Measurement Systems as Market Foundations: The Role of Mensuration in Generating Economic Knowledge

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Abstract:
This paper shows how markets develop mensuration practices to make measurements reliable and how these practices enabled the propagation of useful economic knowledge. This observation, based on an analysis of the British wheat markets, is one way of understanding measurement systems as market foundations. My paper addresses three questions of analytical importance. How do mensuration practices emerge? How do they make measurements reliable? How do they generate economic knowledge? The main point I make is that mensuration practices emerge as 'institutional bundles' that establish context-specific interconnections between institutional rules, technological artefacts, and people.

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Introduction

Recently, economic historians have been able to show there was a large degree of integration in international commodity markets in the late nineteenth century, particularly in terms of reduction in price gaps and increasing market efficiency [(Persson 2004); (Mette, et al. 2008); (Klovland 2005)]. Evidence from international wheat markets suggests that the price spread between transatlantic markets declined as real prices converged towards the end of the century, after controlling for quality and varietal differences. It is argued that such convergence occurred notwithstanding the decline in transportation and transaction costs, which was a somewhat parallel occurrence and cannot be taken as the reason for price convergence between markets (Federico and Persson 2007). Integration and efficiency of commodity markets is understood in this sense of convergence towards one price.

This rather stylized fact must be set against another set of facts about international wheat markets of the nineteenth century. In Britain, there was an explosion in the different of types of wheat available in domestic markets, suggesting a varietal shift in domestic production as well as diversification in the types of wheat imported after c1860 (Walton 1999). At least 16 different domestic wheat types were available for sale in British markets in the 1850s, whereas by 1884 more than 25 domestic varieties and about 40 foreign ones were available (Walton 1999); (Jago and Jago 1911). The heterogeneity of wheat varieties implied that this commodity was costly to measure and required complex systems to economize on quality measurements (Pirrong 1995).

These two sets of facts taken together suggest the following. For wheat markets of the nineteenth century to become integrated and price efficient, they were required to account for the subtle yet significant quality differences between the numerous varieties of wheat. Accounting for quality differences meant establishing effective means of ironing out information asymmetries by capturing and circulating relevant 'facts' about the commodity within the market. Broadly speaking, general knowledge about the commodity had to be effectively available to relevant market groups and the costs of obtaining such knowledge had to be acceptably low. Therefore, an important historical question is how knowledge about a complex, heterogeneous commodity was accumulated and disseminated within nineteenth century wheat markets?

In this paper, I show that understanding the measurement practices within wheat markets enables us to answer this important historical issue regarding the integration of commodity markets. I argue that measurements were used as a way of generating specific knowledge about this commodity and that measurement systems enabled markets to make this knowledge available to relevant economic groups. The general point here is that mensuration practices emerged to make these measurements reliable. Analytically, mensuration practices are different from metrological standards, which refer primarily to units of weights and measures. Mensuration is the manner in which people actually make measurements in particular contexts using metrological standards, defined or accepted rules and protocols, measuring instruments, and other measurement artefacts.[1]

[1] The historical significance of this distinction is discussed in Aashish Velkar, 'Markets, Standards and Transactions: Measurements in Nineteenth Century British Economy ', Unpublished PhD Thesis, (London School of Economics, 2008). 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

Literature on economic knowledge stresses the role of measurements, including measurements within economic models [(Morgan 1990); (Boumans 2007)], accounting and auditing [(Power 1999); (Brackenborough, et al. 2001)], or national income statistics [(Tooze 2001); (Porter 1995)]. However, the economic knowledge generated at a high level of aggregation, i.e. knowledge *about* an economy, must be differentiated from economic knowledge generated at a disaggregated level *within* an economy, i.e. about specific transactions and markets. Measurements could be related to varied economic concerns and decisions, such as what type of products to produce and how to produce them (measurements of specifications), how much quantity of a given product is traded or exchanged and how reliable is this estimate (measurements of quantity or amount), or what is the condition of the product and how functional is it (measurements of quality).[2] Such economic measurements structure basic incentives for exchange and form a fundamental part of economic transactions [(North 1990); (Barzel 1982)].

Measurements at the transactional level relate to the importance of knowledge that is distinct, but just as important as, technical or technological knowledge. (Mokyr 2002) makes this distinction and considers economic knowledge to be important and useful for production and distribution activities. Historically, economic knowledge was not limited to prices and rates of returns, as Mokyr argues, but encompassed information about product qualities and reputation. It is not too difficult to imagine the importance of measurements in generating economic knowledge. The role of measurements costs, as part of the overall transaction costs, is generally accepted in the institutional economics literature. Going beyond this, the study of mensuration practices can shed light on how measurement systems develop and generate economic knowledge as well as manage of measurement costs.

Measurement practices strongly reflect the institutional context within which they emerge and within which people make measurements. This view corresponds with institutionalist literature that proposes the endogeneity of institutions and institutional change (Aoki 2007). It also corresponds with literature on convention theory, which argues that humans create equivalences between themselves and things in a variety of ways [(Thévenot 2001); (Wilkinson 1997)]. One implication of this is that there need not be a single set of institutional rules for governing or coordinating behaviour and that, at least in the case of measurements, context matters. I develop the argument that contextualization is an important part of the measurement activity, in the sense that contextualization is what turns observations and information into useful knowledge. This involves, for instance, classifying or sorting the measurement-information on the basis of one or many (qualitative) parameters: good-bad, acceptable-unacceptable, reliable-unreliable, adequate-inadequate, etc. It also involves developing decision-making rules on 'if-then-else' principles: if the outcome of the measurement is x, then do A, else do B. Context is important for comprehension. Studies show that people take into account the socio-cultural environment while contextualizing objects or information [(Hutchins 1996); (Artman and Waern 1999); (Murphy 1988), (Miller 1996); (Denzau and North 1994)]. Historical measurement practices can reveal the interconnections between

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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). In this paper, mensuration is understood to mean the process or action of making measurements.

[2] See for instance, Aashish Velkar, "Caveat Emptor: Abolishing Public Measurements, Standardizing Quantities, and Enhancing Market Transparency in the London Coal Trade C1830," *Enterprise & Society* 9, no. 2 (2008); Aashish Velkar, "Transactions, Standardisation and Competition: Establishing Uniform Sizes in the British Wire Industry C.1880," *Business History* 51, no. 2 (2009).

people who measure and use the knowledge, the technological tools they use in this context, and the rules they devise that govern them.

This paper about economic measurements in the wheat markets of the nineteenth-century differs from previous studies in several ways. It differs from (Jones 1999) and (Wilson and Dahl 1999) in terms of its geographical and historical scope; they focus on information, quality and measurements issues in the late twentieth-century grain markets with particular emphasis on the US. In comparison, I study nineteenth-century British wheat markets, with a special emphasis on the period of international market integration towards the end of the century. This paper also differs from literature on the emergence of quality grading in the late nineteenth and early twentieth century [(Hill 1990); (Pirrong 1995)], which considers the development of grades by commodity exchanges and does not study measurements, and the information they capture, prior to c1860. Further, this paper considers the 'market' for wheat in a fairly broad sense and brings information issues facing both producers as well as buyers (e.g. millers) into perspective. To that extent, it overcomes the potential limitation offered by a focus primarily on trade and distribution aspect of wheat markets or on technological issues: e.g. (Perren 1990) or (Jones 2001). In many ways, this paper bridges the gap between studies of eighteenth-century wheat markets (Sheldon, et al. 1996) and studies of twentieth-century wheat markets.

This paper analyzes how market groups managed a particular kind of economic knowledge within British wheat markets in the nineteenth century through a detailed study of measurements used to assess the quality of wheat. Section II details two specific measurement issues surrounding the sale of wheat, and discusses why this was an important issue. It highlights how the same measurement set was used to address two key informational issues. The manner in which these informational issues began to diverge giving rise to different measurement practices is discussed in sections III and IV. The paper studies in some detail how market groups attempted to measure the quality of wheat, both from the perspective of the merchant seller as well as the buyer (i.e. the millers). This is included in section IV, which demonstrates the various measurement practices that emerged to capture knowledge surrounding the quality of wheat that was traded internationally. A framework linking the measurement issues and the institutions that emerged to address those issues is discussed in section V. Here the notion of 'institutional bundles' is introduced, and the manner in which it is applicable in understanding measurement practices within the wheat trade is discussed. The final section offers some concluding remarks.

II

In the nineteenth-century, the British wheat markets faced two major measurement issues. How to measure the quality of wheat, particularly as the market price could vary significantly according to the quality of the grain? And, how much did a *bushel* of wheat weigh, i.e. what was the weight equivalent of a *bushel* of wheat, which was nominally a volumetric measure?[3] These were important, and related, issues that occupied the attention of grain merchants, large buyers of grain (e.g. millers) and the British state throughout the nineteenth century.

