.2 Popular engineering industries by area of study - United Kingdom

In this sub-section, we consider popular engineering industries by area of study. By looking at this measure, we consider whether there are engineering fields that are more popular with students relative to others. While it is likely that more engineers are required in some disciplines than others, in some cases, the demand for certain engineering skills far outpaces the supply. For example, Tim Askew pointed out that while United Kingdom industry often comments on the skills shortage across engineering, digging deeper would suggest that there are particularly acute shortages in certain types of engineer – such as materials engineers. As such, businesses affected have to look to engineers from other parts of the world to fill these vacancies.

In the United Kingdom in 2014/15, of the total engineering qualifications obtained (45,005)[84], the majority were in electronic and electrical engineering (10,585). This remains true even when degree level qualifications are considered (9,120).[85] This may reflect a higher demand for engineers within this area of expertise, or greater awareness of this engineering industry. Aerospace engineering and 'chemical, process and energy engineering' were notably less popular choices, with 2,920 and 3,565 degree level qualifications obtained in these subjects in 2014/15, as illustrated in Table 2. This suggests that these engineering industries may be less well understood among students, which is discouraging take up of degrees in these areas.

The total number of engineering students compares with a total of 50,020 degree or higher qualifications in creative arts and design in the same year, and 121,350 degree or higher qualifications in business and administrative studies. This illustrates the relative lack of graduates in engineering compared to other fields in the United Kingdom.

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[83] **http://www.journals.elsevier.com/computers-and-electrical-engineering/**

[84] Including just higher degrees, other postgraduate and first degrees, the total for engineering amounted to 39,820 in 2014/15.

[85] i.e. excluding foundation degrees, HND/Dip HE and other undergraduate qualifications.

Table 2: Qualifications of United Kingdom engineering students, 2014/15

	Total higher degree	Total other graduate	Total first degree	Total degree or higher qualifications	Total other	Total qualifications obtained
Computer science	4,230	485	10,995	**15,710**	2,220	**17,930**
Electronic and electrical engineering [92]	3,680	250	5,190	**9,120**	1,465	**10,585**
Mechanical engineering	2,260	110	6,605	**8,975**	1,135	**10,110**
Civil engineering	3,400	235	4,305	**7,945**	690	**8,635**
General engineering	2,090	245	2,285	**4,615**	1,090	**5,705**
Chemical process and energy engineering	1,520	170	1,870	**3,565**	130	**3,695**
Aerospace engineering	895	55	1,975	**2,920**	455	**3,375**
Production and manufacturing engineering	1,105	70	805	**1,975**	190	**2,165**
Others in engineering	385	45	100	**530**	25	**555**
Metallurgy	140	5	35	**175**	5	**180**

Source: Higher Education Statistics Agency

According to the Institution of Engineering and Technology (IET), in the United Kingdom, demand for engineering skills is strong with 53% of employers of staff with engineering and technology skills reporting that they are currently seeking new recruits. Demand for engineering skills is observed across all sectors, with companies in construction, aerospace, computing and IT, electronics and transport experiencing higher than average demand for engineering and technology and skills, as illustrated in Figure 13.

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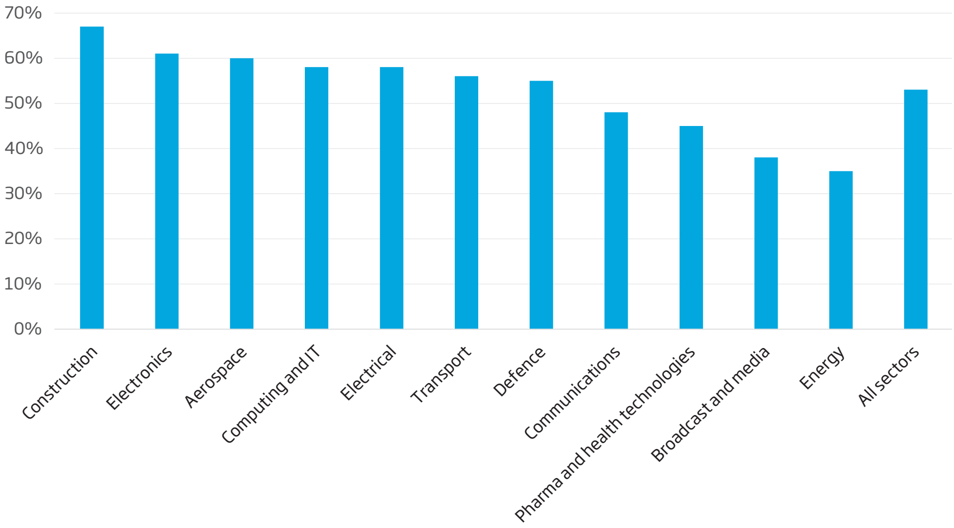
86 Encompasses: electronic and electrical engineering, electronic engineering, microelectronic engineering, integrated circuit design, electrical engineering, electrical power, electrical power generation, electrical power distribution, communications engineering, telecommunications engineering, broadcast engineering, satellite engineering, microwave engineering, systems engineering, digital circuit engineering, analogue circuit engineering, control systems, instrumentation control, control by light systems, robotics and cybernetics, robotics, cybernetics, virtual reality engineering, optoelectronic engineering, electronic and electrical engineering not elsewhere classified.

Figure 13: Share of engineering employers currently seeking new recruits with engineering and technology skills in the United Kingdom



Source: IET, 2015

However, whether the supply of graduate engineers in specific sectors will meet industry's demand in the United Kingdom is unclear. Given the lack of data on the number of students studying particular types of engineering, it is possible that United Kingdom industry itself is not aware where future engineering skills shortages will lie. In addition, engineers' skills are held in high regard in many fields. This means that while it can appear that the supply of engineering graduates is relatively healthy, this is not reflective of the true number that go on to become engineering professionals.

4.3 Engineering skills shortages

Globally, engineering appears to be experiencing a skills shortage.

The type of engineering that students are studying does not always match the type of engineers required by specific countries. In addition, just because people are studying engineering, it does not mean there will be sufficient amounts of engineers to meet demand, as many engineering graduates choose to take employment in fields other than engineering, shrinking the pool of available engineers. Sir James Dyson OM CBE FREng FRS, inventor of the Dyson vacuum cleaner, has previously emphasised that his company can fill all its engineering vacancies in Singapore and Malaysia but struggles to fill positions in the United Kingdom.[87] This may in part be due to a mismatch in the engineering skills between these countries, with the United Kingdom not producing enough engineers in a specific engineering discipline, as opposed to in general.

In South Africa, engineers dominated the scarce skills list in 2014, as highlighted in Table 3.[88] There, the biggest skills gap was in electrical engineering, followed by civil and mechanical engineering.

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[87] **http://www.telegraph.co.United Kingdom/finance/newsbysector/industry/engineering/10287555/Shortage-of-engineers-is-hurting-Britain-says-James-Dyson.html**

[88] The occupations are defined as 'scarce' because either such skilled people are not available or they are available but do not meet criteria.

Table 3: South Africa National Scarce Skills List (number 1 is most scarce), 2014

Rank	Occupational title	Rank	Occupational title
1	Electrical engineer	11	Construction project engineer
2	Civil engineer	12	Mining engineer
3	Mechanical engineer	13	Accountant (general)
4	Quantity surveyor	14	Energy engineer
5	Programme or project manager	15	Materials engineer
6	Finance manager	16	Electronics engineer
7	Physical and engineering science technicians	17	Metallurgical engineer
8	Industrial and production engineers	18	Public health manager
9	Electrician	19	Telecommunications engineer
10	Chemical engineer	20	Energy engineering technologist
			Millwright

Source: South African Department for Higher Education and Training

> **"In the short to medium term, the quality of training is the largest problem facing African countries"[89]**

South Africa is not the only African nation suffering shortages in engineers. A 2013 study by the Royal Academy of Engineering found evidence of shortages of engineers in Rwanda, Mozambique, Malawi and Tanzania, and a lack of data in many other countries.[90] In addition, the study found notable levels of unemployment among engineering graduates, suggesting that these shortages may go beyond the issue of supply. There is a great deal of existing literature that questions the quality of engineering degrees from some universities, suggesting that graduates do not have the right skills and experience to secure engineering employment. Professor Calestous Juma also highlighted the insufficient level of training for engineers in Africa, which acts as a constraint on the advancement of engineering on the continent.

Furthermore, it is possible that in Africa, the need is not just for more engineering education alone. African countries may also require more capital and investment in infrastructure to support engineers and help them get exposure to more challenging engineering projects to further their careers and knowledge. Retaining the top engineering talent in the continent is also an issue. Many of the well-qualified engineers in Africa, who graduate from the top universities, choose to go to other continents, such as Europe and North America rather than staying in Africa.

The shortages of engineers in different disciplines across the world highlights the importance of ensuring that the right talent and skills are available in the sector, a critical factor in allowing engineering to continue to make its key contribution to economic development.

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[89] Martin Manuhwa, ibid.

[90] It also found a lack of data in relation to skills shortages for many African countries.

4.4 Public perception of engineering

In many developed countries, despite the significant impact that engineering has on people's lives, many remain unaware of the full breadth of opportunities in and impacts of engineering. The Queen Elizabeth Prize for Engineering report, *Create the Future*,[91] highlighted that the way in which engineering is viewed by people varies significantly across cultures. In this report, Paul Westbury CBE FREng, Group Technical Director at Laing O'Rourke, discussed the fact that the engineering profession still struggles to "broadly and accessibly communicate what it does". He argues that "more work is needed to communicate what we do" and that the profession needs to be clear about the positive impact that it has on the world around us.

In the United Kingdom for example, this lack of awareness could be the result of the broad definition of the term 'engineer', encompassing both chartered engineers as well as engineering technicians. The Royal Academy of Engineering and the United Kingdom Engineering and Technology Board commissioned a survey in 2007 that highlighted that in the United Kingdom, people have limited awareness and knowledge of engineering.[92] While engineering as a profession was viewed positively and perceived as making a good contribution to society, young people in particular were found to have a limited understanding of engineering, which is likely to impact their decision to study the subject. In the Queen Elizabeth Prize for Engineering report, Steve Holliday FREng, Chief Executive of the National Grid, emphasised that there is an outdated idea that jobs in the engineering sector are "grubby, underpaid and 'not for girls'".

These findings, alongside those from our interview programme, highlighted earlier in the report, suggest that more can be done to improve the perception of engineering. While many people hold engineering in high regard, there appears to be a lack of understanding of what an engineer does. Some of this is a result of the misinterpretation of the word 'engineer' – with it used interchangeably for both those with a degree qualification and those classified as a technician. Further to this, there is a lack of cohesion in engineering qualifications across the world, with insufficient engineering institutions in some countries leading to varying standards in the quality of engineering education. In many, often developed countries, it appears that more needs to be done to aid people's perception of engineering and to break down stereotypes.

In addition, work carried out by non-governmental organisations, foundations and private companies in developing countries can also act to improve the perception of engineers and promote engineering, when publicised effectively. This allows the public to clearly see the positive impact engineering has on society and the how it can make a difference to people's lives.

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[91] Queen Elizabeth Prize for Engineering report, 2015. *Create the Future*. Available at; **http://qeprize.org/wp-content/uploads/2015/11/QEPrize-Create-the-Future-Report.pdf**

[92] Source: **http://www.raeng.org.United Kingdom/publications/other/public-attitude-perceptions-engineering-engineers** accessed on 22 June 2016.

5. Infrastructure and the need for engineering

The potential for engineering to contribute to a country's economic development is not something that can be considered in a vacuum. The quantity and quality of existing infrastructure is important, as this determines the scope for catch-up growth and hence the impact that engineering can have.

Looking at those countries and regions that are in need of engineering and are seeing infrastructure investment has informed some of the indicators used within our Engineering Index. Specifically, the index uses data on the 'quality of overall infrastructure' from the World Economic Forum (WEF) and also considers digital infrastructure within the index, by looking at the number of internet servers per one million people.

5.1 Affordability of infrastructure

Infrastructure has a high capital cost, meaning that affordability can be a significant factor in determining investment in infrastructure. From our interview programme, we understand that a key issue is a lack of access to public sector finance to develop the required infrastructure in developing countries. Furthermore, mobilising private sector finance can also prove to be a challenge.

However, it appears that in Asia, affordability is less of an issue, with the Chinese investing across a broad range of infrastructure projects, for example the OBOR project. The Asian Infrastructure Investment Bank (AIIB) was also set up as a bank dedicated to lending for projects relating to infrastructure.

The number of Chinese investments made across the world have been steadily increasing over time. This is the result of the Chinese government encouraging and supporting Chinese investment overseas in order to support the Chinese economy. Over the period 2010-15, the largest investment made by China was the China National Offshore Oil Corporation's (CNOOC)[93] investment in Nexen, a Canadian oil and gas company, which was purchased by CNOOC for $15 billion. Over this period, Europe was the main destination for Chinese investment, with 153 deals. This was followed by the US (113 investments) and East Asia (109 investments). China owned just one project in Africa but was present in the funding of 13 projects and the construction of 42 projects. China's investments were focused primarily in the energy sector (187), followed by real estate (115). The annual value of China's global investments in transport increased by over 250% in this period. The value of Chinese investments globally over the period 2010-15 is illustrated in Figure 14.

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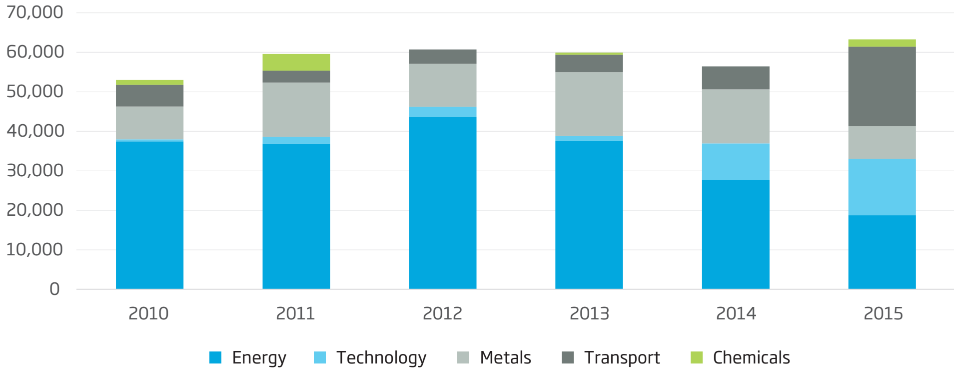
[93] China's largest producer of offshore crude oil and natural gas. It is a major subsidiary of China National Offshore Oil Corporation.

