1 Markets and measurements

An introduction

> As we trace the history of our metrology from the beginning we shall have ample evidence of [considerable] effort which ensured that the exchange of goods was equitable, with the consumer relying ultimately on kingly support of his claim for justice in the market-place.
>
> – R. D. Connor, *The Weights and Measures of England* (1987)

Metrology, mensuration and measurement practices

Measurements defined the foundations of justice, safeguarded property and ensured the rule of right, wrote Patrick Kelly in his book *Metrology* (published 1816). Kelly, an accountant, a mathematics teacher, former master of Finsbury Square Academy and an astronomer, argued that measurements were fundamental to all commercial and economic activity, as 'productions of land and labour, or nature and art' were estimated on the basis of weights and measures.[1] The diversity of weights and measures that prevailed 'throughout the world' greatly concerned him. As an expert on bookkeeping, currency exchange and other commercial matters, he reckoned that diversity must be an 'interruption to trade and commerce'.[2] This diversity was well documented in a parliamentary report of 1820 that listed the immense variety of local and customary weights and measures in a thirty-page appendix.[3] Kelly despaired that

[1] P. Kelly, *Metrology; or an exposition of weights and measures chiefly those of Great Britain and France . . .* (London, 1816). Ashworth describes Kelly as an 'executive business astronomer' as he was among the several business-minded people, such as Francis and Arthur Baily, Henry Colebrooke, Stephen Groombridge and Charles Babbage, who founded and were dominant within the Astronomical Society in London. W. J. Ashworth, 'The calculating eye: Baily, Herschel, Babbage and the business of astronomy', *The British Journal for the History of Science* 27 No 4 (1994).

[2] Kelly, *Metrology*. See 'Introduction'. Kelly was also the author of *The universal cambist, and commercial instruction* (London, 1811), a text on coinage and currency exchange, and *The elements of book-keeping* (London, 1801), a text on single-entry and double-entry bookkeeping.

[3] *Second report of the Commissioners on Weights and Measures*, [P]arliamentary [P]apers Vol. VII 1820, pp. 475–509.

although there were numerous plans for correcting this diversity by adopting universal standards, the plans were as 'visionary and impractical as proposals to establish a universal language'.[4]

British historians have generally echoed Kelly's views. The overall consensus in the literature on the long nineteenth century is that diversity and nonuniformity of weights and measures tended to disrupt internal trade.[5] The presence of numerous local measurement units throughout the country is taken as evidence of how fragmented markets were in eighteenth-century England: 'a chain of local and regional markets at this date [rather] than as one emerging national economy'.[6] There is little dissension within the historiography of British markets that the diversity in its weights and measures had a detrimental impact on transactions and market exchanges, created uncertainties and costs, erected internal barriers to free trade and ultimately inhibited market integration.[7] In many other respects, late-eighteenth-century Britain may have been economically developed, but in terms of fragmented markets and diverse weights and measures, it was as undeveloped as the rest of Europe.

The confusing array of weights and measures was tidied up during the nineteenth century, especially through two major legislative reforms in the 1820s and 1870s. The Imperial system of weights and measures that was introduced in 1824 was the culmination of scientific, administrative and legislative efforts of scientists, MPs, civil servants and instrument makers in the late eighteenth and early nineteenth centuries. This reform of Britain's weights and measures, and the subsequent reform of 1878, eventually rid the statute books of duplicative and arcane acts, introduced a simplified and hierarchical system of measurement units and instituted a well-defined organisational structure to enforce this system nationally.

In many respects, this was a significant institutional change. Britain finally had a uniform system of weights and measures, a political quest that had been periodically attempted since the Magna Carta of 1225 had declared that 'there shall be one measure of wine, one measure of ale, and one measure of corn'.[8] Britain was one of the few nations in Europe to have a unified metrology in the first half of the nineteenth century.

[4] Kelly, *Metrology*, p. xi.
[5] J. Hoppit, 'Reforming Britain's weights and measures, 1660–1824', *The English Historical Review* 108 No 426 (1993): p. 82.
[6] G. V. Harrison, 'Agricultural weights and measures', in J. Thirsk (ed.) *The agrarian history of England and Wales*, Vol. VII, *1640–1750 (agrarian change)* (Cambridge, Cambridge University Press, 1985), p. 815.
[7] M. J. Daunton, *Progress and poverty: an economic and social history of Britain 1700–1850* (Oxford, Oxford University Press, 1995), p. 278.
[8] House of Commons Reports (1738–65) 1758 Vol. II, *Report of the Carysfort committee on weights and measures*.