[3] In other words, what was the density of 1 *bushel* of wheat? 1 *Imperial bushel* = 1.03 *US bushel* (approx.) = 36.36 *liters* (approx.)

That a *bushel* uniformly did not mean the same measure of quantity across domestic markets in Britain was a well recognized fact by the nineteenth century. Depending upon the commodity being measured, the *bushel* could be used either as a volumetric unit or a weight unit. It was used to measure many dry goods such as coal, wheat and other grains, fruits and vegetables, etc. When used for measuring fruits the *bushel* was equivalent to 33 *quarts* or 4 *pecks*. In contrast, the *bushel* used to measure wheat, rye, barley, oats, flour or salt was based on a unit of weight and was linked to the *pound*.[4] The *bushel* unit also varied between geographical locations. 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*. Wheat was measured in Cheshire and Liverpool using a *bushel* of 70 *lbs*, but in Stockton it was equivalent to 60 *lbs*. In Cheshire and Liverpool, barley was measured using a *bushel* of 60 *lbs* whereas in Devonshire it was measured using a *bushel* of 50 *lbs*. In Penrith, potatoes and barley were measured using a *bushel* of 20 *gallons*, whereas in Staffordshire and Shropshire barley was measured using a *bushel* of 9.5 *gallons*. Barley was sometimes measured in Liverpool using a *bushel* of 34.5 *quarts* or 9 *gallons* (Winchester measure), whereas wheat was measured in Oxfordshire using a *bushel* of 9 *gallons* and 3 *pints*.

Nevertheless, there was a method to this seeming madness. Wheat was sold using a combination of volume and weight measures in many British wheat markets[5]. In such cases, the *bushel* measure was guaranteed to weigh a specified amount, say 60 *lbs*. If the actual weight was more or less than the guaranteed weight per volume, the contract price was adjusted proportionately. A contract for wheat from Boston c1830 guaranteed delivery weight to be 18 *stone* per *quarter* (i.e. 8 *bushels*) and 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 18 *stone* 4 *lbs*.[6] In another contract from Sheffield, weight per *load* (equivalent to 3 *bushels*) was guaranteed by the seller to vary from 12 *stone* 19 *lbs* to 13 *stone* 10 *lbs* according to the quality of wheat. Also, wheat brought into this market from Gainsborough and Lynn was sold by the *quarter* weighing 504 *lbs*, whereas wheat from Hull was to be delivered at 480 *lbs* per *quarter*.[7] There are similar examples from other market towns such as Lincoln, Stamford, York, Leeds, Wakefield, Hull, Whitby, Malton, Durham, Stockton, Darlington, Newcastle-upon-Tyne, Whitehaven, etc.

Evidence from corn inspectors from 136 market towns in 1834 suggest that two-fifths of these towns were selling wheat according to weight per *bushel*, or some combination of weight per unit volume, i.e. density. By 1878, more than half of these same 136 towns were selling grain on the basis of weight per unit volume or density (figure 1).[8] This practice reflected the reasoning that grain of higher density was of better quality than grain of lower density, and had better bread making ability. The use of density to assess

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[4] British Parliamentary Papers (*PP*) 1820, Vol. VII p. 483 'Second report of the commissioners on weights and measures', Appendix A.

[5] *PP* 1834 *Vol. XLIX* 'Returns from Corn Inspectors', p. 251 ff.

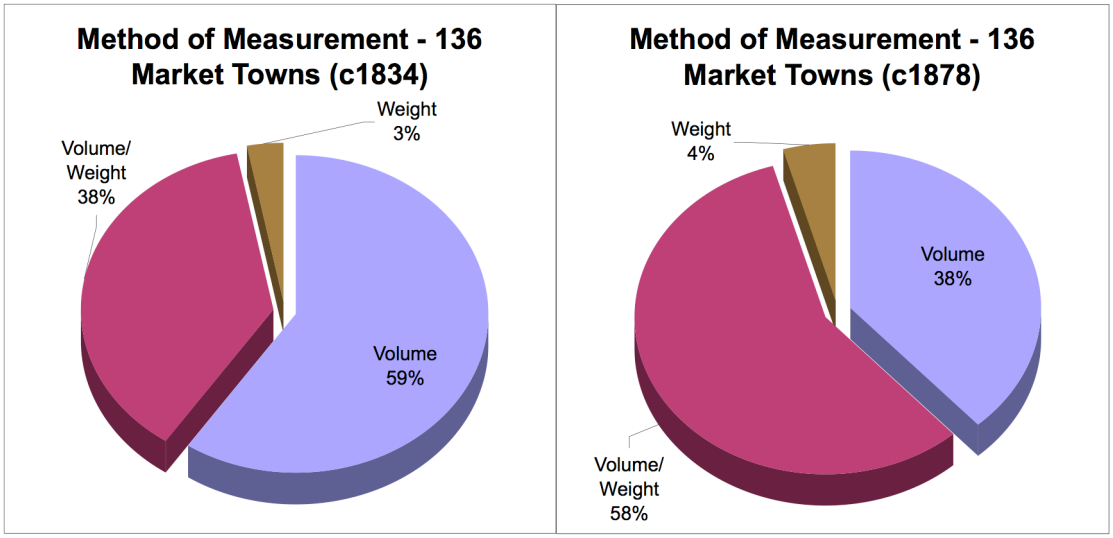
[6] *PP* 1834 *Vol. XLIX* 'Returns from Corn Inspectors', p. 259. 1 *stone* equals 14 *lbs* or 6.35 *kgs*.

[7] *PP* 1834 *Vol. XLIX* 'Returns from Corn Inspectors', p. 262

[8] Of the top twenty towns accounting for about 60% of the corn sold in domestic markets in 1880, eleven markets were reported to be using weight per volume measurements as a basis for wheat contracts. These included towns such as Norwich (10%), London (4%), Boston (3.5%) and Northampton (3%).

the quality of wheat was not unique to Britain. French bakers regularly used this method in the eighteenth-century to distinguish between a *setier* of good wheat and average quality wheat. As weight of wheat brought into Paris would vary sharply from year to year, a 'three-quality-range' had emerged in the mid eighteenth-century. The *setier*, the Parisian measure of volume, was equated to either 240, 230 or 220 *pounds* for a normal year, the highest weight representing the best quality wheat (Kaplan 1984).

Figure 1



Source: Data for c1834 from PP 1834 Vol. XLIX; data for c1878 from PP 1878-79 Vol. LXV

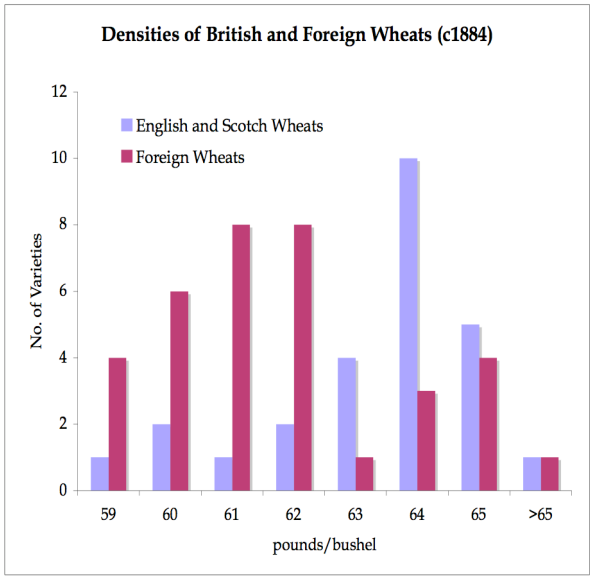
This brief survey shows how domestic British markets managed two key informational requirements – the amount of wheat traded and the quality of the grain – through the practice of making wheat contracts based on the grain's density.[9] This was a *de facto* grading system that emerged before commodity exchanges began establishing formal or numerical grades. It was also a practical system that the trade relied upon to make a rapid and straightforward assessment of quality.[10]

There was a wide variation in terms of the density of wheat sold in the domestic markets. It ranged from 470 to 512 *lbs* per quarter, that is from 58 to 64 *lbs* per *bushel* (see figure 2). In the late 1870s approximately sixty percent of the domestic grain was sold on the basis of 63 *lbs* per *bushel*, about twenty percent was sold according to the *bushel* weighing between 60 and 63 *lbs*, and another fifteen percent was sold according to the bushel weighing less than 60 *lbs*. Foreign wheats showed a similar variation in terms of their densities (Jago and Jago 1911).