Figure 14: The value of Chinese investments globally, USD, 2010-15



Source: American Enterprise Institute, China Global Investment Tracker, Cebr analysis

Mike McWilliams also highlighted South America's success in attracting inward infrastructure investment. This "could be attributable to its credit ratings or its ability to provide sovereign guarantees and make the infrastructure projects bankable". He commented that funding infrastructure projects in Africa appears to be becoming much harder. Yet, with returns on investment elsewhere much lower, infrastructure is increasingly seen as a good investment.

5.2 Quality of existing infrastructure

The WEF Global Competitiveness Index[94] records how people perceive the 'quality of infrastructure' in their countries. Using this measure, we find that the majority of highly scoring nations are developed. CAETS countries are also well represented in the top 20, with Switzerland coming top across 135 economies. Figures 15 and 16 show the top and bottom-ranked countries.

However, while many of the CAETS countries perform well, Argentina is in the bottom 20 countries in terms of the quality of overall infrastructure measure, with a score of three. This suggests that it requires more infrastructure investment to enable it to 'catch-up' with other economies. The bottom 20 countries are populated by those in sub-Saharan Africa and South America, highlighting the potential for these economies to harness the power of engineering to enhance their infrastructure.

Economies that score poorly in relation to physical infrastructure could derive significant benefits from increasing road, rail and port density so as to increase the ease of doing business. Increasingly, ICT infrastructure, such as telephone lines and broadband access, is also an important area to aid communication and ease financial transactions between trading partners.[95] Professor Calestous Juma highlighted that some countries in Africa are unable to increase their exports, as they do not have a road connected to the coast. Many people do not recognise this as an engineering issue but it is essential that engineers build the relevant infrastructure capabilities to enable growth and development. For example, according to the Food and Agriculture Organization of the United Nations, in 2013 Nigeria produced 53 million tonnes of cassava, accounting for 19% of world output. However, Nigeria only exported 510 tonnes, which is 0.0047% of international cassava trade. Professor Juma identified that part of the problem for Nigeria is that cassava is produced in states with no all-weather roads connecting to ports. Thailand, in contrast, produced 30 million tonnes and exported 8.2 million tonnes

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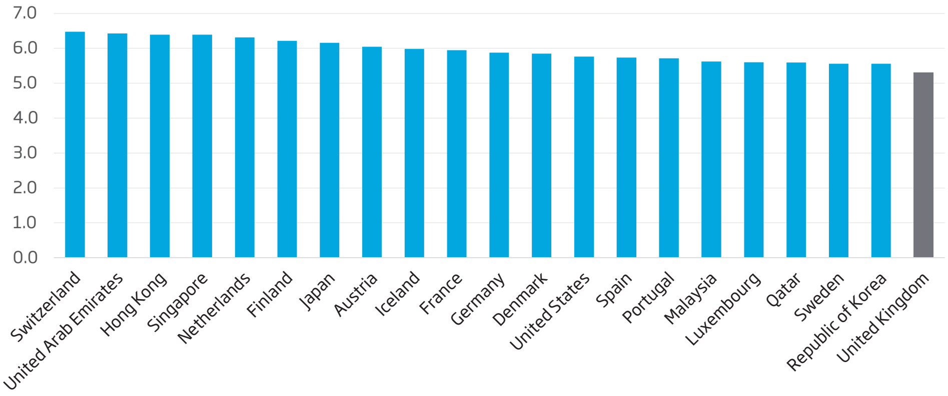
[94] **http://www.un.org/en/development/desa/population/theme/urbanization/index.shtml**

[95] Ismal, N. and Mahyideen, J.,2015, The impact of infrastructure on trade and economic growth in selected economies in Asia , ADBI Working Paper 553.

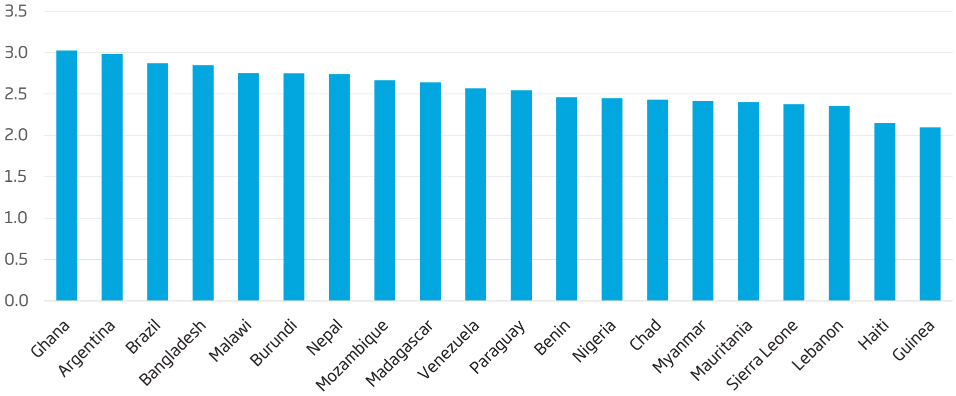
earning $2.5 billion and accounting for 76% of world cassava trade in 2013. Professor Calestous Juma also commented that most of the existing railway networks, for example, were designed to move traditional cash crops and minerals from Africa's interior to a few ports. This has left large parts of the continent with no ability to export new products, especially from agriculture, and it is only now that African countries are starting to explore how to extend them to agricultural areas.

Figure 15: Top countries by their score on the WEF Global Competitive Index (GCI) 'quality of overall infrastructure' metric (1 = extremely underdeveloped, 7=well developed and efficient by international standards); country-level data from 2014 (United Kingdom included for comparison)



Source: World Economic Forum Global Competitiveness Index

Figure 16: Bottom 20 countries by their score on the WEF GCI 'quality of overall infrastructure' metric (1 = extremely underdeveloped, 7=well developed and efficient by international standards); country-level data from 2014 for 135 economies



Source: World Economic Forum Global Competitiveness Index

To continue and expand this growth across other African economies, infrastructure growth, and consequently the need for engineering, is imperative.

5.3 The need for engineering

Africa

According to the 2014 International Monetary Fund (IMF) World Economic Outlook, over half of the world's fastest-growing economies globally were in Africa. To continue and expand this growth across other African economies, infrastructure growth, and consequently the need for engineering, is imperative. Engineering in Africa is largely focused on addressing the challenges of capacity building and sustainable development.

The need for infrastructure growth in African countries is further driven by rapid urbanisation across the continent. According to the UN Population Division[96], Africa has 22 of the 30 countries with the highest average annual percentage change in urban population in the world. Rwanda tops the list of African countries that have seen their urban population increase fastest between 2010 and 2015, at 6.4% per year. This is followed by Burkina Faso (5.9%), Burundi (5.7%) and Uganda (5.4%). This will increase demands for water, transportation, food, housing and sanitation in these countries, all of which depend on engineering.

Existing research by the Royal Academy of Engineering[97] has found that infrastructure development in sub-Saharan Africa significantly lags behind that of other developing regions. It is well understood that the region suffers from poor road and electricity infrastructure, among other areas of need. This leads to issues such as power shortages, fractured road networks and limited access to services. To develop its infrastructure, in turn supporting economic growth, the region needs access to engineering and the skills and services required to undertake major infrastructure projects.

One example of where infrastructure has aided economic development is Kenya, which has made significant investment in energy, particularly renewables, such as geothermal, hydro and wind.[98] These investments have been supported by favourable regulatory frameworks such as the National Energy and Petroleum Policy. The investments have helped to provide more access and to lower energy costs for people across the country, with electricity costs estimated to have fallen recently by about 30%, attributed to heavy investment in geothermal energy.[99] Increased energy infrastructure will have supported farming and manufacturing and enabled schooling and better medical care.[100] In addition, businesses are able to flourish and in turn, create new jobs. Therefore, this investment in energy can be expected to have played a role in supporting Kenya's economic development.

As part of the interviews for this research, Dr Allyson Lawless highlighted that in South Africa, large-scale investment in infrastructure associated with winning the bid for the 2010 World Cup, and recognising the need for additional economic infrastructure, played a role in increasing GDP growth in the preceding years (except for the temporary shock experienced when the worldwide recession hit in 2008).[101] This scenario also highlights the importance of sufficient and ongoing finance for infrastructure projects, so that they can realise their full potential.

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[96] **http://www.un.org/en/development/desa/population/theme/urbanization/index.shtml**

[97] Africa-United Kingdom Engineering for Development Partnership (October 2012), 'Engineers for Africa: Identifying engineering capacity needs in Sub-Saharan Africa'. Available at: **http://www.raeng.org.United Kingdom/publications/reports/engineers-for-africa**

[98] Torrie, M., 2014. *Future of Kenyan Electricity Generation.*

[99] **http://cleantechnica.com/2015/03/02/electricity-cost-decreases-30-kenya-due-geothermal/**

[100] **http://www.afdb.org/en/blogs/afdb-championing-inclusive-growth-across-africa/post/renewable-energy-in-africa-8829/**

[101] The International Development Corporation (2013) *South African economy: an overview of key trends since 1994*, reports an average growth rate of 3.3% p.a. between 1994 and 2012. There was also a substantial acceleration in fixed investment spending averaging 12.2% p.a. between 2003 and 2008, with a steep rise in fixed investment in construction works. Large infrastructure investment programmed included the 2010 FIFA World Cup, rail links, investments in energy infrastructure, etc.

Based on this evidence, alongside the WEF Global Competitiveness Index evidence shown above, it appears that there is a significant need for engineering in many of the African nations. However, the extent to which there is a need in each individual African country is unclear, largely due to a lack of data on what is currently there, and what infrastructure would be best suited to help the country. However, we note that while Africa has a clear need for engineering, we expect that many projects may suffer because of declining commodity prices.

In 2015, Deloitte[102] highlighted East Africa as an area of the continent that has seen significant progress in terms of infrastructure building and expansion, with the region representing 20% of all projects in Africa in that year. According to Deloitte[103], in 2015 the total value of projects under construction in Africa increased by 15% year on year, to reach $375 billion. These projects are largely government owned (71%, 214), followed by private domestic owners (13%, 38). China owned just one project but was present in the funding of 13 projects and the construction of 42 projects. Alongside the existing investment in energy infrastructure, Africa is likely to need to invest in transport infrastructure to facilitate both domestic and international trade, thereby supporting economic growth.

Ethiopia, in East Africa, is one country that looks set to see increased demands for engineering in the coming years. It is the second most populous country in sub-Saharan Africa, and has one of the fastest-growing economies in the world. With such a large population and fast growth, the country is likely to require further engineering capacity. Ethiopia formed a fully fledged Industrial Development Strategy (IDS) in 2002/03. This was followed by various sub-sector strategies and successive development plans such as the Sustainable Development and Poverty Reduction Programme (SDPRP) 2002/03-2004/05; Plan of Action for Sustainable Development and Eradication of Poverty (PASDEP) 2005/06-09/10; the Growth and Transformation Plan (GTP) 2010/11-15/16. Each of these strategies will require engineering's contribution to help achieve their goals. In addition, Ethiopia appears to recognise the importance of engineering capacity, with its education sector shifting its focus towards engineering-related programmes.

The potential for engineering to drive growth was emphasised by the experts we interviewed. Martin Manuhwa highlighted that once Africa collectively starts to devote a greater share of its resources to infrastructure development, engineering will take on even greater importance in the development of the continent. Professor Calestous Juma emphasised that "regional integration is likely to drive the need for engineering in Africa." He commented that because many African markets are currently small and fragmented, the role of engineering is presently limited to facilitating imports. In Professor Calestous Juma's view, "greater investment in engineering relating to manufacturing" and "greater levels of regional integration" are needed. Furthermore, increasing globalisation opens up more potential sources of inward investment in Africa, creating greater potential for economic development in heavily underdeveloped areas.

There have been a number of significant infrastructure projects across Africa, for example the East Africa Railway in Kenya (the first section was close to completion as of May 2016), the Grand Ethiopian Renaissance Dam in Ethiopia (40% complete as of 2014) and the Karuma Power Station in Uganda (to be completed in 2018) to name but three. The majority have been undertaken across a range of sectors, from energy and power to transport and agriculture. These projects are regularly undertaken by overseas

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[102] Source: **https://www2.deloitte.com/content/dam/Deloitte/za/Documents/manufacturing/ZA-ConstructionTrendsReport-2015.pdf**

[103] Source: **https://www2.deloitte.com/content/dam/Deloitte/za/Documents/manufacturing/ZA-ConstructionTrendsReport-2015.pdf**

engineering companies, particularly those from Europe and the US. In order to ensure sustainable engineering capacity and associated economic growth, it will be important for Africa to build a robust indigenous engineering workforce in the coming years that is aware of the individual complexities of different African regions and where and what type of infrastructure is most needed.

Latin America

In Brazil, Latin America's biggest economy, infrastructure investment has fallen from 5.2% of GDP in the early 1980s to 2.5% of GDP in 2013, accentuating Brazil's infrastructure gap.[104] However, several rounds of spending plans have been announced, and in 2016, Brazil is expected to see the greatest level of Chinese investment of all Latin American countries. Energy infrastructure is important for Brazil; the China Three Gorges Corporation's Brazilian arm won auctions as the sole bidder for two hydroelectric plants in November 2015. China's State Grid is also developing two transmission lines delivering power from the Belo Monte Dam to south-east Brazil. Elsewhere in the region, Chile has also been expanding its infrastructure investment, with its roads and urban transport requiring significant levels of investment, followed by its energy sector. It has made significant investments in its renewable energy industry that will require engineering expertise and contribute to economic development.

The majority of respondents in a survey by the *Financial Times* expected Chinese investment in Latin America to increase in 2016.[105] As such, it seems reasonable to expect that Latin America will see an increased need for engineering. However, in terms of its specific engineering requirements, little existing literature exists that specifies the type of engineers it requires.

Other continents

Consistent with the finding earlier in the report that it is set to experience high infrastructure growth, India has also experienced significant growth in its urban population, which is predicted to increase by 500 million over the next 40 years.[106] This will naturally require additional infrastructure spending in sectors such as energy and telecommunications.[107] However, 'bottlenecks' – such as poor quality planning and contracts, land acquisition delays, below-par engineering skills and insufficient skilled manpower have been identified as hampering the development of infrastructure in India.[108]

Denmark, previously a leader in ship-building, is now a key player in biomedical engineering and robotics.

Professor Calestous Juma highlighted the strong demand for engineering in industrialised countries as well. For example, California, US, is taking the lead in electric vehicles and Denmark, previously a leader in ship-building, is now a key player in biomedical engineering and robotics. While some areas of the world may require infrastructure in the form of energy and transport, others will require more schools or infrastructure for their ageing populations. However, Professor Calestous Juma emphasised that for those countries that are yet to establish a strong basic level of infrastructure, the gains from engineering are likely to be the greatest.