The other major European powers would not achieve this until later: France (c. 1840), Germany (c. 1870), Italy (c. 1860), Russia (c. 1920). They adopted the metric system that was developed during the French Revolution in the 1790s. Britain narrowly rejected adoption of the metric measures in 1871, voting to retain the Imperial measures as the basis of its national measurement system for at least another century or so.[9]

The recalcitrant attitude of the British state towards metric measures was born partly out of resistance to change. Mr Fothergill, industrialist and MP, pointed out the insurmountable difficulties in adopting the metric system and was certain that

> [it] would be met with strong disfavour of the working classes, who knew the present system perfectly well and understood all its working, [and would] have all their habits and notions in regard to work and wages upset by the introduction of a new system.[10]

Reforming Britain's weights and measures was fraught with tension between those who held fast to local, customary measures and those who were the proponents of uniformity and standardisation.[11] Efforts to enforce legislated measures had historically been unpopular and were often met with stiff local resistance. In the eighteenth century, people in the south-west of England led a popular revolt against the imposition of the Winchester bushel by the state.[12] Such resistance was replayed in the nineteenth century too: the Winchester bushel, which was outlawed in the 1820s, continued to be used to measure grain in the 1870s. Reforming legal measures meant striking a balance between scientific ideals, administrative practicality and local resistance. Consequently, nineteenth-century reforms of British weights and measures were generally conservative as the reformers wanted to ensure the success of reforms.[13]

The scientific principles underlying Britain's new metrology were also the subject of bitter disputes and disagreements. There were vociferous

[9] E. F. Cox, 'The metric system: a quarter-century of acceptance (1851–1876)', *Osiris* 13 (1958). R. D. Connor, *The weights and measures of England* (London, HMSO, 1987). R. E. Zupko, *Revolution in measurement: Western European weights and measures since the age of science* (Philadelphia, American Philosophical Society, 1990).

[10] *Hansard Parliamentary Debates*. Series 3 Vol. 208. 26 July 1871. 'Weights and Measures (Metric System) Bill.' cc295.

[11] Hoppit, 'Reforming Britain's weights and measures'.

[12] R. Sheldon et al., 'Popular protest and the persistence of customary corn measures: resistance to the Winchester bushel in the English west', in A. Randall and A. Charlesworth (eds) *Markets, market culture and popular protest in eighteenth-century Britain and Ireland* (Liverpool, Liverpool University Press, 1996).

[13] Hoppit, 'Reforming Britain's weights and measures'. This is true of reforms in the 1820s well as in the 1870s.

arguments about the length standard and whether it should be taken as the distance between two lines engraved on a bar or between the ends of a line engraved upon it.[14] Joseph Whitworth and George Airy crossed swords on this issue more than once. Similarly, Whitworth's gauges, James Clerk Maxwell's electromagnetic measures or James Joule's measures of mechanical equivalent of heat were equally contestable and contested as scientific measurements.[15] Telegraph engineers debated whether the size of telegraph cables should be expressed in terms of mass-length or diameter and whether they should be arranged on a geometric scale. Britain's new metrology was supposed to challenge traditional measurements and practices, and yet this new metrology was also expected to confirm existing knowledge through expert measurements. This apparent paradox, Schaffer argues, could only be resolved when Britain's new metrology was conceived as being traditional. Tradition on which the new metrology was to be based had to be newly invented and forged through public controversy and painstaking labour.[16]

Notwithstanding the political and scientific debates surrounding the reforms, the question is, did the reform of Britain's metrology affect internal trade? Did the introduction of uniform weights and measures help business groups overcome the measurement problems that contributed to internal barriers, trade disruption and uncertainty in market exchange?

The historical consensus is that it did. The long process of standardisation of British weights and measures is taken as a clear indication of the emergence of an integrated national market. Such conclusions rest on a major assumption: that there exists a direct correspondence between 'measures' (i.e. the system of weights and measures units) and 'measurements' (i.e. the information that the act of measuring captures). Existing literature implies that this direct correspondence is why multiplicity, nonuniformity or incoherency of historical measures translated into multiplicity, nonuniformity or incoherency of measurements, which in turn had the disruptive impact on trade and market exchange – the corollary being that the introduction of uniform and invariable measures eliminated unreliability in measurements, simplified economic transactions and helped integrate markets.

