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A methodology for estimating the volume of Baltic timber to Spain using the Sound Toll Registers: 1670–1806

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Abstract

The Sound Toll Registers Online project has opened a trove of information for historians, but calculating the actual volume of the trade it represents remains a challenge. Attempts have been made for products that were measured in weight or volume, but timber products were usually recorded by the number of pieces in a ship's cargo. Different timber products varied greatly in size, so the amount of pieces is not useful for determining the volume of timber. Here I propose an approach for estimating the volume of Baltic timber trade using Spain as a case study. Such an estimate can be made by dividing distinct products and assigning them predictable dimensions. First, the process of converting the amount of timber pieces into volume is discussed. I then discuss the possibilities and problems with estimating tonnage. The article concludes with a discussion of the problems and limitations of this methodology.

Keywords

Baltic, methodology, Spain, timber, trade, volume

The Sound Toll Registers (STR) are an unusually complete record of Baltic trade through the Danish Sound. The registers record the products that came through the Danish Sound, their amounts and their port of origin. From 1669 onwards, they consistently include intended destinations for the products that were recorded and taxed. In 2009, the Sound Toll Registers Online (STRO) project began with the goal of digitizing all of the STR

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records into an online database.[1] At the time of writing, the project is expected to be complete in 2017, but currently all records have been digitized from 1634–1857. The data are freely available to anyone interested.

This has opened up remarkable possibilities for historians to analyse the trade data from the STR. However, because the STRO was transcribed directly from the source without changes to the original spelling, individual places and products in the database may have hundreds of different spellings. Furthermore, measurement systems varied from port to port during the time period covered in the STR. Therefore assessing the actual volume of Baltic trade remains a challenge. Werner Scheltjens has offered a convincing methodology for converting the products measured in volumes or weights to metric values, but timber products require a different methodological approach since they were most often recorded in the amount of pieces that were carried in a cargo.[2]

Given that different timber products varied greatly in size, the number of pieces is not useful for determining the volume of timber transported via the Danish Sound. Here I propose an approach for estimating the volume of the Baltic timber trade using Spain as a case study. At first glance, it seems like forming a convincing estimation of the volume of timber products through the Danish Sound would be an impossible task. However, I argue here that it is not only possible but can be done with a fair degree of confidence. First, I outline the process of identifying the relevant products. Next, the method for converting these from pieces to volume is outlined. I then discuss the possibilities and problems with estimating tonnage. The article concludes with the problems and limitations of the proposed methodology.

This methodology was developed in the course of researching timber imports to Spain for shipbuilding during the early modern era. Although the STRO covers a time period reaching back to the sixteenth century, the study begins in the 1670s, as this was the first complete decade with recorded destinations. It continues through to the first decade of the nineteenth century. This is a convenient cut-off point since Baltic imports to Spain ceased from 1807 to 1809, due to the Napoleonic Wars.

Shipbuilding was so essential to the security and maintenance of early modern Spain's world empire that legal efforts were taken to protect Spanish forest resources for shipbuilding as early as the 1540s.[3] We know that Spain utilized its own forests as much as possible and prioritized protecting their longevity, but also displaced a significant amount of shipbuilding to the Americas and began importing timber from northern Europe as early as the sixteenth century.

1. University of Groningen (RUG) and Tresoar, *Sound Toll Registers Online*, http://www.soundtoll.nl/ [accessed 8 February 2015]. For more information on the Sound Toll Registers Online project see Erik Gøbel, 'The Sound Toll Registers Online Project, 1497–1857', *International Journal of Maritime History*, 22 (2010), 305–324. All analysis of Sound Toll Registers data comes from Sound Toll Registers Online.
2. Werner Scheltjens, 'The Volume of Dutch Baltic Shipping at the End of the Eighteenth Century: A New Estimation Based on the Danish Sound Toll Registers', *Scripta Mercaturae*, 43, No. 1 (2009), 83.
3. John T. Wing, 'Keeping Spain Afloat: State Forestry and Imperial Defense in the Sixteenth Century', *Environmental History*, 17, No. 1 (2012), 116–45.

By the end of the medieval era and the beginning of the early modern era, forest resources were in high demand by a growing population. Forests were cleared for agriculture, and harvested for fuel, construction materials, food, cordage, and many other purposes. According to John Wing, deforestation became a concern, but the nature of Spanish forest management in the early modern period was political rather than ecological. Clearing of forests for agriculture and use of wood for fuel were the primary reasons for deforestation, rather than shipbuilding or construction, yet 'naval interests were behind the growing amount of forest legislation'.[4] Early forest regulation was aimed at solving municipal common law abuses, but throughout the sixteenth century this shifted to 'meeting the needs of naval shipbuilders by regulating the use of forest space and tree species best suited for naval access and use'.[5] In this way, the government 'increasingly centralized control over timber access'.[6]

Spain's shipbuilding industry experienced a serious depression in the seventeenth century in spite of forest protection measures. Past dialogues have focused heavily on trying to determine the cause of this decline and Spain's increased dependence on northern timber throughout the seventeenth century. For example, Abbott Payson Usher suggested that it was Spain's failure to keep up with contemporary shipbuilding technologies that lead to the industry's decline, whereas Lawrence Clayton cites an increase in shipbuilding costs and a shortage of labour rather than forest resources.[7] Regina Grafe rejected assumptions of a supply shortage, stating, 'it is obvious that the massive arrival of northern European vessels in Spain had less to do with bottlenecks [in timber supply] and more with changing global trading patterns'.[8]

The suffering shipbuilding industry experienced a revival under the Bourbon dynasty in the eighteenth century, and forest protection measures became better defined and easier to enforce. Most notably, a series of *ordenanzas* passed in 1748 protected all forests within 25 leagues (139 km) of the sea and navigable rivers for the Royal Navy.[9] By 1783, Spain had the second largest navy in the world, after Great Britain.[10] Wing attributes this recovery in part to an effective system of forest management, but it certainly would not have been possible without the help of foreign resources.[11] Still, the severity of Spain's 'dependence' on Baltic timber has so far been accepted by historians rather than critically examined.

