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A contribution to the analysis of local units of measurement in Italian keyboards

Denzil Wraight

This conference is concerned with regional characteristics in instrument making, thus, it would have been appealing to have written about the different traditions to be found on the Italian peninsular. Although we now have a much better view of the activity of instrument makers in the various Italian centres than we did 30 years ago, there are nevertheless disagreements between experts on where some unsigned instruments might have been made. To be sure the number of disputed cases is relatively few, but the issues involved concern the criteria we apply to distinguish say a Neapolitan harpsichord from one made in Rome or Florence, so there are basic gaps in our understanding.

I have chosen to tackle a fairly small part of the puzzle. There is one particular instrument which suggested the subject for this paper, a harpsichord which is part of the Russell Collection in Edinburgh, an instrument which was originally made with split sharps in the keyboard, as John Barnes discovered.[1] Although I have not been able to find any definitive evidence from the mouldings to identify the maker, I suggested a Florentine or possibly Roman origin, based on stylistic considerations.[2] Later Grant O'Brien stated that »the unit of measurement used in its design and construction shows clearly that it was made in or near Naples«.[3] In 2010 Darryl Martin published a detailed article examining the construction and O'Brien's methodology, concluding that a Florentine origin was more probable.[4]

What would help us make further progress in understanding these issues is

1 John Barnes wrote a long report which is kept in the files of the Russell Collection, but a shorter summary of his findings was published in: *The specious uniformity of Italian harpsichords*, in: Keyboard Instruments: studies in keyboard organology 1500–1800, ed. by E. M. Ripin, Edinburgh 1971, pp. 1–10, see pp. 2–3.

2 Denzil Wraight, *The stringing of Italian keyboard instruments c. 1500–c. 1650*, Ph. D. dissertation, Queen's University of Belfast, 1997 (UMI order no. 9735109), Part 2, p. 327.

3 Grant O'Brien, Russell Collection website: http://www.music.ed.ac.uk/russell/instruments/hs1a16202/datasheet.html, accessed 19.07.2003, but still available 20.02.2011. Further details were published at O'Brien's website http://www.claviantica.com as *The determination of the location of the centre of construction of the anonymous Italian harpsichord, c. 1620, Russell Collection of Early Keyboard Instruments, Edinburgh, Cat. No. HS1-A1620.2* (accessed 20.02.2011). Since the website uses a frame-based system a URL for this file cannot be given.

4 Darryl Martin, *EUCHMI (4302): A case study of harpsichord identity*, in: Galpin Society Journal 63 (2010), pp. 17–47.

knowing in more detail how old makers worked, and this is where my contribution aimed.

One of the essential design procedures of harpschords involved the coordination of the string lengths with the keyboard. This means that the maker had to decide how wide his stringband and how wide the keyboard would be, in order to create the width of the instrument, or to fit them within a planned width.

Birkett and Jurgenson, suggested that, as a generalisation, the makers used one unit of their Werkzoll, that is one unit of their workshop measurement, for each keytail or space for the strings.[5] This Werkzoll, as they argued, need not even correspond to a local unit of measurement. O'Brien had previously published some analyses of instrument keyboards and jackslides which found that some such spacings could be expressed in half inches of local units of measurement.[6] Thus, his evidence supported the interpretation that makers worked with their own local inches when laying out a keyboard and string band, rather than using some measurement specific to their workshop.

In a paper I gave in Edinburgh in 2008 I briefly mentioned the unsigned Italian harpsichord which was originally made with a compass of C/E–f^3 with seven split sharps, that is, the compass had 57 notes in all.[7] Now 57 half inches is $28^1/_2$ inches in total. I noted that the width of the keyboard was close to $28^1/_2$ Roman inches and posed the rhetorical question whether this might reveal something about the maker's intentions. In other words, could we infer a Roman origin for the harpsichord based on this unit of measurement?

The time has come to examine this keyboard issue in more detail. What Birkett and Jurgenson, and O'Brien have given us, is a clear working hypothesis which can be examined empirically. I can reduce it initially to one question: Did the old makers invariably work with half an inch of their local measurement in order to lay out the string band and the keyboard?

What is implied by Birkett and Jurgenson's examination of this subject is that the half inch was the basic unit, from which as many keys could be assembled as were required. They gave a list of instruments where there was a clear relationship between the overall keyboard width expressed in units of local measurement and the number of notes required by the keyboard. However, there were only three Italian instruments on this list, all by Cristofori, who worked in Florence.

5 Stephen Birkett and William Jurgenson, *Why Didn't Historical Makers Need Drawings? Part II – Modular Dimensions and the Builder's* Werkzoll, in: Galpin Society Journal 55 (2002), pp. 183–239.

6 Grant O'Brien, *The use of simple geometry and the local unit of measurement in the design of Italian stringed keyboard instruments: an aid to attribution and to organological analysis*, in: Galpin Society Journal 52 (1999), pp. 108–171.

7 *A construction principle in Venetian harpsichords*, available at my website: http://www.denzilwraight.com/CPinVH002.pdf.

The method by which I have proceeded has been to collect data on as many instruments as possible from the same workshop. In this way the quantity of data should give a clearer view of what a maker did, than would simply selecting a few instruments at random. However, since the aim of examining this data is to arrive at the guiding ideas, I present them as an appendix, to which the reader may refer as required, rather than burdening the text with too many figures.

So what data do we need to examine? For the purposes of dealing with Italian harpsichords and virginals, it is sufficient to start with the C/E–c^3 compass, since this shows a situation we find in most Italian compasses, namely, that the top and bottom keylevers do not have an adjacent sharp. This means that the end keylevers could be as wide at the keytails as at the keyfronts. So how did the Italian makers deal with this situation? It is helpful to consider Fig. 1. This shows a simplified view of a keyboard with the keyfronts and keytails. We can see that there are essentially two solutions adopted by the old makers. One could say, two solutions and one or two variations.

Example 1. The maker divided the entire width of the keyboard by the number of keytails required, that is width/45 (hereinafter W/45). This is the solution most often found in virginals, but also used in harpsichords, especially if the keyboard has extra notes through the use of split sharps.

Example 2: He divided the keyboard width into 47 units, or perhaps 46. That is, there are two or one extra spaces respectively. In the version with 46 spaces, we have keylevers which are nearly straight, and this has the practical advantage of reducing rattling noise at the balance guide and the rack. The variation on this, which I call 2A, uses 47 spaces but the end keylevers are as wide at the keytails as at the keyheads, that is, the keytails for C and c^3 occupy two keytail widths. One finds this occasionally in harpsichords. Birkett and Jurgenson were aware of these various arrangements and therefore suggested that the width of a keyboard was composed of a number of units, plus an additional constant.[8] In this sense the »additional constant« they described is the extra one or two spaces I have mentioned.

This means that when we collect data on a keyboard it is not sufficient to know the width at the keyfronts. We need at least to know the width across the keytails, but ideally we should be able to see the keytails in order to understand how the maker designed the layout.

Such data is not readily available in catalogues and it has not always been possible for me to remove the keyboard in an instrument I have examined. However, it transpires from the data I have been able to collect that useful conclusions can be drawn.