We also note that while some countries and regions have the potential to experience rapid infrastructure development, especially as infrastructure spending increases, the extent to which this can be realised is dependent upon a number of factors. Infrastructure investment in many emerging markets has been hampered by the

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[104] IMF Working Paper WP/15/180, 2015. *Filling the Gap: Infrastructure Investment in Brazil.*

[105] Source:
http://www.ft.com/cms/s/3/c33c6854-2351-11e6-aa98-db1e01fabc0c.html#axzz4FcWvqyTO

[106] Cebr forecast

[107] UN Population Division of the Department of Economic and Social Affairs. *World Urbanisation Prospects*, 2012.

[108] McKinsey and Company, 2009. *Building India: Accelerating Infrastructure Projects.*

environment being challenging for investors, caused by falls in commodity prices, poor transport capacity in developing countries and the bottleneck factors described above. Engineering firms have also been plagued by unpredictable regulations and bureaucratic delays. Emerging markets will need to ensure that they provide a strong enabling environment for the infrastructure growth to occur, with the correct blend of economic, social and environmental factors to attract investment.

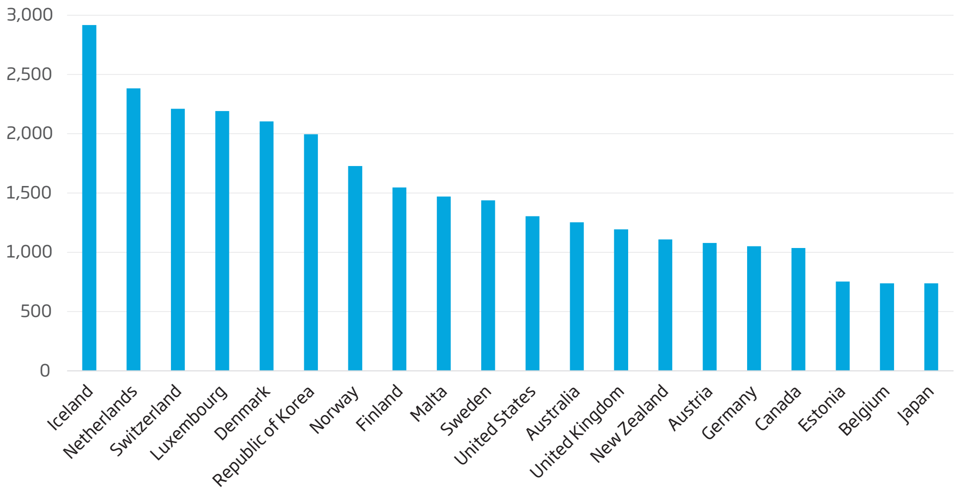
5.4 Digital infrastructure

Our Engineering Index also takes into account digital infrastructure, as communications networks are essential to economic growth and development. Communications infrastructure can drive an economy's efficiency, productivity and global integration. In addition, the quality of communications infrastructure can play a key role in the investment decisions made by domestic and foreign investors. Consequently, ICT infrastructure is a major tool in terms of economic development.

To capture the quality of communications infrastructure across the world's economies we use the number of internet servers per one million population (Figure 17). The greater the prevalence of internet servers across a country, the faster information can be shared. Quality communications infrastructure can facilitate efficient and effective business communication. We find that developed nations tend to have the highest quality of communications infrastructure, as measured by our proxy. This implies a strong correlation between quality communications infrastructure and economic development.

Figure 17 below illustrates that the Scandinavian nations such as Denmark, Norway, Finland and Sweden all had, on average, almost 2,000 internet servers per one million people in the population in 2013, suggesting that they have some of the highest quality communications infrastructure in the world. Other European countries such as Denmark, the United Kingdom, and Germany also rank well; however, Japan is the only Asian nation to appear in the top 20.

Figure 17: Top 20 countries by number of internet servers per one million population in 2013

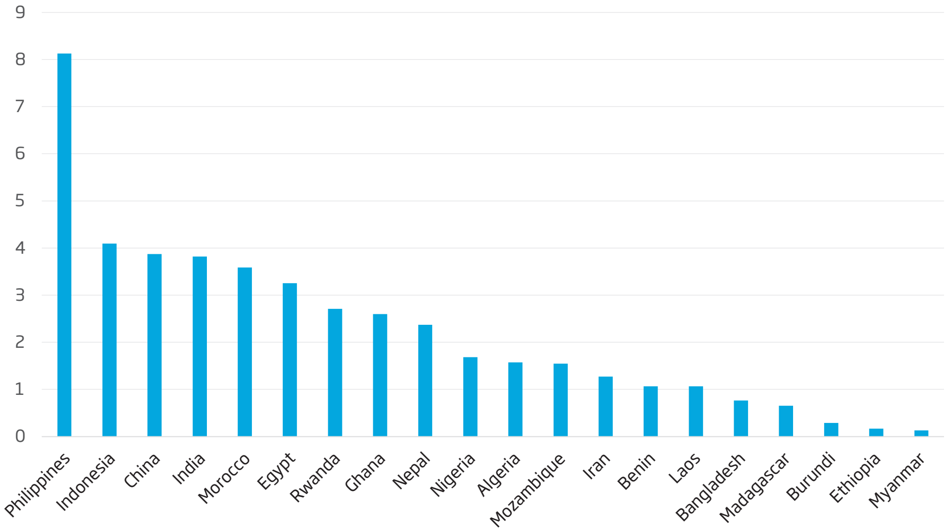


Source: WDI, Cebr analysis

By contrast, Asian economies and African nations are a main feature at the lower end of our scale (Figure 18). In fact, economies such as Myanmar, Ethiopia and Bangladesh have less than one internet server per one million population. Notably, China is the only major economy to appear at the lower end of our scale, with just under four internet servers per one million people in the population.

While communications technologies are an important function of government investment, private sector involvement is vital to lowering costs and ensuring value for money and accessibility. In addition, independent regulatory authorities have a significant role to play in encouraging competition and fair prices. Furthermore, to capitalise on the economic opportunities that telecommunications offer, access to and affordability of communication services to encourage usage is vital.

Figure 18: Lowest 20 countries by number of internet servers per one million population in 2013



Source: WDI, Cebr analysis

6. Engineering research

In this section of the report, we use data relating to the performance of universities to consider whether a country is engaging in cutting-edge engineering research, as well as looking at spending on research and development across countries. Research acts to stimulate innovation, with improved innovation leading to the creation of new goods and services. This in turn stimulates economic growth and development within countries. Some of the data presented in this section also helps to inform the Engineering Index, discussed in the next section of the report.

6.1 Engineering and academia

Universities
Using the *Times Higher Education* World University Rankings we investigated those countries that have engineering and technology departments that rank within the top 100 in 2015/16. A significant proportion of the CAETS countries performed well based on this measure, in particular the US, which had 31 engineering departments in the top 100, of which four were in the top five:

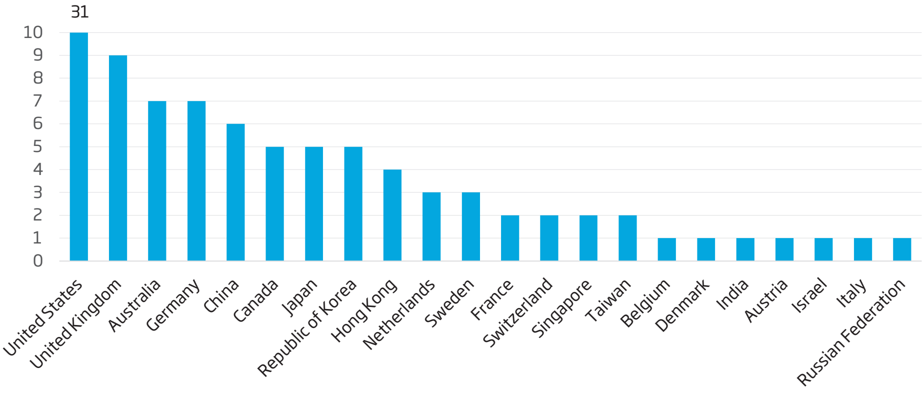
1. Stanford University, US
2. California Institute of Technology, US
3. Massachusetts Institute of Technology, US
4. University of Cambridge, United Kingdom
5. University of California, Berkeley, US

While no other countries came close to the US dominance in the ranking of engineering departments, the United Kingdom had nine in the top 100, and Australia and Germany each had seven engineering departments in the top 100. Excluding the CAETS countries, Hong Kong performed the best, with four engineering departments in the top 100. These results are illustrated in Figure 19.

The universities with engineering and technology departments ranked within the top 100 are mostly from developed countries. Therefore, while emerging countries are often drawing high numbers of students to study engineering, the quality of their engineering departments appear to lag behind those of developed nations.

> ... while emerging countries are often drawing high numbers of students to study engineering, the quality of their engineering departments appear to lag behind those of developed nations.

Figure 19: Number of university engineering and technology departments ranked within top 100, 2015-16, by country



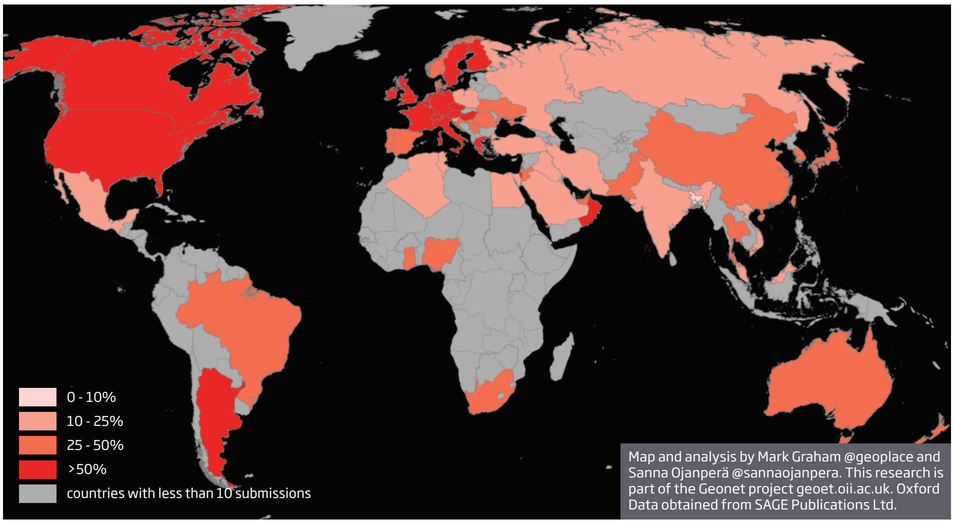
Source: *Times Higher Education* World University Rankings

Acceptance in engineering journals

In this sub-section, we consider the quantity of research papers from each country that are accepted into engineering journals. This measure provides an indication of the investment being made in engineering research within a country and the quality of its engineering research. Research acts to stimulate innovation, and innovation stimulates economic growth and development within a country.

Figure 20 below illustrates the acceptance rate to engineering and computing journals by the country of the submitting author. The highest-ranking contributors, with acceptance rates exceeding 50%, include the US, Canada, Argentina, France, Germany and the United Kingdom. The research also illustrates the relatively high prevalence of authors from Brazil as well as South Africa and China. Argentina appears to be performing particularly well in terms of acceptance, given its comparatively low take-up of engineering degrees. Oman also has a high acceptance rate for engineering and computing journals. Countries in Africa for which data was available – such as Egypt – had acceptance rates of less than 50%.

Figure 20: Acceptance rate (in percent) by country of submitting author to engineering and computing journals in 2014



Map and analysis by Mark Graham @geoplace and Sanna Ojanperä @sannaojanpera. This research is part of the Geonet project geoet.oii.ac.uk. Oxford Data obtained from SAGE Publications Ltd.

Source: Oxford Internet Institute, 2015

Our interview programme highlighted the close link between infrastructure spending in a country and the uptake of engineering courses, suggesting that the visibility of engineering and its impacts increases interest in studying it. A greater number of people studying engineering could increase the volume of academic research in engineering, which channels through to innovation and in turn growth and development. It is therefore interesting to note that Nigeria has both the highest number of infrastructure projects in West Africa, followed by Ghana, and a high acceptance rate of papers to engineering and computing journals of 25-50%, relative to other West African countries for which data is available.

6.2 Other indicators

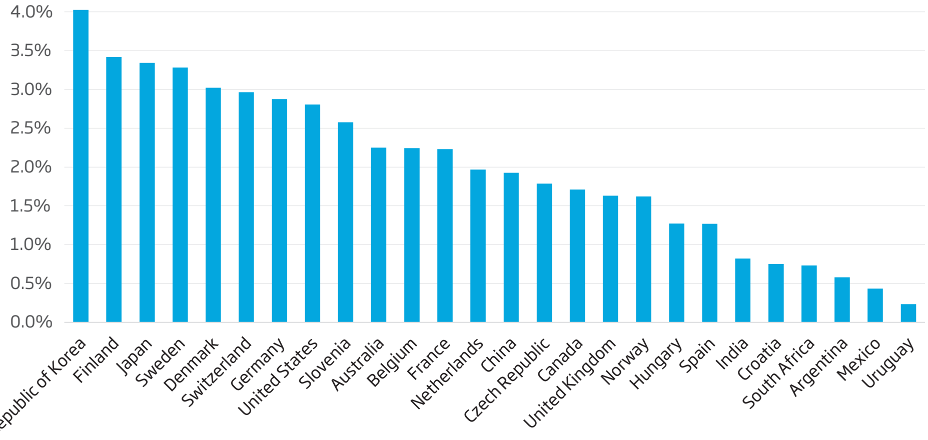
Alongside indicators directly related to engineering research, here we examine the extent to which different economies are investing in research. The capacity of a country to innovate is crucial to its economic development and growth. However, alongside having the capacity, it is also important that there is demand from businesses to use these innovations and research findings to help increase productivity and in turn, growth.

Spending on research and development

In the context of engineering, research and development is activity that aims to better understand problems, find new and innovative solutions or create new goods, services or management systems. It is important that firms are able to stay up to date with modern developments, to develop new production techniques and to constantly seek improved methods of production. This can in turn increase profitability and growth.

Across the CAETS countries, emerging economies spend a smaller proportion of GDP on R&D relative to more developed economies, as illustrated in Figure 21.

Figure 21: Research and development expenditure as a percentage of GDP, CAETS countries, 2012



Source: World Bank, Cebr analysis

Economic theory highlights the importance of accumulating R&D and human capital to support economic growth. It can act to increase productivity and output, as well as stimulating innovation. Those countries that spend a relatively low proportion of GDP on R&D may need to change policies to influence businesses' decisions to invest. At a 2007 summit, African Union (AU) leaders committed all AU countries to invest 1% of their GDP in R&D expenditure by 2010; South Africa is notably thought to have failed to achieve this target,[109] and it is unclear whether other African nations have achieved the target due to a lack of available data.[110] Adjustments to competition policy and regulation may prove to be beneficial to supporting greater levels of R&D investment.

