How Did Markets Manage Measurement Issues? Lessons from 19th Century Britain

Aashish Velkar

London School of Economics & Political Science

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Abstract

This paper examines how historical markets and institutions managed measurement issues. The paper makes a distinction between metrology (the science or systems of measurements) and mensuration (the activity or process of measurements), and argues that while historical metrology has been studied, few studies of mensuration practices exist. The main argument made here is that, historically, managing product measurements involved managing issues of mensuration as well as metrology. Focussing on the latter, this research uses three historical case studies of mensuration practices to make the following points.

A standardized metrological system (i.e. a system of weights and measures) did not eliminate the need to have functioning market institutions that could manage this aspect of transactions. Institutions influenced the product attributes that were measured, the manner in which measurements were made, and the metrological standards that were used to make the measurements. Mensuration practices could be considered as 'institutional packages' that were comprised of standardized processes, measurement instruments, standards of comparison, and the rules and conventions that managed product measurements.

'The costliness of information is the key to the costs of transacting, which consists of the costs of measuring the valuable attributes of what is being exchanged and the costs of protecting rights and policing and enforcing agreements. These measurement and enforcement costs are the sources of social, political and economic institutions.'[1]

Douglass C North (1990)

'The problems and costs of measurement pervade and significantly affect all economic transactions.'[2]

Yoram Barzel (1982)

1. Introduction

This paper deals with the question of how historical markets managed measurement issues and struggled to make product measurements reliable. If we accept the view that transaction problems consist of measurement issues as well as issues of enforcement (see quotes above), then measurements were fundamental issues that markets historically had to manage. Economists contend that product attributes have to be measured in order to form perceptions about products because 'people will exchange only if they perceive what they get to be more valuable than what they give.'[3] Traditionally, issues surrounding the measurement of product attributes have been considered as problems involving the *accuracy* of measurements i.e. variability of measurements around some 'true' value caused by measurement error, which could leads to rent seeking opportunities.[4] This is a rather narrow and simplistic way of looking at product measurements; historical measurements were fairly complex and multi-faceted. The measurement error-approach also has limitations in uncovering the causes of measurement problems and how markets managed these issues.

Historically, measurements were crucial for the producer (craftsman, artisan, estate-owners, engineer-entrepreneur, etc.) in terms of deciding what to produce and how:

[1] D. C. North, *Institutions, institutional change and economic performance* (Cambridge University Press, 1990), p. 27.

[2] Y. Barzel, 'Measurement cost and the organization of markets', *Journal of Law and Economics* 25 No. 1 (1982): p. 48.

[3] Ibid.

[4] Ibid.: p. 28.; S. C. Pirrong, 'The efficient scope of private transactions-cost-reducing institutions: the successes and failures of commodity exchanges', *The Journal of Legal studies* 24 No. 1 (1995): p. 233.; for a theoretical discussion on measurement accuracy see M. Boumans, ed. *Measurement in economics: a handbook* (Elsevier Inc, London & Amsterdam, 2007), p. 15 ff.; or M. N. Wise, ed. *The values of precision* (Princeton University Press, Princeton, NJ, 1995), p. 9. for a more conceptual discussion.

these were measurements used in product specifications, in production processes, in design and control, etc. Similarly, measurements were required to estimate the amount of product produced or exchanged. Traded quantities and delivery estimates required a somewhat different kind of product measurements than design specifications. Then again, measurements used in the assessment of quality were of a different nature. Such measurements had to capture the compositional element (what is a product made of), the conditional element (how usable was it), and the functional quality (did it do what was expected). It is not obvious that any of these measurements had to conform to any one 'true' value of measurement. It is therefore not obvious that measurement problems were limited to problems of error or that managing them involved the management of measurement costs. The management of measurement variability needs to be considered differently, something other than as the quest for measurement accuracy or managing measurement costs.

This conceptual difference is also of historical importance. Current literature implies, or at least assumes, that metrological standardization in the nineteenth century (i.e. simplifying weights and measures) was the only and/or the best outcome to manage transaction problems arising due to variable measurements.[5] The explanatory focus of this literature has also been mainly on the state administration's efforts to manage these issues and less on the market institutions that had traditionally helped to manage measurements. Such assumptions tend to confuse metrology (system of measures) with mensuration (the activity or process of measurement), and imply that changes in the former coincided with changes in the latter.[6] The economic historian Witold Kula presented an insightful discussion of the significance of measurements in historical

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[5] R. D. Connor, *The weights and measures of England* (HMSO, London, 1987).; R. E. Zupko, *Revolution in measurement: Western European weights and measures since the age of science* (The American Philosophical Society, Philadelphia, 1990).; K. Alder, 'A revolution to measure: The political economy of the metric system in the ancien régime', in *The values of precision*, M. N. Wise. ed. (Princeton University Press, Princeton, 1995).; J. Hoppit, 'Reforming Britain's weights and measures, 1660-1824', *The English Historical Review* 108 No. 426 (1993).; R. Sheldon et al., 'Popular protest and the persistence of customary corn measures: Resistance to the Winchester bushel in the English west', in *Markets, Market Culture and Popular Protest in Eighteenth-Century Britain and Ireland*, A. Randall and A. Charlesworth. eds. (Liverpool University Press, Liverpool, 1996).; W. J. Ashworth, *Customs and excise: Trade, production, and consumption in England, 1640-1845* (Oxford University Press, Oxford, 2003).

[6] 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. (accessed online on June 2, 2008)

markets, how markets used these measurements, and how the various measurement units (i.e. measures) used historically were anthropocentric in nature. Both he and Ken Alder describe how institutions and institutional rules were important when markets used multiple metrological standards, when for instance the bushel and the gallon varied considerably between different geographies. However, Kula's review dovetails into the history of the metric system.[7] He makes the implicit suggestion, as most historians do, that the management of measurement issues was coordinated by a standardized metrology after the nineteenth century, i.e. by adopting a unified system of measures, such as the metric system.[8] Alder reckons that the metric system serves as the 'universal idiom of the modern mechanism of exchange.'[9] The underlying argument is that standardized metrology helped to resolve transactional problems that allegedly arose due to variability of measures, and the explanatory focus for the eighteenth and nineteenth century shifts to the efforts to standardize the metrology by the state.[10] We thus have an unsatisfactory and untested conclusion within this historical literature that metrological standardization obviated the need for other market institutions to manage measurement problems.

In this paper, I argue that managing measurements involved managing issues of metrology as well as mensuration. Managing both these elements was crucial, but mensuration activities have not been studied independently. This paper focuses on mensuration practices to understand how historical markets dealt with measurement problems. Metrology forms an important part of mensuration, but is of distinct historical importance; the strict study of metrology is focussed too narrowly to reveal how markets tackled measurement issues and managed transactions. I also argue that the manner in which metrological standards were used for different purposes in different ways was institutionally determined. In fact, market institutions influenced what product attributes were measured, how the measurements were made, and what metrological standards were used to make the measurements. Finally, I argue that metrological standardization, an important historical event of the nineteenth century, was not the

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[7] Kula claims that 'as befits a historian of the metric system, I am its admirer', W. Kula, *Measures and men* (Princeton University Press, Princeton, New Jersey, 1986), p. 287.

[8] In fact, Kula writes that 'thanks to this [i.e. the metric system], gone are the countless, daily opportunities for the strong to injure the weak, for the smart to cheat the simple, and for the rich to take advantage of the poor', Ibid.