My list of Francesco Poggi's instruments, made in Florence, comprises 15 ex-

8 S. Birkett, W. Jurgenson, *Why Didn't Historical Makers Need Drawings?*, p. 204.

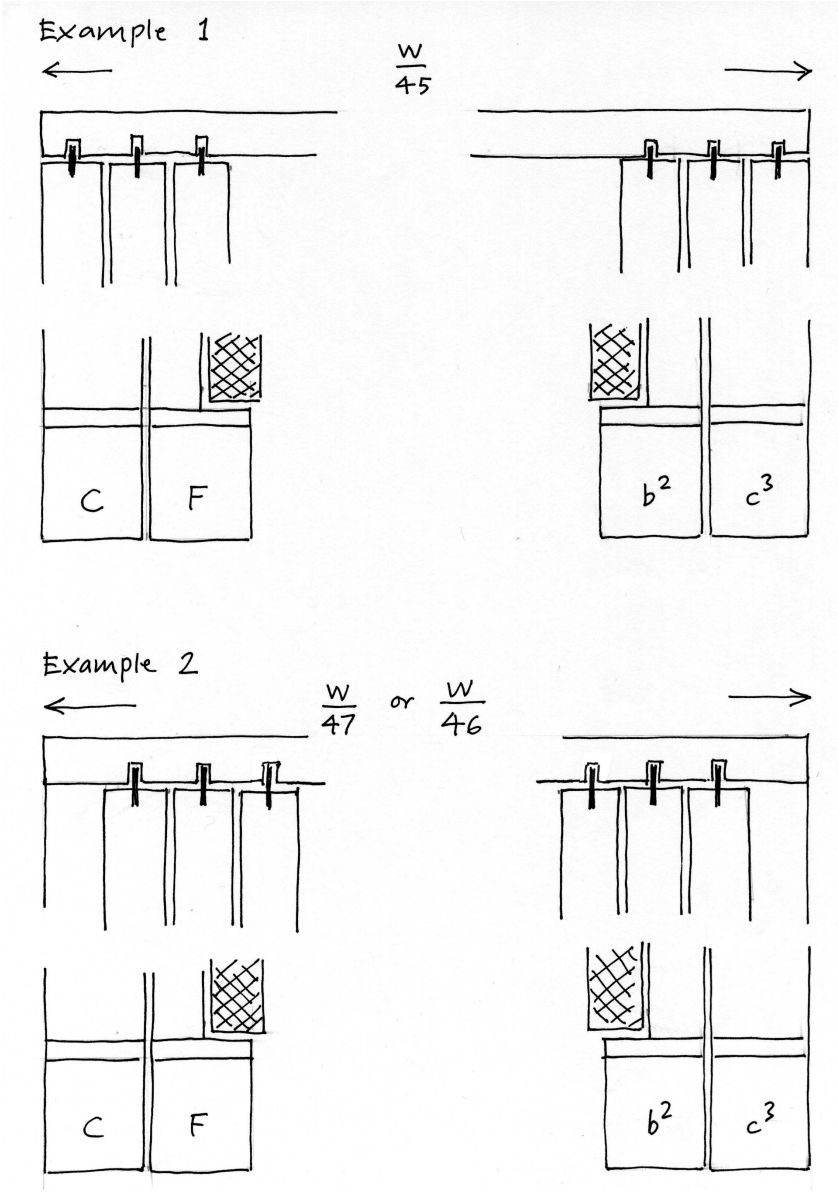

Fig. 1: Simplified view of a keyboard with the keyfronts and keytails

amples, although only one of these is a harpsichord. There are also lists of seven instruments by Bolcioni and five each by Querci and Migliai, all of whom also worked in Florence, thus the activity in this city is well documented. The instruments made by Cristofori and Ferrini provide an important source of evidence, but time did not permit their consideration here.

The most useful set of data comes from the instruments made by Dominicus Pisaurensis, or Domenico da Pesaro, to give him his name in the vernacular, who worked in Venice in the 16th century. This list includes seven harpsichords, seven virginals, and a clavichord.

When we begin to examine the data it transpires that the question I set out above, breaks down into two: Which width did the maker choose for the keyfronts? Which width did he choose for the keytails?

It should now be clear that when we start looking for the width of the keyfronts or keytails, we will check whether the C/E–c^3 compass, which has 45 notes, was created with a width of 45 half inches, that is $22^1/_2$ inches for example 1. If the keyboard is made according to example 2 or 2A, then we would expect that 47 half inches were involved, or $23^1/_2$ inches. Similarly for a 50-note compass we might find a width of 25 inches, or 26 inches if the construction of example 2 or 2A is used. In practice, we also find that one additional space was used in the keytail division, and that this was spread between the bass and treble end, for example 50 levers, but 51 spaces. This arrangement results is the best straightness of the keylevers.

Of course, of particular interest regarding the Edinburgh unsigned harpsichord is what happens when more than 50 notes were required for a C/E–f^3 compass, that is, when split sharps were involved. Nevertheless, what we need to do first is to understand what happens in normal practice, before we proceed to exotic instruments with extra, split sharps.

We find two harpsichords made by Migliai with a C/E–c^3 compass where the width is $23^1/_2$ Florentine inches at the keyfronts and the keyboard has been divided into 47 parts at the keytails, using the method of example 2. However we also find instruments where $25^1/_2$ Florentine inches have been used for a 50-note compass, with the layout method of example 1. These clearly do not use half an inch for each note.

What do we find in Venice? Let us now consider the list of Domenico's instruments in the appendix. The list is fairly self-explanatory with the smallest and narrowest compasses at the top. In the fifth column I have entered the width of the keyfronts to the nearest Venetian half inch. In order that we see how close the actual keyboard is to the theoretical size in Venetian inches, I have placed the theoretical length of the Venetian inches expressed in mm in square brackets underneath. In the last column I have entered the type of keytail division method used, as far as I have been able to establish it.

When we compare the keyboard widths in mm and their Venetian inch equivalents, we find a close correspondence. Some keyboards are a few mm narrower, others a few mm wider. In no case is the error more than 7 mm, and the average error is slightly less than 3 mm. Given that the errors are almost equally divided

between being too large and too small, it is clear that Domenico was working with essentially the Venetian inch measure as we understand it from documentary sources, which is taken here to be 347.7 mm for the foot, comprising 12 inches.[9] This inference has indeed already been drawn by O'Brien when he noted that 25 and 24 1/2 inch keyboard widths were used in Venice,[10] but the wider empirical base is of value here, since we are considering objections to his findings, which were published later by Birkett and Jurgenson. I have given further lists of Venetian keyboard width in the appendix, which show how Celestini and Baffo used the Venetian measurement.

When we examine the data of Domenico's instruments we see that there are three examples of 22 1/2 inches used for the 45-note compass, i.e. half an inch per note, as measured at the keyfronts. However, of the seven examples of the 50-note compass, only four of these use the 25 Venetian inch size, which corresponds to half an inch per note. Although Domenico has left us no known example with a 24 1/2 inch wide keyboard, Celestini used this width in seven instruments which have a 50-note compass. Domenico used either a 24 or 25 inch size for the 50 note compass, but no fewer than three different sizes for the 45 note compass: 21, 21 1/2, and 22 1/2 inches. Thus, we may conclude that these Venetian makers were not using a half-inch-per-note rule in order to design the width of their keyboards, as measured at the keyfronts.