4. John T. Wing, *Roots of Empire: Forests and State Power in Early Modern Spain, c. 1500–1750* (Leiden, 2015), 28.
5. Wing, *Roots of Empire*, 41.
6. Wing, *Roots of Empire*, 45.
7. Abbott Payson Usher, 'Spanish Ships and Shipping in the Sixteenth and Seventeenth Centuries', in A. P. Usher, ed., *Facts and Factors in Economic History* (Cambridge, MA, 1932), 198. Lawrence Clayton, 'Ships and Empire: The Case of Spain', *Mariner's Mirror*, 62 (1976), 244–5.
8. Regina Grafe, 'The Strange Tale of the Decline of Spanish Shipping', in Richard W. Unger, ed., *Shipping and Economic Growth, 1350–1850* (Leiden and Boston, 2011), 94.
9. Wing, *Roots of Empire*, 45.
10. Wing, *Roots of Empire*, 7.
11. Wing, *Roots of Empire*, 7.

Such an investigation can provide clues about the state of local timber supply in Iberia or the consequences of Spain's forest protection laws. It is necessary to identify trends in timber imports in order to evaluate the extent of Spain's dependence on Baltic timber and see when any major changes occurred. The STRO is an excellent resource for beginning to answer these questions, but first there has to be a meaningful way to express the volume of the timber trade it contains.

Timber products related to shipbuilding were of particular interest to this study, but the intended purpose of a product is rarely specified in the STR. Because of this, there is no easy conclusion to the exact amount of Baltic timber that went toward shipbuilding. There is a small subset we can be sure about, and a subset that was likely not for shipbuilding, but the majority is ambiguous. Therefore, all timber products were considered in this study rather than just timber that was explicitly for ships.

Product identification

The first step towards determining the volume of timber is to identify and separate distinguishable products. Nina Bang categorized most timber products for her tabulation of the STR, so her lists were useful for identifying relevant products. As Hans Christian Johansen explains, these products were most often classified as balks (*bjælker*), planks (*planker*), boards (*brædder*), deals (*dehler*), laths (*lægter*), and cask staves (*staver*).[12] Other common timber products in the STR include masts (*master*), spars (*spirrer*), wainscot (*vognskud*), clapboards (*klapholt*), rafters (*sparrer*), handspikes (*haandspiger*), boat-hook shafts (*baadshagestager*), and ledges for ships (*ribber*). Various other processed or semi-processed products such as compass timber (*krumholt*), knees (*knæer*), French wood (*fransholt* or *franstræ*), oars (*årer*), and pumps (*pompe* or *pompetrær*) also appear in the registers, but with much less frequency. Of course, unprocessed timber (*tømmer, holt, trae*) was also transported from the Baltic.[13] Lutz Volmer et al.'s *Glossary of Prehistoric and Historic Timber Buildings* and Richard Steffy's *Wooden Shipbuilding and the Interpretation of Shipwrecks* were helpful for understanding how some of these products were defined and the purposes for which they were used.[14]

Rectangular products such as planks, boards, and deals had conventional widths and thicknesses, and staves came in various sizes based on the type of cask they were meant to construct. Masts and spars were often measured by their circumference, from which one can derive a length based on the conventions of historic shipbuilding. Even the dimensions of squared timber can be predicted to some degree based on how it was named.

12. Hans Christian Johansen, *Shipping and Trade Between the Baltic and Western Europe* (Odense, 1983), 108.
13. The Danish word *tømmer* translates to lumber, while *tommer*, the plural for the *tomme*, translates to inches, which was a measurement often used with timber products. Context is very important when dealing with these terms since the Danish 'ø' is often transcribed as 'o' in the STRO.
14. Lutz Volmer, W. Haio Zimmermann and Emma Bentz, *Glossary of Prehistoric and Historic Timber Buildings* (Rahden, 2012); Richard Steffy, *Wooden Ship Building and the Interpretation of Shipwrecks* (College Station, TX, 1994).

Many of these products were sporadically given a measurement in the source that determined how they were taxed. For example, the length was sometimes specified with boards, planks, and deals. Circumferences were sometimes specified for masts and spars, and thicknesses for squared timber such as balks and rafters. However, with many of these products a dimension was not given, and they were simply listed generically. Some products, such as boards and deals, had an 'ordinary' or standard version with defined dimensions, so when they are not specified in the source, they can be assumed to fit this standard. 'Typical' dimensions for products that did not have a standard are more conjectural, but can be determined with some confidence by taking averages from those products which are given a specified dimension, weighted to the amount of times that specification occurs, or by using contemporary trade lexicons that state how dimensions affected the taxation rate.