There is little distinction in most historical accounts between standardising measures and standardising measurements, and the former is

[14] N. Atkinson, *Sir Joseph Whitworth: 'the world's best mechanician'* (Gloucestershire, Sutton, 1996). Chapter 5: 'The history of measurement'.
[15] S. Schaffer, 'Metrology, metrication and Victorian values', in B. Lightman (ed.) *Victorian science in context* (Chicago, University of Chicago Press, 1997).
[16] Ibid., p. 467.

expected to have translated into the latter. Ken Alder alluded to this distinction when he wrote that the scientifically motivated thrust of the French metric reforms of the 1790s was to replace an older economic system with a newer one based on measurements of value in terms of price.[17] Sidney Pollard captured the essence of this distinction when he remarked that 'the objectives of businessmen are not to attain perfection [of measurement units], but to keep down costs and increase efficiency'.[18] On the whole, however, most historical accounts fail to clearly emphasise the difference between the *abstract* systems of measures and the *practical* issues of making measurements – and why standardising the former helped to manage the latter.

This book investigates the practical problems that business groups – firms, merchants, entrepreneurs, and so on – faced in their daily commercial activities due to unreliable measurements. It explores why such measurement problems were historically significant and economically fundamental, why business groups sought solutions to such problems and what those solutions were. I refrain from making prima facie assumptions about the relationship between abstract measures and practical measurements. I highlight the difference between *metrology* (i.e. the system of weights, measures and other measurement units) and *mensuration* (i.e. the act of measuring).[19] This distinction between abstract principles and context-driven practices is important in understanding how historical businesses managed measurement problems in economic transactions.

My approach is similar to that of Graeme Gooday, who studies the persistent localisation of Victorian electrical measurement practices, or Bruce Curtis, who studies 'measurement hybrids' in pre-Confederation Canada. Gooday gives a detailed account of the development of electrical measurements by studying why specific experts, measurements and techniques were proposed as trustworthy and not others. He shows this by moving the focus away from laboratories and 'centres of calculation' and

[17] K. Alder, 'A revolution to measure: the political economy of the metric system in the ancien régime', in M. N. Wise (ed.) *The values of precision* (Princeton, Princeton University Press, 1995), p. 59.

[18] S. Pollard, 'Capitalism and rationality: a study of measurements in British coal mining, ca. 1750–1850', *Explorations in Economic History* 20 No 1 (1983): p. 125.

[19] The *Oxford English Dictionary* defines the two terms as follows: metrology, (*n.*) 1. A system of measures, *esp.* one used by a particular nation, culture, etc., 2. The study of systems of measurement; the science of measurement; the branch of technology that deals with accurate measurement; mensuration, (*n.*) 1. The action, process, or art of measuring; measurement, 2. The branch of geometry that deals with the measurement of lengths, areas, and volumes; the process of measuring the lengths, areas, and volumes of geometrical figures.

to the actions of practitioners.[20] In Bruno Latour's view, 'centres' enable scientists and bureaucrats to give the outside world a form through metrology. An 'enlightened network' links the powerful centre to the periphery via 'metrological chains', enabling scientific facts to survive in the outside world. Metrological chains also enable the bureaucratic 'centre' to act at a distance on the periphery and to translate what the periphery does back towards the centre. The chains make it possible to translate local relations into administratively pertinent forms, according to this view.[21]

While powerful scientific and bureaucratic metrological centres did emerge in the nineteenth century, I have steered the historical focus of this book away from such centres. I am interested in understanding what the new metrology did to the local measurements in historical markets and whether it made them reliable in the local context. I reflect on the relations between centralised metrology and diverse local measurement practices, as Curtis does in his sociological study of metrological reform in pre-Confederation Canada.[22] I argue that mensuration processes (i.e. the activities or steps through which particular information is captured at the local level) are responsible for shaping these local measurement practices. Chapter 3 offers a more complete discussion on the mensuration process and how the act of measuring can broadly be understood in terms of three distinct elements: observing and recording relevant information, comparing these observations to standards and eventually contextualising the comparisons. Several tools, instruments, standards and protocols (i.e. rules, norms or conventions) are essential in conducting this activity. 'Measurement', that is the information gathered from this act, is the end result of this activity. Through detailed case studies, I explore how business groups (merchants, firms, etc.) conducted this activity within different economic contexts, the distinct groups that shaped the measurement activity, the various measurement issues that they faced and the solutions that were proposed.

I show that historical markets actually faced two measurement problems. The first was undoubtedly the diversity in weights and measures – the proliferation of local or regional measurement units and the presence of a confusing array of weights and measures that potentially disrupted

[20] G. J. N. Gooday, *The morals of measurement: accuracy, irony and trust in late Victorian electrical practice* (Cambridge, Cambridge University Press, 2004). B. Latour, *Science in action: how to follow scientists and engineers through society* (Cambridge, MA, Harvard University Press, 1987).

[21] B. Curtis, 'From the moral thermometer to money: metrological reform in pre-confederation Canada', *Social Studies of Science* 28 No 4 (1998): p. 551.