Thus, the question I set earlier, whether the maker invariably used half an inch in order to determine his keyboard width can be definitively answered: it was not an invariable rule, but it was sometimes applied. However, I have not attempted to determine in this article whether it was the keyframe width or the width of the keylevers which was measured.[11]

We will probably not discover why Domenico used such a large range of keyboard sizes, although it is likely that customer preferences were the motivating factor. Is it possible to infer a method in laying out the keyboard? On this issue we have a clear indication from the maker's layout practice of how he proceeded.

In several Venetian harpsichords there are lines drawn parallel to the spine on the baseboard which were used as part of the layout procedure for the case, but not necessarily for the jackslide or keyboard. These lines appear to represent the

9 A substantial contribution to the collection of foot sizes used was made by Herbert Heyde, *Musikinstrumentenbau*, Wiesbaden 1986, see pp. 70–78. A more complete compendium of sizes for Italy has been given by G. O'Brien, *The use of simple geometry and the local unit of measurement in the design of Italian stringed keyboard instruments*, Tables 11 and 12, pp. 164–171.

10 G. O'Brien, *The use of simple geometry and the local unit of measurement in the design of Italian stringed keyboard instruments*, p. 145.

11 See also note 19 below on this matter.

position of the f strings. I have found that it was common in 16th-century Italy to use the f notes for orientation in the layout of harpsichords and virginals. There is usually a line to indicate the position of the front edge of the wrestplank and often the nut positions are drawn. Only in two instruments has it been possibe to see the whole drawing on the baseboards since they had been removed from the instrument.[12] These indicate that a case outline was derived from the string and bridge positions. In instruments where no string lines can be found on the baseboard the maker must have worked in some other way to derive his case shape. This may have been from existing patterns, but the bridge position and case design could have been developed directly on the soundboard and then transferred to the baseboard. I have no direct evidence for this hypothesis, but it could explain why we often find no baseboard markings.

This case layout may not have been the first step. There is a harpsichord made by Baffo in which jack-shaped indentations are visible on the baseboard beside the string lines scribed on the baseboard.[13] It seems that the jackslide was laid on the baseboard and the f-string positions marked by hammering a jack-shaped piece of wood through the slide onto the baseboard.

It appears that the manufacture of the keyboard may also have preceded the marking of the baseboard. The 1570 Domenico da Pesaro harpsichord (listed in the appendix) has a keyboard which is 4 mm wider than the nominal 24 inches, and significantly, this extra width is reflected in the spacing of the string lines on the baseboard. However, the inside case width is exactly 26 inches, indicating that the oversize keyboard did not lead to the design-value case width being expanded. Thus, we may infer that both the jackslide and keyboard could have preceded the case layout in the order of manufacture and in some instances probably did precede the case layout.[14]

In five of Domenico's harpsichords we find such string and other construction lines; the instruments are indicated with an asterisk in the 3rd column. This is a fortunate circumstance for us since we can compare his procedure in building instruments of different sizes rather than being left to interpret only one drawing. There are scarcely two Domenico instruments which share the same case dimensions, so to find a consistent method at the basis of the design indicates we have found a foundation of his design procedure. Fig. 2 shows one such baseboard drawing.

12 The 1538 Alexander Trasontini harpsichord in the Musical Instrument Museum, Brussels, and an unsigned harpsichord in the Kunstgewerbe Museum, Schloß Köpenick, Berlin. This is W366 in my catalogue, see *The stringing of Italian keyboard instruments*, Part 2, p. 344–345.

13 1579 Baffo, Musée de la Musique, Paris, E.951 C.324.

14 G. O'Brien, *The determination of the location of the centre of construction of the anonymous Italian harpsichord* argues that the maker designed his instrument starting with the layout of the baseboard. In this respect my interpretation is significantly different from O'Brien.

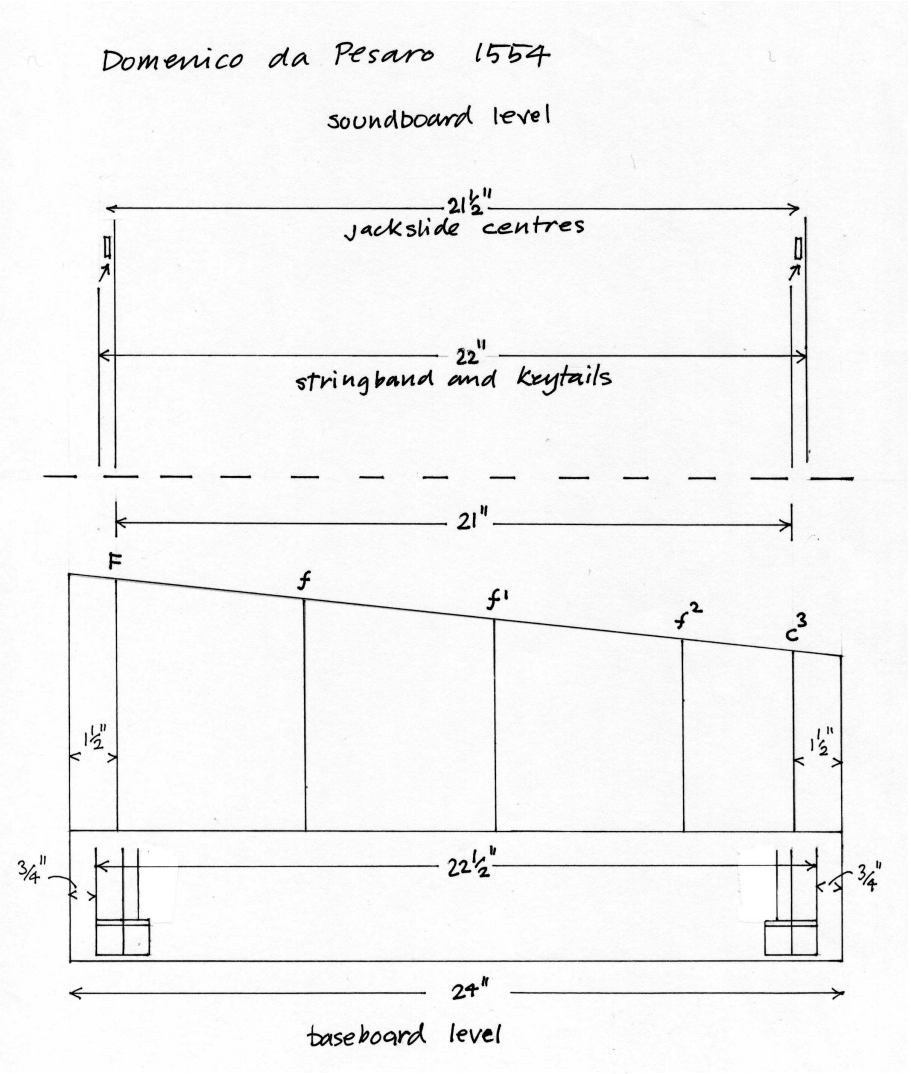

Fig. 2: Lines drawn on the baseboard under the area of the wrestplank of the harpsichord by Domenico da Pesaro 1554

What we see are the lines drawn on the baseboard under the area of the wrestplank of the 1554 Domenico harpsichord in Paris, which originally had a compass of C/E–c^3 with 8′ and 4′ registers.[15] The front edge of the wrestplank is marked with a line across the whole width of the instrument, which was common practice, even when other lines were not scribed. This line may have been seen as the beginning of the instrument, with the playable part of the keyboard thought of

15 Musée de la Musique, Paris, E. 2109.

as *outside* the instrument.[16] The lines running parallel to the spine are nominally the flines (F, f, f^1, f^2 etc.), starting with F and ending, in this case, on c^3. There were also lines drawn for the nuts, which I have omitted for clarity. The sloping line at the back is the visible edge of the bellyrail.

