The importance of the measurement infrastructure in economic recovery

Executive Summary

This paper describes the many, evidenced-based benefits to the economy of a well-developed measurement infrastructure. In particular, it explains how assuring confidence in measurement may be used to accelerate economic recovery including in emerging sectors such as the digital economy. Recommendations are made for providing near term support for national recovery whilst also demonstrating the advantages of sustained development of the measurement infrastructure in the medium-term to maximise the potential of future innovative and disruptive technologies.

Introduction

Science, technology, medicine, trade and industry – in fact all human life – relies on measurement. Importantly, these systems work because we have **confidence** in the measurements made. Our measurements are trustworthy at the level we need them to be to achieve our objectives.

This confidence does not happen by accident but is a result of a well-established infra-technology – our **measurement infrastructure**: agreed globally and implemented locally – an invisible glue that binds together science and technology and enables all progress. The measurement infrastructure is like the road network, allowing the smooth passage of traffic, or measurements, adding value for the economy and quality of life, continuously delivering real world impact and enabling new technologies to solve current challenges. It covers everything in the measurement chain from the definition of measurement units agreed globally by governments, through agreed standard methods for measurement, to the reliability of end user measurements in the field, in hospitals or in factories – for example by enabling worldwide stable and consistent dimensional measurement to ensure automotive parts made in several different locations always meet required tolerances and as a result may be assembled quickly, with confidence and without waste.

Benefits of Metrology – The Evidence

Metrology, the science of measurement, oversees the maintenance and improvement of this measurement infrastructure, continually responding to evolving societal needs. By achieving global agreement on how measurements should be made, expressed and used, metrology has generated systems and frameworks for measurement quantification and through these underpins consistency and assurance in all measurement. Those using our measurement system benefit from their measurements being stable over time, comparable with others and accurate, allowing known confidence in measurement results. Adopting the principles of metrology has the following benefits:

1. Improves the effectiveness and efficiency of science and the trust in its outcomes
2. Reduces waste and increases value for money and productivity
3. Unlocks the potential of innovation faster, allowing earlier market entry
4. Decreases the time to implement change and add value
5. Is essential for the development and assessment of evidence-based policy and accelerates progress in science and in society

Each of these benefits is supported by a solid evidence base:

1. *Improves the effectiveness and efficiency of science and the trust in its outcomes:*
    - (Tassey, 2004) argues that the efficiency with which generic knowledge is converted into proprietary knowledge depends on having access to research tools, techniques, and standards. These public goods ('infra-technologies') determine the *productivity* of private R&D.
    - (King & Renedo, 2020) makes the case that improvement in productivity through the UK achieving its target of investing 2.4% GDP into R&D mainly depends on businesses investing more in R&D. However, the UK is close to the limit of what can be achieved through current funding mechanisms. Hence, policy makers should consider other forms of intervention aimed at fundamentally altering the effectiveness of R&D without just resorting to further subsidies.
    - A survey of organisations that used the NMS[1] labs between 2014 and 2017 found that two thirds (68%) of academic collaborators said they work with the NMS labs to better inform their strategy and research direction. Moreover, a third of these users (34%) said the impact created by working with the NMS labs could not have occurred without their support[2].

2. *Reduces waste and increases value for money and productivity:*
    - (Kunzmann, et al., 2005) argues that 75% of all errors that occur are pre-determined in the earliest phases of production. However, 80% of these failures are not detected until later, either during the manufacturing process (including inspection) or after sales.
    - (Orji, et al., 2009) investigates how metrology influences the cost function. Advanced metrology allows tighter production processes with better control of parameters that influence the quality of a final product.
    - (Belmana, 2020) found a 5.5% increase in employment between 2009 and 2017 among businesses receiving regular support from the NMS. Around 80% of this growth was additional, in the sense that it was not seen in a matched control group. Moreover, employees moving to these NMS supported businesses received an annual wage premium of £ 2,600, with this premium remaining significant even after controlling for their characteristics. This is significant because economists believe that wages closely track labour productivity[3].

3. *Unlocks the potential of innovation faster, allowing earlier market entry*:
    - (Hawkins, 2017) discusses how R&D creates inventions that must be commercialised and brought to market as innovations. A key driver in accelerating this process is giving potential customers or regulators (public or private) confidence that a new technology works as well

[1] The National Measurement System (NMS), funded by BEIS, is the technical and organisation infrastructure which ensures a consistent and internationally recognised basis for measurement in the UK. It has two central objectives: a) to enable individuals and organisations in the UK to make measurements competently and accurately and to demonstrate the validity of such measurement, b) to coordinate the UK's measurement system with the measurement systems of other countries.

[2] A summary of this survey has been published by NPL. This document can be accessed here.

[3] Belmana's report has separate results for both the impact of the NMS labs and the grants from Innovate UK. The results detailed in this analysis have passed through BEIS' peer-review process. Currently, Belmana's technical report is in the process of being turned into two separate reports, one relating to the NMS labs, and the other one relating to Innovate UK. Both reports will be published in due course.

as its owner claims it does. This is easier to do when there are established methods for testing the performance of a product or process.

- A survey of organisations that used the NMS labs between 2014 and 2017 found that around 80% of the NMS labs' business customers made a change to their products or processes. Furthermore, 1 in 5 (19%) of those who made a change believe that the change would not have happened without the support they received from the NMS labs.
- (Nwaigbo & King, 2020) analyse the impact of the Measurement for Innovators (MFI) programme which provided free support to a selection of innovative businesses who applied to the programme. The study finds that the probability of filing for a patent among companies who completed the MFI programme was around 11% higher during the year of support against a comparator group of similar firms. Applicants who did not receive support still produced new patents, but it took them longer to generate such patents than was the case for the supported firms.