A great obstacle to grouping these products in the STRO database is the multitude of spellings that occur in the source. In order to solve this issue, a standardization process called 'coding' was used. Ports of destination were first indexed in a separate table with each unique spelling. They were then given a numerical code if the destination was located in Spain or Portugal. This task was eased greatly by the standardized place names created by George Welling as an ongoing process to standardize the ports that appear in the STR. The few ports that were not yet standardized by Welling were also given a numerical code. Once these destinations were successfully coded and connected back to main cargoes (*Ladingen*) table, it was possible to use the code value to isolate only those passages that went to the Iberian Peninsula. This greatly reduced the amount of product spellings that had to be coded as the cargoes that went directly to Portugal or Spain represent about four per cent of all westbound loads in the entire STRO database.

Commodities and their unique spellings that occurred in the STRO were also indexed with the amount of times that they occur. In the entire STRO database 198,421 different spellings of products occur. The same product was often spelled in many different ways in the registers, which makes it nearly impossible to search specific products with confidence. However, since those records to the Iberian Peninsula were isolated, it was possible to filter for only the relevant cargoes. This subset yields a much more manageable list of 6372 product spellings. All products destined for Iberia were coded, rather than limiting this to those that fell within the target set of dates, in case the date range was to be changed for any reason. Starting with the most commonly occurring products, and later switching to an alphabetical approach, timber products were given a numerical code in order to standardize them. This yielded 3061 timber product spellings, each of which was given a three-digit code and a standardized English name to identify the type of product that they represented.

This creates a flexible system of categorization based on the needs of the researcher. The products are identified by a number and corresponding name rather than hundreds of unique spellings, and the first number in the three-digit code allows the products to be given a 'level', or 'class'. In this case values 100–199 are timber products that are directly related to shipbuilding, 200–299 are timber products that could be applied to shipbuilding, but also have other uses, and 300–399 are timber products that were not likely to be used in shipbuilding. Not all possible numbers were used to identify a product, so this system allows the easy addition of categories in case a new product should be added or it is decided that one type of product should be separated from another. For example, bowsprits (*bugsprit*) could easily be separated from masts, and therefore counted separately and given their own dimensions for calculating volume (discussed below). Some products that were initially identified were filtered out once the date range was chosen for this study. From this point, only products that occurred between 1670 and 1806 are discussed. A complete list of the products considered in this study is included in an appendix to this article.

Initial analysis after product identification shows that timber was one of the most significant imports from the Baltic. Of 21,781 cargoes destined for Spain via the Danish Sound from 1670 to 1806, 9622 (44 per cent) were classified as some kind of timber product. Other significant types of products included flax (about 11 per cent), wheat (about eight per cent), iron (about seven per cent), hemp (about six per cent), tar and pitch (about three per cent), canvas and sailcloth (about two per cent), and wax (about two per cent). It is clear that timber was significant, but since there were many different kinds of timber products specified in the STR, counting them by individual cargoes in this way could be misleading. For example, timber on a ship may consist of boards, planks, masts, spars, and barrel staves, which were all recorded separately, while all the tar on board was simply recorded as one cargo of tar. This is another reason why a reliable volume estimate is important when considering timber in relation to other products.

Calculating products in pieces

The second step toward arriving at volume is to calculate the number of pieces of each product. Most timber products were recorded by the number of pieces carried on board a ship, but this took several common denominations such as pieces (*stuk*, one), dozen (*tylter, dusin*, 12), schock (*skok*, 60), hundred (*hunderd, centner*, 120), and ring (240).[15] As such, the spellings of these denominations were first isolated by those that were relevant to Iberia, and then given their numerical equivalent in a separate field (one for piece, 12 for dozen, etc.). At that point, it was possible to multiply the number in the source by its numerical factor, such that one dozen would yield 12 pieces, rather than one.

At this point there were still two main problems. First, many products were not given a denomination in the source, and therefore the amount did not have anything to be multiplied by. In these cases, it is logical to assume that the amount given is simply the total number of pieces (i.e. a factor of one) but ideally this should have some sort of check, since there might be a 'default' value for some products, if they are always measured in dozens for example. Second, some numbers have the potential to be very far off the true value, typically due to recording errors when the source was transcribed. Again, this requires some kind of check.

15. Horace Doursther, *Dictionnaire universel des poids et mesures anciens et modernes* (Brussels, 1840), 95, 132, 402 and 465. There are several possible denominations for 'cent' or '*hundert*', which are partially dependent on port of origin and partially on the product that is measured. The most common denomination is 120 (two *skok* or ten dozen). This is assumed to be the most likely denomination for timber products. In the dataset for this article, this measurement was only used with cask staves.

A good check for both of these issues comes from calculating how much tax was paid per piece of a product. This is possible since each cargo was taxed individually in most cases. *Rigsdaler* and skilling values were converted to a combined decimal value of *rigsdaler* and added together to obtain the tax per load. This total was then divided by the number of pieces to arrive at the tax per piece. These numbers turn out to be very consistent for different products, and thus is it easy to spot outliers. If the tax per piece is suspiciously high, it is likely that product amount is too low, and if the tax per piece is extremely low, it shows that the product amount is too high. High product quantities are especially important to find because they can throw off the volume estimate considerably.