[9] Alder, 'Revolution to measure'.

[10] See for instance Hoppit, 'Reforming Britain's measures'.; Zupko, *Revolution in Measurement*.

only way in which markets solved measurement problems. Other ways of managing measurements were equally important and are worth investigating.

These arguments are developed on the basis of three detailed historical case studies on measurements issues within the British economy during the nineteenth century. The focus of the case studies was to examine how people made measurements within different economic contexts. Three such contexts have been studied dealing with different measurement problems: reliability of quantity estimates during product delivery/trade (the case of coal measurements), unreliable measurements of product/ technical specifications (measurements of wire sizes), and reliability of measurements of quality (grading the quality of wheat). These cases have been analyzed on the basis of a conceptual framework developed to study mensuration in a micro-context. This framework, described in the following section, helps to examine how people historically made measurements within different economic contexts. This section also describes the nature of measurement problems examined in each of the micro-contexts. The main results of the case studies based on the evidence of mensuration practices are presented in section 3. The results are presented on the basis of two important parameters: the institutional processes that are evident, and the different ways managing measurements. Section 4 presents some concluding remarks.

2. Mensuration: A Framework to Analyze Measurement Activity

What is mensuration? For the purposes of this paper, mensuration is assumed to be a process involving three broad stages – observing and recording, comparing observations to standards, and contextualizing the comparisons. Analytically, “measurements” are the end result of this mensuration process. In the first stage of observing and recording, there could be several steps involved. These include determining the information required, selecting the property or aspect of an object that should be measured to provide that information, choosing an appropriate measurement method, metrological standard, measuring instruments, measurement protocols, etc.[11] Also, depending upon the information required and who is making the measurements, the property or aspect of the economic asset that is measured has to be chosen. How such choices were made is one of the issues explored in this paper.

[11] P. Kircher, 'Measurements and managerial decisions', in *Measurement: Definition and Theories*, C. W. Churchman and P. Ratoosh. eds. (John Wiley & Sons, Inc., New York, 1959), p. 68.

While it is somewhat difficult to draw a distinct parallel between measurements used in science and the type of measurements that I deal with in an economic context, broadly speaking most of the measurements encountered in the economic sphere would be of the indirect associative type in Brian Ellis' nomenclature of scientific measurements.[12] Two aspects of associative measurements – association between two or more properties of objects and the principles of correlation between them – are useful concepts.[13] If we assume that most of the measurements encountered in everyday economic life are of the associative kind, then the association and correlation between two or more properties of an object raises some very interesting issues revolving around the choice of the associative property to be measured as well as the choice of the principles of correlation.

This can be illustrated through an example. Let us assume that the sellers and buyers are interested in obtaining information about the quality of a product that they wish to exchange, say tea. The quality of tea is not directly observable or measurable, and requires the measurement of another property; say the length of the leaf.[14] To measure quality in this case using the leaf length measurements requires making two decisions. That the length of the leaf is an associative property of the quality of tea is the first decision that has to be made. That a particular length of the leaf corresponds to a particular level of quality is the other decision that has to be made. For the leaf-length: tea-quality correspondence, several possible relationships could be established and choosing one requires deliberate decision-making. Understanding how such decisions were made requires the study of mensuration practices.

These decisions that sellers, merchants, and buyers make are different compared to abstracting a set of attributes to measure from amongst all the attributes that could be measured. This abstraction is motivated by the costliness of information: it would be costly to measure all possible attributes in addition to leaf length to assess the quality of tea, not to mention that such measurements would probably be redundant many times

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[12] B. Ellis, *Basic concepts of Measurements* (Cambridge University Press, Cambridge, UK, 1966), p. 90 ff.; his distinction is based on N R Campbell's classification of measurement scales. Common example of associative measurements are temperature measurements, also p. 183, appendix I; see also H. Chang, *Inventing Temperature: Measurement and Scientific Progress* (Oxford University Press, New York, 2004).

[13] Ellis' definition states that 'associative measurements depend on there being some quantity *p* associated with quantity *q* to be measured, such that when things are arranged in the order of *p*, under certain specified conditions, they are also arranged in the order of *q*.' (p. 90)

[14] D. M. Forrest, *A hundred years of Ceylon tea: 1867-1967* (Chatto & Windus, London, 1967)., Appendix III; 'Orange Pekoe' grade (OP) may be defined as 'long, thin, wiry leaves,…', whereas 'Pekoe' grade may be defined as 'shorter leaves, and not so wiry as OP…'

over.[15] Both types of decisions – the associative as well as abstractive – are usually made during this first stage of mensuration. Who makes these choices (or decisions), which groups are involved in making the choice, and how they are made become non-trivial.

The second stage of the measurement process involves the comparison of the observations to some comparator or standard in order to ascertain its reliability or usability. I consider reliability, or rather unreliability, to be somewhat different from measurement error. This can best be illustrated through some historical examples. An important consideration for many historical markets was whether measurements remained *consistent* over time, i.e. were the measurements made in one year consistent with measurements made a year ago, a few years before, a decade earlier, etc. Heaped measurements are a case in point. Historically, about one-eighth of the amount estimated by a volumetric measure, say one *bushel* of grain, was contained in the heap that was formed on top of the *bushel* measure.[16] Gradually, over centuries the amount within the heap increased to about one-fourth to one-third of the total amount, implying that the total amount contained within one *bushel* itself had increased.[17] In such cases, the measurement nominally remained the same, one *bushel*, although the actual amount estimated differed. In practical terms, whether grain was sold using the heaped measure or not (i.e. the *stricken* measure) from one year to another in the same market affected the consistency of measurements.

Another way of thinking about reliability is to consider measurement *precision*. Were the measurements over repeated observations closely clustered around some average value? This was particularly significant in the case of manufactured products such as screw threads, metal strips or wire, interlocking pieces of machinery, etc. The issue here was to determine whether several pieces of a product measured using a given attribute (length, weight, etc.) all conformed to a pre-agreed specification. Such measurements were useful tools in decision-making: if measurements are precise, then do x, otherwise take alternative action. The source of variation in this case need not be due to instrument error, or errors in making measurements, or due to some other random factors, but due

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[15] Barzel, 'Measurement cost'.; Pirrong, 'Commodity Exchanges'.

[16] Dry goods were usually sold in terms of their volumetric measures rather than their weight, and the bushel was a fairly typical metrological unit used for such purposes. Connor, *English Measures.*; C. W. Pasley, *Observations on the expediency and practicability of simplifying and improving the measures, weights and money* (Egerton's Military Library, London, 1834).

[17] Connor, *English Measures.*

to confusion, or disagreement, regarding the measurement specification. For instance, confusion or disagreement regarding whether wire size no. 32 should be 0.009th or 0.0115th of an inch contributes to the imprecision in the measurement of wire dimension, regardless of the sophistication of the measurement instrument.

A third way to think about reliability is to consider whether measurements were *uniform* across geographies or groups, i.e. do all groups use or make a given set of measurements in a uniform manner. Historically, dry goods such as coal, grain, fish, etc. were sold either on the basis of their weight or volume, depending upon the market. In almost three-fifths of British market towns wheat was sold using volumetric measurements, another 38% sold it using a combination of weight and volume, and the balance few towns sold wheat using weight measures.[18] In commodities like coal, different parts of the same trade route would use different ways of measuring the same commodity, or use different measurements altogether.[19] Even when the same measurement unit was used, the value of that unit could differ according to markets. In the early nineteenth century, the *bushel* used to measure potatoes in Cheshire, Derbyshire and Lancashire was equivalent to 90 *lbs*, whereas in Leicestershire it was equivalent to 80 *lbs*, in Surrey it was 60 *lbs* and in Middlesex it was 56 *lbs*.[20] The question of unreliability would arise when such variations in practices and local norms were either not generally known, difficult to ascertain, or where merchants dealing with multiple markets or sellers found it difficult to manage the great amount of variation.