[9] Why the density is important for quality is discussed further on in this paper.

[10] *PP 1834 Vol. VII*, 'Report from select committee on the sale of corn', p. 87. Evidence by Patrick Stead, a corn merchant.

Figure 2



Source: Based upon analysis reported in Jago and Jago, 'Breadmaking', 273-79

The density of a particular variety of wheat was notoriously difficult to maintain, as it was sensitive to climatic and other conditions.[11] Even under controlled conditions variation in the density of a specific wheat variety on the same plot could vary over time. Density variations occurred not only across different varieties of wheat, but also across years and different conditions for the same variety. It implies that the degree of control that the producer had on this particular attribute was limited by a variety of factors, many of which were beyond his control. This was exactly what the density measurement system was designed to capture: variations in quality from one season to another for the same variety or between two stocks of the same variety.

However, there were several issues with the use of density measurements. British grains with the highest 'specific gravity' did not always register the highest 'natural weights'[12]. Due to the shape of the grain itself it left empty spaces – or large volumes of air in between the grains - when the *bushel* measure was used. Air being lighter than wheat, the high specific gravity of British wheat did not necessarily translate into high natural weight when compared to American spring and winter wheats, which were relatively uniform in shape.[13]

This issue could be overcome by packing the grain in a compact manner into the bushel measure. 'Closely filled' grain would increase the natural weight estimate compared to 'loosely filled' grain in the same volume. The height from which grain is poured into the measure determined whether grain was loosely or closely packed: the greater the height,

[11] *Miller*, Mar 1 1880, p. 109, 'Chemistry of Breadmaking – Part III: Lectures by Prof. Graham. Refer to table by Lawes & Gilbert showing influence of seasons on the character of wheat crops.

[12] It is important to consider the difference between *specific gravity* and *natural weight* in this context. Specific gravity measurements usually refer to the density of individual wheat grains. Natural weight on the other hand refers to the density of a bunch of wheat grains measured together.

[13] John R Walton, "Varietal Innovation and the Competitiveness of the British Cereals Sector, 1760-1930," *Agricultural History Review* 47, no. 1 (1999): 51.; A Stephen Wilson, *A Bushel of Corn* (Edinburgh: David Douglas, 1883), 21.;

the closer the grain was packed, and hence greater the density when measured.[14] In addition, the practice of heaping increased the amount of grain that could be packed into a *bushel* measure, by as much as one-eight to one-quarter. The extent of the heap in turn was dependent upon the physical shape of the vessel. The flatter the vessel, the greater the volume of the heap would be and vice versa.[15] Even when the bushel measure was not heaped, the method used for 'striking the grain', that is ensuring that grain was filled only to the brim of the measuring vessel and no more, could make a difference. Experiments conducted around c1830 confirmed that when the same variety of wheat was 'stricken' using a round cylindrical roller as opposed to a flat ruler, the difference in natural weight could be as much as 6 *lbs* per bushel (56 *lbs* instead of 62 *lbs* respectively).[16]

The use of density measures as a basis for setting contract terms was further complicated by the multiplicity of metrological units used to make such measurements. Some markets used *load* per *quarter*, or *stone* per *quarter* or *pounds* per *quarter*, other markets measured in *bushels*, still other used *gallons*, *coombs*, *bags*, *bolls*, *sacks* and *centals*.[17] Even the configuration of the *bushel* itself differed across markets. The smaller *Winchester bushel*, preferred by the state before the nineteenth-century, was not acceptable to the merchants and growers in the southwest where a larger *bushel* measure was used.[18] In Cumberland, the measure used was the *Carlisle bushel*, which was three times the size of the 'ordinary one'.[19]

Thus, variation in density estimates was a result of the variation in the wheat grain as well as due to variability of measurement practices. In other words,

$$w_n = f(d, m)$$
$$d = f(v_w, E, T, S)$$
$$m = f(p_{(l,c)}, h, s_{(r,f)})$$

where w_n captures the variation in natural weight, d captures the changes in specific gravity of grain and m captures changes due to the prevailing method of measurement. The specific gravity estimate was dependent upon the particular variety of grain v_w, the environmental conditions E (such as quality of soil, climatic and other geographical conditions, etc.), the method of cultivation or the level of technology T, and other social

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[14] Issac Roberts, 'Determination of the Vertical and Lateral Pressures of Granular Substances', *Proceedings of the Royal Society of London*, Vol. 36. (1883 - 1884), pp. 225-240, p. 240; Witold Kula, *Measures and Men*, trans. R Szreter (Princeton, New Jersey: Princeton University Press, 1986), 47-49.; A D C Simpson, "Grain Packing in Early Standard Capacity Measures: Evidence from the Scottish Dry Capacity Standards," *Annals of Science* 49, no. 4 (1992): 342-344.; Also "Report from Select Committee on the Sale of Corn," in *PP Vol. VII* (London: 1834)., Appendix 12; R T Balmer, "The Operation of Sand Clocks and Their Medieval Development," *Technology and Culture* 19, no. 4 (1978): 615-632.

[15] Robert Dickson Connor, *The Weights and Measures of England* (London: HMSO, 1987).; Kula, *Measures and Men*, 49-51.

[16] *PP 1834 Vol. VII*, 'Report from select committee on the sale of corn', Appendix 12.

[17] C R Fay, "The Sale of Corn in the Nineteenth Century," *The Economic Journal* 34, no. 134 (1924).; *PP* 1834 *Vol. XLIX* 'Returns from Corn Inspectors'; *PP* 1878-79 *Vol. LXV* 'Summary of Returns by Corn Inspectors'.

[18] Richard 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*, ed. Adrian Randall and Andrew Charlesworth (Liverpool: Liverpool University Press, 1996).; Fay, "Corn Sales," 212.

[19] Fay, "Corn Sales," 216.

factors *S* (e.g. civil disturbances, political instability, etc.).[20] The variation due to method of measurement was dependent upon whether the grain was loosely or closely packed ($p_{(l,c)}$), the extent to which heaped measures were provided (h), and the method of striking grain if the measure was not heaped ($s_{(r,f)}$). Thus, without understanding the measurement practices, or indeed standardizing them, it was difficult to separate the effect of changing quality of wheat on its natural weight measurements. This unpredictability or inconsistency of density estimates drove efforts during the nineteenth century to standardize both the measurement units – such as the *bushel* – as well as mensuration methods to determine *ex ante* the quality of wheat.

III

During the nineteenth-century, there were numerous, unsuccessful, attempts to standardize the measurements used in sale of wheat.[21] The question of how much should a *bushel* of wheat weigh, and whether it should weigh the same across all markets where wheat was sold, continued to dodge those with an interest in the trade throughout the nineteenth-century.

The state dealt with the multiplicity of customary measures in a non-interventionist manner. Returns by inspectors were required to be expressed in terms of *Imperial bushels*, even if the trade made grain contracts using local measures. For this, uniform weight equivalents of the bushel were necessary and all inspectors had to use the same conversion ratio: for converting from locally used measurement units into the legally specified *Imperial bushel* and to use the same weight equivalents for the *bushel* across all markets for which the corn returns were made. Early nineteenth-century legislation specified weight equivalents of grain for both the *Imperial* as well as the *Winchester bushel*, whereas in later legislation the weight equivalents are specified only for the Imperial *bushel*.[22] As far as the corn returns were concerned, in c1820 the density of wheat was assumed to be 59 *pounds* per *imperial bushel*, that of barley was 51 *pounds*, oats 37 and rye 57 *pounds* per *imperial bushel*.[23]

Throughout most of the nineteenth-century, the state interest in standardizing grain measurements reflected its endeavours to accumulate, as consistently as possible, the average price of grain in domestic markets through the corn returns. As long as these returns were seen to be capturing fluctuations in grain prices, the use of different measurement units in local markets was left undisturbed. This is reflected in the following extract from a memorandum by the Comptroller of Corn Returns:

> "The maximum error which may arise through sales being made by weight instead of by measure [i.e. volume], or by weight and measure combined,

[20] The basis of this is the report by Prof. Graham appearing in *Miller*, Mar 1 1880, p. 109, 'Chemistry of Breadmaking – Part III.

[21] Hansard's *Parliamentary Debates*, Apr. 27, 1858; May 18, 1858; July 4, 1859. Also, *PP 1868-69 Vol. II, Bill to Establish Uniform Measurement in the Sale of Corn,* p. 5; *PP 1883 Vol. II, Bill to Ensure Uniformity of Weight in the Sale of Corn,* p. 193; and other such Bills as included in *PP 1890-91 Vol. I*, p. 427; *PP 1898 Vol. I,* p. 381, etc.