When checked against the source on the STRO website, it is often clear right away what the problem is. Typically, either the number or the measurement was transcribed incorrectly, causing the amount to have an extra digit or resulting in multiplication by a factor of 60 instead of one. Transcriptions errors like this are rare (only 15 records needed to be adjusted in this way for cargoes destined for Spain from 1670 to 1806), but they can have a significant impact on final results. Corrected values were recorded and updated in the coded cargoes table rather than the original. In this way, the original data remained undisturbed.

For those products that did not have a numerical factor to begin with, a separate field was added as an estimate, which can be multiplied by the amount in the source. This allows easy experimentation without disrupting the given numbers. As suspected, when a numerical factor is absent, it implies the product amount is given in individual pieces. In other words, multiplying the amount by one returns the expected tax value per piece in almost every case.

Timber products in the STRO were occasionally specified by weight, volume, value, or some other measurement, such as length or thickness. This is almost certainly an input error in all cases where products are given a length or thickness as their amount value. For example, if the product should have been entered as '6 allen bræder', it was instead entered with '6' as the amount, '*allen*' as the *maat* or measure, and '*bræder*' as the product name. Staves are subject to the same kind of error, since the type of stave (pipe, hogshead, barrel, etc.) may have been entered as the *maat* rather than as part of the product name. These types of errors cannot easily be corrected in bulk since an amount or measurement might have been left out. Therefore they should either be checked in the original scan of the STR record or discarded.

In other cases, products that were normally recorded in pieces were given a weight. The most commonly occurring weight in this case is *skippund*. This often occurs with deals, a product that was commonly recorded in pieces or *skok*. Using a few samples, the *skippund* value was converted to metric tonnes, and turned out to be unfeasibly heavy. This is another type of input error where the symbol for *stykker* (pieces) was mistaken for the symbol for *skippund*.

Once totals were calculated, there were only 112 timber loads out of 9639 (1.16%) in the relevant dataset without a number of pieces because the amount given was a volume or weight value, or, in some rare cases, an amount was not given at all. These records were checked individually in the source. Of these, 46 were easily correctable, 30 were recorded in *rigsdaler* values (see below), and 36 were discarded due to difficulty in reading or interpreting the source.

Unprocessed timber, simply recorded as *tømmer, holt*, or *trae* with no additional explanation, was often given with a *rigsdaler* value rather than a count. These records represent a very small percentage (0.3%) of the dataset of cargoes to Spain from 1670 to 1806, but were deemed too important to discard since some of them were specifically for shipbuilding. Werner Scheltjens suggested an estimate of 56.8 kg per *skilling* or 2727.7 kg per *rigsdaler* for products expressed in *rigsdaler*.[16] While this returns a feasible weight for some timber products, it is far too high for others. It is likely that the best indication for the volume of these records would come from additional research on timber prices in archives, but this was not deemed worth the investment of time for such a small number of records. As such, a different approach was taken by dividing the tax per load of raw timber recorded in *rigsdaler* values by the average tax per piece of raw timber recorded in pieces, yielding an estimate of how many pieces the load contained.

Calculating volumes of timber products

With the destination ports and timber products coded and total pieces calculated, it is easy to query the database to determine how many pieces of each product where shipped to Spain by year, decade, or any other measure of time. Products were assigned dimensions in order to calculate the cubic metres one piece occupied. This value was then multiplied by the number of pieces to arrive at the total volume for that particular product.

Three main approaches were used to arrive at a feasible volume for a piece of a given timber product. The first was using primary and secondary documents that discuss the size of these types of products. It is essential to examine primary sources to see how these products were understood in the context of Baltic trade. The most useful kinds of sources for this purpose are contemporary marine and trade lexicons, which define these products to varying degrees. Examples include the English *London Commercial Dictionary* (1816), the Danish *Chronologisk Register over de Kongelige Forordninger og aabne Breve* (1844), and the *Dansk Marine Ordbog* (1839).[17] Horace Doursther's *Dictionnaire universel des poids et mesures anciens et modernes* (1840), is invaluable for converting the multitude of regional measurement units into their metric equivalents.[18] Secondary examples include Hans Christian Johansen's *Shipping and Trade Between the Baltic and Western Europe*, and Lutz Volmer et al.'s *Glossary of Prehistoric and Historic Timber Buildings*, which tell how these different products were classified and what dimensions were expected for them.[19]

The second method is to use a weighted average of given measurements in the Sound Toll Registers. This is useful when a product's dimensions are highly variable, but often specified, such as with the length of boards or the circumference of masts.

16. Scheltjens, 'Volume of Dutch Baltic Shipping', 103.
17. William Anderson, *London Commercial Dictionary* (London, 1816); Jacob Schou, *Chronologisk Register over de Kongelige Forordninger og aabne Breve* (Copenhagen, 1844); Carl L. Harboe, *Dansk Marine Ordbog* (Copenhagen, 1839).
18. See note 15.
19. Johansen, *Shipping and Trade*; and Volmer et al., *Glossary of Prehistoric and Historic Timber Buildings*.

Once dimensions have been determined with confidence, it is possible to work these into the coded database in order to query volume.

The third approach is to use archaeological evidence to support feasible dimensions for a product when one dimension is missing or highly variable. These methods were helpful in checking standard dimensions for planks and staves.