In the 1554 harpsichord the width of the keyboard is $22^1/_2$ inches, but the full width of the keyboard is not drawn on the baseboard. I have added a sketch of the top and bottom two notes to indicate their position. The blocks either side of the keyboard occupy $^3/_4$ inch, thus the total *inside* case width (between the case sides) is $^3/_4$ in + $^3/_4$ in + $22^1/_2$ in = 24 in. In some instruments Domenico used a keyboard block which is 1 inch wide.[17]

The apparent F string and c^3 string lines occupy a width of 21 inches and were each drawn $1^1/_2$ inches inside the case edge. Domenico used this procedure of having the keyboard $^3/_4$ inch wider than the string band on either side, in four of the instruments I have listed here, even though the keyboards have different sizes. It follows from this, that the alignment of the apparent string line with the keyboard varied slightly, although it was obviously sufficiently accurate for all practical purposes.

The apparent F line corresponds approximately to the left hand edge of the F keylever, and the apparent c^3 line to the left hand edge of the c^3 lever. At the level of the soundboard it would be necessary to add another string to the left of the F for the bottom note of C, and in the treble a string would be added to the right for a 4′ string (or for a second 8′). That which we call the stringband is the distance between the bottom and top strings. Once we have defined the width of the stringband we know the width of the keytails, or alternatively, the the width of the keytails defines the stringband.

My inference is that Domenico would simply have added $^1/_2$ inch to the left of the F line and $^1/_2$ inch to the right of the c^3 line, i. e. the stringband or keytail width would have been $^1/_2$ in + $^1/_2$ in + 21 in = 22 in. However for the length of the jackslide he need only add $^1/_2$ inch to the left of F, $^1/_2$ in + 21 in = $21^1/_2$ in and he has found the distance for the centre to centre measurement of the C to c^3 jackslots.

This would have given him workable approximations for making the jackslide and keyboard, but the interesting thing about this procedure is that although we have a $22^1/_2$ inch wide keyboard at the keyfronts, which implies half an inch for each note of a 45-note compass, Domenico has not taken advantage of this at all

16 There is a possible indication of this way of thinking when Vicentino describes various dimensions of parts of the keyboard as being »fuore del strumento« i. e. »outside the instrument«: *L'Antica Musica Ridotta Alla Moderna Prattica*, Rome 1555; Reprint ed. by E. E. Lowinsky, (=Documenta Musicologica 1st series, 17), Kassel 1959, fol. 100 v.

17 The 1570 harpsichord and the 1533 harpsichord in the University of Leipzig collection.

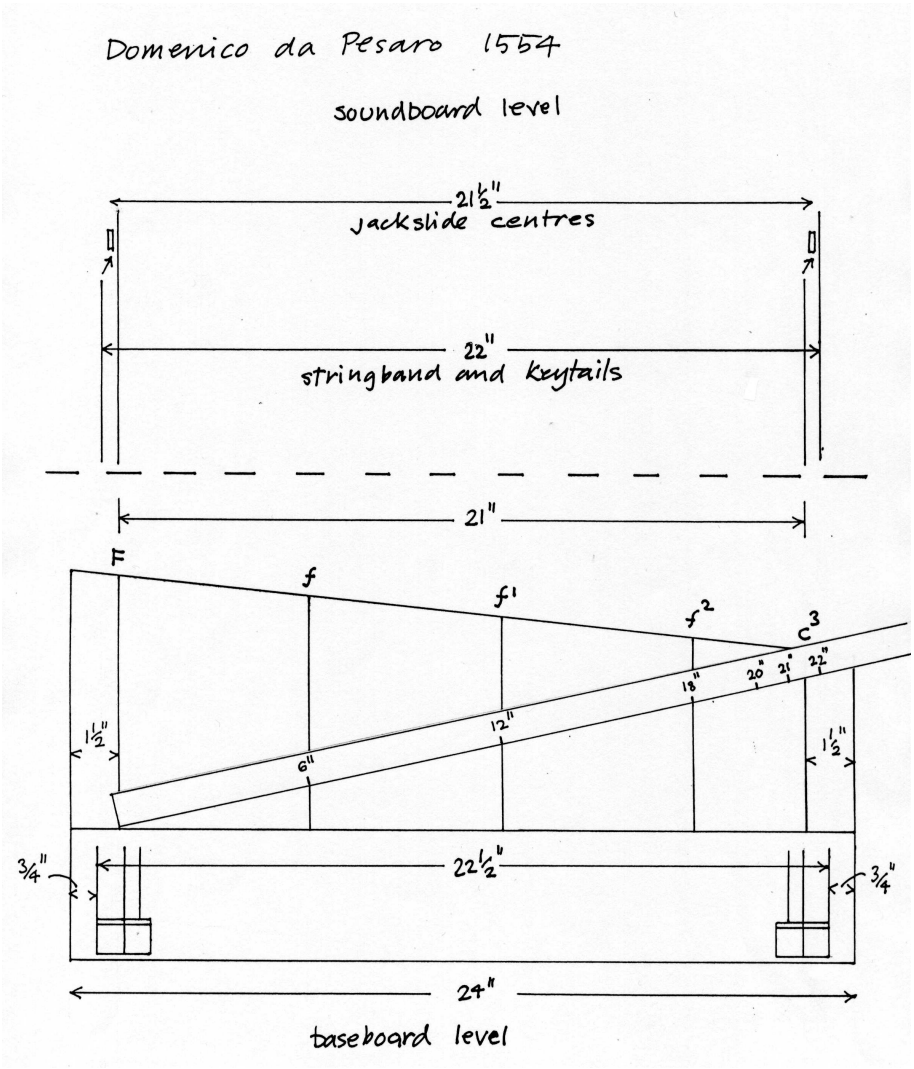

Fig. 3: Exact division of the harpsichord by Domenico da Pesaro, 1554

in laying out the keytails. How then did the maker work in order to produce a division?

Although one can divide up the whole length of 21 1/2 inches for the jackslide with a pair of dividers, it is tedious and time consuming to set the two legs so that the basic unit yields exactly the right length after 44 steps with the dividers, in order to derive the needed 45 points.

If we return to the baseboard drawing (Fig. 2) we see that an interesting division has already been performed. The F and c^3 lines are 21 inches apart, but how do you divide the distance into three octave spaces and a space for f^2 to c^3? f^2 appears

to be 17 1/2 inches from F and dividing this into 3 yields approximately 5 7/8 inches. In fact 17 1/2 inches is only an approximation, the correct value is 17 25/43 inches, which is such a difficult fraction that direct measurement will not yield a correct solution, although it might be used for an approximation. I will now show how an exact division can be made with simple means (cf. Fig. 3).