[22] "Returns from Corn Inspectors," in *PP Vol. XLIX* (London: 1834).; Order in Council under Corn Returns Act, 1882, reproduced in *PP 1888 Vol. X, Report of Select Committee on Corn*, p. 134 ff. The *Winchester bushel*, which was predominantly used for wheat measurements in the south and south west of Britain, was abolished by legislation in c1835. However, its use persisted for much of the nineteenth century in domestic markets even if official corn returns were no longer compiled using this measure.

[23] *PP* 1834 *Vol. XLIX* 'Returns from Corn Inspectors'

> and the improper return of such sales is very inconsiderable, apparently less than one per cent [and] even the existence of so much error is not proved. It is also an error of a kind that would be compensated in good seasons in consequence of the Imperial [bushel] weighing more than the customary [measures] by which sales with weight and measure combined are made."[24]

By requiring that all grain measurements be reported in standard measurement units, the issue of 'how much quantity did a bushel of corn contain' was resolved rhetorically at level of the state.

Notwithstanding this, a parliamentary select committee reporting in 1834 on the various methods of selling wheat in domestic markets had concluded that the standard practice to be used throughout all markets for the sale of grain should be a combination of weight and volume measurements. The report claimed that 'the combination may be used for the purpose of identification [of quality, as well as] employed as the standard of quantity.'[25] Nevertheless, disagreements as to the significance of measuring the density of wheat continued within the trade. Some groups claimed that density measurements were actually weight measurements, whereas others countered this by claiming that they were actually volume measures qualified by their weight equivalents.[26] Both volume-only and weight-only measurements for grain each had their strong proponents throughout the nineteenth-century.[27] Merchants from the south preferred the sale of corn by volume-only measurements, whereas merchants in the north preferred the sale by weight-only measurements, especially in markets such as Liverpool.[28]

By the late 1870s, several merchant groups had come to prefer weight-only measurements. There were some debates within the trade around c1878 as to which metrological unit – the *hundredweight (cwt)* of 112 *lbs* or the *cental* of 100 *lbs* – should be regarded as the standard.[29] Grain merchants in Liverpool, for instance, began using the *cental*, a unit of weight measure equivalent to 100 Imperial *pounds,* particularly on the US-Liverpool trade routes. The intention in this case was to replace the allegedly cumbersome *hundredweight* of 112 pounds with the *cental* as its subdivision into smaller units – using decimal division - was considered to be easier. The use of the *cental*, which became recognized as a legal measurement unit in 1879, did not extend much beyond the wheat trade in the immediate vicinity of Liverpool, although it experienced a brief surge in popularity in the United States between c1860 and c1900.[30]

The use of the *cental* in British wheat markets diminished towards the end of the century, and the trade mostly used the Imperial weight units such as the *bushel*, *pound* and the *cwt*. In fact, the *bushel* came to be used primarily as a unit of weight and not of

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[24] *PP* 1878-79 *Vol. LXV* 'Memorundum by Comptroller of Corn Returns', p. 134. Letter to the Board of Trade in 1879.

[25] *PP 1834 Vol. VII*, 'Report from select committee on the sale of corn', p. xxvi}

[26] *Parl. Deb.*, Apr. 27, 1858.

[27] *Parl. Deb.,* Apr. 27, 1858; May 18, 1858; July 4, 1859.

[28] *Parl. Deb.,* May 18, 1858; July 4, 1859.

[29] The National Archives (TNA), Board of Trade Papers (BT) 101/43, extract from J E Beerbohm's *Evening Corn Trade List*, dated Nov 5, 1878 p. 7; BT 101/49; BT 101/127.

[30] Lowell D Hill, *Grain, Grades and Standards: Historical Issues Shaping the Future* (Urbana & Chicago: University of Illinois Press, 1990). Appendix A; G J S Broomhall and John H Hubback, *Corn Trade Memories: Recent and Remote* (Liverpool: Northern Publishing Co. Ltd, 1930), 23.

capacity in the wheat trade. Sale of grain by the bushel assuming a weight equivalent was thought to be 'nominally by measure of capacity, but in reality by weight'.[31] By c1890, most within the trade had come to prefer the weight-only measurements for the sale of grain in general. The Corn Sales Act of 1921 eventually made it mandatory to sell grain by weight-only measurements. As the following section shows, these developments mirrored other changes in measurement practices that had occurred in the late nineteenth-century and the declining importance of density measurements within the wheat trade in general.

IV

Measurement of quality became even more critical when by 1840 several new wheat varieties were added to the existing low yielding British varieties. The 16 different domestic wheat types available for sale in English grain markets in the 1850s differed not only in gluten content – the chemical substance which determines the bread-making ability of wheat - but also in terms of yield (i.e. quantity of grain per acre) (Walton 1999). In addition to the domestic varieties, wheat imports after c1860 greatly increased the total number of varieties available for sale in British markets. The 40 or so foreign wheat varieties available in British markets were used mainly in the manufacture of flour, particularly in South England (Jago and Jago 1911).

Historically, *corn factors* were an important conduit for the trade buyers of wheat (e.g. *millers*), and the commodity was sold in organized terminal markets, such as the Corn Exchange at Mark Lane in London. Wheat that was not sent to London was sold to country millers, although it was not unusual for country millers to obtain wheat from London based factors.[32] The *importing merchant* became an important member in this chain as wheat imports increased. The structure of the trade at the exporting country also became significant in the nineteenth century. The nodes at which quality was measured changed and varied as the structure of the trade changed between the eighteenth and nineteenth centuries. At what stage in the long value chain was the quality of wheat measured and who measured it? Why were quality measurements made at different nodes along different trade routes? Did the sellers and buyers of wheat use the same set of measurements or did they use different attribute sets to measure quality? These are some questions considered below.

Quality Measurements from the trade's perspective

Until the mid-nineteenth century, quality of wheat was ascertained by inspecting samples submitted for inspection, in markets such as Mark Lane, where quality was measured on the basis of several important physical attributes. Although many contracts were specified using density measurements, as was discussed in an earlier section, such measurements did not capture information about the *condition* of the grain, such as the presence of impurities, dryness or moisture content, texture, etc. These physical attributes were equally important to the miller and the baker in addition to the *composition* of the grain.

[31] *PP* 1893-94 *Vol. XI*, 'Report of Select Committee on Corn Sales', p. vii & xiii.

[32] C R Fay, "The London Corn Market at the Beginning of the Nineteenth Century," *The American Economic Review* 15, no. 1 (1925): 72-73.; Dennis Baker, "The Marketing of Corn in the First Half of the Eighteenth Century: North-East Kent," *Agricultural History Review* 18, no. 2 (1970): 138.

Information about the condition of the grain in the early years of the nineteenth century was verified through sampling and visual inspection. Merchants depended upon their tacit knowledge to a large extent to assess quality of wheat and 'the eye, nose and hand were necessary [in] judging the value of grain and dealers could determine its quality by "merely taking up and poising a small quantity of it in their hands"'.[33] Thus quality was measured both numerically, using density measurements (e.g. *pounds* per *bushel*) as well as non-numerically through the visual inspection of the sample's other attributes such as colour, dryness, cleanliness, etc. However, inspecting samples was problematic as samples sometimes hid the extent of variation in the quality and there were frequent complaints against corn factors who exposed only a selection of their samples so that the buyers did not get a complete picture of the actual quality of the stock.[34]

From the mid-nineteenth century onwards, commodity exchanges began to develop detailed mechanisms to measure and grade this complex commodity.[35] The British exchanges, such as the London Corn Trade Association (LCTA) and the Liverpool Corn Trade Association were primarily concerned with grading imported wheats, not domestic ones: there is no evidence that either of these exchanges developed formal grades for the domestic trade. Developing grades involved selecting a finite set of characteristics, or 'summary criteria', such that the commodity could be graded into a manageable number of classes. Criteria used to determine the commercial grade of wheat from the samples submitted for inspection included moisture content, density, freedom from foreign material (cleanliness), condition and texture of the kernels, general condition ('whether the grain is cool and sweet or it musty and sour'), etc.[36]

Out of four distinct grading methods, the FAQ method was the one that was most commonly adopted in London for grading wheat quality.[37] Under this method, samples of all grain imported into UK, including several ports in Europe, were periodically collected by LCTA who would then arrive at the grades for any given year. The actual mechanism or methods used to describe the grades could not be determined from LCTA's archival records. It is difficult to establish whether the FAQ grades were standards – as in a reference point that establishes conformity or deviation – or as ranked categories into which the different samples could be sorted. Since the grades were developed on a responsive basis, i.e. based on annual samples collected, it is likely they functioned as ranked categories rather than as standards.