I

Planks, boards, and deals are similar products but imply different dimensions. Planks were the thickest and strongest of the three. According to Hans Christian Johansen, planks 'had very large dimensions but were sawn through length-wise into a rectangular cross-section, they were over 1¾ inches (0.046m) thick, over 11 inches (0.279m) wide and 12–24′ (3.66–7.32 m) long'.[20] The *London Commercial Dictionary* confirmed that planks were 'Thick strong boards, cut from various kinds of wood, especially oak, pine, and fir. Planks are usually of the thickness of from one inch (0.025 m) to four (0.102 m)'.[21] The *Dansk Marine Ordbog* was more specific, defining planks as having a thickness between two and four *tomme* (0.053–0.105 m).[22] Planks thicker than four inches (0.102 m) were classified by the English as 'thick-stuff', which were called *bohler* or *bielkeplanker* in Danish.[23]

The dimensions given in these sources still leave a wide range for what to consider a 'typical' plank. The most sensible place to start is by taking the middle measurement from the ranges provided. This would yield a plank that is 0.073 m thick, 0.279 m wide, and 5.5 m long based on the English range and 0.079 m thick, 0.288 m wide, and 5.57 m long based on the Danish range. For thickness and width, the best solution is to take an average of the English and Danish measurements. However, planks were sometimes specified by length in the STR, and calculating the weighted average of these lengths yields 5.3 metres, so this is the plank length that is used in the estimate. So, the estimated plank is 5.3 m long, 0.284 m wide, and 0.076 m thick, or 0.114 m^3. The same measurements were used for ship's planks.

A check for the plank estimate is a case study of the flute-ship *Anna Maria* of Stockholm. This ship was carrying 1360 kg of copper plate, 116,239.33 kg of bar iron, 924.8 kg of steel, and 848 dozen sawn pine planks when it was wrecked in the Baltic in 1709.[24] Since the mass of the cargo is known, except for the planks, it offers an excellent opportunity to check the volume and mass estimate for planks. The ship had a capacity of 274 Swedish lasts, or 657.6 tonnes. The non-timber cargo weighed a total of 118.53 tonnes, leaving a remainder of 539.07 tonnes of capacity for the planks.[25] Using a density

20. Johansen, *Shipping and Trade*, 108.
21. Anderson, *London Commercial Dictionary*, 590.
22. Harboe, *Dansk Marine Ordbog*, 312.
23. Robert Albion, *Forests and Sea Power* (Cambridge, MA, 1926), 9–10; Thomas Mortimer, *A General Commercial Dictionary* (London, 1823), 750.
24. Christian Ahlström, *Looking for Leads* (Helsinki, 1997), 106–7.
25. Ahlström, *Looking for Leads*, 106–7.

range of 550–600 kg/m^3 for Scots Pine, this means that the planks averaged 0.088–0.096 m^3 in volume.[26] This is smaller than the volume estimate used (0.114 m^3), but it certainly fits comfortably within the ranges previously described and shows that the estimate is feasible.

The same measurements were used for thick-stuff as planks, except for the thickness. These types of thick planks were favoured for certain parts of the planking on ships, including the wales and clamps, so the average of the range of thicknesses for wales specified in the *Dansk Marine Ordbog* was used as the thickness for thick-stuff.[27] This yields a thickness of 0.137 m, which is reasonably about twice that of a typical plank. Therefore the final estimated measurements for thick-stuff and wales are 5.3 m long, 0.284 m wide and 0.137 m thick, or 0.206 m^3.

Like planks, boards also had variable dimensions, but there was also an expected standard. According to Johansen, boards were 'usually 1–2 inches (0.025–0.0508 m) thick, 12–15 inches (0.254–0.381 m) wide, and 12–15′ (3.66–4.572 m) long'.[28] However, the *Dansk Marine Ordbog* specified that boards were never more than 1 *tomme* (0.026 m) thick. For lack of better evidence, the averages of Johansen's ranges were used to represent length and width of an ordinary board, resulting in a board that is 4.115 m long, 0.343 m wide, and 0.026 m thick. When boards were not listed with a measurement they were assumed to be ordinary. Boards with specified lengths that were sent to Iberia were an average of 4.896 m long, so this is the measurement that was used for boards of specified length. This results in a standard board of 0.037 m^3 and specified boards of 0.044 m^3.

Deals came in various standards, but were also occasionally specified by length. The most common type of deal was either unspecified or 'ordinary'. According to Johansen, these were 'about the size of Swedish boards'.[29] The *London Commercial Dictionary* described a 'Russian standard deal' of 3.66 m long, 0.279 m wide, and 0.038 m thick, a 'Christiania standard deal' of 3.35 m long, 0.229 m wide, and 0.038 m thick, and 'another standard of deals in Norway at Dram' that were 3.05 m long, 0.229 m wide, and 0.038 m thick.[30] The most consistent dimension here is the thickness, which was used for all deals except the Prussian deal which was understood to be '27′ (8.23 m) long and two inches (0.051 m) thick'.[31] When deals were specified to be Norwegian, the Norway measurements were used, and when they were specified as 'Swedish' the same measurements for ordinary boards were used. As mentioned, some deals were specified by length, and those that went to Iberia averaged 5.285 m long (see Table 1).