Domenico the instrument maker would have had in the forefront of his thinking that the lines F–f^2 encompassed 36 notes, and f^2 to c^3 only 7 notes, that is 43 in all. Thus, he only needed to lay his Venetian ruler with the start at the wrestplank-to-F intersection and rotate it until the mark for 21 1/2 inches intersected the c^3 line. Then he could have read off the intermediate f lines at 6, 12, and 18 inches.[18] The baseboard drawing shows that the division is exactly correct with only a 1 mm error at f^1. The accuracy of the overall spacing these lines, and others he drew, suggests to me that he worked from the total width required, not building up in octaves or part octaves. This is a significant interpretation which deserves further consideration since the general perception of this subject is still influenced by measurements of three octaves (the Stichmaß measurement) or octave widths.[19]

Now we can easily imagine how the maker divides his 21 1/2 inches into 44 parts for his jackslide. Of course this method of working is well known, using one division on the hypotenuse of a triangle to derive another division across a smaller length on the adjacent of a right-angled triangle.

I suspect that in practice, the Venetian harpsichord maker produced his jackslide and then divided the keytails from the jackslide.[20] In this way, any slight accumulated error in making the jackslide would be compensated and great accu-

18 John Koster asked during the discussion whether any marks were visible on the baseboard which could be interpreted as the division by means of such a ruler. I have examined the photographs of the baseboard which I took but cannot find evidence of marks at every line, although there are some unexplained point marks. It appears that the division was not accomplished directly on the baseboard.

19 See for example Grant O'Brien's analysis of the 1690 oval spinet made by Cristofori, *The Development Of An Idea: From The Design To The Instrument*, pp. 63–79 in Gabriele Rossi-Rognoni, *Bartolomeo Cristofori. La spinetta ovale del 1690* (Sillabe, Livorno 2002), in which the three-octave width of the keyboard was considered and found to be close to 18 inches. Then by inference, the octave width is assumed as the design size. The inferred 6 inch octave width leads to a keyboard width of theoretically 23.14 inches. Interestingly, the overall width of the keyboard is not even given in this publication, it having assumed a subordinate position in the interpretation. However, the design may have been based on a 23 1/2 inch width for the keyframe, the actual keylever width being then a little less. This type of measurement procedure was suggested by S. Birkett, W. Jurgenson, *Why Didn't Historical Makers Need Drawings?*, pp. 203–204.

20 The slides were made by gluing small blocks of endgrain wood between strips in order to create slots for the jacks, a procedure which can easily lead to error, compared with the theoretical length the slide should have.

racy is not necessary. This is what my available data on the Domenico instruments seems to confirm.

We can also infer from my hypothesis about the division procedure that a foot ruler with an inch size slightly larger than the actual units required would work well for the maker, although he could have used any calibration which served this purpose. A Neapolitan foot size with its smaller inch would have been unsatisfactory for the division, although the overall keyboard width might have been defined with its assistance.[21]

What can this now tell us about our approach to understanding how the old maker worked, and how we should proceed in order to follow the path back towards his intention? O'Brien has noted that one jackslide he examined had 50 slots in 25 Florentine inches, thus indicating a spacing of half a Florentine inch.[22] Birkett and Jurgenson imagined a method of construction which built up the overall width of the jackslide or keyboard from multiples of a basic unit. Before I undertook this examination of my data, I had the impression that the half inch was much more prevalent as a unit of keyboard division than I have since discovered. This has been one of the most revealing findings.

The data adds confirmation to the interpretation that keyboards, as measured at their keyfronts, were designed using local units of measurement, as O'Brien has argued. From my first sight of this Italian data, I cannot find any substantiation for Birkett and Jurgenson's idea that the unit for constructing the string band might have been a single workshop-specific measurement, or Werkzoll. It seems that the reverse order is the case: that an overall width was decided upon, or constructed as in Domenico's practice, and then divided as required. Thus, in two Domenico harpsichords, the 1554 and W112, the calculated unit size is 13.62 mm and 14.17 mm respectively.

Neither, it transpires, need the unit for the string band correspond to half an inch of local measure, although it sometimes does. To take an example from Florence, the overall stringband width could, for example, be an identifiable 25$^1/_2$ Florentine inches, but the division might be into 50 parts, rather than the more convenient 51 units. In cities with smaller foot sizes, the inch tends to be a little too small for the size of keyboards used, thus, half an inch per note is not practicable.

Coming back to the example of the Edinburgh harpsichord with 57 notes, we find by way of comparison that there are two harpsichords by Boni, both dated 1619, and made in Rome, which have 26 inch wide keyboards for 52-note

21 The inch size G. O'Brien, *The determination of the location of the centre of construction of the anonymous Italian harpsichord* gives for Naples is 21.834 mm.

22 G. O'Brien, *The use of simple geometry and the local unit of measurement in the design of Italian stringed keyboard instruments*, pp. 146–148.

compasses.[23] These use the method of example 1 for the keytail division, so the keytails are divided into 52 parts: half an inch per keytail. However, comparison with other Boni instruments shows that this was not his standard procedure.

The original keyboard of the Edinburgh harpsichord, at about 697 mm, would have been within an acceptable tolerance for 28 1/2 Roman inches (= 705 mm) and could have been designed on the principle of half an inch per note for the 57 notes. However, given the results of my survey of Italian keyboards, one cannot reliably infer the compass from the width.

We might consider whether the absolute width of the keyfronts could lead us in any reliable way to an identification of the origin. The data shows that the absolute sizes used by makers in different cities for their keyboard widths were similar, although of course they would have been expressed in different units. 24 Venetian inches (= 695 mm) is remarkably close to 25 1/2 Florentine inches (= 697 mm). Stylistic considerations would lead us to exclude the Edinburgh harpsichord as a Venetian instrument, but the Roman 28 1/2 inches (= 705 mm) come close enough to the Florentine 25 1/2 inches (= 697 mm) that it is not easy to separate the two. If the keyboard was made accurately, then its size appears to indicate Florence as the city of its manufacture. However, the Roman origin is not excluded, nor is it proven. Thus, the issue of the Edinburgh harpsichord is not decided by these details, although they may help to clarify other issues about construction.

There is another instrument on which my findings do shed new light, or rather permit a slight adjustment in our thinking and enable us to re-interpret existing data. The 1627 Bolcioni harpsichord originally had 53 notes, but has long since lost its original keyboard.[24] Until Grant O'Brien found the marks on the jack-slides it was not possible to confirm the hypothesis that it was made with split sharps.[25] O'Brien used regression analysis to determine the spacing between the jackslots, from which he noted that 50 slots occupied a space of 24.1 Florentine inches. He therefore inferred that Bolcioni might have designed the slide with the aim that 50 slots should occupy 24 inches, the calculated inch having a size of 27.46 mm. The thinking behind this hypothesis is probably that the maker would

23 The inch of 24.75 mm is based on a 297 mm foot of 12 inches. In the discussion, Grant O'Brien said that he had found the use of a different inch size for Roman instruments. The two other foot measures he gives in *The use of simple geometry and the local unit of measurement in the design of Italian stringed keyboard instruments* of 233.42 mm and 248.99 mm would give a marginally worse fit for the Boni keyboards I have listed in the appendix, but the difference is not large.