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[33] Stanley Dumbell, "The Sale of Corn in the Nineteenth Century," *The Economic Journal* 35, no. 137 (1925): 144.

[34] Benoit Daviron, "Small Farm Production and the Standardization of Tropical Products," *Journal of Agrarian Change* 2, no. 2 (2002): 169.; Hill, *Grain, Grades and Standards*, 6.; Fay, "London Corn Market," 73.; J C F Merrill, "Classification of Grain into Grades," *Annals of the American Academy of Political and Social Science* 38, no. 2 (1911): 63. Sampling was also problematic in other commodity trades. Cotton sellers in Liverpool often accused brokers of carelessly handling samples, which 'prejudiced the sale of the whole lot and often put the seller to the expense of re-sampling'; see Thomas Ellison, *The Cotton Trade of Great Britain : Including a History of the Liverpool Cotton Market and of the Liverpool Cotton Brokers' Association* (London: E Wilson, 1886), 177.

[35] Stephen Craig 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): 234.; R B Forrester, "Commodity Exchanges in England," *Annals of the American Academy of Political and Social Science* 155, no. 1 (1931).; C Chattaway, "Arbitration in the Foreign Corn Trade in London," *The Economic Journal* 17, no. 67 (1907).

[36] Lloyd S Tenny, "Standardization of Farm Products," *Annals of the American Academy of Political and Social Science* 137 (1928): 209.

[37] The four methods were certificate final, sealed sample, fair average, and fair average quality (FAQ) method; Forrester, "Commodity Exchanges," 202.

FAQ quality descriptions depended upon the source of the produce. For instance, when Indian grain was graded on FAQ terms, allowance was made for dirt and other impurities (such as non-farinaceous seeds).

'[Not over] 3% of impurities of which 1(1/2)% may be dirt for shipments to the 30th June, and 3(1/2)% [impurities], of which 2% may be dirt, for the remainder of the seasons shipments'[38]

Similarly, grades for New Zealand wheat were described separately for round berried and long berried wheat.[39] North American grain was gradually accepted on the basis of 'official certificate of inspection to be final as to quality', i.e. according to the quality guaranteed by the official inspection certificates issued in the US. Even so, LCTA would sometimes inspect the samples prior to accepting the grades.[40]
LCTA would also take into account the differences in the natural weight of the grain from Argentina, Australia, California or other locations. For example, while fixing the standard for Australian wheat in 1894, the LCTA fixed an average weight of 63 *lbs* per *bushel* for that seasons wheat. On the other hand, the average weight of Californian White was assumed to be 60.5 *lbs* per *bushel* while fixing the standards for 1895. Similarly, for grain imported from the Black Sea ports, the committee had developed rules to account for the natural weight, especially for rye and barley.[41] LCTA also used other criteria, such as cleanliness and colour, to establish its grades, as in the case of grain from India.

These developments in Britain mirrored those in the US where commodity exchanges, such as the Board of Trade of the City of Chicago (CBT) in 1858, began classifying grades of grain according to descriptions of colour, quality and general condition.[42] Even though density, or 'test weight', was one of the attributes used to describe wheat quality, lack of approval from the trade for 'standardized' densities meant that specification of this criteria was left to the discretion of the grain inspectors when ascertaining grade.[43] Before the turn of the century, a numerical system of grading the various varieties of red, white, winter and spring wheat had emerged. For instance, No. 1 white winter wheat was defined as that which was pure white, sound, plump and well cleaned. No. 3 was defined as not clean and plump enough for No. 2 but which weighed not less than fifty-four *pounds* to the measured bushel. These grades were accepted as guarantee of quality in British markets and wheat certified by US exchanges was not graded by LCTA.[44] Nevertheless, the numerical grades in the US were not entirely based upon *quantitative* measurements of quality. Quantification of quality attributes continued to remain

[38] London Corn Trade Association (LCTA), 'Minutes of East India Grain Committee: Vol. 1 (1888-96)', entry for 8th Aug 1889.

[39] LCTA, 'Minutes of American and Australian Grain Committee: Vol. 1 (1882-96)', entry for 9th April 1891; John George Smith, *Organised Produce Markets* (New York: Longmans, Green and Co, 1922), 24-25.

[40] LCTA, 'Minutes of American and Australian Grain Committee: Vol 1 (1882-96)', entry for 1st Jan 1891; LCTA Subcommittee to Examine Rules of Arbitration suggested alteration of Contract Forms 1898, proposed by the Liverpool Corn Trade Association on 8th Nov 1897 and accepted by committee.

[41] LCTA, 'Minutes of American and Australian Grain Committee: Vol 1 (1882-96)', entry Sep 24, 1895; Feb 20, 1894, etc.; LCTA 'Minutes of Black Sea Grain Committee: Vol 1 (1890-1901)', especially the comparative table for the regulation of the natural weight of rye; also, Forrester, "Commodity Exchanges," 202.

[42] Merrill, "Grain Grades," 58.

[43] Hill, *Grain, Grades and Standards*, 13-16.

[44] 'The Forty-Seventh Annual Report of the Trade and Commerce of Chicago', *Chicago Board of Trade*, (Chicago, 1905), pp. 30-33.

problematic and elusive. In c1914, numerical grades continued to be based upon descriptions such as sound, dry, reasonably clean, sweet, mature, plump, etc.[45]

The foregoing discussion highlights several issues regarding quality measurements in the British wheat trade. Quality was a multi-faceted concept and no single set of measurements could comprehensively capture it. Consequently, the set of attributes used to measure quality differed according to the trade route and sources of imported wheat. Further, the elevator system that developed in North America in the latter half of the nineteenth-century required the development of formal grading, as grain from different sources was mixed together for storage and transportation. The segregation of seller's identity from that of the grain and quality certification prior to storage strengthened the incentives of those shipping the grain to maintain quality during transportation (Pirrong 1995). In contrast, cruder handling facilities in other exporting countries (Argentina, Australia, India, etc.) made it more efficient to transport wheat in sacks, thereby retaining links to the seller's identity and making inspection of quality at the importing end of crucial importance. The ex-post system of FAQ measurements by the LCTA was particularly suited in the latter case. This led to differences in terms of who measured quality as well as how it was measured along different trade routes.[46]

Finally, there is the question of whether quality measured according to the grading systems could capture the bread-making ability of wheat – an important test of grain quality of from a miller's (and a baker's) perspective. If not, how was quality on this important *functional* attribute measured? Understanding the buyers' perspective of wheat quality will shed some light on these issues.

Quality from the buyers' perspective

In the latter half of the nineteenth century, there were corresponding and equally significant changes in the milling industry. Being one of the largest buyers of wheat, these changes were not merely coincidental. After c1870, we discern a 'professionalization' of skills required in the milling industry as the process of milling became highly specialized and technically sophisticated. The introduction of roller milling technology vastly improved the quality and the whiteness of flour obtained for the same proportion of grains used to produce the coarse 'household' grade flour using the older grinding technology.[47] The speed and extent of adoption of this new technology, and the subsequent structural reorganization (e.g. the concentration of production), was shaped by at least three important factors: increasing domestic demand for white flour, unsuitability of softer domestic wheat varieties, and increase in the imports of foreign flour and hard wheat varieties. [48]

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[45] Hill, *Grain, Grades and Standards*, 76., table 3 comparing grades specified by USDA and those used in three major grain markets of New York, Chicago and Minneapolis.

[46] See also James Stewart, "Marketing Wheat," *Annals of the American Academy of Political and Social Science* 107 (1923): 187-188.; Merrill, "Grain Grades," 66.

[47] Richard Perren, "Structural Change and Market Growth in the Food Industry: Flour Milling in Britain, Europe and America, 1850-1914," *The Economic History Review* 43, no. 3 (1990): 423.

[48] H Macrosty, "The Grainmilling Industry: A Study in Organization," *The Economic Journal* 13, no. 51 (1903).; Glyn Jones, *The Millers: A Story of Technological Endeavour and Industrial Success, 1870-2001* (Lancaster: Carnegie Publishing Limited, 2001)., esp. Chap. 1; Perren, "Flour Milling."; Jennifer Tann and Glyn Jones, "Technology and Transformation: The Diffusion of the Roller Mill in the British Flour Milling Industry, 1870-1907," *Technology and Culture* 37, no. 1 (1996).