An alternative way to handle this would be to use the Swedish measurements when an ordinary or unspecified deal is from Sweden, and to treat those from Memel and Danzig as 'Prussian deals'.[32] Since many deals came from Prussia, without being specified as

26. Eric Meier, *The Wood Database*, http://www.wood-database.com/ [accessed 8 February 2016, last updated 2015]. See also Steffy, *Wooden Ship Building*, 258–9.
27. Harboe, *Dansk Marine Ordbog*, 502–4.
28. Johansen, *Shipping and Trade*, 108.
29. Johansen, *Shipping and Trade*, 112.
30. Anderson, *London Commercial Dictionary*, 187.
31. Johansen, *Shipping and Trade*, 112.
32. Johansen, *Shipping and Trade*, 112.

Table 1. Estimated dimensions of deal variants.

Product	Length (m)	Width (m)	Thickness (m)	Volume (m^3)
Deals, ordinary/unspecified	3.658	0.280	0.038	0.039
Deals, Prussian	8.230	0.250	0.060	0.123
Deals, Swedish	4.115	0.343	0.026	0.037
Deals, specified lengths	5.285	0.280	0.038	0.056
Deals, Norse	3.350	0.229	0.038	0.029

'Prussian deals', this would affect the final volume estimate greatly, but since 'Prussian deals' and 'Swedish deals' were so often specified, this was interpreted to imply certain dimensions rather than the product's specific port of origin. This could also explain why 'Norwegian deals' passed westward through the Danish Sound.

II

The best indication of the dimensions of squared timber comes from contemporary trade lexicons, shipbuilding treatises, and archaeological examples of certain beams on ships, as this would likely be a common use for balks. Names for these products in the STR include *bjælker, sparrer, viertel holt* and *ribber*.

Of these, balks (*bjælker*) were the most common and important. Johansen defined balks as 'large, square or occasionally octagonal, trimmed logs, most often fir or spruce but sometimes oak'.[33] The British considered a balk to be up to eight inches (0.203 m) thick and 24 feet (7.32 m) long.[34] The best indication that the Danish lexicon gives was that balks with more than four sides that were seven to 15 palms should be treated as *sparrer* for taxation.[35] Palms were used to measure circumference, so these measurements yield thicknesses from 0.197 m to 0.423 m using a palm of 0.0886 m.[36] The middle ground between these then is 0.31 m. Thicknesses were sometimes specified in the STR in *tomme* (0.026 m in Denmark) and these range from six to 16 *tomme* and are more commonly between nine and 12 *tomme*. The average of nine and 12 *tomme* is 0.275 m. The *Dansk Marine Ordbog* specified deck beams for ships from four and a half *tomme* (0.118 m) for sloops up to one *fod* four *tomme* (0.418 m) thick for ships of the line. Sven-Erik Åström described balks as being over nine inches (0.229 m) thick.[37] So it is clear that there was a wide range of thicknesses for balks, but given these measurements a typical balk was probably about 0.257 m thick, which is the average of all these measurements.

33. Johansen, *Shipping and Trade*, 108.
34. Anderson, *London Commercial Dictionary*, 38–9.
35. Schou, *Chronologisk Register*, 475.
36. Doursther, *Dictionnaire universel*, 374. No specific Danish palm is given. The Bergen palm was used in this case, as the measurement Doursther provided was based on a division of the Danish *tomme*.
37. Sven-Erik Åström, *From Tar to Timber* (Helsinki, 1997), 124.

The English threshold for the taxation of balks was above or below 24 feet (7.315 m). This was the best indication given, and is a reasonable size to use as a beam for a mid-size ship. Lengths were rarely specified for balks in the dataset for Iberia, and those that were average to 8.83 m. The average between this value and the British value is about eight metres, and thus this was used in the final measurement, yielding each balk eight metres long and 0.257 m thick, or 0.528 m^3.

Another type of squared timber is confusingly (for the English speaker) called *sparrer* in Danish and other Scandinavian languages. This product presents the risk of being confused with *spirrer*, which means 'spar' in English. Luckily, the letter 'a' and the letter 'i' are clearly distinguishable in Danish Gothic handwriting, so the potential for a transcription error is low. The most appropriate English translation for *sparrer* is 'rafters', which are primarily used in roof construction.[38] Like other squared timber, these were typically measured in *tomme* rather than palms. Åström described *sparrer* as being between five and six inches (0.127–0.152 m) or six to nine inches (0.152–0.228 m) thick.[39] When measurements were given in the STR they were typically between five and eight *tomme* (0.131–0.209 m). Rafters under five *tomme* were considered 'ordinary'.[40] As such, a standard measurement of 0.13 m thickness was used for rafters in the estimate. In the absence of a satisfactory figure for length, the same length as for balks was used for rafters. This results in rafters of eight metres long, 0.131 m thick, and therefore 0.137 m^3 in volume.

A similar, but less common, product is *viertel holt*, or quartered timber in English. Volmer et al. describe quartered timber as 'heart timber, which has been split or sawn into four quarters'.[41] This suggests that it is essentially a balk that has been cut into four smaller pieces, so it is logical to use half of the thickness used for balks in the estimate. This results in quartered timber of eight metres long and 0.129 m thick, for a volume of 0.133 m^3.

Ledges (*ribber* or *ricker*) were thin beams that went between the deck beams on ships to provide additional support for the deck planks.[42] The *London Commercial Dictionary* specified *ricker* to be under four inches (0.102 m) thick and 24 feet (7.31 m) long.[43] The *Dansk Marine Ordbog* specified that the thickness of the ledges should be about a third of the deck beams.[44] Given that a thickness of 0.257 m was used for balks, the English measurements for ledges are quite reasonable. If this thickness of a balk is divided in three, the result is 0.086 m, making the final estimate for ledges 7.31 m long and 0.086 m square, or 0.054 m^3.