Those countries that are engaging in high levels of R&D are likely to see their economic growth supported by this investment. Countries that perform strongly in terms of their R&D expenditure are also well represented in the acceptance to engineering journals measure detailed previously.

This suggests that those countries that commit relatively larger amounts of resource to R&D spending will be well placed to be able to lead new engineering discoveries and innovation. These countries include the Republic of Korea, the US, Japan, Canada, the United Kingdom, Germany and France. Notable exceptions include Argentina and Oman, which commit relatively low proportions of their GDP to R&D despite their high rates of acceptance to engineering journals.

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[109] University World News, 27th April 2013. "Survey shows failure to reach R&D target of 1% of GDP"

[110] African Observatory of Science, Technology and Innovation (2013). Monitoring Africa's Progress In Research And Experimental Development (R&D) Investments

Key areas of engineering research

With regard to R&D in the engineering industry specifically, there are certain areas that could stand to benefit from greater investments, for example:

- **Sustainable and low carbon construction** [111]
  In the United Kingdom, the government's *Construction 2025* strategy aims to achieve a 50% reduction in greenhouse gas emissions in the built environment by 2025 and an 80% carbon reduction by 2050, also in the built environment. An example of R&D in support of these aims is R&D into biomimicry, the design and production of materials and structures modelled on biological processes and the natural environment, which is being undertaken and applied in both developed and developing economies. For example, the Eastgate Centre in Zimbabwe has modelled its ventilation system on that of termite nests in order to use significantly less energy than conventional systems.

- **Smart construction and digital design**
  Building information modelling (BIM)[112] is at the forefront of developments in smart construction and digital design. R&D into sensors and data management technologies will assist progress towards a digital economy, particularly with the growing use of the Internet of Things. This will improve the maintenance and operation of engineering projects.

- **Virtual and augmented reality**
  This area has already seen significant investment, but is likely to benefit from further R&D to contribute to advances in the digital economy. After recent increases in virtual and augmented reality due to advances in portable software, there is still scope for further development. Further R&D in this area may include integration with existing BIM software and higher degrees of accuracy.

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[111] HM Government, 2003. Construction 2025. Available at:
https://www.gov.United Kingdom/government/publications/construction-2025-strategy

[112] BIM can be defined as an intelligent 3D model, allowing projects to be designed collaboratively.

7. The Engineering Index

In this section, we set out the findings of our Engineering Index, an index that ranks 99 countries by their strength in engineering. The Engineering Index combines many of the datasets identified in the earlier sections of the report to provide an indication of the strength of engineering across the world based on aggregating a range of indicators into the index.

We begin by explaining the different components that combine to form the Engineering Index; the data sources used, and how different component weightings are applied. Further detail can be found in the annexes.[113]

7.1 Creating the Engineering Index

The Engineering Index and its components

The Engineering Index is a composite index, combining various engineering-related fields as components into a single, directly comparable index value for each country. This single index value then enables us to rank countries by their strength in engineering. The Engineering Index has been constructed using data from 99 countries from across the globe. It includes all 26 CAETS countries.[114] The Engineering Index is comprised of the following engineering related indicators:

- employment in engineering-related industries
- number of engineering businesses
- the gender balance of engineers
- wages and salaries of engineers
- human capital investment in engineering
- the quality of infrastructure
- the quality of digital infrastructure
- exports of engineering-related goods.

The Engineering Index has been constructed using data from 99 countries from across the globe.

Data sources

In order to gather data for the components listed above, we have used various sources including The World Bank, UNESCO, the International Labor Organization (ILO), the OECD and Eurostat. We have also used data from national statistics sources across countries. Table 4 details the components of the index, the format in which they are expressed, and the data sources. Unfortunately, a complete set of data points for each of these components was not available for all countries; our approach for missing data is discussed later in this section.[115]

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[113] A full set of countries and their Engineering Index scores can be found in Annex A of this report; further information on the Engineering Index can be found in Annex B. Annex C contains information on data availability by country.

[114] The full list of countries is provided in Tables A.1 and A.2 within Annex A of this report.

[115] Tables C.1 and C.2 in Annex C provides a full list of data availability and highlights the missing data points.

Table 4: Engineering Index components and sources

Component	Description	Format	Source
Research	Degree of cutting-edge research in engineering, proxied by the number of universities in the top 100 ranking of engineering departments	Number	United Kingdom *Times Higher Education* World University Rankings
Gender balance	Gender balance of engineers, using the % of graduates from engineering, manufacturing and construction programmes in tertiary education who are female	Percentage	UNESCO
Employment	Number of people employed in engineering jobs	Per capita	Eurostat, ILO, Cebr analysis
Wages	Average wages and salaries for engineers	US dollars, price purchasing parity (PPP)	Eurostat, National Statistics sources
Businesses	Number of engineering enterprises	Per capita	World Development Indicators, Eurostat
Human capital	Number of graduates in engineering fields of study	Per capita	World Economic Forum, UNESCO
Infrastructure quality	World Economic Forum 'quality of overall infrastructure' metric (1 = best, 7 = worst)	Inverse of score	World Economic Forum
Digital infrastructure quality	Quality of digital infrastructure, proxied by the number of internet servers per one million people	Number	World Development Indicators
Engineering exports	Exports of engineering-related goods, proxied by the sum of total merchandise exports relating to manufactures, ores and metals, and fuel	Expressed as a % share of total exports	World Development Indicators

Source: The World Bank, Eurostat, UNESCO, ILO, various, Cebr analysis

Creating the Engineering Index scores

The raw data presented in Table 4 cannot be used in itself to directly compare engineering performance across countries. For example, if Country A recorded higher average wages in engineering than Country B, but Country B recorded a higher number of engineers, how should the two countries be ranked overall? Therefore, the first step in creating the Engineering Index involves taking the raw data listed in Table 4 and converting this raw data into individual standardised index scores. The purpose of this is to enable a direct comparison of scores across the nine different index components. This process is described in further detail within Annex B of this report.

The Engineering Index is calculated by combining the individual index scores from the various components listed above, with weights applied to different components. Where data is unavailable for an individual index component for a particular country, it has been interpolated using an average of the other scores available for that country. Version 3a of the Engineering Index has been presented in the remainder of this section. A more detailed explanation of the different versions of the Engineering Index, and the weights and interpolation applied to each, can be found in Annex B of this report.

7.2 Engineering Index scores

To provide an example of the Engineering Index scores resulting from our analysis, Table 5 sets out index scores and rankings for three countries: Australia, Hungary and the United Kingdom, including their composite scores. Engineering Index scores ranked by GDP per capita and region are set out in further detail in the remainder of this section; a full set of Engineering Index scores for each country can be found in Annex A.

Note that where an index component score is 100% this means that the country ranks top relative to other countries based on that measure; it should not be interpreted as the country having necessarily achieved its potential in that particular measure. Similarly, a component score of 0% should not be interpreted as a country having no data, or no engineering strength in a particular measure; it reflects that this country ranks bottom relative to other countries.

Table 5: Engineering Index and component scores, and ranking, for Australia, Hungary and the United Kingdom

Country	Overall Index score	99 country ranking	Engineering Index component score								
			Research	Human capital	Gender balance	Infrastructure quality	Wages and salaries	Engineering businesses	Engineering exports	Engineering employment	Digital connectivity
Australia	70%	7th	93%	60%	34%	61%	100%	56%	56%	59%	83%
Hungary	42%	49th	0%	42%	36%	58%	35%	61%	71%	54%	44%
United Kingdom	63%	14th	100%	54%	36%	71%	73%	35%	47%	36%	81%

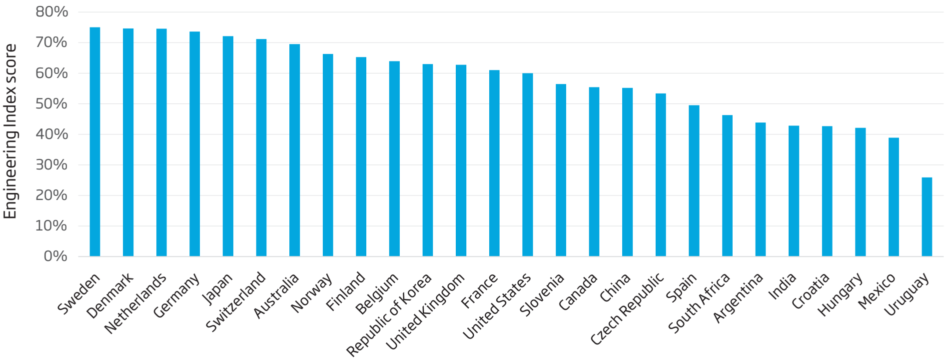
Source: Cebr analysis

Australia ranks highly, 7th among the CAETS countries and 7th overall. This is chiefly due to its high engineering employment, and its strong performance in the research category: Australia has seven university engineering departments among the world's top 100. It also boasts a high score in digital infrastructure quality; in 2013 Australia had approximately 1,250 internet servers for every million people in the population, putting it 12th in this category and against an average of around 900 across the CAETS countries.

The United Kingdom also ranks highly, with its score boosted in research (the United Kingdom has nine of the world's top 100 university engineering departments) and high-quality digital infrastructure. However, its overall score is weighed down by other factors, such as the low proportion of engineering graduates who are female (22.2%). In contrast, Hungary has a relatively low Engineering Index score; it ranks 24th among the CAETS countries and 49th overall. Low component scores in human capital (where Hungary ranks 44th overall for the number of engineering graduates per capita, with less than 0.1%) and wages are key causes.

Figure 22 below shows the full set of Engineering Index scores and rankings for the 26 CAETS countries. Sweden ranks 1st in the Engineering Index – across both the CAETS and all countries – due to high individual scores across many of the indicators used to compile the Index. In contrast, while the US ranks highly within the categories of research, wages and quality of digital infrastructure, it has a relatively low ranking in employment, businesses and the gender split.

Figure 22: Engineering Index scores and ranking for the CAETS countries



Source: Cebr analysis

GDP per capita and the Engineering Index

In this sub-section, we compare the richest and poorest countries, as measured using GDP per capita, with their Engineering Index scores. GDP per capita measures represent the total output of a country divided by the total population, enabling direct comparisons across countries, while also acting as an indicator of the standard of living.

Figure 23 compares countries with the highest levels of GDP per capita in 2013 with their Engineering Index scores. To enable a meaningful comparison between countries, GDP per capita is expressed in US dollars and in price purchasing parity (PPP) terms,[116] with data sourced from The World Bank's World Development Indicators. Notably among the 26 richest countries, there are no countries with an Engineering Index score below 40% (the 99-country average is 44%), indicating a positive correlation between GDP per capita and strength in engineering. This association is examined in greater depth in the next section of the report.

Qatar appears to be something of an outlier among these richest countries; while the country ranks highest with GDP per capita of $138,067 in 2013, it ranks 24th in our Engineering Index rankings. This is largely attributable to Qatar's relatively low scores in the quality of its digital infrastructure (in which it ranks 39th among the 99 countries) and research (Qatar currently has no top-ranking university departments in engineering).

In contrast, while the Netherlands ranks 11th in terms of GDP per capita, it has a very high Engineering Index ranking of due to its strong performance in engineering employment, wages and quality of digital infrastructure. The Netherlands ranks joint 1st, 9th and joint 1st respectively across all countries in these categories.

Notably among the 26 richest countries, there are no countries with an Engineering Index score below 40%.

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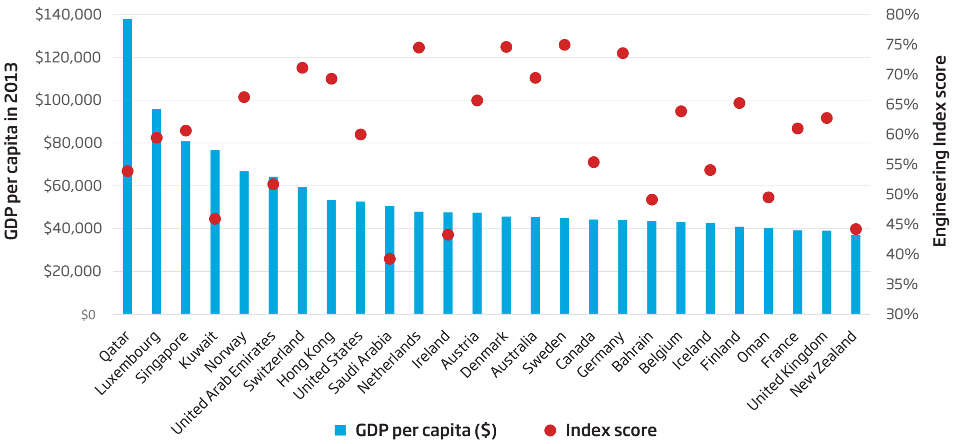
[116] Price purchasing parity (PPP) is a means by which the value of different currencies can be directly compared. In this context, PPP is used to convert wage income or GDP from different countries into a common currency: international dollars. If we simply took GDP or wage income from different countries and applied the relevant exchange rate to express everything in US dollar terms, this would not be a fair reflection of the size of incomes across countries. Exchange rates simply reflect demand for and supply of currencies, and can fluctuate rapidly. PPP reflects both the exchange rate and the relative cost of living across countries, reflecting the fact that the quantity of currency needed to buy goods and services will vary across countries.

Figure 23: Highest-ranked countries by GDP per capita (international $ PPP terms, LHS) and Engineering Index score (RHS)

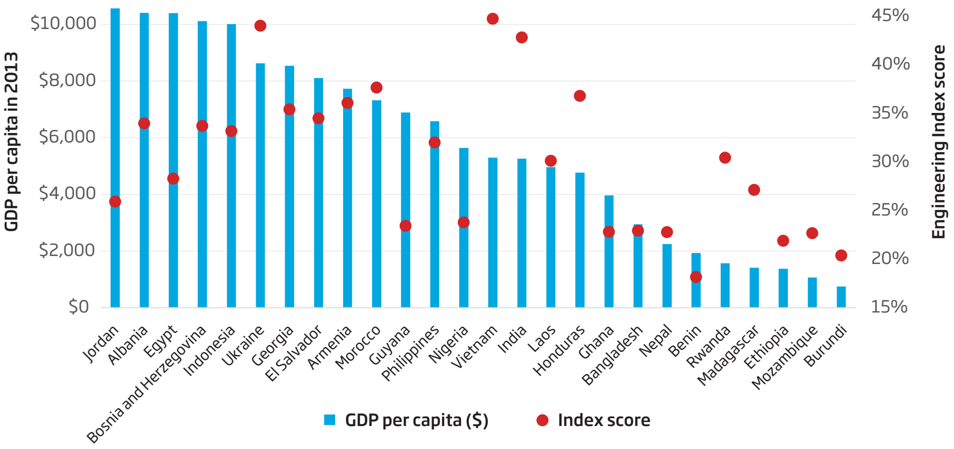


Source: Cebr analysis.