The significance of measuring the quality of wheat to the millers must be examined in the context of these changes. The value to the miller of a certain variety of wheat depended upon the quality of flour it provided. Wheat of least specific gravity was known to yield a lower quality of flour and the millers, and bakers, preferred denser wheat varieties to the 'soft', less dense wheat varieties.[49] Lighter, coarser grains could yield a larger proportion of flour, but at the cost of including coarse bran and thereby reducing the overall quality of flour.[50]

But it wasn't only the density of the grain that was important to the miller: the 'strength' of the grain or flour was crucial to the miller (and the baker) as well. Strength was initially defined as the ability to absorb and retain moisture, which later was modified to indicate the quantity and quality of gluten the grain contained.[51] Stronger flour was preferred because the number of loaves obtained from a given weight of flour were more than those obtained from weaker flour.[52] Hard wheat varieties of the high densities were considered to be stronger wheats, whereas softer wheats were considered to be of the weaker kind; British wheats, on the whole, were considered to be of the weaker kind.[53] The miller basically had to balance both the density as well as moisture characteristics of the grain, as those varieties with the highest-bushel weight with low moisture content usually gave the greatest amount of flour.[54]

One of the greatest skills that a miller had to possess was to know which varieties of wheats to mix together as 'grist'; i.e. flour that the bakers would accept as being of consistent quality. Flour itself could be graded into different types, and although millers scarcely recognized a consistent system of grading flour, each flour grade required a different quality of wheat to be mixed.[55] Mixing also eked out the supply of expensive best quality wheat, and enabled the miller to enhance his margin by mixing expensive and inexpensive wheats and still sell the mixed flour at a price higher than that of inferior quality flour. A typical mixture recommended in the eighteenth century included one part best quality wheat to one part second-best quality wheat to two parts inferior quality wheat.[56] Such a mixture implied a price ratio of about 100:91:81 for best, second and inferior quality wheat respectively.[57]

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[49] *PP 1834 Vol. VII*, 'Report from select committee on the sale of corn'; Walton, "British Cereals," 39-40.

[50] *Miller*, May 5, 1879, Technical Issue, p. 193; Nov. 3, 1879, p. 682.

[51] William Jago and William C Jago, *The Technology of Bread-Making* (London: Kent & Co., 1911), 291.; also, Jones, *The Millers*, 60.

[52] John Percival, *Wheat in Great Britain* (Reading: 1934), 69.

[53] Ibid., 71.

[54] Ibid., 72.; See also Jago and Jago, *Breadmaking*, 369.; Jones, *The Millers*, 59-60.

[55] J Kirkland, "The Relative Prices of Wheat and Bread," *The Economic Journal* 6, no. 23 (1896): 479.; Christian Petersen, *Bread and the British Economy, C1770-1870*, ed. Andrew Jenkins (Aldershot, England: Solar Press, 1995), 53-54.

[56] *PP 1814-15 Vol. V*, p1353, evidence by E G Smith; Petersen, *Bread and Britain*, 158-159.; Petersen, *Bread and Britain*, 159; Historically, wheat had been divided into 'best', 'second' and 'third' quality categories according to some quality attributes for the purpose of setting the Assize of Bread, 12 Henry VII cited in *PP 1814-15 Vol. V*, p. 1344.

[57] Petersen, *Bread and Britain,* table 6.2 on 160. The average prices in the table have been calculated from evidence provided to the Select Committee on Sale of Corn by Richard Page, *PP 1834 Vol. VII*, p356. These are unweighted averages and weighting them with the mix proportion suggests an average price index of 88 (assuming best quality price to be 100) for the grain mix compared to the relative prices of individual grain qualities.

As the availability of foreign wheat increased, good quality imported wheat was mixed with lower quality domestic varieties.[58] By the latter half of the nineteenth century, the miller's craft had begun to demand a great deal of experimentation and risk. Millers had to consider, for each variety of wheat, whether it would contribute to one or more aspect of flour quality: strength, colour, taste or general appearance. Consequently, wheat buying was governed by experience, general principles and a considerable degree of detailed knowledge, and no two millers agreed on what constituted good quality.

For example, one miller invited comment on whether the following mixture 'ought to make a good sack of bakers flour': 3 sacks red winter; 2 sacks Michigan; 2 sacks No. 2 spring and 5 sacks of English white.[59] He received at least five suggestions from other millers, and all of them were different. One correspondent suggested that the proportion of English wheat was too high and instead recommended that 3 sacks of Michigan be used instead of 2, and that English white be limited to 2 sacks. Another correspondent suggested the original mixture would result in 'lack of strength and colour' and suggested eliminating English white altogether and adding an extra sack of No. 2 spring to the mixture: alternatively, the red winter, No. 2 spring and the English white could be mixed in equal proportions. A third correspondent suggested leaving the English white out altogether, grinding the remaining mixture separately, and then letting the meal sit in the sack for a few days before mixing. The fourth correspondent suggested that if this was milled in the country then 6 parts each of No. 1 American spring with 'sound' new English white wheat, mixed well in a bin a week before grinding, could give the desired results. The fifth correspondent recommended one sack each of Dantzic and American spring, three sacks each of American white and American winter and four sacks of English white (part new and part old).[60] Thus, there was dissonance amongst the millers as to the quality differences between the various varieties and quality was a relative rather than an absolute value in this industry.

A direct volumetric relationship existed between grain inputs and flour output. Consider this example from more recent times. The Chicago CBT specified grade number 2 soft red winter wheat uses a 58 pound per bushel as criteria. A miller usually bases grain price to flour ratios on the assumption of a 73% flour extraction rate, implying that 2.36 bushels would be required to produce 100 pounds of flour. A reduction of weight from 58 pound to 57 pound per bushel has two implications. First, at the same extraction rate, the miller now needs 2.40 bushels of wheat to produce 100 pounds of flour. Second, a reduction of weight, and hence quality of the grain, is likely accompanied by a reduction of extraction rate to say 70% which further increases the quantity of grain required, 2.50 bushels, to produce the same quantity of flour. The resulting cost differential of wheat to flour is not always reflected in the price discounts for the different wheat qualities.[61] Of course, to the British miller in the late nineteenth century it was not only the price of individual variety of wheat that was of ultimate importance, but the relative costs differentials between the individual varieties due to the blending of flours. The miller had to balance his margins according to the price of bread and the price of wheat.[62]

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[58] Petersen, *Bread and Britain*; *PP 1834 Vol. VII*; *PP 1814-15 Vol. V*, various testimonies.

[59] *Miller*, Feb 2, 1880, Letter no. 669, p. 922.

[60] *Miller*, Letters: reply to 669, Mar 1, 1880, p. 45-46; Apr 5, 1880, p. 119; See also Kirkland, "Bread Prices," 481., for yet another example of grist mixture.

[61] Eluned Jones, "The Role of Information in Us Grain and Oilseed Markets," *Review of Agricultural Economics* 21, no. 1 (1999): 250-251.

[62] Kirkland, "Bread Prices," 481-482.

The foregoing highlights the particular meaning of wheat quality to the miller. As the milling process became more specialized and sophisticated, the *differences* in quality between varieties as well as the *consistency* of quality in a given variety became crucially important. Managing wheat quality was necessary to achieve the desired quality of flour, and to enable the millers to remain profitable.

How did the millers measure the quality of grain? Throughout most of the nineteenth century millers relied upon the visual inspection of samples to purchase grain, the attributes of relevance being the density, colour, texture, and the extent of cleanliness. When the volume of imported grain increased and the number of varieties available multiplied, the millers, like the merchants, began to rely upon the grades and standards set by the various commodity associations, such as the LCTA or the Liverpool Corn Trade Association. We discern a trend of shifting reliance from visual inspection and assessment of quality to a gradual acceptance of the grading and standards developed by the various commodity associations.

Notwithstanding this shifting reliance on grades, assessing the quality of grain still depended upon the 'empiricism of the practical miller'.[63] The following extract from *The Miller*, c1875 is illustrative:

'In purchasing wheat and choosing the description necessary to secure a uniform brand of flour, millers must often feel the want of a reliable test to guide them. It requires a very long and constant experience to judge the quality of even those wheat appearing daily in our markets; but we are left with the most unpleasant uncertainty when new descriptions are introduced to our notice.'[64]

By the last quarter of the nineteenth century, techniques for assessing the quality of wheat were still fairly uncertain. One expert wrote in 1890 that 'it will be well for mixing purposes to consider wheat as coming under one of three heads – strong, coloury or neutral (*sic*)'.[65] He further pointed out that wheat buying was governed by experience, general principles and by what varieties of wheat happened to be available in supply. After 1880, changes in milling technology were accompanied by development and improvements in testing and measuring the different quality attributes. The increased understanding of the chemical composition and properties of gluten, the substance in grain that lends strength to the flour, aided these developments. Various testing methods and instruments were made available for assessing the quality of flour: Pekar's method of assessing whiteness of flour, Boland's aleurometer to test the strength of gluten, and Robine's method for estimating quantity and likely bread output are some examples.[66] Even so, each miller had to discover for himself the strength of any given flour, as there was 'no satisfactory method of numerically registering strength except through a baking test'.[67]

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[63] Jones, *The Millers*, 61.