Practically, reliability of measurements was dependent upon a combination of such considerations. It is not evident that in any of the three examples described above, measurement variability resulted from a lack of standards or from a lack of unchanging, invariable metrological units. Nor is it obvious that any of the measurements described above had to conform to some 'true', as in ideal, value – a value derived from some natural, physical phenomenon, which could objectively be ascertained. In this sense, measurement reliability need not be linked to variability of the metrological unit in use (the standardization problem) or to deviation from some true value (the accuracy problem).

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[18] *Parliamentary Papers* (*PP*) 1834 Vol. XLIX p. 256

[19] S. Pollard, 'Capitalism and rationality: A study of measurements in British coal mining, ca. 1750-1850', *Explorations in Economic History* 20 No. 1 (1983).

[20] *PP* Vol. VII 1820, *Second report of the commissioners on weights and measures*., Appendix A

A pertinent question is whether variability in the manner described above – inconsistency, non-uniformity, imprecision, etc. – usually translated into unreliable measurements. The problem with equating reliability to variability is that, historically, variability of measurements was sometimes a desired attribute.[21] Variable measurements at times had a moral function: a system of handicapping the less privileged.[22] Sometimes they had an economic function: e.g. adjusting for changes in the market value without a corresponding change in money value, as with the Assize of Bread where the weight of the bread-loaf was altered according to the price of grain without changing the price of the loaf.[23] At other times, variability was the result of persistence of local custom stemming from some symbolic meaning or communal memory: 'we have always done it like this over here.'[24] Thus, invariability was not universally desired and reliability need not always be equated with it. The issue of who demanded invariability, and why, became an important historical issue, particularly in the late eighteenth- and early nineteenth-century.[25]

The third stage in the measurement process involves contextualizing the observations and the comparisons. The basic premise here is that context is crucially important for comprehension (of information) and that people are remarkably clever contextualizers.[26] This is inherently a cognitive process, wherein the individual took into account the reasons for making the measurements, such as how to produce or manufacture a given product, how to ascertain whether the product is of an acceptable quality, or how to determine the amount of product exchanged during trade.[27] Each purpose required a

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[21] Kula, *Measures and men*.; Alder, 'Revolution to measure', in.

[22] Hoppit, 'Reforming Britain's measures': pp. 89-90.

[23] J. Davis, 'Baking for the common good: A reassessment of the assize of bread in medieval England', *Economic History Review* 57 No. 3 (2004).

[24] Sheldon et al., 'Customary corn measures', in, pp. 34-35.

[25] Hoppit, 'Reforming Britain's measures'.

[26] G. A. Miller, 'Contextuality', in *Mental Models in Cognitive Science*, J. Oakhill and A. Garnham. eds. (Psychology Press, UK, 1996), pp. 2-3.; G. A. Miller, 'On knowing a word', *Annual Review of Psychology* 50 (1999): p. 11 ff.; also G. L. Murphy, 'Comprehending complex concepts', *Cognitive Science* 12 (1988).

[27] This kind of situated cognition is helpful in understanding how individuals comprehend the information about objects that measurements capture. The cognitive ability to contextualize need not be bounded by the physical human body (i.e. people's minds or brains) but can extend out to the environment such that the environment can also become a resource for comprehension. This 'distributed cognition' view lays particular emphasis on the artefacts and protocols, and considers them as external elements of a cognitive system. 'Situated cognition: origins', *International Encyclopedia of the Social & Behavioral Sciences*, 21, 14126-29.; E. Hutchins, *Cognition in the wild* (The MIT Press, Cambridge, Mass. & London, England, 1996).; E. Hutchins, 'How a cockpit remembers its speeds', *Cognitive Science* 19 (1995).; H. Artman and Y. Waern, 'Distributed cognition in an emergency co-ordination center', *Cognition, Technology & Work* 1 (1999).

specific kind of information. For instance, to know how to produce a product required information regarding its dimensions and specifications that could then be used in production routines or processes; this information formed part of the product's overall design. Similarly, to ascertain whether the product was of an acceptable quality required information about specific attributes of the product in terms of its composition (what was it made of), condition (was it usable), or performance (did it do what was expected). Similarly, the amount of product exchanged usually required quantitative estimates of the number of discreet units exchanged, either in each instance of trading or within a given period. These were estimates of quantity (as opposed to quantitative estimates). The information obtained in the first two stages of the mensuration process, and which was subsequently contextualized on the basis of some specific economic purposes thus became a 'measurement' that groups could use.

The mensuration process is conjoined with measurement tools, which includes instruments, protocols and standards. Measuring instruments could be either physical artefacts or mental constructs. In fact, any construct that enables us to observe and record phenomenon of interest to us by 'picking them out in a particular way' can be considered as a measurement instrument.[28] Protocols are rules and conventions that coordinate the mensuration process. The analytical issues here include the degree to which such rules are procedural or institutional, the degree to which they are formalized, and the manner in which they emerge.

An interesting aspect of metrological units (e.g. pounds, kilograms, gallons, litres, etc.) is that they could be part of measurement instruments or metrological standards. When used to record a phenomenon or make an observation they function as measuring instruments or as part of measuring instruments. However, they are standards in their own right, and when used within metrological standards usually acquire a particular value or a range of values. For instance, while measuring the length of a tea leaf, the metrological unit to be used could be millimetres (mm). This unit is part of the recording instrument, and as such functions as an instrument. But if the merchant specifies that the acceptable length of a batch of tea leaves has to be, say, 10mm or between 8 and 10mm, then the metrological unit has become part of a metrological standard. Metrological

[28] M. Morgan, 'Making measuring instruments', *History of Political Economy* 33 No. Annual Supplement: The Age of Economic Measurement (2001): pp. 236-38.; M. Power, 'Counting, control and calculation', *Human Relations* 57 No. 6 (2004).

standards tend to be chameleonic in nature: i.e. the same standard could be used as a technical standard under some circumstances, a reference or performance-measuring standard in other circumstances, or a quality-assessment standard in yet another set of circumstances.

The process and the tools together help to define a mensuration practice situated within each specific context. The framework considers historical mensuration practices to be influenced by different groups that had an interest in the measurements, often for different purposes. The groups comprised of merchants, traders and middlemen, producers, buyers and consumers, legislative bodies, state departments, and local government authorities, market associations, scientific societies, etc. These groups in turn faced several factors that were social, economic, political and technological in nature. Such factors helped to shape the incentives and decisions of these various groups. The groups and the incentives determined how the mensuration activity was conducted in varying degrees of complexity. The case studies uncover how and why different groups influenced different aspects of mensuration: e.g. selection of attributes to measure, selection of measurement tools to be used, developing metrological standards, standardizing mensuration practices, etc.