24 Russell Collection, Edinburgh.

25 See J. Barnes, *The specious uniformity of Italian harpsichords*, pp. 1–2 and G. O'Brien, *Towards establishing the original state of the three-manual harpsichord by Stefano Bolcioni, Florence, 1627, in the Russell Collection of Early Keyboard Instruments, Edinburgh*, in: Galpin Society Journal 53 (2000), pp. 168–200.

be working from some previously-used standard (50 notes in 24 inches), possibly a dedicated strip of wood, which he then modified for this instrument.

If we now draw on the manner of thinking which I have outlined, then we should be looking for a total stringband width as the design objective, not part of a jackslide which was then extended. Adding an extra space (nominally 13 mm) to the existing jackslide width gives us a stringband of 683 + 13 = 696 mm, which is 25 1/2 inches, closely matching the 27.345 mm Florentine inch, which O'Brien derived from the case dimensions.[26] This re-interpretation removes the slight inconsistency in the sizes of the inch in the case and jackslide in O'Brien's interpretation.

The result of this stringband width is that a keytail width of 25 1/2 inches is implied. If the keyboard was made with the layout of example 1, then the keyfronts would also have been 25 1/2 inches wide, a size which was often used in virginals by Poggi, who also worked in Florence. Furthermore, the keyfronts would then not be narrower than the keytails, which followed from the 25 inches that O'Brien suggested.[27] The size of the keys then would fall within the normal range used by both Bolcioni and others in Florence.

I would summarise my findings as follows:

1. This survey increases the empirical evidence for the interpretation that keyboard widths, as measured at the keyfronts, were based on local units of measure. It remains to be clarified whether the keyframe or width of the keylevers was the initial measurement.

2. Sometimes makers arranged their stringband and keytail spaces in a way that they correspond to a half inch of their local measure, although the method may not have involved building the width from half inch units.

3. The keyboard and stringband design was, according to my interpretation of the evidence, accomplished by distributing the required number of units in the total width. In practice, the resulting unit size can have varied from instrument to instrument and need to have been used as a unit of measurement (Werkzoll) in the rest of the instrument.

4. The operation of division presented no particular problem for them since the makers could use any pre-divided scale to accomplish their results.

5. Although the local foot measure would often be a convenient tool for the procedure of dividing the stringband or keylevers, in towns where the inch size was smaller that the units to be derived, it would not have been suitable.

6. Although the number of notes in a keyboard sometimes equalled the num-

26 In fact 25 1/2 in × 27.345 mm = 697.3 mm, but a jackslide which comes this close to the theoretical value shows a creditable level of accuracy on the part of the maker.

27 G. O'Brien, *Towards establishing the original state of the three-manual harpsichord by Stefano Bolcioni*, pp. 183–184 and Fig. 4 which shows the keyboard layout.

ber of half inches of keyboard width, there were other sizes used that it is not possible to infer the compass of an instrument from the width of the keyboard. The practice may show regional variation.

7. The layout of the case of an instrument was not necessarily the first step in realising the design since the jackslide and keyboard may already have been made.

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APPENDIX

Explanation of the columns in the tables below:

Instrument: The instrument is described by its usual designation of date and maker. When this is not known then catalogue numbers are used. It is expected that the reader will consult my catalogue of Italian keyboard instruments for further details of the location or of the instrument.[28]

Original compass: Only the original compass is given. In some instances the original compass is no longer complete or has been altered, but these details have not been documented here.

Number of notes: The number of original notes provided in the instrument.

Keylever width at naturals' front: The width of the keylevers measured at the natural covers near the player's end.

Nearest inch: nearest »***« inch. This indicates the nearest half inch of the local foot measure considered. The inch size given for Florence, 27.34 mm, derives from Grant O'Brien's findings based on the analyses of instruments by Bolcioni.[29] This measurement is intended as an illustration of the fit to local foot

28 Denzil Wraight, *The stringing of Italian keyboard instruments c. 1500–c. 1650*, Part 2.

29 See G. O'Brien, *The use of simple geometry and the local unit of measurement in the design of Italian stringed keyboard instruments*, p. 135.

measure and not as an argument for it or proof of it. The possibility must also be considered that a size of 27.56 mm was used in Florence, perhaps as applied to the keyframe width. – The Roman inch is given as 24.75 mm, the Venetian at 28.98 mm.

Stichmaß: The three-octave measurement has been calculated from the actual width, with decimal values rounded up. This provides an easy means of reference for keyboards from different cities, with which the reader will be familiar, although it is not implied that the makers used this modern convention.

Type/Division: This refers to the manner of arranging the jack ends of the keylevers, as indicated in Fig. 1 in the article. The number of keytail divisions across the width of the keylevers is given, where known.

Abbreviations used

H	harpsichord
H & P	harpsichord and pianoforte (combination instrument)
PV	polygonal virginal
RV	rectangular virginal
TV	Trapezoidal virginal
S	bentside spinet
CD	clavichord
[A]	attributed to this maker in my catalogue of instruments.
[A?]	possibly by this maker

Stefanus Bolcioni – Florence

Instr.	**Comp.**	**Notes**	**Width**	**Nearest Inch** (Florentine)	**Stichmaß**	**Type**
W506[A] RV	C/E–c^3 + F♯, G♯	47	670	24 1/2 [=670]	521	
1631 Bolcionius W45 H	C/E–f^3	50	688	25 [=683.5]	482	Ex. 2?
Leipzig Nr. 62 W319[A] RV	C/E–f^3[30]	50	709	26 [=711]	496	probably Ex. 1
1641 Bolcionius W46 RV	C/E–f^3 + F♯, G♯ + 2 split sharps	54	711[31]	26 [=711]	498	
1629 Bolcionius W77 RV	C/E–f^3 + F♯, G♯ + 4 split sharps	56	731	26 1/2 [=724.5] or 27 [=738]	512	
W271[A] RV	C/E–f^3 + F♯, G♯ + 5 split sharps	57	725	26 1/2 [=724.5]	507	Ex. 1
W50[A] RV Smithsonian 60.1392	C/E–f^3 + F♯, G♯ + 4 split sharps	56	740	27 [=738]	518	

W319. The 52 divisions implied by the 26 inch keyboard width could suggest that the end keys are double width or that there is a space. However, as judged from a photograph of the jacks' slot positions in Henkel's catalogue, it would appear that the outside keys are parallel with the keyframe.[32] If this were the case then a 50 note division has been spread over 26 inches.

1631 Bolcionius. My data for this instrument only suffices to indicate that the C key originally was slanted in. It is probable that the same procedure was used for f^3, but I have no notes or photo to document this. As a result we can infer that there were at least 51 divisions of the keytails, but probably 52. It is likely that a space was used either side of the outside keys. Thus the probable 52-keytail division is not explained by the half inch rule.

W271. Since the outside keys C and f^3 are approximately double the normal spacing at the keytails, there are effectively 59 divisions of the keytails, with 2 divisions each for C and f^3. The keyboard width is 26 1/2 inches or 53 half inches, so the division is not explained by the 1/2 inch = keytail rule.

Although data is not available for the keylevers of the last four listed instruments with split sharps, it is apparent from the number of notes and the nominal keyboard widths expressed in Florentine inch that we cannot explain the keytail division through the use of one 1/2 inch = one note + a space of 1/2 inch at either end. It is possible that W506 and W319 follow this rule, but it has not yet been established. However, the fact that the 1631 harpsichord has the same original

30 Hubert Henkel, *Musikinstrumenten-Museum der Karl Marx Universität Leipzig, Katalog*, Bd. 2, *Kielinstrumente*, Leipzig 1979, p. 50.

