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To cite this article: W P Fisher Jr *et al* 2019 *J. Phys.: Conf. Ser.* **1379** 012023

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Why metrology? Fair dealing and efficient markets for the United Nations' Sustainable Development Goals

W P Fisher Jr¹, L Pendrill², A Lips da Cruz³, A Felin²

¹ Living Capital Metrics LLC, Sausalito CA 94965 USA, and BEAR Center, Graduate School of Education, University of California, Berkeley, 94702 USA

² RISE Research Institutes of Sweden, Gothenburg, Sweden

³ ALDC Partnership, Stockholm, Sweden

E-mail: wfisher@berkeley.edu

Abstract. Why metrology? What special value does it offer to the design and use of sustainability impact metrics, and so to the realization of the United Nations Sustainable Development Goals? One answer in short, is, "For justice." The balance scale is a universal symbol of fairness, development and equality. A second brief reply is, "For efficient markets." Common currencies for the exchange of value are well known as a key factor in lowering transaction costs and supporting property rights, both essential to market formation. The repeatedly encountered dilemma, of course, is how to design, calibrate, and use measures of economic, environmental, human, and social value that lower costs and are just in more than name alone, serving some but not others. Longer answers justify metrological traceability to consensus unit standards as a key factor in realizing the SDGs by showing how it contributes to (a) the cultivation of shared meanings and improved communication; (b) the grounding of pragmatic expressions of verified trust; (c) making real, reproducible developmental trajectories visible and manageable; and (d) creating the multilevel systems of systems required for managing and governing complex, adaptive, self-organizing forms of social, political, legislative and economic life. A more complete answer to the question, "Why metrology?," then focuses on how the SDGs' diverse stakeholder interests may be most effectively fulfilled via collective actions facilitated on the basis of shared values.

1. Metrology: What, why, and how

Initiated in January, 2016, the United Nations' (UN) Sustainable Development Goals (SDGs) offer the nations and people of the world a forum in which to coordinate efforts at eliminating poverty, protecting the environment, and ensuring peace and prosperity. The 17 goals overlap in ways that will build synergies across interrelated domains ranging from democratic governance, climate change, economic inequality, education, and health care, to innovation, sustainable consumption, reduced violence, and social justice. The SDGs are key to UN Development Programme (UNDP) efforts in 170 countries, and will guide planning and funding until 2030. The UNDP is actively partnering with governments, the private sector, civil society, and citizens to integrate the SDGs into policies and practices at every level.

1.1. What exactly is metrology?

Metrology is "the science of measurement and its application" [1], especially as concerns the definition and reproduction of mathematically rigorous, experimentally validated quantities. Measurement science



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focuses on models, quantities and uncertainty, estimation, and construct theory. National metrology institutes work with this science and more broadly with traceability in support of product comparability, instrument conformity assessment, consensus standards formation, legal and regulatory issues in the wider quality infrastructure. A matter of essential concern is traceability, which is a "property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty" [1].

Though it may come as a surprise to many, social and cultural expectations and norms are likely a bigger barrier to the achievement of metrological traceability in the SDG domains than technical problems are.

Despite a wealth of evidence supporting the feasibility, viability, and desirability of metrological traceability, and despite the many advantages to be gained from creating traceability systems, instruments measuring the same human, natural and social constructs are not usually calibrated in common units in either research or practice. These constructs are very different from the economic and financial key ratio information used in accounting. Precision measurement of abilities, health, trust, and environmental quality provides actionable detail that is otherwise unavailable, and that is essential to the achievement of the SDGs.

Even though these systems have not been referred to as metrological until recently, they not only incorporate the measurement science and theory characteristic of metrology, they also serve as models for new initiatives at national metrology institutes [8-10]. Systematic presentations of philosophical and methodological issues are available in multiple forums [2-16].

Human abilities, attitudes, and behaviors have in fact long been measured in ways respective of individual differences while also being read from instruments calibrated in accord with models mathematically analogous to the balance scale [2-5]. Thousands of well-calibrated individual instruments and hundreds of millions of individual measures combining coherent continuity with local improvisations have been produced and used in social and psychological research and practice [6-7].