[64] *Miller*, Oct 4 1875, 'The study of a method to meet the requirements of millers in the analysis of wheat and wheaten flour', p 196-7.

[65] W R Voller, *Modern flour milling*, Gloucester, 1889, as cited in Jones, *The Millers*, 59.

[66] Ibid., 59-61.

[67] Jago and Jago, *Breadmaking*, 291.; also, Jones, *The Millers*, 60-61.

To summarize, the milling industry, towards the end of the nineteenth century required more sophisticated ways of assessing the quality of wheat compared to the relatively crude test of density measurements and visual inspection. The millers sought to capture the grain composition in more explicit terms of gluten and protein content. They were beginning to rely upon the grades established by LCTA to assess the condition of grain reaching Britain. This was an iterative process with the grading of quality helping the milling industry to become more professional, which in turn, and in conjunction with other changes in the industry, required further refinement of the quality grades themselves. The industry thus played an important role in the standardization of *ex ante* assessment and guaranteeing of wheat quality based on its composition and condition. Even so, assessment and testing on the basis of performance criteria remained the miller's responsibility. The millers had to rely upon baking tests and other measurements to ascertain quality *ex post*.

V

There are several lessons we can glean from the changes in the measurement practices in the wheat markets studied here. As shown in an earlier section, practices specifying the density of wheat in domestic market contracts effectively managed two information requirements – the amount of wheat exchanged as well as the likely quality of the wheat grain. Economic and technological changes, coinciding with the increase in imports of wheat into Britain after c1860, fundamentally altered how such basic information about the commodity was managed. Central to this change was the de-linking of the delivery and unloading processes from the quality testing process; the institutional link had been at the heart of the domestic market practices.

Historically, grain was measured by the *bushel* when it was put into sacks from the ship's hold and weighed once it was hoisted on to the deck. Determining wheat's density required measuring the same stock of grain twice, once in terms of volumetric units and again in terms of its weight.[68] Changes in the transport and discharging technology in the latter half of the nineteenth-century altered this unloading process. The sacking process in UK ports was partly eliminated when foreign grain began arriving in sacks.[69] The introduction of pneumatic elevators in the 1890s, where grain could be vacuumed from the ship's hold and poured onto scales for weighing, further made the sacking process redundant.[70] Also, development of instruments such as the condrometer or the grain tester helped to reduce measurement costs by directly measuring the specific gravity of grain without duplicating measurements – first its volume and then its weight.[71]

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[68] *PP 1834 Vol. VII*, 'Report from select committee on the sale of corn', pp. xix-xx}; Dumbell, "Corn Sales," 142.; Broomhall and Hubback, *Corn Trade Memories: Recent and Remote*, 24.

[69] Bryson Cunningham, *Cargo Handling at Ports: A Survey of the Various Systems in Vogue, with a Consideration of Their Respective Merits* (London: Chapman & Hall, 1923), 4-5.; Grain from India and Australia would be packed in twill bags and could support repeated handling and did not require re-bagging at British ports. But, grain arriving from Argentina and the Pacific coast of North America often had to be re-bagged.

[70] Hugo Van Driel and Johan Schot, "Radical Innovation as a Multilevel Process: Introducing Floating Grain Elevators in the Port of Rotterdam," *Technology and Culture* 46 (2005): 63. Prior to the use of such pneumatic elevators, bucket elevators were used in places such as Glasgow, Cunningham, *Cargo Handling*.; "Pp 1834 Vol. Vii," xx. However, only once the pneumatic elevators became widespread could large volumes of grain be discharged effectively in much less time.

[71] *PP 1890-91 Vol. XII, Report of Select Committee on Corn Sales,* p. 53-56.

Decoupling of the two measurement processes meant that measurements of wheat's compositional quality, i.e. its density, were no longer technically interrelated with measurements of quantity i.e. amount of grain exchanged. Since quality measurements did not have to be physically made during the time of delivery or unloading, it made quality grading by third-party organizations, such as commodity exchanges like LCTA, practically feasible. It also made it possible for the state to enforce the standardization of the metrological units used by the trade. Measuring the quantities of wheat traded in terms of its weight became standard practice in the wheat markets by the end of the nineteenth century, as the rationale for measuring the density using a volume-weight measurement combination was eliminated.

De-linking the two measurement processes, and segregating metrological standardization from standardization of mensuration practices, made it possible to develop independent measurement methods to capture both sets of information – quality and quantity – effectively. It also enabled stable institutional rules to emerge that could generate and circulate knowledge about the commodity (stocks, traded quantities, quality, etc.) in a more transparent manner. However, no single set of rules emerged to manage the measurements of quality, as there was no one way of capturing information about the commodity.

The LCTA & CBT (American) wheat grades were based on several attributes, including density, moisture content, cleanliness, and other descriptors (such as long or round berried for New Zealand corn), i.e. on the basis of the grain's composition as well as its condition. The grades and methods of measuring quality differed according to the source of the grain reflecting the different incentives facing the shipper, the conditions in which it was transported and peculiarities of the composition of the grain itself. Further, quality to the miller had a different significance as compared to the merchant seller. Changes in the milling technology, science (primarily in chemistry) and education influenced the measurements used by the millers to ascertain the quality of wheat. Scientific study of the wheat grain and the nutritive value of its different parts focused on understanding the chemical and physical properties of its proteins, especially gluten.[72] An increased understanding of the chemistry of wheat and advances in testing increased the sophistication of quality assessment techniques in comparison with the relatively crude and unreliable estimation of quality using density measurements and visual inspection. This example implies that the buyers and sellers had begun to depend upon different sets of measurements to quantify quality by the late nineteenth century.

The role of market organizations, such as the commodity exchanges and trade associations, was very important in developing measurement methods and the dissemination of knowledge within the market. For example, the development of quality grades by commodity exchanges changed who measured what, and at what stage of the commercial process. The LCTA grades and the measurements used to describe them sought to standardize the information regarding the quality of imported wheat reaching British markets, reflecting similar changes occurring in the US. These associations functioned as quality assurance and dispute resolution centres, apart from aiding in the assessment and measurement of quality. Dispute resolution of quality related issues by arbitration became widespread in the latter half of the nineteenth-century as the corn trade associations set up transparent

[72] Harriette Chick, "Wheat and Bread: A Historical Introduction," *Proceedings of the Nutrition Society* (1957): 3.; Jago and Jago, *Breadmaking*, 272-273 & 369-370.

mechanisms.[73] Also, British associations helped to address quality problems concerning US graded grain by raising these issues directly with CBT or other exchanges.

Similarly, the National Association of British and Irish Millers (NABIM), formed in 1878 increased efforts to educate millers in the 'science of milling'. The NAIBM organized meetings, presentations, symposia, technical classes, etc. between 1884 and 1890 on topics such as 'Bookkeeping for millers', 'Gradual reduction milling', 'The Carter and Zimmer sorting system', 'The world's wheat crop and wheat values', etc.[74] The association also acted as a 'pressure or lobby group' when it wrote to the Board of Trade in 1878 expressing the opinion of the milling trade regarding the metrological units to be used in the sale of wheat and other grain.[75] NABIM was also involved in the quality standardization and grading process for wheat. For example, it proposed various amendments to the LCTA standard contract forms in 1896. One particular amendment it suggested regarded the proportion of dirt and foreign matter that should be allowed in the grain imported from India. This suggestion was, however, rejected by the LCTA on the basis that the limits suggested by NABIM were 'impracticable'.[76]

Another set of institution that had a similar impact on the industry were the various technical and trade journals, such as the journal *Miller*, was started in 1875 by William Dunham and the journal *Milling* started by G J S Broomhall in 1891.[77] Publications such as these served as forums to exchange information, knowledge, opinions, developments, etc. that directly affected the trade. In it one would find information about new developments in the milling process pioneered by milling engineers such as Herbert Simon, or about the state of the wheat crop in Britain or its foreign sources, letters seeking opinions about the best method of mixing grain to get the ideal flour, news articles on developments affecting the wheat, milling and baking trades, etc. The editorial, technical, commercial and correspondence content was supplemented by the growing amount of advertising. Such journals provided much of the basis of news, ideas and discussion for both formal and informal networks of communication throughout the industry.[78]

One interesting aspect of this case is the relative absence of the state in directing the changes to the measurement activity: relative because the state's influence was not completely absent. Several groups within the state attempted to influence or regulate the metrological units used by the trade; parliament, state departments (agriculture, treasury, etc.), Board of Trade, etc. had all variously tried to standardize metrological units used by the trade (see section III). However, as far as the measurement of quality were concerned, there is no evidence of direct state participation. This contrasts with the involvement of the USDA in the early twentieth century in determining a uniform

[73] Robert B Ferguson, "The Adjudication of Commercial Disputes and the Legal System in Modern England," *British Journal of Law and Society* 7, no. 2 (1980): 145.; Chattaway, "Arbitration."