Note: Qatar GDP per capita for 2013 was $138,067 and for presentation is capped within the chart.

At the other end of the spectrum, Figure 24 below considers the lowest ranked countries by GDP per capita. This illustrates that the lower the GDP per capita, the lower Index scores tend to be. The exceptions to this appear to be Ukraine and Vietnam, as both score comparatively strongly in the Engineering Index.

Figure 24: Bottom-ranked countries by GDP per capita (international $ PPP terms, LHS) and Engineering Index score (RHS)



Source: Cebr analysis.

Ukraine's anomalous position in Figure 24 may be attributable to external unrelated factors that have driven GDP down in recent years, such as political unrest. Ukraine's Engineering Index score of just under 34% is attributable to its joint top ranking in the categories of human capital (the number of graduates in engineering fields of study) and the gender balance (the proportion of female graduates in engineering fields). In 2013, Ukraine recorded that 25.62% of graduates from engineering, manufacturing and construction programmes in tertiary education who are female, against the non-CAETS country average of 28.1%.

Vietnam's high rates of GDP growth in recent years – stimulated in part by major structural changes in the economy since the 1980s – suggest that GDP per capita will continue to rise in line with its relatively high Engineering Index score. The Engineering Index score of 45% is attributable to the relatively high proportion of graduates in engineering-related fields who are female in Vietnam. In our analysis, Vietnam ranks 18th in the gender category, with 35% of graduates from engineering, manufacturing and construction programmes in tertiary education who are female. This almost outstrips the percentage in all of the CAETS countries in 2013 (the only exception is Argentina with 35.4% in 2013).

Of the bottom ten countries in GDP per capita terms (Honduras, Ghana, Bangladesh, Nepal, Benin, Rwanda, Madagascar, Ethiopia, Mozambique, and Burundi), eight of these also rank in the bottom ten countries in our Engineering Index (Madagascar, Bangladesh, Ethiopia, Burundi, Nepal, Mozambique, Ghana and Benin). All of these countries have low scores across all of the Engineering Index components.

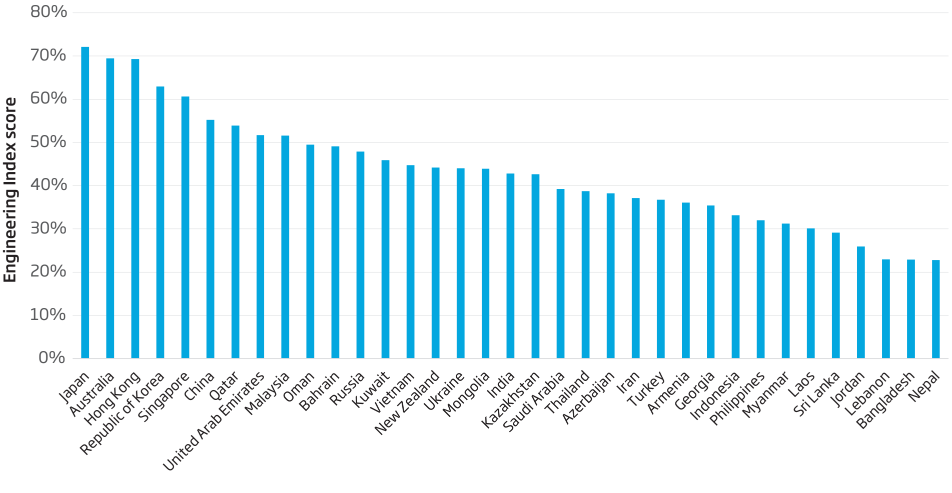
The values shown in Figure 23 and Figure 24 should not be used to directly interpret the correlation between GDP per capita and the Engineering Index, as the other 73 countries are not shown. However, there is a clear positive correlation between GDP per capita and the Engineering Index. This is discussed in more detail in Section 8, in which we further examine the relationship between these two variables.

Engineering Index rankings by region

Figure 25, Figure 26 and Figure 27 compare Engineering Index scores across countries in the five broad regional groups: Asia and Oceania, Europe, Africa, North and Central America, and South America. Countries in Asia and Oceania and Europe comprise a majority (69) of the 99 countries considered as part of this study, largely due to data availability. A full set of country data for Engineering Index country scores by region can be found in Annex A of this report.

Figure 25 considers countries in Asia and Oceania. Japan and Hong Kong are the highest-ranking countries in the Asia and Oceania region, largely due to these countries' strong performance in the categories of research, engineering employment and the quality of infrastructure. Japan in particular ranks joint first in its engineering employment component score (alongside other high scoring countries such as Luxembourg, Sweden, Switzerland, Denmark and Norway and the Netherlands).

Figure 25: Engineering Index scores by country: Asia and Oceania

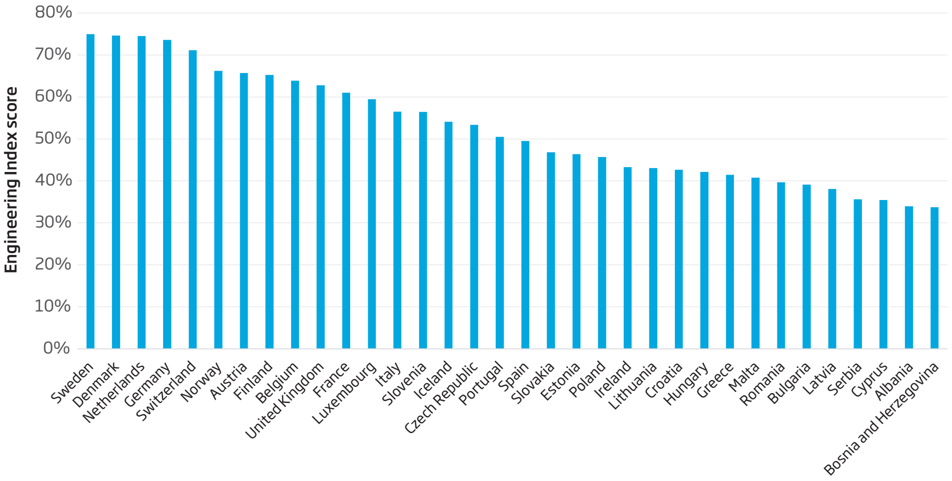


Source: Cebr analysis

Iran – with an Engineering Index score of 37% – notably outranks several countries, including Turkey, Armenia, Laos and Indonesia. Once again, this is due to higher than average performance in the gender and human capital categories, in which Iran ranks very highly in the list of 99 countries. With engineering graduates making up 0.30% of the Iranian population in 2013 – compared to a CAETS country average of 0.1% – Iran lies only behind Russia (0.32%) and ahead of other countries in the region such as Malaysia (0.19%), Australia (0.13%) and India (0.05%).

Figure 26 shows the Engineering Index scores for European countries. The United Kingdom lies 14th in the rankings with a score of 62.8%, ahead of France (61.0%) and Italy (56.5%), and behind Germany (73.6%) and the Netherlands (73.6%). Germany's strong position is generated by seven of its universities being in the top 100 engineering departments (thereby yielding a high component score in research) and the high infrastructure quality scores. The highest ranked non-CAETs country is Hong Kong (69.3%).

Figure 26: Engineering Index scores by country: Europe

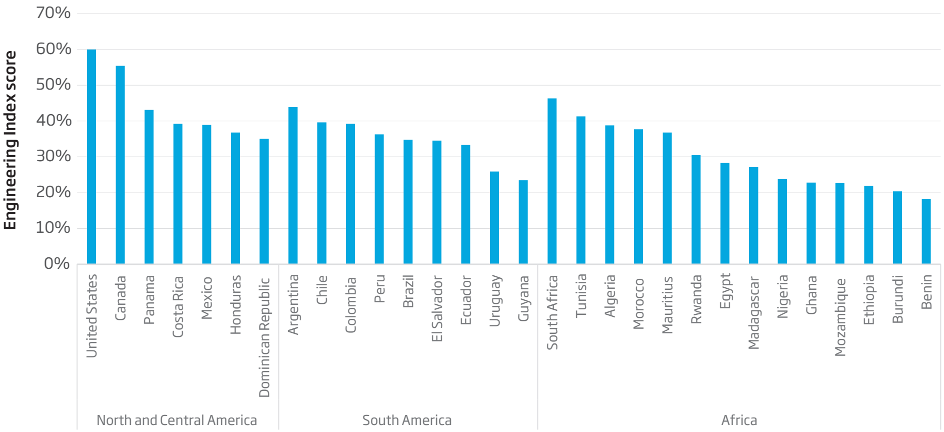


Source: Cebr analysis.

Finally, Figure 27 shows Engineering Index country scores for the three remaining regions: North and Central America, South America and Africa. The US ranks highest within the North and Central America region with an Engineering Index score of 60%, supported by the highest research component score (the US has the highest number of top university engineering departments in the world, with 31) and very high engineering wages (just under $83,000 in US dollar PPP terms). Consequently, the US ranks 14th among the CAETS countries and 17th overall. With relatively high rankings in infrastructure (22nd), digital infrastructure (17th), and research (6th), Canada ranks 2nd in the region. There is then a significant drop in the Engineering Index score for the next three countries in the region: Panama (43%), Mexico (39%), and Costa Rica (39%).

Within South America, Argentina ranks highest with an Engineering Index score of 43.5%, ahead of countries such as Chile (39.7%)and Uruguay (25.9%). This is partly attributable to Argentina's slightly higher than average share of graduates from engineering, manufacturing and construction programmes who are female in 2013 (35.4%). Within Africa, South Africa ranks highest in our Engineering Index (46.3%) ahead of Tunisia (41.3%) and Morocco (37.7%). The highest proportion of countries with an insufficient level of data to feature within the Engineering Index rankings are located in Africa.

Figure 27: Engineering Index scores by country: North and Central America, South America and Africa



Source: Cebr analysis

7.3 Concluding remarks

In this analysis, an Engineering Index has been constructed in order to measure and compare the strength in engineering across 99 countries from five different regions across the globe. Some of the key findings from this analysis are as follows:

- The Engineering Index brings together nine separate indicators of capacity and strength in engineering, using historical information from The World Bank, the ILO and other data sources. We find that Sweden, Denmark, the Netherlands, Germany and Japan rank highest with Engineering Index scores all above 70%. The United Kingdom ranks 14th, with the US 17th, China 22nd and India 46th.

- CAETS countries perform strongly in the Engineering Index. Of the top 20 countries as ranked by index score, 15 are CAETS countries. The other five countries in the top 20 are Hong Kong, Austria, Singapore, Luxembourg, and Italy. However, some CAETS countries such as South Africa (35th), Mexico (59th) and Argentina (42nd) have relatively low Engineering Index scores and rankings.

- Data availability has restricted Engineering Index coverage to 99 countries, of which the majority lie in Europe (34), and Asia and Oceania (35). Within Europe, Sweden, Denmark, the Netherlands, Germany and Switzerland rank highest. Within Asia and Oceania, Japan, Australia and Hong Kong rank highest. Some of the greatest potential for higher engineering performance lies in Africa, where only two countries (South Africa and Tunisia) have an Engineering Index score above 40%.

- There appears to be a correlation between GDP per capita and Engineering Index scores across countries when using data available for 2013. Aside from notable outlier countries such as Qatar, Vietnam and Ukraine, we observe that higher output per capita is associated with higher Engineering Index scores. This trend is examined in greater depth in the next section.

8. Econometric analysis of the Engineering Index

In this section we describe the econometric analysis undertaken using the Engineering Index. The purpose of this analysis is to model the relationship between prevalence in engineering (as measured by the Engineering Index) and two key indicators of economic development: GDP per capita and investment in physical capital.

8.1 Overview

To understand the importance of engineering to economic growth and development, we have constructed econometric models to estimate the empirical relationship between a key macroeconomic indicator (the dependent variable, e.g. economic output) and the Engineering Index (an independent variable). This has allowed us to examine whether there is a positive and robust relationship between economic development and the Engineering Index.

Many different factors influence economic growth and development, the influence of engineering notwithstanding. To attempt to analyse all of these factors would be a huge undertaking and is beyond the scope of this analysis. However, we have attempted to control for a selection of these factors before adding the Engineering Index to the different models constructed. Based on existing evidence and studies, these 'control factors' across countries include the average years of schooling, life expectancy, the availability of business credit and a country's openness to trade.

The econometric models constructed for this study draw upon the full dataset of 99 countries with coverage for the year 2013, the latest year for which most of the data is available. The models constructed are therefore cross-sectional in nature; the lack of time series data for several of the Engineering Index components prevented us from utilising a panel model specification for this analysis. The results should therefore be treated with caution; however, the availability of data for 99 countries does allow for inferences to be drawn on the relationship between economic development and the Engineering Index.

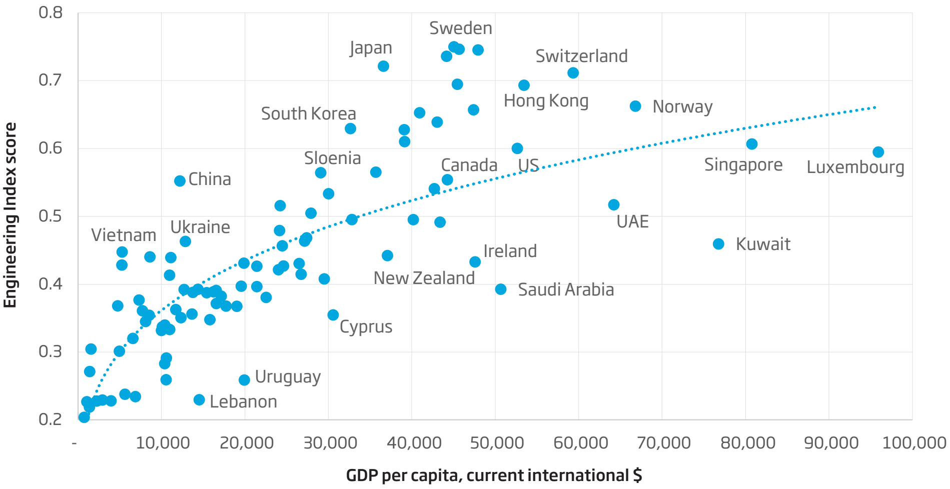
To test the robustness of the Engineering Index, we have used the five different versions of the Engineering Index as described in the previous section, which place different weights on engineering-specific index components.