4. *Decreases the time to implement change and add value:*
    - (King, et al., 2017) discuss how the efficiency or speed with which one type of knowledge is converted into another type of knowledge depends on having good access to appropriate research tools, techniques, and standards. These elements form the infra-technology needed for the reproducibility of experimental phenomena.
    - As an example of what happens in the absence of an appropriate infra-technology, (Tassey, 2004) points to the very low success rate of biotechnology firms in the 1980s and 1990s. He claims that 25 years after Genetech became the first biotech company, only 12 of the 50 largest companies were profitable and the biotech industry was still losing money in 2005.

5. *Is essential for the development and assessment of evidence-based policy and accelerates progress in science and in society*:
    - (Font, et al., 2015) aimed to fingerprint emissions from six municipal waste incinerators and then test if these 'fingerprints' could be found in ambient air samples. The analysis finds no evidence of incinerator emissions in ambient metal concentrations around four UK waste incinerators. The conclusions of this paper were picked up and used in Parliamentary briefing notes on waste incineration facilities, as well as, for the incineration of industrial and commercial waste.
    - (Giannis, et al., 2019) is a thorough report by NPL produced in consultation with industry, through a cross-sector workshop organised by NPL on behalf of the Composites Leadership Forum (this report can be accessed here). The main recommendations of this report are:
        - the acceleration of standardisation and publication of technical documentation that address identified gaps in the regulatory infrastructure,
        - the design and implementation of a digital tool and mentoring scheme to help industry adopt and certify novel materials,
        - the creation of an advanced materials assurance centre to bring together the materials supply chain and regulators to deliver a central resource to provide access to trusted materials data.

Implementation of these recommendations would influence regulatory decisions in the field, unlock current regulatory barriers and thereby increase the use of composite materials across the advanced manufacturing sector.

Summary

Embracing the measurement infrastructure is an essential requirement for reproducibility of outcomes and therefore progress in science and in society. The virtuous circle of improved measurement, driving improved technology, driving improved measurement, is the motor that propels economic and social progress.

The application of metrology is universally relevant across all sectors and to all users of measurement. Metrology should be part of everything and a partner of everyone.

Nonetheless metrological principles are not always fully embraced. For instance this is sometimes the case in academia where measurement methods are developed in isolation, not compared or standardised, and hence it takes longer to make progress, with a larger number of studies and at higher cost than necessary. As another example, SMEs often lack appropriate training in good measurement, delaying the development of new products and stifling innovation. With metrology embedded, progress would be faster, cheaper and more robust.

Increasing the adoption of better measurement will provide significant competitive advantage for the UK, in industry and academia, as all nations struggles to recover from the shock of COVID-19. This will accelerate the recovery, making up for lost time and then going on to add significant extra value. Even more importantly metrology will be an anchor of stability that we can use to help accommodate, validate and implement the new working, living, operating and manufacturing practices which will need to be developed.

It is essential for metrology to identify the weakest links in the measurement chain under these 'next normal' conditions and work directly alongside industry, government and academia to strengthen these and build new measurement infrastructure. **We have proposed a modest programme of work to our BEIS sponsor, based on our successful Analysis For Innovators initiative, to enable NPL and partners to engage directly with industry to help drive innovation and development in the restart phase, post COVID-19 lockdown.**

Recommendation

Looking past immediate challenges, **a new measurement infrastructure** is required in order to unleash the potential of a number of emerging topics that will revolutionise society and the economy. These topics, a mixture of challenges and technologies, include big data and the digital world, clean growth and achieving net zero carbon emissions by 2050, artificial intelligence, industry 4.0 and future communications, personal medicine and an ageing population. They are not covered by the traditional measurement infrastructure whose history evolved from the physical world of weights and measures. Nonetheless, to advance rapidly and realise their benefits faster, these areas need the order, stability and control that the application of measurement science brings.

This new framework would still provide the stability and comparability expected of the traditional measurement infrastructure but would achieve this by a novel approach not involving physical measurement standards. The new framework would provide the focus for national and **global leadership in the development, validation and agreed standardisation of measurement methods**, and in the dissemination of best practice for data assessment, interpretation, curation and reuse. This new measurement infrastructure would provide significant impact and has many benefits:

- Enables the faster, more productive and efficient transfer of science into innovation;
- Provides a new national infra-technology that supports technologies and challenges equally;
- Is future-proofed and flexible, allowing underpinning support of yet to be conceived technologies;
- May be led by NPL as the leading national laboratory for industry and innovation;
- Makes the UK a world leading superpower in these areas, and providing a competitive advantage over other economies;
- Puts innovation at the heart of economic recovery and future growth;
- Has the ability to be delivered across the regions and nations of the UK, wherever the need for support was greatest;
- Is a progressive approach that ensures the UK attracts and retains a highly skilled, diverse workforce;
- Accelerates progress towards the government's 2.4 % R&D target.

The underpinning and flexible nature of this new measurement infrastructure makes it agile and universal, able to apply its principles to support, at short notice, new demands on the economy and UK government, providing **resilience to cope with any future national requirements or crises**.

In particular the movement towards a digital society needs the principles of metrology for these innovations to make rapid progress. Metrology is the existing framework for delivering confidence in processes and outputs, which would support: agreed digital nomenclature, quality assured data production, and standard methods of data expression, transfer and curation. **A world leading measurement infrastructure is essential to the rapid, harmonious and widespread adoption of the digital economy.**

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