[74] Jones, *The Millers*, 150-156.; Tann and Jones, "Technology and Transformation," 68.

[75] TNA, BT 101/43, letter by William Chatterton, president of NABIM, Nov 7, 1878.

[76] Subcommittee to Examine Rules of Arbitration, 1884. Entry for 1896 suggesting the participation of the millers associations in defining quality standards.

[77] Jones, *The Millers*, 18-21., Broomhall had started another publication covering the corn trade called the *Liverpool Corn Trade News* (1888).

[78] Ibid., 20-21.

system of grading for US wheat.[79] Measurements of wheat quality in Britain were mostly managed by markets and market institutions.

Analytically, this point is interesting as it brings into focus two important aspects: the role of the state concerning standardization of measurements, and the distinction between legal standards and voluntary consensus standards. Metrological units are an example of legal standards, where the involvement of the state (the government, bureaucracy, parliament, etc.) in terms of the standard setting process was high. Quality measurements, particularly those used in the grading of wheat, are an example of voluntary consensus standards, where the involvement of the state in Britain, unlike the US was minimal.[80] It is worthwhile reflecting upon the fact that measurement systems within the wheat markets incorporated both legal as well as voluntary standards, and that, broadly speaking, measurement practices developed as voluntary consensus standards rather than legal standards, unlike metrological standards.

One notion of the dynamic that links the measurement practices, institutional rules and the institutions to economic knowledge and organization within the wheat markets is that of institutional 'bundles' or 'packages'. For example, measurement systems can be understood as bundles or packages comprised of standardized processes, measuring instruments, standards of comparison, and rules, regulations and protocols that govern the measurement activity as a whole in particular contexts.[81] This concept of an institutional package – in the context of measurement activity – stresses the interconnections between rules, artefacts and people. It also considers the interplay between inward beliefs and institutional rules, an issue alluded to in the introductory section with regard to contextualization.

Institutional interconnections are evident within the wheat markets studied here. For instance, the density measurements used for specifying wheat contracts in domestic markets until the late nineteenth century depended upon particular interconnections between metrological units (e.g. the *bushel* and the *pound*), locally known and accepted rules that governed the method of making the measurements (e.g. weighing of grain from the ship's hold, pouring the grain into the bushel from a particular height, etc.), and the people who depended upon these measurements to make decisions (e.g. if the density is *x lbs* per *bushel* then pay *y* amount, else reduce/increase the price to *z*). The strength of these interconnections lent resilience to the institutional bundles, making them more, or less, susceptible to changes. This institutional arrangement rested upon the shared belief that the density of the grain was the best indicator of its bread-making ability.

Changes to this institutional arrangement occurred due to a variety of factors. These included technological factors, such as the elimination of the sacking process, introduction of new measuring instruments, better understanding of grain chemistry

[79] Hill, *Grain, Grades and Standards*.

[80] Craig N. Murphy and JoAnne Yates, *The International Organization for Standardization (Iso): Global Governance through Voluntary Consensus* (New York: Routledge, 2008). and K. Tamm Hallström, *Organizing International Standardization : Iso and the Iasc in Quest in Authority* (Cheltenham Edward Elgar, 2004). give an excellent account of the ISO as an example of voluntary standards and the standard setting processes involved.

[81] This view of an institutional package is somewhat different from the one proposed by Sheilagh Ogilvie, to whom an institution is a package of both efficient and inefficient activities; Sheilagh Ogilvie, "'Whatever Is, Is Right'? Economic Institutions in Pre-Industrial Europe," *Economic History Review* 60, no. 4 (2007): 668 & 674-675.

leading to refinements in the flour making process, etc. Economic factors influencing the older institutional arrangements included the reorganization of trade routes due to increasing imports, explosion in the varieties of wheat available in domestic markets, professionalization and restructuring of the milling industry, etc. Additionally, other institutional factors also played an important role, such as the activities of commodity exchanges and trade associations, metrological standardization coordinated through the state, greater value attached to white flour compared to wholemeal flour, etc.[82] The new institutional arrangements surrounding the measurements of quality in the late nineteenth century, with it's a different bundling of standards, measurement artefacts, rules and protocols, and different market groups should be considered in the context of changes to the earlier arrangement and institutional bundling. The quality measurements were also based upon different shared beliefs: that quality measures could be quantified, and that there were no universally applicable indicators of quality.

This notion of institutional bundles is particularly useful in understanding how markets transformed measurements into useful economic knowledge. The interconnections within the institutional arrangements not only coordinated the measurement activity, ensuring that the observations were reliably made and reported, but also helped to place the measurements into the proper context. There was nothing intrinsically good or bad about particular density measurements except in the context in which they were used to pronounce that a particular stock of a specific wheat variety in a given year was of acceptable or unacceptable quality. Similarly, the acceptability of a particular level of impurities in the shipment of wheat that would qualify for a superior or inferior grade of wheat was institutionally determined. Even the sharing of knowledge between millers and the debates revolving around the best combination of wheat varieties to obtain good quality flour depended upon which attributes were used to measure the 'strength' of the grain: did it depend upon moisture retaining ability, or the extent of albuminoids, or on the colour of the grain? There was no concrete or universal answer to such questions. In other words, the context in which measurements were made, reported and used determined the knowledge about the commodity they conveyed.

The scope of this present research makes it difficult to establish the mechanics of transforming measurements into knowledge.[83] However, the historical evidence presented here undeniably demonstrates that measurements of wheat used by the trade were highly specific and complex, depended upon multiple standards and measuring instruments and required a clear organizational structure by the end of the nineteenth century. They were designed to capture particular information about the commodity and the conditions under which it was traded. The institutional arrangements helped both merchant sellers and the buyers make important economic and business decisions.

[82] Metrological standardization refers to the changes to the weights and measures legislation, the efforts to fix the weight of the bushel used to measure wheat, etc. Regarding flour, there is no intrinsic reason why white flour should be of better quality than wholemeal flour, and therefore the value distinction is institutional rather than technical.

[83] A possible framework is outlined in Velkar, A. 'Markets, Standards and Transactions: Measurements in Nineteenth Century British Economy ', Unpublished PhD Thesis, (London School of Economics, 2008), Chapter 3.

VI

Measurement systems and measurements have been variously classified as infratechnologies [(Temple and Williams 2002); (Tassey 1982)], institutions (Antonelli 1994) or standards (Kindelberger 1983).[84] This paper has argued that measurement systems incorporate standards, technological artefacts, standardized protocols, rules and regulations, etc., which are applicable across a range of contexts and whose applicability is coordinated by a host of institutions. The notion of institutional bundles is particularly helpful in this case as it emphasizes the interconnections between people, rules and objects and the manner in which they are configured and re-configured.

The paper has demonstrated a need to distinguish between standards as artefacts (such as metrological units or quality grades) and standardized practices (such as mensuration practices). In the wheat trade, instead of rationalization from many to few standards, we notice the introduction of new specialized standards. The commodity trade, which by the end of the nineteenth century had become highly complex was using a set of standardized mensuration practices to manage a highly complex system of quality measurements employing a variety of measurement standards. Analytically, it becomes important to make distinctions between systems and standards and between standardized artefacts and practices.

Markets are complex systems and knowledge is a fundamental resource that helps to coordinate activity within such a complex system. This paper has also shown how measurements have an important role in generating knowledge that aids everyday economic activity. This economic knowledge goes beyond the knowledge of prices and rates of return, but informs at the transactional level. The crucial point here is that mensuration practices are developed to make such knowledge reliable. This reliability is distinct from, but is connected to, that achieved by standardizing artefacts and instruments (e.g. metrological units). Because many economic measurements do not have to conform to a single value, and because there are often multiple attributes that can be measured, mensuration practices assume a greater significance in ensuring the reliability of such knowledge. It is the interconnections within the institutional bundle forming the mensuration practices that help to generate relevant economic knowledge.

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[84] Kindelberger considered them to be public goods, however, according to Romer's definition they could be thought of as non-pure private goods; see, Paul M Romer, "Endogenous Technological Change," *The Journal of Political Economy* 98, no. 5-Part 2 (1990).

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