8.2 GDP per capita and the Engineering Index

The correlation between GDP per capita and the Engineering Index
We have firstly considered the relationship between GDP per capita and the Engineering Index. GDP per capita measures the total output of each country divided by the total number of people in the country – enabling a comparison of the relative economic performance of one country versus another. It is an appropriate measure for economic development to apply here, as it is a widely accepted measure for living standards across countries. GDP data for 2013 has been sourced from The World Bank's World Development Indicators. GDP per capita is expressed in PPP terms to enable a meaningful comparison across each of the 99 countries. For a description of PPP and its function, please refer to the previous section in this report.

Figure 28 below plots GDP per capita in 2013 against Engineering Index scores for each country, with certain countries highlighted. A trend line has also been included to highlight the correlation between the two variables.

Figure 28: Correlation between GDP per capita and the Engineering Index



Source: The World Bank, Cebr analysis

Figure 28 above illustrates the strong correlation between the GDP per capita and the Engineering Index. Japan, Switzerland and Sweden record some of the highest Engineering Index scores and are among some of the richest countries in the world. One particular outlier observed is Luxembourg; while the country has the highest GDP per capita of over $80,000, it ranks 18th in the Engineering Index rankings. In contrast, while Slovenia has a relatively low GDP per capita of around $18,600, its Engineering Index score is relatively high at around 58% and ranks 20th across the 99 countries considered.

The trend line shown in the figure above is non-linear (logarithmic), which suggests that any relationship between the Engineering Index and GDP per capita is unlikely to be constant as GDP per capita increases. We examine this further in the sub-section below.

8.3 Constructing econometric models using the Engineering Index

Modelling the relationship between GDP per capita and the Engineering Index

To examine the nature and strength of the relationship between GDP per capita and the Engineering Index, we have created econometric models featuring GDP per capita, the Engineering Index and other factors that influence economic development. There is a great deal of evidence for these other factors, but several appear frequently in growth accounting literature: human capital investment, physical capital investment, the quality of life and openness to trade. These other factors are referred to henceforth as 'control variables' in the context of the analysis.

The rationale for including these control variables is that many other factors will influence economic development; a model that simply includes GDP per capita and the Engineering Index will be flawed for two key reasons. Firstly, its ability to explain differences in GDP per capita across countries ('explanatory power') will be weakened. Secondly, by not reflecting the other factors influencing economic development, it will potentially suffer from bias affecting the Engineering Index component. This bias would then lead us to incorrectly specify the importance of engineering to economic development. We have assigned proxies for these control variables as follows:

- Human capital investment: this is proxied for by the average years of schooling for those aged 15 and over, as sourced from the Barro and Lee dataset[117].

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[117] Barro-Lee Educational Attainment Dataset, **http://www.barrolee.com/**

- Physical capital investment: this is proxied for using gross fixed capital formation (GFCF) per capita, as sourced from The World Bank World Development Indicators.

- Quality of life: this is proxied for by life expectancy across both genders, as sourced from The World Bank World Development Indicators.

- Trade openness: this is proxied for by the total of imports and exports as a share of GDP.

By progressively adding these control variables to the model, we can test whether the positive relationship between GDP per capita and the Engineering Index is robust. If the Engineering Index is an important and distinct driver of economic development – and that is the hypothesis – the positive relationship should remain significant when other control variables are added to the model. To account for the seemingly non-linear relationship between GDP per capita and the Engineering Index, the impact on GDP per capita from a higher Engineering Index score has been modelled in percentage growth terms (rather than level terms, i.e. the increase in GDP per capita by US dollars amounts).

Summary of the results

Table 6 shows the modelling results. A full set of results can be found in Annex D of this report.

Table 6: Econometric analysis of GDP per capita and the Engineering Index

Factor	Change	Associated with GDP per capita growth of:			
		Model #1	Model #2	Model #3	Model #4
Human capital investment	+ 1%	+1.55%	+1.31%	+0.96%	+0.97%
Physical investment	+ 1%	-	+0.35%	+0.29%	+0.29%
Quality of life	+ 1 year	-	-	+0.05%	+0.05%
Trade openness	+1 ppt	-	-	-	+0.18%
Engineering Index score	**+ 1 ppt**	**+3.14%**	**+1.60%**	**+1.01%**	**+0.85%**

Note: models above include a constant term, but which is not shown above

Note: PPT = percentage point

Source: Cebr analysis

As expected, all four control variables are positively associated with GDP per capita when progressively introduced into the model. Taking the example of Model 4 – when all of the variables are present in the model – we see that human capital investment is most positively associated with higher GDP per capita. The results suggest that a 1% increase in human capital investment – the average years of schooling among the adult population – is associated with a 0.97% increase in GDP per capita.

The inclusion of the Engineering Index yields a positive and significant relationship with GDP per capita in each version of the model. From Model 4, we observe that a one-percentage point increase in the Engineering Index score is associated with a 0.85% increase in GDP per capita. While this relationship is likely to differ from country to country, we can place this result in context. For example, a scenario in which the United Kingdom had boosted its Engineering Index ranking from 12th to 10th (overtaking Belgium) would have involved the United Kingdom raising its index score by 1.1ppt. The model suggests that this would have been associated with a GDP per capita increase of $366, from $39,111 to $39,477 in 2013.

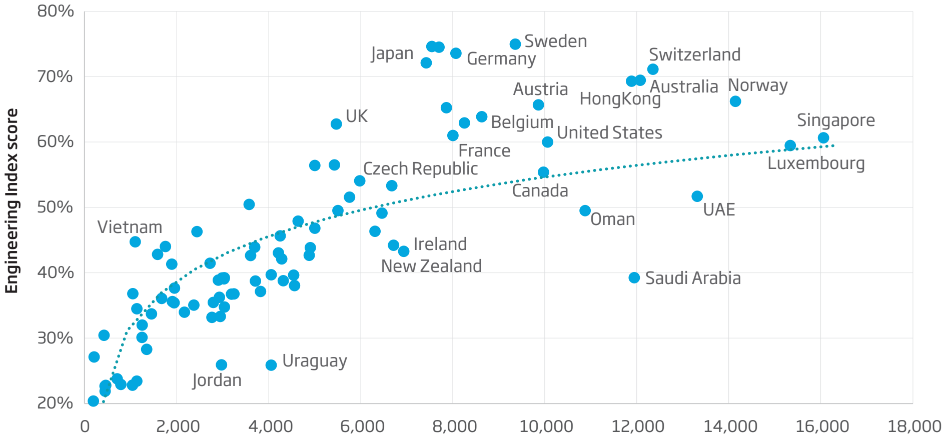
8.4 Investment and the Engineering Index

We have then considered the relationship between levels of investment and the Engineering Index, using GFCF as a proxy for physical investment. GFCF is the net increase (or decrease) in physical assets over a certain period, typically a year or quarter. As a measure, it incorporates an array of different investments, including: plant, machinery, and equipment purchases; the construction of roads, railways, schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.

GFCF data for 2013 has been sourced from The World Bank's World Development Indicators. GFCF is once again expressed in PPP terms to enable a meaningful comparison across each of the 99 countries.

To enable a comparison of investment across countries, we have used the measure of GFCF per capita, i.e. the level of investment divided by the population level. Again, GFCF and population data has been sourced from The World Bank's World Development Indicators, with GFCF values expressed in US dollar PPP terms. Figure 28 plots investment per capita and the Engineering Index; a trend line has also been included to highlight the correlation between the two variables

Figure 28: Correlation between GFCF per capita and the Engineering Index



Source: The World Bank, Cebr analysis

As with Figure 29, a strong positive and non-linear correlation is observed between the Engineering Index and investment. Countries ranking highly both in terms of their levels of investment and their Engineering Index score include Norway, Singapore, Australia, Sweden, Switzerland and Luxembourg. Taking the example of Singapore, it has the highest recorded level of investment per head at around $16,600, and ranks 16th in the Engineering Index rankings – outranking several CAETS countries. Switzerland recorded investment per head of around $12,400 in 2013, complementing its high Engineering Index score of 71% (and sixth in the country rankings).

Countries such as Slovenia and Vietnam also appear to be outliers, in that they are ranked relatively highly in terms of their Engineering Index score, but at the same time have recorded relatively low investment per head. As infrastructure quality is a key component of the Engineering Index, this suggests that these countries could potentially raise their index scores even further by raising greater investment and directing it towards digital and wider infrastructure. Vietnam's Engineering Index score relates to its relatively high share of female graduates in engineering, while Slovenia (a CAETS country) has a relatively high number of engineering graduates and engineering businesses per capita.

Modelling the relationship between investment and the Engineering Index

To establish the relationship between investment and the Engineering Index, we have created a model featuring GFCF, the different versions of the Engineering Index and control variables for the change in business inventories[118] and access to credit. We have assigned proxies for these control variables as follows:

- Size of the economy: proxied for by GDP per capita, as expressed in US dollar PPP terms, with data sourced from The World Bank World Development Indicators.

- Change in business inventories: proxied for by the change in inventories expressed in US dollar PPP terms. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, as well as work in progress. Data has been sourced from The World Bank World Development Indicators.

- Access to credit: proxied for by the total amount of domestic credit, expressed in US dollar PPP and per capita terms (the total amount of credit for each person in the population). Domestic credit and population data has been sourced from The World Bank World Development Indicators.

Table 7 shows the modelling results. A full set of results can be found in Annex D of this report.

Table 7: Econometric analysis of GFCF per capita and the Engineering Index

Factor	Change	Associated with GDP per capita growth of:			
		Model #1	Model #2	Model #3	Model #4
GDP per capita	+1%	+0.89%	+0.75%	+0.57%	+0.38%
Change in business inventories	+1%	-	-	+0.25%	+0.23%
Access to credit	+1%	-	-	-	+0.10%
Engineering Index score	**+ 1 ppt**	**-**	**+1.30%**	**+1.77%**	**+1.87%**

Note: models above include a constant term, but which is not shown above

Source: Cebr analysis

An economy's size is strongly associated with levels of investment: a 1% growth in GDP per capita is associated with a 0.38% growth in investment. Crucially, the association between investment and the Engineering Index remains positive and robust in each of the models, with Model 4 suggesting that a one percentage point increase in a country's Engineering Index score is associated with a 1.87% increase in investment per capita. As with the GDP per capita results presented earlier in Table 6, while this increase is likely to differ from country to country, we can use the example of the United Kingdom to place this result in context. If the United Kingdom had raised its Engineering Index score by 1.1ppt in 2013, this would have been associated with an investment per capita increase from $5,473 to $5,586 (expressed in PPP terms).

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[118] Inventory investment is the amount that firms invest in inventories, which are produced goods held in storage in anticipation of later sales. Firms also stockpile raw materials and intermediate goods used in the production process. Goods held in inventories are counted for the year produced, not the year sold

Annex A: Full list of countries with Engineering Index scores and rankings

In Annex A, we provide the full set of Engineering Index scores for each of the 99 countries considered in our study. We start by considering the top 20 countries as ranked by their Engineering Index score, before setting out the Engineering Index scores for the CAETS and non-CAETS countries.

Table A.1: Engineering Index and component scores for the top 20 countries

		Engineering Index component								
Country	**Engineering Index score**	Research	Gender balance	Engineering employment	Wages and salaries	Engineering businesses	Human capital	Infrastructure quality	Digital connectivity	Engineering exports
Sweden	**75%**	64%	56%	100%	67%	100%	64%	77%	91%	46%
Denmark	**75%**	50%	73%	100%	81%	32%	63%	84%	100%	30%
Netherlands	**75%**	64%	32%	100%	80%	68%	42%	94%	100%	67%
Germany	**74%**	93%	71%	75%	79%	38%	56%	84%	76%	67%
Japan	**72%**	79%	9%	100%	82%	70%	62%	91%	63%	76%
Switzerland	**71%**	57%	13%	100%	64%	30%	60%	100%	100%	58%
Australia	**70%**	93%	34%	59%	100%	56%	60%	61%	83%	56%
Hong Kong	**69%**	72%	70%	50%	78%	70%	70%	96%	59%	62%
Norway	**66%**	0%	29%	100%	100%	64%	42%	65%	100%	58%
Austria	**66%**	50%	33%	74%	77%	52%	63%	88%	77%	57%
Finland	**65%**	0%	35%	95%	61%	42%	84%	92%	95%	52%
Belgium	**64%**	50%	34%	63%	89%	59%	54%	73%	63%	88%
Republic of Korea	**63%**	79%	41%	22%	55%	42%	100%	77%	100%	69%
United Kingdom	**63%**	100%	36%	36%	73%	35%	54%	71%	81%	47%
France	**61%**	57%	45%	62%	67%	35%	71%	86%	54%	50%
Singapore	**61%**	57%	61%	54%	49%	61%	61%	96%	58%	53%
United States	**60%**	100%	27%	22%	100%	0%	42%	82%	85%	43%
Luxembourg	**60%**	0%	35%	100%	80%	64%	21%	78%	100%	0%
Italy	**57%**	50%	85%	43%	68%	90%	43%	43%	42%	66%
Slovenia	**56%**	0%	42%	76%	50%	90%	74%	61%	56%	81%

Source: Cebr analysis

Annex A

Table A.2: Engineering Index and component scores for the CAETS countries

		Engineering Index component score								
CAETS country	**Engineering Index score**	Research	Gender balance	Engineering employment	Wages and salaries	Engineering businesses	Human capital	Infrastructure quality	Digital connectivity	Engineering exports
Argentina	**44%**	0%	73%	56%	85%	34%	22%	17%	36%	26%
Australia	**69%**	93%	34%	59%	100%	56%	60%	61%	83%	56%
Belgium	**64%**	50%	34%	63%	89%	59%	54%	73%	63%	88%
Canada	**55%**	79%	55%	31%	51%	21%	55%	72%	75%	58%
China	**55%**	86%	58%	78%	11%	58%	58%	52%	35%	89%
Croatia	**43%**	0%	57%	41%	46%	34%	66%	54%	42%	30%
Czech Republic	**53%**	0%	53%	68%	41%	85%	60%	61%	57%	86%
Denmark	**75%**	50%	73%	100%	81%	32%	63%	84%	100%	30%
Finland	**65%**	0%	35%	95%	61%	42%	84%	92%	95%	52%
France	**61%**	57%	45%	62%	67%	35%	71%	86%	54%	50%
Germany	**74%**	93%	71%	75%	79%	38%	56%	84%	76%	67%
Hungary	**42%**	0%	36%	54%	35%	61%	42%	58%	44%	71%
India	**43%**	50%	58%	48%	28%	42%	42%	40%	35%	47%
Japan	**72%**	79%	9%	100%	82%	74%	62%	91%	63%	76%
Mexico	**39%**	0%	53%	56%	18%	45%	48%	44%	36%	79%
Netherlands	**75%**	64%	32%	100%	80%	68%	42%	94%	100%	67%
Norway	**66%**	0%	29%	100%	100%	64%	42%	65%	100%	58%
Republic of Korea	**63%**	79%	41%	22%	55%	42%	100%	77%	100%	69%
Slovenia	**56%**	0%	42%	76%	50%	90%	74%	61%	56%	81%
South Africa	**46%**	0%	59%	34%	79%	43%	43%	48%	38%	64%
Spain	**50%**	0%	49%	51%	58%	53%	58%	81%	45%	47%
Sweden	**75%**	64%	56%	100%	67%	100%	64%	77%	91%	46%
Switzerland	**71%**	57%	13%	100%	64%	30%	60%	100%	100%	58%
United Kingdom	**63%**	100%	36%	36%	73%	35%	54%	71%	81%	47%
United States	**60%**	100%	27%	22%	100%	0%	42%	82%	85%	43%
Uruguay	**26%**	0%	24%	65%	0%	30%	22%	35%	38%	4%