The case studies effectively examine how people made measurements within three specific economic contexts: the case of the measurements in the coal trade, the case of measuring wire sizes, and the case of measurements to grade the quality of wheat. The case study of the London coal trade c1830 investigates the factors that led to three significant reforms within the trade: the abolition of public measurement system, the abolition of the heaped measures, and the switch from using volume measures to weight measures. These reforms were introduced to address a fundamental measurement issue facing this trade: were the measurements regarding quantities (i.e. amount) used for delivering the product during market exchanges reliable? In other words, could the buyers rely upon measurements used in the trade such that the amount of coal that they received was actually the amount of coal they purchased?[29] The case of the wire measurements focuses on the incentives facing buyers and sellers of wire products in the nineteenth century and how these incentives gave rise to different notions of desirable

[29] The detailed case study of the measurements used in the London coal trade is included in a recently published article; A. Velkar, 'Caveat Emptor: Abolishing Public Measurements, Standardizing Quantities, and Enhancing Market Transparency in the London Coal Trade c1830', *Enterprise & Society* 9 No. 2 (2008).

measurements. The case study highlights the struggles to define a standard 'one-size-fits all' gauge to measure wire sizes, which could be legally enforced and would overcome the disputes arising from incompatible and multiple gauges. In other words, it studies the rationalization of multiple measurement standards into a single uniform metrological standard.[30]

The case study of wheat highlights how the measurement of quality became a complex and sophisticated process, involving measurement of numerous product attributes using multiple standards (a standard in this case being an arbitrary reference point to which individual observations were compared). The measurement issue that the trade faced was which 'summary criteria', i.e. a set of product attributes, could capture *ex ante* the important aspects of product quality – in terms of the product's composition, condition and functionality. The analysis of the three cases seeks to highlight how different solutions emerged to address the different mensuration issues: metrological standardization, standardizing protocols, third party monitoring of measurements, coordination by trade associations, etc. The historical cases aim to understand mensuration practices, explore the role of market institutions, and to demonstrate that a narrow focus on metrology or measurement error cannot uncover how markets managed measurement issues. The following section presents the significant results from the three case studies.

Mensuration, Markets and Institutions

The evidence from the detailed case studies is discussed in this section on the basis of two main criteria. What institutional processes were evident? What were the different ways of managing measurements? The historical processes studied include the selection of attributes to measure, the selection of measurement tools (i.e. what standards, instruments and protocols to use while measuring), and the shaping of the mensuration activity on the basis of incentives facing the different groups. The following examines each in turn.

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[30] A detailed account of this case is included in No. 18, Working papers on How Well Do "Facts" Travel? (www.lse.ac.uk/collections/economicHistory/pdf/FACTSPDF/HowWellDoFactsTravelWP.htm)

Institutional Processes

Selecting Attributes to Measure

One of the institutional processes evident from the case material is the selection of attributes to measure. Why is the choice of the product attribute to measure an institutional one? Examining the evidence from the British wheat trade of the nineteenth century, we notice that the attributes used to measure wheat quality changed as the nature of this trade changed dramatically. During the nineteenth century the sources of grain for the British markets changed significantly: more wheat was imported than was being sold in the domestic markets and by 1880 the quantum of foreign imports were roughly eight times the domestic sales. The different groups involved in the trade had increased in their specialization, there was enormous heterogeneity of wheat varieties available, and rapid changes had occurred in the milling technology and the demand for specific types of wheat, etc. Organizational changes, combined with changes in technology (milling, transportation, port infrastructure, etc.), had made it possible to separate the quality assessment process from the delivery process.[31] This important watershed influenced both who measured quality as well as the attributes measured in subsequent periods.

Historically, buyers developed their own individual criteria for evaluating the quality of produce. Samples of wheat sold in important markets such as London or Liverpool were submitted for inspection and the natural weight of the grain (i.e. its weight per cubic capacity), its colour, dryness, presence of impurities and other physical characteristics were important attributes on which quality was assessed. The extent to which tacit knowledge was used to assess quality was high as 'the eye, nose and hand were necessary [in] judging the value of grain and dealers could determine its specific gravity by "merely taking up and poising a small quantity of it in their hands"'.[32] Grain quality was assessed on the basis of such attributes before the advent of systematic grading and most millers made their selection of grain with 'care and deliberation'.[33]

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[31] Historically, quality assessment would occur at the point of unloading as the grain was being discharged from the ship's hold. PP Vol. VII 1834, *Report from select committee on the sale of corn*.

[32] S. Dumbell, 'The sale of corn in the nineteenth century', *The Economic Journal* 35 No. 137 (1925): p. 144.

[33] Ibid.

The increasing 'professionalization' of the milling industry led to the introduction of more sophisticated and comprehensive grain testing methods towards the end of the nineteenth century. Development of such methods were encouraged not only by the introduction of new roller milling technology in Britain during the 1870s and 1880s (from Hungary and the US), but also by the emergence of certain institutions within the milling industry, such as trade associations (e.g. the National Association of British and Irish Millers) and technical education and journals (e.g. the trade journal, *The Miller*, and several technical schools teaching the milling techniques).[34] The trade associations gave the milling industry a voice within the London Corn Trade Association (LCTA) once it began grading imported wheat after 1878. At the same time, better understanding of the composition of the wheat grain (due to research in grain chemistry), and a means of overcoming the knowledge and skills 'deficit' through technical education meant that grain quality could be understood and measured in more sophisticated terms. Millers could test and measure the gluten or protein content by c1900 and no longer had to depend upon crude measurements such as 'natural weights' i.e. density of grain. The issue facing the miller was which *ex-ante* quality measurements were reliable indicators of good quality wheats. Even by the end of the nineteenth century, the milling profession felt that there was 'no satisfactory method of numerically registering strength [one of the important qualities] except through a baking test.'[35]

Formal quality grading too did not rely on a single set of attributes to define grain quality. The quality measurements defined by the London Corn Trade Association (LCTA) differed according to the source of the grain: Argentinean wheat was mostly graded on the basis of its density, Indian wheat according to the extent of impurities, New Zealand wheat according to the roundness of its berries, etc.[36] In 1858, the Board of Trade of the City of Chicago (CBT) began classifying grades of grain numerically according to colour, quality and general condition and at the same time certifying to those grades.[37] In the 1880s and 1890s CBT grades became acceptable in London markets

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[34] See G. Jones, *The millers: A story of technological endeavour and industrial success, 1870-2001* (Carnegie Publishing Limited, Lancaster, 2001).

[35] W. Jago and W. C. Jago, *The technology of bread-making* (Kent & Co., London, 1911), p. 291.; also, Jones, *The millers*, pp. 60-61.

[36] Various minute books of sub-committees of the London Corn Trade Association, Guildhall Library, London, UK

[37] J. C. F. Merrill, 'Classification of grain into grades', *Annals of the American Academy of Political and Social Science* 38 No. 2 (1911): p. 58.

as guarantors of quality alongside grades established by LCTA. In an iterative process of improving the value of the information that the quality grades captured, the associations continually refined the grades by including several quality attributes in the definition of the grades. For instance, the description of US No. 1 wheat in the six important markets of Toledo, Chicago, Baltimore, Indianapolis, New York and St. Louis around c1860 included many terms for describing various quality attributes including the terms *sound* and *clean*; Toledo and Chicago included the word *pure*; Baltimore, Indianapolis, New York, and St. Louis included the reference to *dry*; Toledo, Chicago, Indianapolis, and St. Louis also specified *plump*.[38]

There are several key lessons from this case. There was no universal set of attributes that buyers, sellers, merchants, etc. could use for all the wheat that was sold in British markets. Markets and institutions developed different attribute sets to measure quality that varied according to the source of grain or according to the group that was making the measurement. Standardization of quality into grades did not decrease the number of attributes that were measured. Rather, it made it possible to *increase* the number of product attributes that were measured to express wheat quality. As the role of quality assessment gradually shifted from the individual seller and buyer to third-party organizations (following changes in the transportation, storage and distribution practices and the separation of the producers identity from that of the produce) the overall measurement activity could become specialized and complex. Nevertheless, quality measurements were not completely centralized and millers continued to test for attributes other than those used to grade the wheat.