31 Ibid., p. 112.

32 Ibid., Tafel 19.

compass as W319 but is 1 inch narrower shows that this was not an invariable rule, even for »normal« instruments without split sharps.

The 1629 Bolcionius keyboard width falls between 26 1/2 and 27 Florentine inches which is an unusual inaccuracy considering the other instruments. The fact that W271's 57-note original compass has a 26 inch keyboard width, yet the W50 with 56 notes has a 27 inch keyboard width shows us that we cannot reliably predict the original compass from Bolcioni's keyboard width.

Francesco Poggi – Florence

Instr.	**Comp.**	**Notes**	**Width**	**Nearest Inch** (Florentine)	**Stichmaß**	**Type**
1603 W537 PV	C/E–c^3	45	635[33]	23 [=629]	494	
1586 Stuttgart PV W202	C/E–c^3	45	650	23 1/2 [=642] 24 [=656]	506	
W354 PV Nuremberg	C/E–f^3	50	692	25 1/2 [=697]	484	
W190 RV Horniman	C/E–f^3	50	695	25 1/2 [=697]	486	Ex. 1
W548 PV priv. Germany	C/E–f^3	50	695	25 1/2 [=697]	486	
W759 PV Metz	C/E–f^3	50	700.5[34]	25 1/2 [=697]	490	Ex. 1
W559 H Leipzig Nr. 87	C/E–f^3	50	701[35]	25 1/2 [=697]	491	
1588 Tagliavini W489 PV	C/E–f^3	50	705[36]	26 [=711]	494	
W301 PV Smithsonian	C/E–f^3	50	707	26 [=711]	495	
W114 RV Boston	C/E–f^3	50	712	26 [=711]	498	
W203 RV Yale	C/E–f^3	50	714	26 [=711]	500	
W327 RV Russell Coll.	C/E–f^3 + $F\sharp$, $G\sharp$ + 5 split sharps	57	723[37]	26 1/2 [=724.5]	506	
W440 RV Stockholm	C/E–f^3 + $F\sharp$, $G\sharp$ + 4 split sharps	56	727[38]	26 1/2 [=724.5]	509	

33 Personal communication from John Koster, 1989.

34 Information kindly supplied by Charles Metz.

35 H. Henkel, *Katalog Leipzig*, p. 94.

36 Luigi Ferdinando Tagliavini and John Henry van der Meer, *Collezione Tagliavini. Catalogo Degli Strumenti Musicali*, Bologna 2008, vol. 1, pp. 311–312. They give the keyframe width as 700 mm, i. e. 5 mm narrower. Normally the keyframe is slightly wider than the keys in order to prevent the keys rubbing on the case, thus, there may have been a transposition of data.

37 The measurement is taken from the collection data sheet, based on the replacement keylevers which were made for the original keyframe. Darryl Martin and Malcolm Rose kindly provided information and clarification on this instrument.

38 Dan Johansson, personal communication 3.10.2010.

W374 RV Berlin Nr. 329	C/E–f^3 + F♯, G♯	52	738[39]	27 [=738]	517	Ex. 1[40]
W21 RV Liverpool	C/E–f^3 + F♯, G♯ + 4 split sharps	56	uncertain keywell 754		[528?]	
W451 RV Brussels	C/E–f^3 + F♯, G♯ + 4 split sharps	56	unknown + keyblocks			
Poggi[A?] W171 RV Smithsonian	C/E–f^3	50	722	26 1/2 [=724.5]	505	

It is clear from the keyboard widths used for 45-note and 50-note virginals that there was not a single principle used for the keyboard dimensions.

W190 and W759 show that the width was not chosen as 25 1/2 inches in order that one could make 51 keytail divisions using 1/2 inch: there are 50 evenly-spaced keytail divisions.[41]

A comparison of W440 and W374 shows that a wider keyboard width was chosen for W374, even though fewer keys had to be accomodated. Thus, the keyboard width was clearly not dependent on the number of keys provided.

Poggi used at least three different sizes of keyboard for a 50-note original compass, 25 1/2, 26, and 26 1/2 inches so it is clear that his guiding principle could not have been the use of 1/2 inch per keytail.

Querci – Florence

Instr.	**Comp.**	**Notes**	**Width**	**Nearest Inch** (Florentine)	**Stichmaß**	**Type**
1625 Querci W209 TV	C/E–c^3, d^3	47	637	23 1/2 [=642]	478	
W290 H Leipzig Nr. 75	C/E–c^3 + F♯ + G♯ + 3 split sharps?	50	658	24 [=656]	512	
W242 PV Brussels	C/E–f^3	50	695	25 1/2 [=697]	487	
W619 PV Beurmann	C/E–f^3	50	696	25 1/2 [=697]	487	
W206 H Querci? Poggi? Smithsonian	C/E–f^3	50	715	26 [=711]	501	

39 D. Droysen-Reber, J. H. van der Meer, M. Elste, G. Wagner, H. Rase, *Kielklaviere*, ed. by D. Droysen-Reber, Berlin 1991, p. 222.

40 Abb. 145 in the catalogue (ibid.) shows that C would probably be the same width as the other keytails.

41 The confirmation is provided by my photo.

Antonio Migliai – Florence

Instr.	**Comp.**	**Notes**	**Width**	**Nearest Inch** (Florentine)	**Stichmaß**	**Type**
W370 [A] H	C/E–c^3	45	643	23 1/2 [=642]	500	Ex. 2 47[42]
MIR 1078 H W109 Nuremberg	C/E–c^3	45	645	23 1/2 [=642]	502	
1682 W183 H Hasselburg	C/E–f^3	50	718[43]	26 [=711]	503	
W478[A] H Halle	FF, GG–c^3[44]	55	739	27 [=738]	485	
1702 H W185 Leipzig Nr. 82	FF, GG, AA–c^3[45]	54	757	27 1/2 [=752]	497	

Boni – Rome

Instr.	**Comp.**	**Notes**	**Width**	**Nearest Inch** (Roman)	**Stichmaß**	**Type**
1619 Boni H W7 Vizcaya	C/E–c^3 + F♯, G♯ + 5 split sharps	52	647	26 [=643.5]	503	Ex. 1
1619 Boni H W51 Brussels	C/E–c^3 + F♯, G♯ + 5 split sharps	52	647	26 [=643.5]	503	Ex. 1
W355[A] H Fitzwilliam	C/E–c^3	45	627	25 [=619] 25 1/2 [=631]	488	Ex. 1
W500[A] H MacKenzie	uncertain bass –c^3 + F♯, G♯ + 5 split sharps	57	689	28 [=693]	499	Ex. 1
W359[A] H Dubuisson	C/E–f^3	50	703	28 [=693]	492	

1619 Boni, W7: A photo from Hubard's restoration report on the instrument (kindly communicated by Doris B. Littlefield), shows that the guided ends of the outside keys are approximately double the width of the other keytails, which implies a keytail division of 54 widths. This is striking considering the similarity of W51 below which has keytails of essentially consistent width. Malcolm Rose kindly supplied the measurement of the width of the keyboard.

1619 Boni, W51: The end notes are slightly wider at their guided ends than the other keytails, but not enough to qualify as a double width. Thus, the keytail division is 52 and each division is nominally 1/2 inch.