III

Round timber, which was most commonly classified as masts (*master*) or spars (*spirrer*), was measured in palms, which indicated circumference. One can derive the length

38. Volmer et al., *Glossary of Prehistoric and Historic Timber Buildings*, 266.
39. Åström, *From Tar to Timber*, 124.
40. Schou, *Chronologisk Register*, 502.
41. Volmer et al., *Glossary of Prehistoric and Historic Timber Buildings*, 401.
42. Steffy, *Wooden Ship Building*, 274.
43. Anderson, *London Commercial Dictionary*, 219.
44. Harboe, *Dansk Marine Ordbog*, 97.

	Masts		Yards	
	Length yds. ins.	Diam. ins.	Length yds. ins.	Diam. ins.
Main	24.24	20	22.16	15
Top	14.38	$12^1/_2$	15.9	$10^1/_2$
Gallant	7.30	$6^5/_8$	9.21	5
Fore	22.33	$19^1/_8$	21.1	$13^3/_4$
Top	14.9	12	14.8	10
Gallant	7.9	$6^5/_8$	8.27	$4^1/_4$
Mizon	17.26	$13^3/_4$	19.6	$9^5/_8$
Top	9.34	9	10	$7^1/_2$
Gallant	3.3	$4^1/_4$	None	
Bowspritt	14.30	$19^3/_4$	14.8	1.0
Crossjack	....	....	13.0	$8^5/_8$
Jibb	10.20	$7^1/_8$	....	....

Figure 1. Dimensions of masts and yards.
Source: Gilles Proulx, Between France and New France: Life Aboard the Tall Ships (Toronto, 1984), 138.

from the palm measurement with some confidence, since masts and spars were proportional in thickness and length. For example, in Amsterdam, one Amsterdam palm (0.094 m) of circumference corresponded to about 4¾ Amsterdam feet (1.345 m) of length, such that a main mast of 18 palms circumference (1.692 m) was 87 feet (24.633 m) long.[45] Because masts and spars were often specified with their palm measurement, it is possible to use the information in the database to arrive at a typical mast or spar. Unlike inches, palms varied quite a bit by region. The vast majority of masts and spars going to Spain came from Riga or Memel, thus the Riga palm of 0.069 metres was used in the estimate.[46]

Once a weighted average of the thickness was obtained for each mast or spar type, it was necessary to determine the relative length. A contemporary example is provided in Proulx *Between France and New France*, in which he laid out the length and thickness of all the masts and yards on a mid-sized French frigate from 1760 (see Figure 1). These measurements were converted into metric values, and an average thickness to length proportion was calculated separately for the masts and yards. The mast proportion was used to estimate the length of masts in the database, and the yard proportion was applied to spars. This yielded the values shown in Table 2.

45. Ab Hoving, *Nicolaes Witsen and Shipbuilding in the Dutch Golden Age* (College Station, TX, 2012), 144.
46. Doursther, *Dictionnaire universel*, 375. 82.7% of masts and 69.6% of spars to Spain came from the Riga or Memel. Another 9.1% of masts and 8.3% of spars came from St. Petersburg, which likely used the same palm.

Table 2. Estimated dimensions of masts and spars.

Product	Length (m)	Diameter (m)	Volume (m³)
Masts	12.970	0.320	1.040
Boat masts	6.290	0.155	0.120
Spars	13.206	0.223	0.520
Small spars and rods	4.720	0.080	0.024

Table 3. Estimated dimensions of cask stave variants.

Product	Length (m)	Width (m)	Thickness (m)	Volume (m³)
Staves, barrel/unspecified	0.990	0.118	0.0380	0.004
Staves, hogshead	1.212	0.118	0.0425	0.006
Staves, pipe	1.585	0.118	0.0425	0.008

IV

Cask staves (*staver*) varied in size depending on the type of cask they were meant to build. There were many different cask types, but the most common denominations for staves in the STR are barrel (*tonde*) staves, hogshead (*oxhoved*) staves, and pipe (*pibe*) staves. A hogshead had twice the capacity of a barrel and a pipe had twice the capacity of a hogshead, so the staves used to make them had significantly different dimensions. When the type of stave was not specified, they were assumed to be barrel staves. According to the *London Commercial Dictionary*, barrel staves were three feet (0.91 m) long, hogshead staves were four feet (1.22 m) long, and pipe staves were five feet (1.52 m) long.[47] The *Dansk Marine Ordbog* defined *tonde* staves at 41 *tomme* (1.07 m) long, hogshead staves at 46 *tomme* (1.2 m) long, and pipe staves at 63 *tomme* (1.65 m) long. They also defined the width and thickness of all staves as four and a half *tomme* (0.118 m) by 1½–1¾ *tomme* (0.039–0.046 m).[48] The English and Danish figures are slightly different and were therefore averaged for the final estimate (Table 3).