Selecting appropriate measurement tools

Another institutional process that is evident from the study is the selection of appropriate measurement tools: addressing the 'how to measure' issues. Examining the evidence from the London coal trade, we observe some radical changes occurring in the measurement infrastructure in the early nineteenth century. The measurement tools used in the London trade in c1830 remained virtually unchanged since the fourteenth century. The merchants in the London trade used numerous measurement units. Coal was loaded in the north using the Newcastle chaldron (NCh) - a *weight* measure,

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[38] L. D. Hill, *Grain, grades and standards: Historical issues shaping the future* (University of Illinois Press, Urbana & Chicago, 1990), pp. 19-20.

whereas it was unloaded in London using *volumetric* measures - the London *chaldron* (LCh) and the coal *bushel*. By the nineteenth century, the practice of 'heaping' coal while measuring with the *bushel* and the *chaldron* had become a source of major variation in the amount of coal delivered and caused many debates about whether a volume or weight standard was a more reliable estimator of quantity.[39] The case analysis shows that variation due to conversion from weight measurements to volume measurements was relatively minor compared to the variation resulting from the use of 'heaped measurements'. Close monitoring by the public meters, i.e. state appointed officials who were responsible for measuring all the coal that was delivered from the ships and on the wharves, was supposed to ensure that measurements of delivery quantities were to conform with those intended by both custom and regulation.[40]

However, this public measurement system (known as the metage system) itself had become ineffective by the nineteenth century. The Corporation of London was faced with the problem of monitoring the coal meters. One internal memo lists several offences reported among the meters including absence from duty, drunkenness, making erroneous returns, giving short measure, etc. [41] Additionally, given the extent of revenue that the metage system generated for the City of London, in comparison to the expenses of maintaining this elaborate system, the continuation of the system was just not worth it from the City's point of view.[42] With the inefficiencies and ineffectiveness of the public metage system contributing to the overall unreliability of quantity measurements, local views about the measurement problems are succinctly captured in this contemporary complaint:

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[39] R. Smith, *Sea-coal for London: History of the coal factors in the London market* (Longhams, London, 1961).

[40] *PP* Vol. VIII 1830, *Report of the select committee on coal trade*, pp. 77, 87.

[41] Corporation of London Records Office (CLRO COL/CC/CCN/03/012, Papers of the committee on coal and corn meters, Coal and Corn Committee Papers, Jan. 1829 - Jul. 1830. Letter by principal meters dated 1 Oct. 1829.

[42] Duties and taxes on coal added to the overall retail price of coal in London and contributed to the state's fiscal revenue. The London trade contributed about half of the government's revenue from coal: in 1828 this amounted to more than £440,000; M. W. Flinn, *The history of the British coal industry (Volume 2: 1700-1830)* (Clarendon Press, Oxford, 1984), p. 284.; CLRO COL/CC/06/01/0357/1, Papers of the Court of Common Council, Common Council Reports, 1830. Petition dated 25 Nov. 1830. In comparison, the City of London faced a deficit of £666 on a metage revenue of £4,962 collected by the meters in 1829 within the City of London, *PP* 1830 Vol. VIII. Appendix Nos. 8, 10, 11 and 12.

> *"I buy all other articles by number, measure or weight, except these coals; [is it] too much trouble to obtain satisfaction, that I am supplied with fair measure. I have no faith in the guessing work of the coalmen."*[43]

London city merchants made a petition to the Corporation of London to reform the metage system.[44] Major debates followed in the Parliament regarding this issue of the measurement problems and consequently the measurement infrastructure within the London trade was reformed in 1831.[45]

There were several reasons why these reforms were initiated: political economy of taxes on coal, distribution bottlenecks, and continuing measurement frauds were the major reasons. The reforms centred on the metage system and addressed several key questions. Just how unreliable were the measurements? Were public measurements necessary? Could the existing public measurement system be reformed? Do existing metrological standards have to be changed e.g. abolishing volumetric measurements or switching to weight standards? To what extent were the heaped measures contributing to unreliability of measurements? These debates involved both the Houses of Parliament, state departments (e.g. Treasury), the Corporation of London, the politically powerful coal merchants in Newcastle and Sunderland, and coal factors and merchants in London. In other words, the reforms were a process of institutional change.

These reforms resulted in at least three big changes in the London coal trade: the public metage system was abolished; heaped measures were made unlawful; and the volumetric metrological standards were replaced with weight standards. It is difficult to ascribe the change in measurement standards specifically to capitalist rationality[46], or to changes in technology and instrumentation,[47] or to the centralizing influence of the state administration.[48] The changes in the measurement instruments used, the standards adopted, and the convention of *caveat emptor* was the result of fundamental institutional changes within the London trade.

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[43] Letter to the editor of *Times*, dated 13 Feb. 1824

[44] CLRO COL/CC/04/01/007, Minutes of the court of common council, Common Council Reports, 1826-28.

[45] See for instance, Hansard Parliamentary Debates, Mar 24 1829, 'Debate on Coal Trade'; *Act for regulating delivery of coal*, 1 & 2 William IV C.76, 1831.

[46] e.g. Pollard, 'Coal measurements'.

[47] Zupko, *Revolution in Measurement*.

[48] Ashworth, *Customs and excise*.

The lessons we can abstract from this case analysis can be summarized as follows. Variability in measurements was not the result of the lack of metrological standards or due to their non-uniformity; there were long-established, well-defined, and relatively invariable metrological units in use. Several institutional factors, e.g. the practice of 'heaping', contributed to the inconsistency and imprecision of measurements. Negotiations between different economic groups – the parliament (representing mainly private political interests), the state departments (treasury/ customs), local authorities (Corporation of London), coal owner and merchants in north England, London coal merchants, etc. – resulted in changes made to the instruments used to measure the quantity of coal delivered, the metrological standards (weight measurements instead of volumetric standards), and changes to the measurement protocols (abolition of public monitoring, abolition of heaping, etc.). The mensuration activity from 1832 onwards was conducted on the basis of a whole new set of tools that was institutionally selected.

Incentives to measure:

The third institutional process that could be identified was the manner in which incentives facing different groups affected their notions of desirable measurements, and consequently shaped mensuration practices. In other words, incentives helped to shape that wanted which measurements for what purposes. Evidence from the British wire industry c1880 suggests that buyer-incentives influencing measurements did not always coincide with seller-incentives. In this case, the measurement issues stemmed from the multiplicity of wire sizes that British wire makers used in c1875. At least 45 different wire gauges – and as many different ways of expressing wire sizes – were used by British wire makers.[49]

This led to a host of agency problems: buyers purchasing wire from multiple manufacturers, overseas buyers acquiring wire from British manufacturers, buyers whose gauges did not match the manufacturers gauges and vice-versa, etc., faced transaction problems arising from non-uniform wire sizes. Different wire numbers (which were used to notionally identify a given size) on two different gauges could refer to the same diameter of wire (measured in fractions of an inch). Or, to put it differently, the same wire number as measured by two different gauges could refer to different diameters of wire. Latimer Clark, a noted electrical engineer of the late nineteenth

[49] T. Hughes, *The English Wire Gauge* (London, 1879).

century, claimed that he was once personally involved in a contract where the use of one gauge instead of another would have made a difference of £8,000 to the contract value.[50] Thomas Hughes wrote of an order from New York c1879 where the confusion between the different gauges potentially caused price differentials of about £28 per ton.[51] By the 1880s, foreign buyers had become wary of these differences in British wire sizes. Muller, Uhlich & Co. wrote to a New York-based newspaper, that 'the diversity in the gauges of wire, sheet iron etc., is the cause of much trouble, especially when orders are sent from the United States.'[52] There were thus distinct advantages for some groups in making wire sizes uniform.