42 It is clear from the museum drawing that 47 divisions have been used at the keytails, but the drawing does not show whether the C and c^3 keys have a single or double width, i. e. whether this is example 2 or 2A.

43 Source: Andreas Beurmann, *Historische Tasteninstrumente*, München 2000, p. 189.

44 FF and GG are provided as split naturals.

45 Source: H. Henkel, *Katalog Leipzig*, p. 84. FF and GG are also provided as split naturals.

W355 Plate IV in Beckerleg, indicates that the keytails are evenly divided, although the end levers may have been a shade wider.[46]

W500. The width of the keyboard was kindly communicated by the owner, ACN MacKenzie. The top key has a double width at the tail, whereas the bass note only a single width, therefore the effective division of the keytails is 58. Since the keyboard is comprised of the width of 29 naturals, it could be seen as following the 1/2 inch per key rule. However, there are, unusually, two split natural keys in the bass, so that the 58 notes is obtained in a more compact way than would normally be possible.

Although the two 1619 instruments suggest that 26 inches was reserved for 52 notes, following the 1/2 inch rule, W355 with its 25 inches does not follow the same rule for a 45-note instrument. Thus, one cannot derive the number of notes from the width of the keylevers at the front for Boni's instruments.

In the W51 and W500 instruments with split sharps the keytail division is 1/2 inch per division. That this was not an invariable rule is clearly shown by W7's division of the keytails into 54 parts, with two parts allotted to each outside key. Furthermore, W500 with its split naturals' keys is an exotic example of keyboard construction. In the common original compasses (C/E–c^3 and C/E–f^3) it is clear that the 1/2 inch size yielded by the Roman inch is far too narrow for the keyboard size normally used. Thus, the 1/2 inch per keytail size is not a standard design feature of Boni's keyboards.

Albana – Rome

Instr.	**Comp.**	**Notes**	**Width**	**Nearest Inch** (Roman)	**Stichmaß**	**Type**
1628 H Bologna W5	C/E–f^3	50	705	28 1/2 [=705]	494	Ex. 2A
W6 HSmithsonian	C/E–c^3	45	651	26 [=643.5]	506–507[47]	
W383 RV Berlin no. 4649	C/E–c^3	45	589	23 1/2 [=582]	458	

1628 Albana: Since C and f^3 keytails have the full natural width, i. e. double the normal width, the keytail division is 52 parts for 50 keys. Clearly this instrument cannot meet the 1/2 inch per key rule.

46 Trevor Beckerleg, *The Fitzwilliam museum harpsichord, Italian music at the Fitzwilliam*, Cambridge 1976, pp. 23–28.

47 The information comes from a museum data sheet and William Dowd's measuring of the instrument in 1989. A full keyboard width was not given, only the Stichmaß measurement.

Domenico da Pesaro (Dominicus Pisaurensis) – Venice

Instr.	**Comp.**	**Notes**	**Width**	**Nearest Inch** (Venetian)	**Stichmaß**	**Type**
W437 H Stockholm	F,G,A–g^2, a^2	38 *	562	19 1/2 [=565]	492	Ex. 1 41 (42?[48])
1543 H W98 Paris	C/E–g^2, a^2	41 *	580	20 [=580]	487	Ex. 2A 44
1546 H W100 Vienna	C/E–g^2, a^2	41	580	20 [=580]	487	Ex. 2A[49] 44
1575 PV W108 The Hague	C/E–c^3	45	615	21 [=609]	478	
W111 PV Berlin	C/E–c^3	45	624	21 1/2 [=623]	485	
1548 PV Brussels	C/E–c^3	45	647	22 1/2 [=652]	503	
1554 H W103 Paris	C/E–c^3	45 *	650 (¯2)	22 1/2 [=652]	c. 505	Ex. 1 45
1543 CD W99 Leipzig	C/E–c^3	45	651	22 1/2 [=652]	506	n. a.
1570 H W339 France	C/E–f^3	50 *	699[50]	24 [=695]	489	
W387 PV Edinburgh	C/E–f^3	50	697[51]	24 [=695]	489	Ex. 2 51[52]
W112 H	C/E–f^3	50 *	699	24 [=695]	489	Ex. 2 c. 51[53]
W97 PV	C/E–f^3	50	717	25 [=724]	502	Ex. 1 50[54]
W461 PV	C/E–f^3	50	720	25 [=724]	504	
W463 PV	C/E–f^3	50	724	25 [=724]	507	
W96 H Leipzig Nr. 33	C/E–f^3	50	727	25 [=724]	509	

48 It is possible that space was allowed either side of the original outside levers, but certainly not more than one keytail width in total. Since the keyframe has been cut down it is difficult to be sure on this point.

49 The lowest key is two keytails wide, as is the top key, but this has been pulled to the left to fill the space of the missing $g♯^2$.

50 Only C/E–d^3 of the original original compass survives; the total width has been calculated.

51 The measurement has been taken from Grant O'Brien's drawing of the instrument, published by him.

52 The *actual* rack length has been divided into 51 parts, with the extra space divided, half being outside the C key and half outside the f^3 key. The keyframe narrows towards the key ends so that the rack should theoretically have been somewhat wider, which implies that the *theoretical* width of the back of the keyframe has been divided into 52 parts.

53 The keytails are 10 mm narrower than the keyfronts, which implies a 51-part division of the keytails.

54 My photos of the keyboard show that the outside keytails may be a few mm wider than the others, but probably not so wide as to imply the division of the total keytail width into 51 parts.

Baffo – Venice

Instr.	Comp.	Notes	Width	Nearest Inch (Venetian)	Stichmaß	Type
1574 H London	C/E–f^3	50	710[55]	24 1/2 [=710]	497	
1570 PV Ecouen	C/E–f^3	50	723	25 [=724]	506	
1579 H Paris	CC/EE-c^3	57	815–820[56]	28 1/2 [=826]	503–506	

Celestini – Venice

Instr.	Comp.	Notes	Width	Nearest 1/2 Inch (Venetian)	Stichmaß	Type
1589 RV W67 The Hague	C/E–f^3	50	703	24 1/2 [=710]	492	
W445[A] RV Copenhagen	C/E–f^3	50	705	24 1/2 [=710]	494	
1606 RV W73 Vienna	C/E–f^3	50	707	24 1/2 [=710]	495	
1610 RV W75 Brussels	C/E–f^3	50	707	24 1/2 [=710]	495	
1583 RV W68 London	C/E–f^3	50	710	24 1/2 [=710]	497	
W503[A] PV Toronto	C/E–f^3	50	710	24 1/2 [=710]	497	
1587 RV W66 Hasselburg	C/E–f^3	50	714	24 1/2 [=710]	500	
1594 PV W69 Hamburg	C/E–f^3	50	718	25 [=724]	503	
1608 H W74 Hamburg	C/E–f^3	50	720	25 [=724]	504	
W71 H Toronto	C/E–f^3	50	722	25 [=724]	505	

55 This is the width of the original keyframe. Although the original keycovers were retained when the present, GG/BB–c^3 compass was created, it is to be presumed that the keylevers would originally not have been wider than the keyframe, which is the usual practice.

56 The keyframe has been modified twice, with material removed in the bass and added in the treble. There is 828 mm between the wrestplank blocks, where the keyframe would be placed.