1.2. Why metrology?

The question as to why metrology should be important to the realization of these global goals can be answered quite easily: for justice. The idea that everyone should be treated equally, irrespective of their differences, makes the balance scale a universal symbol of global fairness development and equality opportunities. The metric system, the *Système Internationale des Unites*, or SI, is itself a product of the French Revolution's call for "one law, one weight, and one measure" [17] (omitting the reference to "one king"). That said, arriving at just relations in an even-handed way that does not reduce individual differences to false forms of homogenized sameness has proven so elusive many consider it impossible. The idea that a universal measure representing every individual human, organisational and natural resource could be found in globally shared human, organisational and natural characteristics seems antithetical to valuing unique differences, however much more easily managed such measures might be for bureaucracies [18], and however much more they would offer in the way of growth opportunities and profits [19].

In accord with the focus on justice, more complex answers to the question of "Why metrology?" speak to the need for a common language of sustainable development. Communicating what is learned about what works and how to use it demands fair, equitable, reproducible, verifiable, meaningful and efficient representation. Significant difficulties are associated with defining, estimating, and implementing shared standards for fair and equitable measures in an era of increasing global information where the Internet and digitalisation enable sometimes vapid and destructive connectivity.

1.3. The role of metrology in commerce and markets

Huge resources, nationally and internationally, are invested in metrological traceability to the SI reference standards. Those investments are however worth it, since they pay more than proportionate returns by lowering transaction costs, clarifying communications, and supporting property rights in efficient markets [20]. High transaction costs often make it difficult or impossible to determine the

quantity and/or quality of a product or service, which then obscures communication and ownership. Metrology plays a key role in lowering the costs of market transactions, in supporting unambiguous communications, and in establishing legally defensible title. So a second answer to the question "Why metrology?" is "For efficient markets" [19, 13, 20-21].

This role of precision measurement science and metrological traceability in making markets has to date been almost completely ignored in the domain of sustainability. The achievement of the UN SDGs is fundamentally obstructed by widespread use of incommensurable metrics. Because communication is obscured, neither management efforts nor market comparisons are as well coordinated within shared frames of reference as they should be. This comes about even though the economic value of common currencies in trade is widely recognized and implemented in policy and practice, and even though the SI unit standards are universally acclaimed for their role in technological and entrepreneurial innovation.

Efficient markets for the exchange of scientific and economic value plainly require a wide array of stakeholder interests (legal, financial, economic, technical, aesthetic, moral, social, etc.) that are, like musical instruments and scales, both (a) coordinated and aligned relative to shared standards, and (b) open to and expressive of unique individuality and creative improvisation [11, 12, 22]. Metrological research and practice provides the strategic forum in which diverse stakeholders in sustainable policies and practices assert their interests in evaluating and managing the uncertainty, precision, meaningfulness, and use of sustainability information. Historically, metrology is the means by which groups with varied interests (consumers, lawyers, economists, accountants, managers, investors, regulators, financiers, etc.) realize their interests more fully and equitably via collective action than they can in isolation. Conformity assessment, including legal metrology, is an established sphere of activities national metrology institutes use to ensure stakeholder confidence in products and services.

Instrument calibrations, data analyses, estimation algorithms, and reporting mechanisms all require close attention to ensure that everyone is talking about the same thing in the same terms. Trust and confidence are based in verified inspections and accountability demonstrating that the requirements specified in consensus and sustainable standards are met. Conformity assessment is often essential to meeting the needs of the public interest, public health, safety and order, and protections of the environment, consumers, and fair trade.

1.4. How to extend metrology in new directions

And so the question arises as to how we might extend science productively into the new domains of innovation defined by the United Nations Sustainable Development Goals. Four areas of especially urgent interest can be identified. These involve meaning and relevance, trust based in reproducible objectivity, the manageability that follows from measurability, and the complexity required for adaptation to changing circumstances.

In each of these four areas, illustrative examples can be drawn from the target included in UN SDG 3 on Good Health and Well-Being concerning the achievement of "universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all." Differences across global variations in how quality essential health care services are defined must be addressed in new ways if metrological unit standards are to be feasible and viable. Of paramount importance is the need for an inclusive system where equity in health care is assured for all global citizens independently of economic terms and individual countries' forms of constitutional governance.