Equally, some groups found it advantageous in maintaining the ambiguity of wire sizes. Wire manufacturers reportedly secured orders through alleged underselling. However, this was usually the effect of supplying a thicker wire for a given gauge number, which cost less to produce, giving the manufacturer the ability to appear price competitive. Consumers also took advantage of this asymmetric information to gain a price advantage. Some buyers sought to obtain finer sizes of wire for the lower price of thicker wire by claiming that they could obtain, say, no. 36 brass wire at the price of no. 33, potentially saving as much as £84 per ton.[53] Hughes narrates the following anecdote.

> *'A maker [of wire gauges] told me that when a customer used certain sizes [frequently], the gauge made for him had those sizes made smaller [i.e. a lower size number] than they should be, to enable him to purchase wire cheaper. A case in point shortly after came under my observation. A customer used No. 25 wire [frequently]; notch 24 on his gauge was the same size as No. 25 on ordinary gauge; he thereby obtained wire No. 25 at the price of No. 24, saving £4 10s per ton.'*[54]

Uniformity of wire sizes was not universally desired, and various groups had their own reasons for maintaining non-uniformity of sizes, even though the size measurements were consistent and precisely measured by the particular gauge they used.

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[50] L. Clark, 'On the Birmingham wire gauge (Paper Presented to the British Association in 1867)', *Journal of the Society of Telegraph Engineers* 7 (1878): p. 226.

[51] Hughes, *Wire Gauge*.

[52] Reprinted in *Ironmonger*, Mar. 12, 1881, p. 345

[53] *Ironmonger*, Jan 1, 1881, pp. 18-20

[54] Hughes, *Wire Gauge*.

Uniformity could only be possible if all manufacturers used an uniform wire gauge. This is because the wire gauges that were used in the process of manufacturing wire specified the actual dimension of the wire to be 'drawn' in the manufacturing process. They acted as a *technical* standard of measurement, while at the same time acting as a *reference* standard for the buyers to ensure that the wire delivered as per contract actually conformed to specifications. This presented a coordination problem: which was the most appropriate wire gauge to adopt as the standard?

Historically, different groups within the industry preferred their own individual versions of wire gauges to be adopted as *the* industry standard. Engineers such as Charles Holtzapffel, Joseph Whitworth and Latimer Clark proposed gauges between 1847 and 1869 that were based upon the decimal sub-divisions of the inch (for greater precision) and constant decrements in diameter (for regularity).[55] Telegraph engineers, proposed a gauge in 1872 based upon regularly decreasing weight (for consistency in signal transmission).[56] They also tried to resurrect Clark's 1869 gauge in the late 1870s, hoping that this would be adopted uniformly by the industry. Other buyers of wire products mobilized the Associated Chambers of Commerce (ACC) in 1881 to force the manufacturers to adopt yet another version of the gauge. However, the large wire makers (effectively an oligopoly of some ten firms controlling about 80-90% of domestic manufacturing output) cooperated to prevent this and instead proposed their own version that they were willing to adopt.[57] The stalemate between the different groups could only be resolved through the intervention of the Board of Trade acting as an arbitrator. The standard gauge that was legally adopted in 1882 was a compromise solution that was the outcome of intense negotiations between the various groups.

Why was it difficult for the buyers and sellers to agree on a uniform gauge? To the buyers the reliability of wire sizes (consistency, precision, uniformity) depended upon its application. Telegraph cable companies were a large and sophisticated purchasers of wire products, and specifications for wire had become fairly exacting: one contract for a

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[55] C. Holtzapffel, *Turning and mechanical manipulation - Vol. 2* (London, 1847).; J. Whitworth, *Papers on mechanical subjects* (E&F N Spon, London, 1882)., Proceedings of Institution of Mechanical Engineers, 1857; Clark, 'Birmingham gauge, 1867': p. 153.

[56] H. Mallock and W. H. Preece, 'On a new telegraph wire gauge', *Journal of the Society of Telegraph Engineers* 1 (1872).

[57] From various papers of the Board of Trade (BT) relating to the Wire Gauge in The National Archives (TNA).

submarine cable specified the core to be made of seven no. 22 size copper wires (according to a particular gauge) with a total diameter equal to no. 14 wire size and weighing 107 pounds per nautical mile.[58] The introduction of automatic pin-making machines in the middle of the nineteenth century meant that there was now a greater demand for 'exactitude' in wire diameters from pin manufacturers.[59] Hughes echoed this by writing:

> *'Much wire [is] worked up by self-acting machines - such as screws, pins, rivets etc. Unless the wire is accurately drawn, the machine either makes an imperfect article or spoils it.'*[60]

In fact, some contracts required wire makers to manufacture wire not only to a specified diameter but also to a specified weight per gauge and length with diameters expressed in ten-thousandth parts of an inch, or in hundredths of a millimetre.[61] Wire used in fine woven gauzes also had to be made to fairly exacting and *consistent* standards.[62]

In contrast, large wire makers preferred a wire gauge that would help them to control production costs: a gauge that did not require high preparation costs (such as cost of annealing, etc.), or a gauge that would minimize the number of 'draws' and therefore labour costs. Most importantly, the producers were keen to avoid switching costs that the adoption of a new gauge implied. The manufacturers argued that switching from the existing gauges they used to the one proposed by the buyers would increase their cost of production and 'place the English wire trade at a material disadvantage at a time it is suffering severely from foreign competition'.[63] Further, such a change implied 'arranging new prices with the workmen and warehousemen' as it fundamentally involved a change in the method of producing wire.[64] To them, therefore the sizes proposed by the buyers were undesirable. Importantly, before c1880 there is no evidence that wire

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[58] B. C. Blake-Coleman, *Copper wire and electrical conductors - The shaping of a technology* (Harwood Academic Publishers, Reading, 1992), p. 157.

[59] TNA, BT 101/124, notes on conference dated Dec 27, 1882; Pin making was a large volume business where about 50 million pins were being manufactured in Birmingham alone by the late 1880s. These required the equivalent of £100,000 worth of wire per annum.

[60] Hughes, *Wire Gauge*.