Source: Cebr analysis

Table A.3: Engineering Index and component scores for the non-CAETS countries

		Engineering Index component score								
Non-CAETS country	**Engineering Index score**	Research	Gender balance	Engineering employment	Wages and salaries	Engineering businesses	Human capital	Infrastructure quality	Digital connectivity	Engineering exports
Albania	**34%**	0%	82%	31%	21%	30%	35%	39%	35%	37%
Algeria	**39%**	0%	82%	23%	40%	40%	46%	26%	35%	85%
Armenia	**36%**	0%	48%	40%	32%	32%	53%	48%	36%	20%
Austria	**66%**	50%	33%	74%	77%	52%	63%	88%	77%	57%
Azerbaijan	**38%**	0%	35%	46%	43%	43%	27%	59%	35%	76%
Bahrain	**49%**	0%	51%	54%	59%	49%	49%	71%	40%	74%
Bangladesh	**23%**	0%	20%	38%	26%	22%	19%	14%	35%	22%
Benin	**18%**	0%	21%	38%	15%	19%	19%	5%	35%	0%
Bosnia and Herzegovina	**34%**	0%	80%	24%	29%	32%	32%	19%	36%	68%
Brazil	**35%**	0%	56%	46%	47%	31%	29%	15%	37%	40%
Bulgaria	**39%**	0%	68%	37%	30%	31%	66%	34%	40%	53%
Burundi	**20%**	0%	17%	43%	18%	18%	18%	12%	35%	2%
Chile	**40%**	0%	25%	44%	47%	42%	57%	54%	38%	52%
Colombia	**39%**	0%	64%	44%	34%	43%	59%	22%	36%	69%
Costa Rica	**39%**	0%	70%	41%	59%	33%	36%	26%	38%	31%
Cyprus	**35%**	0%	55%	0%	64%	28%	40%	55%	59%	0%
Dominican Republic	**35%**	0%	77%	35%	30%	30%	30%	28%	35%	34%
Ecuador	**33%**	0%	24%	40%	34%	34%	34%	54%	36%	48%
Egypt	**28%**	0%	45%	24%	39%	27%	27%	21%	35%	36%
El Salvador	**35%**	0%	48%	39%	39%	39%	27%	42%	35%	56%
Estonia	**46%**	0%	58%	61%	27%	42%	52%	65%	64%	50%
Ethiopia	**22%**	0%	20%	43%	20%	20%	18%	22%	35%	0%
Georgia	**35%**	0%	57%	50%	29%	29%	29%	46%	36%	11%
Ghana	**23%**	0%	1%	42%	26%	26%	21%	18%	35%	43%
Greece	**41%**	0%	64%	35%	36%	100%	51%	48%	40%	27%
Guyana	**23%**	0%	24%	33%	22%	22%	22%	31%	35%	9%
Honduras	**37%**	0%	88%	39%	30%	30%	24%	34%	35%	30%
Hong Kong	**69%**	72%	70%	50%	78%	70%	70%	96%	59%	62%
Iceland	**54%**	0%	65%	55%	38%	51%	59%	87%	100%	18%
Indonesia	**33%**	0%	34%	43%	33%	34%	35%	37%	35%	54%
Iran	**44%**	0%	47%	26%	24%	46%	100%	39%	35%	46%

Annex A

Table A.3: Engineering Index and component scores for the non-CAETS countries

		Engineering Index component score								
Non-CAETS country	**Engineering Index score**	Research	Gender balance	Engineering employment	Wages and salaries	Engineering businesses	Human capital	Infrastructure quality	Digital connectivity	Engineering exports
Ireland	**45%**	0%	20%	21%	73%	44%	70%	62%	63%	27%
Italy	**54%**	50%	85%	43%	68%	90%	43%	43%	42%	66%
Jordan	**28%**	0%	11%	20%	28%	28%	37%	51%	36%	33%
Kazakhstan	**49%**	0%	56%	49%	51%	51%	51%	46%	35%	82%
Kuwait	**50%**	0%	44%	50%	65%	52%	52%	43%	41%	85%
Laos	**32%**	0%	22%	47%	31%	31%	31%	39%	35%	31%
Latvia	**37%**	0%	49%	42%	19%	27%	63%	60%	45%	40%
Lebanon	**23%**	0%	49%	36%	21%	21%	21%	0%	36%	7%
Lithuania	**44%**	0%	35%	43%	26%	30%	100%	63%	45%	55%
Luxembourg	**59%**	0%	35%	100%	80%	64%	21%	78%	100%	0%
Madagascar	**27%**	0%	42%	48%	26%	26%	19%	9%	35%	32%
Malaysia	**53%**	0%	86%	43%	35%	56%	81%	78%	37%	72%
Malta	**41%**	0%	29%	38%	39%	41%	40%	50%	92%	41%
Mauritius	**33%**	0%	60%	42%	32%	32%	32%	54%	40%	17%
Mongolia	**41%**	0%	83%	39%	43%	43%	69%	24%	35%	70%
Morocco	**38%**	0%	36%	28%	75%	36%	26%	49%	35%	39%
Mozambique	**22%**	0%	31%	29%	24%	24%	0%	10%	35%	69%
Myanmar	**21%**	0%	100%	52%	19%	19%	23%	4%	0%	19%
Nepal	**21%**	0%	13%	52%	19%	19%	17%	12%	35%	18%
New Zealand	**42%**	0%	51%	50%	37%	39%	52%	63%	78%	5%
Nigeria	**24%**	0%	29%	24%	10%	29%	29%	5%	35%	100%
Oman	**53%**	0%	80%	47%	55%	55%	55%	61%	37%	85%
Panama	**38%**	0%	81%	43%	38%	38%	37%	59%	38%	38%
Peru	**36%**	0%	36%	49%	51%	36%	36%	21%	35%	59%
Philippines	**31%**	0%	58%	38%	24%	32%	32%	25%	35%	56%
Poland	**42%**	0%	79%	32%	44%	39%	77%	43%	47%	63%
Portugal	**51%**	0%	65%	44%	46%	66%	72%	80%	43%	50%
Qatar	**33%**	0%	75%	74%	68%	55%	26%	78%	41%	77%
Romania	**37%**	0%	85%	29%	31%	19%	85%	32%	37%	63%
Russia	**43%**	50%	52%	49%	9%	52%	100%	44%	37%	73%
Rwanda	**57%**	0%	43%	46%	31%	31%	21%	51%	35%	22%
Saudi Arabia	**26%**	0%	16%	33%	75%	42%	29%	63%	36%	88%
Serbia	**43%**	0%	71%	39%	28%	36%	54%	21%	36%	36%
Singapore	**46%**	57%	61%	54%	49%	61%	61%	96%	58%	53%

Table A.3: Engineering Index and component scores for the non-CAETS countries

		Engineering Index component score								
Non-CAETS country	**Engineering Index score**	Research	Gender balance	Engineering employment	Wages and salaries	Engineering businesses	Human capital	Infrastructure quality	Digital connectivity	Engineering exports
Slovakia	**30%**	0%	50%	44%	37%	52%	77%	52%	45%	79%
Sri Lanka	**38%**	0%	26%	35%	15%	28%	19%	65%	35%	28%
Thailand	**23%**	0%	39%	58%	41%	39%	39%	41%	35%	56%
Tunisia	**43%**	0%	82%	27%	44%	42%	54%	33%	35%	60%
Turkey	**59%**	0%	51%	30%	33%	39%	50%	61%	37%	52%
Ukraine	**27%**	0%	71%	44%	48%	48%	100%	36%	36%	48%
United Arab Emirates	**52%**	0%	64%	68%	56%	51%	30%	97%	42%	51%
Vietnam	**41%**	0%	100%	60%	49%	49%	53%	29%	35%	67%

Source: Cebr analysis

Annex B: Engineering Index supplemental

In Annex B we provide supplementary information that was used to create the Engineering Index. We show the list of countries used in the creation of the Engineering Index, in addition to detailing the availability of data for each country, and describe the method by which the raw engineering data for each country is transformed into an index score.

Coverage of countries within the Engineering Index

We have included 99 countries in the Engineering Index from across each continent. Tables C.1 and C.2 within Annex C of this report contain the full list of countries and their respective data availability for each of the nine Engineering Index components.

Table B.1 below shows the list of 26 CAETS countries as of 2016:

Table B.1: CAETS countries included in the Engineering Index

CAETS countries						
Argentina	China	Finland	India	Norway	Spain	United States
Australia	Croatia	France	Japan	Republic of Korea	Sweden	Uruguay
Belgium	Czech Republic	Germany	Mexico	Slovenia	Switzerland	
Canada	Denmark	Hungary	Netherlands	South Africa	United Kingdom	

Source: CAETS

Table B.2 below shows the 73 non-CAETS member countries considered as part of the analysis. Some non-CAETS countries have been excluded due to lack of available data for at least four of the Engineering Index components described in Table 3 earlier in this report.

Table B.2 Non-CAETS countries included in the Engineering Index

Non-CAETS countries					
Albania	Colombia	Honduras	Lithuania	Oman	Slovakia
Algeria	Costa Rica	Hong Kong	Luxembourg	Panama	Sri Lanka
Armenia	Cyprus	Iceland	Madagascar	Peru	Thailand
Austria	Dominican Rep.	Indonesia	Malaysia	Philippines	Tunisia
Azerbaijan	Ecuador	Iran	Malta	Poland	Turkey
Bahrain	Egypt	Ireland	Mauritius	Portugal	Ukraine
Bangladesh	El Salvador	Laos	Mongolia	Qatar	United Arab Emirates
Benin	Estonia	Latvia	Morocco	Romania	Vietnam
Bosnia and Herzegovina	Ethiopia	Lebanon	Mozambique	Russia	

Non-CAETS countries					
Brazil	Georgia	Italy	Myanmar	Rwanda	
Bulgaria	Ghana	Jordan	Nepal	Saudi Arabia	
Burundi	Greece	Kazakhstan	New Zealand	Serbia	
Chile	Guyana	Kuwait	Nigeria	Singapore	

Source: CAETS

Creating component index scores
As Table 3 in Section 7 above shows, the various Engineering Index components are expressed in different formats e.g. currency values, numbers of engineers, proportions of graduates. Therefore the first step in the creation of the Engineering Index is to create a single, all-encompassing index measure and it is necessary to normalise each component to achieve a notionally common scale.

To create a common scale, we have transformed each component into a score between 0% and 100%. A score of 100% indicates that a country outstrips all other countries in the prevalence of a particular index component. For example, Australia's index score of 100% in engineering wages reflects the highest relative wages and salaries it pays on average to its engineers, after converting Australian Dollars into US Dollars through PPP terms (the common currency format used in this analysis).

For each component, an index score is calculated by using the average raw (untransformed) score value and then comparing how this value compares to the average across countries, after adjusting this for outliers using the standard deviation of raw scores. Specifically, the score is calculated as follows:

- The first step is to rank countries by their raw scores for each Engineering Index component (taking the example of infrastructure quality, ordering each country by their metric score). The country with the highest raw score is automatically assigned an index component score of 100%, while the country with the lowest score is assigned a score of 0%.

- Countries with no data are by default not assigned a score; our approach for handling missing data is described in the sub-section below.

- The maximum and minimum raw score is then identified, as well as the average of each country's raw score and the standard deviation across the raw scores.

- The threshold two standard deviations away from the average is then calculated, by separately adding and subtracting double the standard deviation value from the average.

- Each country's component index score is the normalised by calculating:
  Component index score = (Raw score – lower outlier threshold)
  / (Upper outlier threshold – lower outlier threshold)

Taking the example of creating a component index score for the United Kingdom's infrastructure quality score:

- The United Kingdom has a World Economic Forum infrastructure quality score of 5.3 (this is the raw score).

- The average score is 4.4, with a standard deviation of 0.97 across all countries.

- The maximum raw score is 6.5 (Switzerland) and the minimum score is 2.1 (Guinea).
- The upper outlier threshold is calculated as 4.4 + (2*0.97) = 6.3.
- The lower outlier threshold is calculated as 4.4 - (2*0.97) = 2.4.
- The United Kingdom's normalised component index score for infrastructure quality is then calculated as (5.3 – 2.4) / (6.3 – 2.4) = 0.74, or 74.4%.

This approach is then applied for all Engineering Index components before the composite index score is calculated.

The different versions of the Engineering Index

We have created five different versions of the Engineering Index in which different assumptions for missing data and component weighting have been applied. Here we describe the rationale behind these assumptions and how each of the versions differ.

The second (2 and 2a) and third versions (3 and 3a) differ by both interpolating missing data points across countries and placing greater weight on the engineering-specific components of the Engineering Index. *Version 3a is the version of the Engineering Index discussed in the main body of the report, and the preferred measure.*

Table B.3 below describes the different versions of the Engineering Index:

Table B.3: The three versions of the Engineering Index and methodology applied

Index component	Version 1	Version 2	Version 2a	Version 3	Version 3a
Research	No weight	No weight	No weight	2 x weight	2 x weight
Gender balance	No weight	No weight	No weight	2 x weight	2 x weight
Employment	No weight	2 x weight	2 x weight	3 x weight	3 x weight
Wages	No weight	2 x weight	2 x weight	3 x weight	3 x weight
Businesses	No weight	No weight	No weight	No weight	No weight
Human capital	No weight	No weight	No weight	2 x weight	2 x weight
Infrastructure quality	No weight	No weight	No weight	2 x weight	2 x weight
Digital infrastructure quality	No weight	No weight	No weight	2 x weight	2 x weight
Engineering exports	No weight	No weight	No weight	No weight	No weight
Interpolation of missing data applied?	**No**	**Yes – across country average**	**Yes – within country average**	**Yes – across country average**	**Yes – within country average**

Source: Cebr analysis

Interpolation of missing data

Unfortunately, data for all of the Engineering Index components is not available throughout the full list of 99 countries considered. In the second and third versions of the Engineering Index we have therefore accounted for this by interpolating missing data. There are two approaches that have been applied to achieve this, as described below:

- The first approach (across country average) uses an average of other countries' index scores for the missing component. For example, there is no available information on the number of engineering businesses in China; therefore China's index score for engineering businesses is derived from the average of the scores of other CAETS countries.