2. Meaning and relevance

Scales that are mathematically rigorous and that effectively concatenate an abstract ideal unit are often in Health and Well-being contexts estimated from nonlinear data using algorithms that are also nonlinear. Individuals do not typically progress and grow along the dimension measured in a strictly linear, incremental fashion, so it is important to understand that change and performance occurs within a range bound by uncertainty. Accepting these limits, meaningful measures stand for things supported by theory and evidence as adding up in linear interval ways. Thus, the truth of meaningless statements:

...depends on what scale or coordinate system is employed, whereas meaningful propositions have truth-value independent of the choice of representation, within certain limits. ...analysis of this distinction leads...to a...technical apparatus focusing upon invariance under changes of scale [23].

Evidence evaluated in sustainability terms ranges from numeric data like economic growth, energy consumption, water usage and the preservation of species to more qualitative perceptions, often scored on categorical scales. Meaningfulness is obtained, however, not only from the relevance of the phenomena observed, but also from the extent to which those phenomena can be communicated effectively, transparently, and efficiently. The metrology of categorical properties scaled in meaningful units of measurement is still in its infancy, despite more than 90 years of applications in many fields.

The meaningfulness of calibrations that remain invariant across the particular choice of representation contrasts with the kind of criteria for universal health coverage specified in the UN SDG 3 target, to take one example. Different countries and different care providers can reasonably be expected to offer services that vary markedly in their quality and terms, such that many higher percentages of enrollees will be included by some, while others with perhaps more stringent, expensive, and higher quality features will enroll lower percentages. A more rigorous approach will specify the operational terms of what services constitute a minimum standard of coverage, so that the experiences of consumers can be meaningfully documented, modelled, estimated, calibrated, and compared.

3. Trust based in demonstrated objectivity

Meaningfulness cannot, however, be created in contexts devoid of trust. When we give our word, we make a promise of trustworthiness that conveys an intention of objective verifiability. That is, multiple independent observers have to be able to reproduce invariant experimental results, just as multiple independent approaches to designing and deploying measuring instruments must reproduce the unit of measurement to within a tolerable range of uncertainty, and just as multiple independent approaches to explaining variation in the calibrations of questions and indicators must also reproduce the same predictive model, also to within a tolerable range of uncertainty. These factors together contribute to the objectivity of results capable of inspiring trust. In this sense, there is an important convergence of moral values concerning just relations with the quantitative values of precision measurement [24].

Trust in a metric for universal health coverage, as is implied in the UN SDG 3 target, cannot, then, be established on a basis of the percentages of enrollees. Taken at face value, these numbers vary meaninglessly across providers, and so cannot support the reproduction of an invariant connection between the numeric expression of quantitative amounts and a stable phenomenon of consumer engagement with health coverage services. Dealing with these numbers alone, as though they automatically meet the need for a quantitative metric, is insufficient to the task.

4. Manageability facilitated by measurability

Metrology facilitates manageability in specific and essential ways that otherwise remain inaccessible. It does so by providing a navigable map of the development terrain to be traversed [3, 6, 11-12, 22]. This map is based in the evidence of observed variation, it is calibrated in the shared language of a standardized unit, and it is validated by the explanatory model of a theory predicting the observed variation. The measured construct, no matter if it involves education, health care, human resource training, organizational learning, community service, or any other form of sustainable development, lays out the sequences through which development, growth, or change progresses. In this context, the maxim, "you manage what you measure," becomes a practical expression of meaningful formative engagement with what matters. Instead of meaningless scores, measures stand for reproducible structures of change and growth that are individually interpretable and actionable.

In this vein, a critical appraisal of the health-related SDGs calls for "a robust formative evaluation system that scrutinises accountability mechanisms and possible double-duty paradoxes embedded in the operationalisation and implementation of the SDGs" [26]. Formative evaluations of just this kind have been developed and used in education and health care for decades [3, 6-7, 11-12, 14, 22]. In the context of the UN SDG 3 target on universal health coverage, a calibrated developmental sequence mapping a

continuum of increasing quality of care lays out a roadmap to the management of improved access. The most easily provided and commonest features of universally accessible care will be rated as present most often by consumers, and the rarest, least easily provided features will be rated as present least often. Later features and programs will rely and build on earlier ones. Not all features and programs will be relevant or needed in different locations; sequences will not be rigidly followed everywhere. Thus we need to deal with complexity to be able to nimbly adapt to varying circumstances and change over time.