[61] *Ironmonger*, Jan 1, 1881, pp. 18-21

[62] J. B. Smith, *Wire, its manufacture and uses* (John Wiley & Sons, Inc., London & New York, 1891), pp. 6-26.; H. I. Dutton and S. R. H. Jones, 'Invention and innovation in the British pin industry, 1790-1850', *Business History Review* 57 No. 2 (1983): p. 190.; *Ironmonger*, Jan. 1, 1881 p. 18

[63] TNA, BT 101/116, letter to the Board of Trade dated Jul 7, 1882

[64] *Ironmonger*, Dec 2, 1882, p. 749; see note **Error! Bookmark not defined.**

makers were interested in an industry-wide uniform gauge. However, fierce competition from German wire makers after 1878, combined with the threat of the industry being locked into the 'wrong' gauge, i.e. the one that the buyers proposed, prompted the dominant producers to cooperate. They formed the Iron and Steel Wire Manufacturers Association in 1881 specifically to promote their own preferred gauge and oppose all others.[65]

How did these different incentives affect the manner in which wire sizes were measured? It is evident that the variability of measurements, i.e. wire sizes in this case, was not the result of a lack of metrological standard or due to the use of variable metrological units. We find that different incentives shaped the notion of desirable measuring instruments, i.e. what each group considered to be an appropriate wire gauge. This greatly affected the mensuration activity and the resulting measurements, or wire sizes. Standardized wire numbers acted as measurement standards with each group preferring their own set of wire number-size combination. The different notions of desirability (of instruments, standards, etc.) meant that uniformity could be achieved mainly through negotiation and compromise, and not through the discovery of an 'ideal' way of measuring wire sizes. There was thus no one 'true' value or set of values that wire sizes had to conform to, and unifying sizes did not depend upon the adoption of a unified metrological system. Uniformity was not universally desired, but it was achieved once sufficient number of groups found it to be preferable. The preference for uniformity was shaped by different incentives facing the various groups.

Managing Mensuration

The review of institutional processes reveals multiple solutions that markets developed to manage the measurement issues or the mensuration activity. The following paragraphs briefly describe three such solutions: metrological standards, governance through regulation, and third party coordination.

Metrological Standards

As expected, the use of metrological standards was evident in the mensuration activities studied. Markets used traceable metrological units and a hierarchical system of units in

[65] F. Stones, *The British Ferrous Wire Industry* (J W Northend Limited, Sheffield, 1977).

their regular mensuration practices. Even when non-Imperial measurement units were in use in the London coal trade (*chaldron, vats,* etc.), these were traceable to legally defined metrological units. Also, the hierarchical relationship between the various metrological units were generally known and accepted: e.g. in the coal trade, four *vats* made up the *chaldron* and 9 *bushels* in turn made up the *vat*. The exception to this is perhaps the domestic wheat trade, where several markets used a mixture of Imperial and non-Imperial measurement units such as *load per quarter*, or *stone per quarter* or *pounds per quarter*, or simply *bushels*, *gallons*, *coombs*, *bags*, *bolls*, *sacks* and *centals*.[66] However, the commodity associations managing quality measurements during the latter half of the nineteenth century, began using fairly standardized metrological units – *pounds per bushel* - for these measurements. Within the wire trade, too, the use of decimal units to measure sizes less than one inch (tens, hundredths, or thousandths of an inch) had become generally accepted. By the late 1870s, orders for wires had begun to specify diameters in decimal length units in addition to gauge numbers. Wire manufacturers had begun printing lists of wire sizes specifying the diameters (in decimal parts of an inch) for each gauge number.[67]

The metrological standards were used in a variety of ways – for technical specifications, for performance monitoring, for quality assessment, etc. For instance, the wire numbers – which were metrological standards for the industry - acted as *technical* standards as well as reference standards. When contracts or orders specified generally accepted wire numbers, these numbers functioned as technical standards telling the manufacturer the diameter of the wire that was required by the buyer. Similarly, they conveyed to the individual wire-drawer the production steps required in order to make wire of a particular size. These same standards functioned as performance standards when, for instance, the buyers used them (and their own wire gauge) to ensure that the product delivered as per contract actually conformed to the technical specifications. In the wheat trade, the 'natural weight' or the density of the wheat grain was used as a metrological standard to convey the likely quality of the wheat. On such occasions, they functioned as quality assessment standards. But, these same standards were often used in domestic contracts to monitor the quantity of wheat exchanged in during trading. This method

[66] C. R. Fay, 'The sale of corn in the nineteenth century', *The Economic Journal* 34 No. 134 (1924).; PP Vol. XLIX 1834, *Returns from corn inspectors*.; *PP* Vol. LXV 1878-79, *Summary of returns by corn inspectors*.

[67] Hughes, *Wire Gauge*.; see also TNA, BT 101/40, copy of advertisement of W & C Wynn & Co.'s gauge, compared to the Stubs gauge, and with diameters in decimal inches.

guaranteed that the contracted volume of grain, say one *bushel*, would weigh a specified amount, say 60 *pounds*. If the actual weight was more or less than the guaranteed weight per measure, the contract price was adjusted proportionately.[68]

Switching metrological standards, or converging towards uniform metrological standards was a market-based process. The coal merchants initiated the process to switch from one set of metrological standards (volumetric units) to another (weight measurements). The buyers and sellers of wire products attempted to define a uniform set of wire numbers and sizes. The wheat merchants and millers developed their own set of metrological standards to assess wheat quality in the UK. The role of the state was certainly not peripheral in all this, but neither was it paramount. It acted to solve various coordination issues facing the markets; such as when the London merchants were compelled by regulation to use weight measurements and uniform wire sizes were negotiated between the buyers and sellers. More importantly, different parts of the state became involved in the standardization process for different reasons. The Board of Trade acted as the arbitrator, the parliament (representing private interests) acted as the legislator, the City of London acted as the monitor or enforcer, etc. However, there is no evidence in these cases that the state, i.e. the centralized bureaucracy, acted as the initiator of metrological standardization.

Finally, the use of metrological standards did not seem to eliminate all the variability in measurements that markets experienced. Inconsistent, imprecise or non-uniform measurements *(not standards)* were the result of other issues, such as differences in attributes to be measured, measurement protocols followed, etc. Markets developed other solutions to deal with these issues in addition to metrological standards.

Governance of Mensuration Activity

Markets developed detailed mechanisms to manage the mensuration activity. Regulating the use of metrological standards was a part of such governance mechanisms. The detailed rules regulating the measurements made by 'coal meters' – publicly appointed before 1831, privately thereafter (see below) – or the rules covering the inspection of grain by grain inspectors in the US are examples of such governance mechanisms. The responsive manner in which the LCTA annually defined grades of

[68] The other methods of selling grain in domestic markets were on the basis of volume–only or weight-only measures. *PP* 1834 Vol. VII. Also, *PP* 1878-79 Vol. LXV.

wheat was also governed by a specific set of rules and conventions. In other words, measurement protocols formed a part of governing mechanisms that specified how the mensuration was to be conducted and which instruments and standards were to be used in the process.

The institutional nature of these mechanisms implied that they reinforced the measurement of certain product attributes (over other possible attributes that could be measured), and enforced the use of certain standards (rather than other standards). Thus, for centuries, coal measurements in London were made on the basis of its volumetric capacity (rather than weight), and changing this protocol involved a change in the governance mechanisms.[69] Similarly, wire gauges measured the diameter of the wire, rather than its weight, even though telegraph engineers at times would have preferred wire sizes specified in weight.[70] Similarly, wheat imported from India was graded on the basis of its impurities, not on the basis of its density, but Argentinean wheat was graded according to its density, not impurities.[71] Wire sizes, similarly, were all measured on the basis of decimal units after c1875, not fractional units as was traditionally done in engineering workshops, but the metrological units used were inches, not millimeters.[72]

Governance mechanisms could have either a formal, regulatory form or a more informal, market-institutions form. Naturally, this determined who enforced these mechanisms – the market or the state. Market based governance was often, but not exclusively, enforced through third parties.