[22] Ibid.

trade and economic exchange before the mid-nineteenth century. The second was an institutional problem stemming from the fundamental economic aspects surrounding measurements: markets may encounter transactional barriers because delineating *complete* information about any economic good is fundamentally costly. Information is normally based upon measurements of multiple attributes of an economic good. This forces the selection of a smaller (more manageable) set of criteria to measure. The selection, in turn, creates a potential for information asymmetry – a classic principal–agent problem.[23] In other words, measurement issues facing historical markets were not limited to the diversity of weights and measures but were of a more fundamental economic nature. The economic issues were manifest in questions such as what attributes should be measured, how they should be measured or who should measure them.

Metrological standardisation (i.e. the introduction of a uniform measurement system) solved the first problem of incompatible standards but not the second economic problem. By exploring how businesses solved the second problem, the historical studies featured in this book chart some of the profound institutional changes of the nineteenth century, in terms of both how people made measurements and the redefinition of economic relationships, within the context of the political economy of a reformed metrology.

This does not imply that the two aspects – metrology and mensuration – were historically independent. On the contrary, they tended to be inextricably linked within measurement systems as a whole. For Kula, systems of measurement include 'all the elements associated with measuring', including systems and instruments of counting, methods of using instruments, different methods of measuring in different social situations and the 'entire associated complex of interlinked, varied, and often conflicting social interests'. In Kula's definition, the system combines the various elements into 'an internally articulated structured whole', and the 'task of science is to investigate this system within the social reality that produced it and within whose framework it functions'.[24] Indeed, as Porter suggests, the bureaucratic imposition of standardised metrology notwithstanding, weights and measures were social measures and

[23] Y. Barzel, 'Measurement cost and the organization of markets', *Journal of Law and Economics* 25 No 1 (1982): p. 27.

[24] W. Kula, *Measures and men*, R. Szreter (trans.) (Princeton, Princeton University Press, 1986), p. 94. The National Measurement Office, UK, succinctly defines the national measurement system as 'the technical and organizational infrastructure which ensures a consistent and internationally recognized basis for measurement' (http://www.bis.gov.uk/).

predated any concern with science.[25] Legislation or standardisation of weights and measures was often an exercise in power that threatened the 'fragile margins of the budgets of poor' and amplified existing class struggles.[26] Measurements are often deployed outside the centres of metrology in the regulation of social and economic relations over large geographical areas.[27] This is starkly evident in the late-eighteenth-century metric reforms in France. The thrust of the French reforms was primarily to replace an economic system based on the measures of the ancien régime to one based upon value, that is, where everything that had economic value could be translated into the single, paramount variable of price (Chapter 2).[28]

British metrological reforms did not seek to dramatically replace existing economic relationships. Nevertheless, the case studies in this book show that disputes amongst the scientists and engineers, and amongst politicians and bureaucrats, were paralleled in the disputes amongst merchants, traders and business groups. Such disputes were resolved in their own microcontexts. They were not necessarily resolved by appealing to scientific ideals, by invoking political power or by imposing bureaucratic procedure. Resolution often required businesses to contextualise the significance of measurements in particular situations. In this context, the analytical distinction between metrology and mensuration – between abstract scientific systems and practical methods of measuring – is a useful one. I show why local measurement practices continued to remain crucially important in the British economy even when a unified metrology was successfully introduced in the nineteenth century.

What made measurements reliable?

The chapters in this book show that metrological standardisation at the centre solved the historical problem of multiple, potentially confusing measurement units but was incapable of solving the institutional problems of measuring multiple attributes. As a result, measurement practices that improved governance and monitoring remained crucially important

[25] T. M. Porter, *Trust in numbers: the pursuit of objectivity in science and public life* (Princeton, Princeton University Press, 1995), p. 23.
[26] Sheldon et al., 'Customary corn measures'. See also P. Linebaugh, *The London hanged: crime and civil society in the eighteenth century* (London, Allen Lane, 1991), p. 162, for the class struggle in the Atlantic tobacco trade as legislation was introduced in the American colonies to standardise the 'hogshead'. Similar class struggles can also be seen in the case measurements of coal in eighteenth-century London (p. 307).
[27] A. Barry, 'The history of measurement and the engineers of space', *British Journal for the History of Science* 26 No 4 (1993): p. 464.
[28] Alder, 'Revolution to measure', p. 59.