5. Complexity

The most fundamentally important answer to the question "Why metrology?" concerns discontinuities between the varying levels of complexity that structure information. This is of special importance today, as digital information increasingly influences the allocation of resources and investments towards SDG targets. We are so habituated to the flexibility language affords us in communication that we tend to ignore, accommodate, or work around instances in which the complexity of information becomes problematic. This happened, for instance, in the formulation of the SDGs, where the word "we" refers to humanity in general when demand for sustainable solutions are the topic of discussion, but refers to a different and unidentified class of people when speaking to issues of accountability [25]. Another disconnection of responsibility from established channels of governance occurs in sustainability impact investing when producers accountable to investors circumvent citizens' reliance on their elected officials, effectively turning people into faceless commodities [26].

This kind of restricted market definition follows closely from the quality of the measurement information used to track and evaluate productivity. Metrics tied to specific indicators are not commensurable across (or even within) providers, and so cannot be the medium of fair trade or efficient markets, since they do not lower transaction costs, enhance communication, or support property rights [13]. But social studies of metrological science show its objects of study "are both plastic enough to adapt to local needs and the constraints of several parties employing them, yet robust enough to maintain a common identity across sites" [27 p 392]. That is, metrological principles and practice can facilitate both local improvisations and general navigable continuity in measurement and management [11]. This capacity is essential to meeting the practical demands for meaning, trust, manageability, and complexity involved in the management of the SDGs.

6. Conclusion

The established viability of metrological traceability for the instruments of human, social, and natural capital and new initiatives set in motion by national metrology institutes [2-16] set the stage for fundamental changes in the organization of approaches to realizing the SDGs.

Sustainability impacts plainly and obviously at present lack common product definitions, objective measures, efficient markets, and associated capacities for competing on improved quality. The absence of these landmarks to date in the domain of sustainability interests is a result of inattention and cultural biases far more than it is a result of the inherent characteristics or nature of sustainability itself. Given the economic importance of these kinds of capacities and the urgent need for new innovations supporting sustainable development, it is curious how even those most stridently advocating new ways of thinking seem to systematically ignore well-established opportunities for advancing their cause. The wealth of historical examples of rapidly emerging, transformative, disruptive, and highly profitable innovations would seem to motivate massive interest in how extend those successes in new directions.

Economists have long noted how common currencies reduce transaction costs, support property rights, and promote market efficiencies. Language itself is well known for functioning as an economical labor-saving device in the way that useful concepts representing things in the world as words need not be re-invented by everyone for themselves, but can simply be copied. In the same ways that common languages ease communication, and common currencies facilitate trade, so, too, do standards for common product definitions contribute to making markets and to innovative quality improvements [21].

Metrologically traceable measurements allow everyone everywhere to know how much of something there is. This is important, first of all, because things have to be identifiable in shared ways if we are to

be able to include them in our lives, socially. Anyone interested in obtaining or producing that kind of thing has to be able to know it and share information about it as something in particular. Common languages capable of communicating specifically what a thing is, and how much of it there is, support claims to ownership and to the fruits of investments in entrepreneurial innovations. Metrology ought, then, to be a top-level priority in SDG programs and policies. How else will sustainable impacts be made universally identifiable, individually owned, efficiently exchanged, and profitable?

The electronics, computer, and telecommunications industries provide ample evidence of metrology's role in reducing transaction costs, establishing common product definitions, securing property rights, and reaping huge profits [21]. The music industry's use of these technologies combines the science of precision measurement with the artistic creativity of intensive improvisations. Instruments tuned to standardized scales are used to achieve wholly unique levels of individual innovation. Much stands to be learned, and even more to be gained, in focusing sustainable development on harnessing the economic power of the profit motive and individuals' capacities for creativity.

The potential for embodying shared moral, economic, and scientific values in common metrological languages [24] should not be judged impossible without thorough investigating its viability, feasibility, and desirability. This task ought to be the defining mission of this generation. The time to act is now.

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