- The second approach ("within country average") uses an average of a countries' available index scores for the missing component. For example, there is no available information on the number of engineering businesses in China; however there is information available for Chinese engineering jobs, wages and exports. An average of scores from these components is then used.

Table B.4 below provides examples for both approaches described above for one non-CAETS country with three missing data points: Hong Kong. The values presented below draw upon Version 3 and Version 3a of the Engineering Index respectively.

Table B.4: Examples of interpolation of missing data for Hong Kong (interpolated data in red)

Index component score	First approach	Second approach	Non-CAETS country average
Research	72%	72%	4%
Gender balance	70%	49%	50%
Employment	50%	47%	47%
Wages	78%	78%	42%
Businesses	70%	49%	49%
Human capital	70%	47%	47%
Infrastructure quality	96%	96%	44%
Digital infrastructure quality	59%	59%	42%
Engineering exports	62%	62%	47%
Within country average	70%	70%	

Source: Cebr analysis

Results presented in Section 7 utilise the second interpolation approach described above. This is based on the rationale that a country with a set of high-ranking individual index scores is likely to have similarly high scores in components with missing data, with the same argument applying to low-ranking countries.

Weighting the Engineering Index

The Engineering Index scores presented in Table 4 and Figures 21-26 have been weighted. The rationale here is that greater emphasis should be placed on the number of engineering employees and wages when calculating the index, rather than assuming equal emphasis with other variables such as infrastructure quality. Table B.5 below uses the example of Denmark. With greater weight placed on employment and wages and with Denmark scoring relatively strongly in these categories, Denmark has a higher Engineering Index score in Version 3a.

Table B.5: Examples of different weightings applied to data for Denmark

Index component	Version 2a		Version 3a	
Research	No weight	50%	2 x weight	50%
Gender balance	No weight	57%	2 x weight	57%
Employment	2 x weight	100%	3 x weight	100%
Wages	2 x weight	81%	3 x weight	81%
Businesses	No weight	32%	No weight	32%
Human capital	No weight	63%	2 x weight	63%
Infrastructure quality	No weight	84%	2 x weight	84%
Digital infrastructure quality	No weight	100%	2 x weight	100%
Engineering exports	No weight	30%	No weight	30%
Overall score		**69%**		**73%**

Source: Cebr analysis

Results presented in Section 7 utilise the third weighting approach described above. This is based on the rationale that a country with a set of high-ranking individual index scores is likely to have similarly high scores in index components with missing data.

Annex C: Data availability

In Table C.1 below we show data availability for the CAETS countries by Engineering Index component:

Table C.1: Data availability for CAETS countries

		Engineering Index component score								
CAETS Country	Data availability	Research	Human capital	Gender balance	Infrastructure quality	Wages and salaries	Engineering businesses	Engineering exports	Employment in engineering	Digital connectivity
Argentina	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Australia	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Belgium	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Canada	8/9	YES	YES	NO	YES	YES	YES	YES	YES	YES
China	7/9	YES	YES	NO	YES	YES	NO	YES	YES	YES
Croatia	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Czech Republic	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Denmark	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Finland	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
France	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Germany	8/9	YES	YES	NO	YES	YES	YES	YES	YES	YES
Hungary	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
India	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Japan	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Mexico	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Netherlands	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Norway	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Republic of Korea	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Slovenia	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
South Africa	7/9	YES	NO	YES	YES	YES	NO	YES	YES	YES
Spain	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sweden	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Switzerland	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
United Kingdom	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
United States	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Uruguay	7/9	YES	YES	NO	YES	NO	YES	YES	YES	YES

Source: Cebr analysis

Table C.2: Data availability for non-CAETS countries

		Engineering Index component score								
Non-CAETS country	Data availability	Research	Human capital	Gender balance	Infrastructure quality	Wages and salaries	Engineering businesses	Engineering exports	Employment in engineering	Digital connectivity
Albania	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Algeria	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Armenia	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Austria	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Azerbaijan	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Bahrain	7/9	YES	NO	YES	YES	YES	NO	YES	YES	YES
Bangladesh	7/9	YES	YES	YES	YES	YES	NO	NO	YES	YES
Benin	7/9	YES	NO	YES	YES	YES	NO	YES	YES	YES
Bosnia and Herzegovina	7/9	YES	NO	YES	YES	YES	NO	YES	YES	YES
Brazil	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Bulgaria	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Burundi	6/9	YES	NO	YES	YES	NO	NO	YES	YES	YES
Chile	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Colombia	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Costa Rica	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Cyprus	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Dominican Republic	6/9	YES	NO	YES	YES	NO	NO	YES	YES	YES
Ecuador	6/9	YES	NO	YES	YES	NO	NO	YES	YES	YES
Egypt	7/9	YES	NO	YES	YES	YES	NO	YES	YES	YES
El Salvador	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Estonia	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Ethiopia	6/9	YES	YES	NO	YES	NO	NO	YES	YES	YES
Georgia	6/9	YES	NO	YES	YES	NO	NO	YES	YES	YES
Ghana	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Greece	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Guyana	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Honduras	6/9	YES	YES	YES	YES	NO	NO	NO	YES	YES
Hong Kong	6/9	YES	NO	NO	YES	YES	NO	YES	YES	YES
Iceland	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Indonesia	7/9	YES	YES	NO	YES	YES	NO	YES	YES	YES
Iran	7/9	YES	YES	YES	YES	YES	NO	NO	YES	YES

Table C.2: Data availability for non-CAETS countries

		Engineering Index component score								
Non-CAETS country	Data availability	Research	Human capital	Gender balance	Infrastructure quality	Wages and salaries	Engineering businesses	Engineering exports	Employment in engineering	Digital connectivity
Ireland	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Italy	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Jordan	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Kazakhstan	6/9	YES	NO	YES	YES	NO	NO	YES	YES	YES
Kuwait	7/9	YES	NO	YES	YES	YES	NO	YES	YES	YES
Laos	7/9	YES	YES	YES	YES	YES	NO	NO	YES	YES
Latvia	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Lebanon	6/9	YES	NO	YES	YES	NO	NO	YES	YES	YES
Lithuania	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Luxembourg	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Madagascar	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Malaysia	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Malta	7/9	YES	YES	YES	YES	YES	NO	NO	YES	YES
Mauritius	6/9	YES	NO	YES	YES	NO	NO	YES	YES	YES
Mongolia	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Morocco	7/9	YES	YES	NO	YES	YES	NO	YES	YES	YES
Mozambique	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Myanmar	6/9	YES	YES	YES	YES	NO	NO	NO	YES	YES
Nepal	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
New Zealand	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Nigeria	6/9	YES	NO	NO	YES	YES	NO	YES	YES	YES
Oman	6/9	YES	NO	YES	YES	NO	NO	YES	YES	YES
Panama	6/9	YES	YES	YES	YES	NO	NO	NO	YES	YES
Peru	6/9	YES	NO	NO	YES	YES	NO	YES	YES	YES
Philippines	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Poland	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Portugal	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Qatar	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Romania	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Russia	7/9	YES	YES	NO	YES	YES	NO	YES	YES	YES
Rwanda	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
Saudi Arabia	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES

Table C.2: Data availability for non-CAETS countries

Non-CAETS country	Data availability	Engineering Index component score								
		Research	Human capital	Gender balance	Infrastructure quality	Wages and salaries	Engineering businesses	Engineering exports	Employment in engineering	Digital connectivity
Serbia	7/9	YES	YES	YES	YES	YES	NO	NO	YES	YES
Singapore	6/9	YES	NO	NO	YES	YES	NO	YES	YES	YES
Slovakia	9/9	YES	YES	YES	YES	YES	YES	YES	YES	YES
Sri Lanka	7/9	YES	YES	YES	YES	YES	NO	NO	YES	YES
Thailand	6/9	YES	NO	NO	YES	YES	NO	YES	YES	YES
Tunisia	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Turkey	8/9	YES	YES	YES	YES	YES	NO	YES	YES	YES
Ukraine	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES
United Arab Emirates	7/9	YES	YES	YES	YES	YES	NO	NO	YES	YES
Vietnam	7/9	YES	YES	YES	YES	NO	NO	YES	YES	YES

Source: Cebr analysis

Annex D: Full set of econometric analysis results

Tables D.1 and D.2 below show the full set of results for the two econometric models described in Section 8 of this report: the first examines the relationship between GDP per capita and the Engineering Index, and the second considers GFCF and the Engineering Index. The different versions of the model draw upon the different versions of the Engineering Index.

Table D.1: Econometric analysis of GDP per capita and the Engineering Index (constant terms not shown)

Factor	Change	Associated with GDP per capita growth of:				
		Model #1	**Model #2**	**Model #3**	**Model #4**	**Model #5**
Human Capital investment	1%	+0.95% *** (0.17)	+0.99% *** (0.18)	+0.97% *** (0.18)	+0.97% *** (0.18)	+0.97% *** (0.18)
Physical investment	1%	+0.27% *** (0.06)	+0.29% *** (0.06)	+0.29% *** (0.06)	+0.29% *** (0.06)	+0.29% *** (0.06)
Quality of life	+1 year	+0.05% *** (0.01)	+0.05% *** (0.01)	+0.05% *** (0.01)	+0.05% *** (0.01)	+0.05% *** (0.01)
Trade openness	+1 ppt	+0.18% ** (0.07)	+0.18% ** (0.07)	+0.18% ** (0.07)	+0.18% ** (0.07)	+0.18% ** (0.07)
Engineering Index v1	+1 ppt	+1.03% ** (0.42)	-	-	-	-
Engineering Index v2	+1 ppt	-	+0.84% * (0.43)	-	-	-
Engineering Index v2a	+1 ppt	-	-	+0.83% ** (0.41)	-	-
Engineering Index v3	+1 ppt	-	-	-	+0.94% ** (0.43)	-
Engineering Index v3a	+1 ppt	-	-	-	-	+0.85%** (0.41)

Source: Cebr analysis. Note: Standard errors are in parentheses; asterisks indicate significance level of coefficients

Table D.2: Econometric analysis of GFCF and the Engineering Index (constant terms not shown)

Factor	Change	Associated with investment growth of:				
		Model #1	Model #2	Model #3	Model #4	Model #5
GDP per capita	+1%	+0.29% ** (0.14)	+0.43% ** (0.14)	+0.38% ** (0.14)	+0.44% *** (0.15)	+0.38% ** (0.14)
Change in business inventories	+1%	+0.24% *** (0.05)	+0.24% *** (0.06)	+0.24% *** (0.05)	+0.24% *** (0.06)	+0.23% *** (0.05)
Access to credit	+1%	+0.12% ** (0.04)	+0.10% ** (0.04)	+0.11% ** (0.04)	+0.10% ** (0.04)	+0.10% ** (0.04)
Engineering Index v1	+1 ppt	+2.47% ** (0.79)	-	-	-	-
Engineering Index v2	+1 ppt	-	+1.81% ** (0.82)	-	-	-
Engineering Index v2a	+1 ppt	-	-	+1.96% ** (0.77)	-	-
Engineering Index v3	+1 ppt	-	-	-	+1.56% (0.84)	-
Engineering Index v3a	+1 ppt	-	-	-	-	+1.87%** (0.73)

Source: Cebr analysis. Note: Standard errors are in parentheses; asterisks indicate significance level of coefficients

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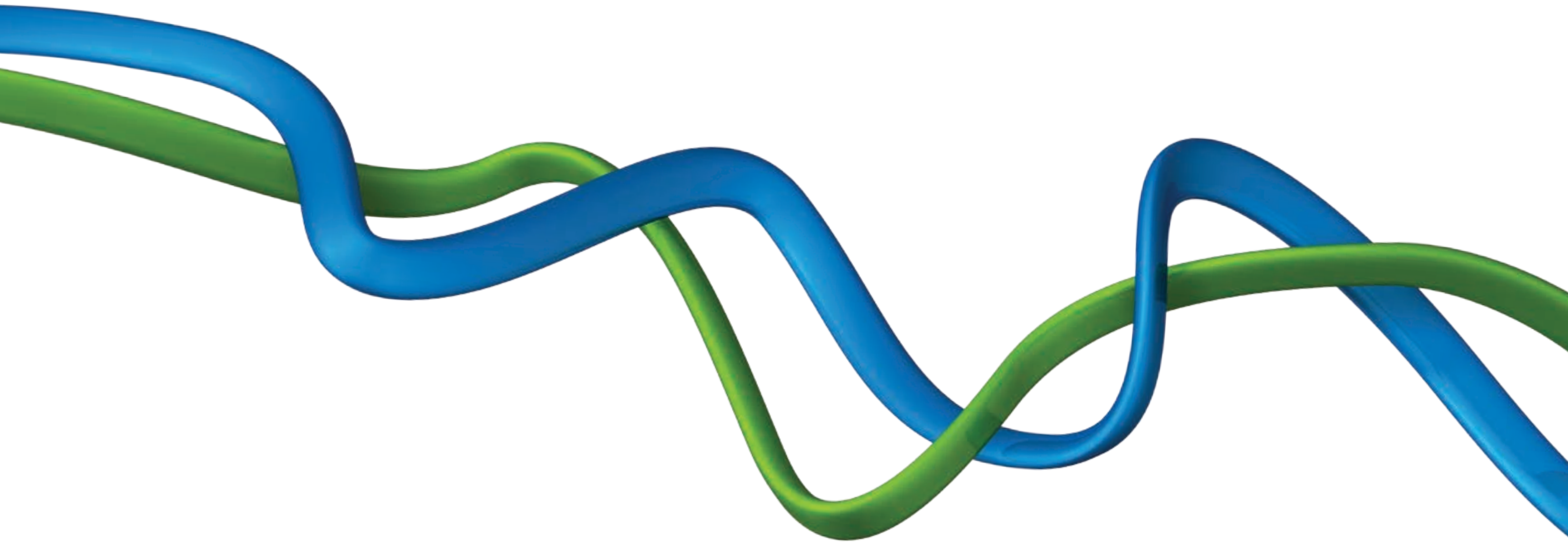
Meeting the UK's needs by inspiring a generation of young people from all backgrounds and equipping them with the high quality skills they need for a rewarding career in engineering.

Position engineering at the heart of society

Improving public awareness and recognition of the crucial role of engineers everywhere.

Lead the profession

Harnessing the expertise, energy and capacity of the profession to provide strategic direction for engineering and collaborate on solutions to engineering grand challenges.



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