Third-Party Coordination

Coordination of the mensuration activity by third parties took various forms: monitoring of mensuration process, enforcement of measurement protocols, product guaranteeing and standardization, etc.

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[69] Velkar, 'London Coal Trade'.

[70] Mallock and Preece, 'Wire gauge'.

[71] Guildhall Library MS 23186/1, Minutes of East India grain committee: Vol. 1 (1888-96), London Corn Trade Association., entry for 8th Aug 1889; Guildhall Library MS 23177, Minutes of American and Australian grain committee: Vol 1 (1882-96), London Corn Trade Association., entry for 9th April 1891; J. G. Smith, *Organised produce markets* (Longmans, Green and Co, New York, 1922), pp. 24-25.

[72] TNA, BT 101/133

Consider the 'coal meters', who were city officials responsible for publicly measuring coal in the early nineteenth century. They were first appointed in the fourteenth century to 'ensure fair measure for the consumers.'[73] By the late 18th century, we perceive two classes of meters; the *sea meters*, employed to measure coal being delivered from the colliers to the lighters; and the *land meters*, who were appointed to conduct measurements on the shore.[74] The duties of the sea meter on board the colliers were to prepare an account of the cargo delivered to the various first buyers on the basis of actual measurements made as the coal was 'heaved up' from the colliers onto the lighters or barges.[75] The land meters were appointed to specific wharves and were expected to 'see all the coal which are sold [was] duly measured, and the due quantity served [and] the whole quantity put into the wagon (sic).'[76] Although these coal meters were an integral part of the state's institutional infrastructure, the coal merchants themselves found the mechanism of 'delegated monitoring' useful. For example, immediately following the abolition of the *public* meters in 1831, the London merchants decided that it was indispensable to appoint *private* meters whose cost was shared equally by the various merchants and middlemen in London.[77] The private meters continued to be employed throughout the nineteenth century, even as in other trades, such as the grain trade, the state continued to employ public meters.[78]

Traditionally, in the wheat markets, measurement of quality would occur at the time of exchange or delivery. For example, a contract for wheat from c1830, guaranteeing delivery weight to be 18 *stone* per *quarter*, specified price and terms as 54s 6d 'pay or be paid' i.e. the farmer was to make a 'proportionate allowance' to the merchant in case the net weight on delivery was under 18 *stone* 4 *lbs*, and conversely the farmer was to receive an allowance from the merchant in case the net weight on delivery was found to exceed

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[73] Smith, *Sea-coal for London*, p. 2.

[74] Ibid., p. 52.; the Sea Meters were originally employed in the fourteenth century, while the Land meters were formed around 1767, when a group of coal merchants successfully petitioned the parliament to secure permission to measure coal 'between the Tower and Limehouse Hole [as] the old Coal Meters of 1330 only operated in the City of London on the river', H. B. Dale, *The fellowship of woodmongers: Six centuries of the London coal trade* (Reprinted from the '*Coal Merchant and Shipper*', London, c1922), p. 82.

[75] House of Commons Reports (1785-1801) Vol. X 1800, *Report from the committee on coal trade*.; See evidence by James Dixon (Coal Meter) and Richard Austen (Deputy Coal Meter), p. 558

[76] *PP* 1830 Vol. VIII.; See evidence by John Bumsted (Principal Land Meter), p. 26

[77] Guildhall Library MS 30679, Minutes of the coal meters committee, Coal Meters Committee Papers, 1831. Minutes for 11 & 15 Oct. 1831, and for meetings between 22 Oct. and 13 Dec.

[78] Smith, *Sea-coal for London*, p. 319.

18 *stone* 4 *lbs*.[79] By the latter half of the nineteenth century, it became possible, both organizationally and technically, to separate the process of grain delivery from the process of quality assessment. As a result, third parties coordinated quality assessment and guaranteeing: grain inspectors, elevator operators, commodity exchanges, etc.

After the elevator-based storage system developed in America, grain (wheat) was graded by the elevator agent for quality at the point when the farmer brought it for storage at the shipping point. The elevator agent upon examining the quality of the grain settled with the farmer both the grade of the grain and its value. This grain was stored in the elevator along with grain of similar quality, thus segregating the identity of the grain parcels from that of the individual sellers.[80] Further, the US government began supplying moisture content certificates for individual shipments, which could then be used to compare with the actual condition of the grain when it arrived at its destination.[81] The LCTA used an *ex-post* (post-shipment) method of quality grading known as the FAQ or the Fair Average Quality. It annually adjusted standards to reflect systematic factors affecting the quality of grain from a particular location (level of quality due to grain composition as well as condition due to storage, transport, handling, etc.), and made fewer quality distinctions between different shipments. Grain imported from countries such as Argentina and Australia, which had crude handling facilities, in the absence of elevators, and which exposed the grain to varying weather and insect condition was graded on the basis of this system. The method minimized the number of potential disputes and economized on measurement costs.[82] Thus management of the mensuration activity involved other strategies apart from metrological standardization.

Concluding Remarks

Market institutions continued to play an important role in managing measurement issues in the nineteenth century, as they had historically done in periods before metrological standardization. During this period, managing measurements was a dynamic process wherein market groups responded to issues of measurement reliability by managing the mensuration practices. Further, management of mensuration

[79] *PP* 1834 Vol. XLIX, p. 259.; 1 *stone* equals 14 *lbs* and 6.35 *kgs*

[80] Pirrong, 'Commodity Exchanges': p. 237.; J. Stewart, 'Marketing wheat', *Annals of the American Academy of Political and Social Science* 107 (1923): pp. 187-88.

[81] Pirrong, 'Commodity Exchanges': p. 237.; Merrill, 'Grain grades': p. 66.

[82] Pirrong, 'Commodity Exchanges': pp. 238-39.

sometimes involved replacing older institutions by newer ones. A standardized metrological system did not eliminate the need to have functioning market institutions that could manage this aspect of market transactions.

The historical evidence shows that institutions influenced the choice of product attributes to measure, the measurement tools and protocols, and the incentives regarding why measurements were required and by whom. Some groups were able to influence the standards used, whereas some others were able to influence or change the protocols by which the standards are used. For instance, the state – by being able to regulate the metrological standards – was able to influence this particular aspect of the overall mensuration activity. When the state did intervene to standardize mensuration practices, it was usually on the behest of certain market groups.

The importance of the institutions is underscored by the realization that there was seldom one *true* way of measuring something, at least within the economic sphere. If measuring is abstracting information about an object, then measurements depend not only upon the cognitive ability but also upon the rules of the society within which the abstraction is made. Historically, there is no reason to assume that management of measurement less variable and more reliable because the metrology was standardized in the 19th century with the introduction of the Metric and Imperial measurement units. In fact, management of mensuration practices enabled measurements to become complex and sophisticated.

Finally, the historical case studies have provided some interesting insights into the nature of standards that emerged. Mensuration practices could be considered as 'institutional packages' that were comprised of standardized processes, measurement instruments, standards of comparison, and the rules and conventions that managed the activity as a whole. Metrological standards formed a part of such a standardized package. The manner in which they were used for different purposes in different ways was institutionally determined. Conceptually, this implies that standardization was not only a process of rationalizing (as in reducing the number and variety of) metrological standards in use, nor was it only about compatibility-building to increase network effects. Standardization in this case was about 'package-creating', in which multiple standards – metrological as well as other – could be used within a complex set or rules and conventions.

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