for ensuring measurement reliability at the local level. The historical quest for a unified and centralised metrology remained elusive until the nineteenth century. The state's repeated attempts to enforce uniform metrological standards had remained largely unsuccessful until then. Market transactions continued to be based upon a host of local, regional or customary measurement units which often bore little resemblance to other similarly termed units and which appeared confusing to the outsider.[29] But nonuniformity did not totally inhibit trade between markets using vastly different measurement units. Merchants, middlemen and dealers would regularly use published dictionaries or tables to convert between different weights and measures.[30] These merchants in fact acted as the translators between local measures, relying upon local norms or market rules to convert from one measure to another along established trade routes.[31] Additionally, other institutions emerged to ensure that proper measurements were meted during delivery or exchange of commodities. The institution of publicly measuring essential commodities such as coal and corn, called the metage system, was important in monitoring measurements and acted as a governance mechanism (Chapter 4). Rules of verification also emerged to manage measurement issues, particularly those related to measurements of quality. The practice of using the *counts* as a measure of fineness of silk thread or cotton yarn or the use of *natural weights* as a measure of grain quality transcended local or legal metrological standards (Chapter 6).[32] In such cases, reliability of measurements depended not so much upon uniformity as upon adherence to locally known market norms, customs and conventions. Markets depended upon such institutional methods to coordinate transactions, structure contracts and generally to avoid confusion.

[29] Sheldon et al., 'Customary corn measures'. N. Biggs, 'A tale untangled: measuring the fineness of yarn', *Textile History* 35 No 1 (2004). C. R. Fay, 'The sale of corn in the nineteenth century', *The Economic Journal* 34 No 134 (1924). Reports of various parliamentary committees on weights and measures in PP 1813–14 Vol. III, *Report from the committee on weights and measures*; PP 1819 Vol. XI, *First report of the commissioners on weights and measures*; PP 1820 Vol. VII, *Second report of the commissioners on weights and measures*; PP 1821 Vol. IV, *Report from the committee on weights and measures*.

[30] E.g. J. Hewitt, *The corn dealer's assistant* (London, 1736). E. Hodgkins, *A series of mercantile letters, with the weights, measures and monies reduced into the English Standard, etc.* (London, 1815). A. Bald, *The farmer and corn-dealer's assistant; or, the knowledge of weights and measures made easy, by a variety of tables, etc.* (Stirling, 1780).

[31] London coal merchants would convert from measures used in the north of England to those locally used on the basis of long-established market norms. R. A. Mott, 'The London and Newcastle chaldrons for measuring coal', *Archaeologia Aeliana* 40 4th Series (1962). See also Hoppit, 'Reforming Britain's weights and measures', p. 92.

[32] C. Poni, 'Standards, trust and civil discourse: measuring the thickness and quality of silk thread', *History of Technology* 23 (2001). S. Dumbell, 'The sale of corn in the nineteenth century', *The Economic Journal* 35 No 137 (1925).

The introduction of the Imperial measurement units in 1824 and the metric units in 1799 signalled a profound institutional shift. Unlike the local and customary units, these standards of weights and measures were supposedly abstract and decontextualised (Chapter 2). They could be employed across all economic contexts and across national and international geographies. In addition, they were arranged in a hierarchical manner, ensuring traceability and verification, and were centrally administered by the state bureaucracy, ensuring enforceability.

This centralisation and standardisation of metrology could not resolve the institutional choices involved in selecting – and limiting – the number of attributes to be measured and the various methods by which measurements could be made. Such choices remained highly contextual and local. Markets, businesses and firms had to adhere to particular measurement practices within microcontexts, which incorporated available metrological standards, governance mechanisms and other institutional rules.

Local measurement practices involved making various ex ante selections or choices (i.e. prior to the actual act of measuring). These included selecting the property or attribute of an object that was to be measured, choosing an appropriate measurement method, selecting the metrological standard, specifying the measuring instruments to be used and seeking agreement regarding measurement protocols (Chapter 3). These activities shaped the measurement practices at the local level. The choices that people made were shaped by the nature of the information that was required, the groups who required the information, their motivations and the purpose for which the measurements were required.

The key issue here is that such practices were localised, although they used so-called universal metrological standards. Often there was no single, uniform, *best* practice that everyone used. There seldom was an ideal or true way of measuring a product attribute. There was no reason why the measurement of wire diameter was inherently better than its weight per length to sort it into different sizes (Chapter 5), nor was there any inherent reason why weight measurements of dry goods represented ideal or true measurements compared to their volumetric measurements (Chapter 4).[33]

Practices depended upon the ease with which attributes could be measured. Thus, search attributes (e.g. colour, weight) were easier to measure at the time of transaction, whereas experience attributes (e.g. taste,

[33] Harrison, 'Agricultural weights and measures'. Marketing dry goods, such as grain or coal, by weight introduced complications which were not entirely appreciated at the time. See also Chapters 4 and 6 in this volume.