V

Raw timber (*tømmer, holt, træ*) was sometimes recorded in pieces. This poses a problem because these pieces could presumably be of any size. However, Jean Boudriot described the expected dimensions for raw timber in the case of French shipbuilding:

> The volume of timber in a tree is estimated at one fifth of the circumference squared, times the height of the trunk: thus a 100 year old tree with a diameter of 56 centimetres and a circumference

47. Anderson, *London Commercial Dictionary*, 774.
48. Harboe, *Dansk Marine Ordbog*, 157.

> of 1.78 metres, yields timber which is 36 centimetres square and 8.10 to 9.27 metres long, a volume of between 1.05 and 1.26 cubic metres. This dimension would be somewhat small for the gundeck beams, and rather too large for the upper deck beams [of a 74 gun ship].

He goes on to say that 'as a general rule the Navy does not use trees with a circumference of less than 1.62 metres'.[49] This provides both an expectation for raw tree size, and information about how much timber that tree was expected to yield. Using the threshold of a 1.62 m circumference and an average of 8.1 to 9.27 m length, this tree would have a total volume of 1.815 m^3 and contain 1.126 m^3 of usable timber. It is not known to what degree generic timber in the database was processed, so an average was used of these figures, and thus a volume of 1.47 m^3 was assigned to 'unprocessed or semi-processed timber' and 'other ship timber'.

VI

Other products that needed to be considered for the estimate were compass timber (*krumholt*), knees (*knæer*), laths (*lægter*), wainscot (*vognskud*), French wood (*fransholt* or *franstræ*), clapboards (*klapholt*), handspikes (*haandspiger*), boat-hook shafts (*baadshagestager*), oars (*årer*), treenails (*trænagler*), and pumps (*pompe* or *pompetrær*). Most of these products have a very low impact on the final estimate, and therefore they were not researched in as much depth as those discussed above. Researchers for whom these products are more significant may wish to be more precise.

Compass timber is naturally curved wood that is especially useful for the framing of ships.[50] It is problematic because these kinds of curved timbers on ships varied in dimension, being thickest at the floor of the ship and tapering towards the bulwarks. Frames also comprised several pieces of widely variant lengths. Of course, these dimensions also varied according to the size of the ship.

Dutch shipwrights in the seventeenth century used a series of proportional measurements based on the length and the width of the ship to determine the dimensions of all the necessary components. One of the most important measurements used for determining the others was the thickness of the stem on the inside of the ship. This was defined as one inch (0.026 m) of thickness for every foot (0.283 m) of the ship's length. The thickness of the floors (the bottom-most frame pieces) were further defined as three-quarters of the inside stem thickness, and the thickness of the futtocks (the pieces of the frame above the floors) were half of the inside stem thickness. For a ship of about 100 Amsterdam feet (28.31 m) long, this yields floors that are 0.193 m thick and futtocks that are 0.129 m thick.[51]

The thickness of the deck beams was in between these measurements and provides a check for later building preferences. As discussed, the middle ground for deck beams in the *Dansk Marine Ordbog* was 0.229 m. A ship of a similar size had deck beams from 0.235 to 0.288 m thick.[52] Given the wide range of possible dimensions, it is reasonable

49. Jean Boudriot, *The Seventy-Four Gun Ship. 1: A Practical Treatise on the Art of Naval Architecture* (Annapolis, MD, 1986), 54.
50. Steffy, *Wooden Ship Building*, 269.
51. Hoving, *Nicolaes Witsen*, 252.
52. Harboe, *Dansk Marine Ordbog*, 502–4.

to place the thickness of compass timber at 0.2 m. The length remains more arbitrary. As the majority of compass timber consisted of futtocks and knees, they probably rarely exceeded two metres. The final estimate for compass timber is two metres long and 0.2 m thick, for a volume of 0.08 m^3.

Knees were a type of compass timber, which was used to secure deck beams to the framing of a ship.[53] They were typically thicker in the centre than at the ends, so consistent dimensions are difficult to define. Only three loads of knees were sent to Iberia during the period of this study, and two of them were measured in values rather than pieces. The number of pieces can be estimated using the method described for timber recorded in *rigsdaler* values. Because of their low impact on this dataset, a highly accurate volume was not a priority and therefore the dimensions for compass timber were simply applied to knees.

Laths might otherwise be called battens, and were thin, relatively short pieces of wood used to hold other pieces together, often temporarily. Eighty-four loads of laths went to Iberia during the period of this study, so they were not very significant for this study. The *London Commercial Dictionary* defines laths as being either three or five feet (0.91 or 1.52 m) long, one and a half inches (0.038 m) wide and half an inch (0.013 m) thick.[54] The Danish trade lexicon specified taxes for laths up to six fathoms (11.3 m) or longer, but more common lath seems to be one fathom long (1.88 m). An average was taken between the minimum English definition and one Danish fathom to arrive at a lath of 1.4 m long, 0.038 m wide and 0.03 m thick, or 0.002 m^3.

Wainscot boards were split radially rather than sawn, but otherwise resembled boards or deals in dimension. The *London Commercial Dictionary* described them as being 12 feet (3.658 m) in length and one inch (0.025 m) in thickness.[55] This most closely resembles an ordinary deal, but is slightly thinner. As such the decision was made to use the width of an ordinary deal, yielding a wainscot board of 3.658 m long, 0.279 m wide and 0.025 m thick, for a volume of 0.027 m^3.

'French wood' is a timber product that was occasionally shipped to Iberia. Rather than implying an origin or destination, this product implies certain dimensions which were defined by the *Dansk Marine Ordbog* as being 36–40 *tomme* (0.942–1.046 m) long, and six to seven *tomme* (0.157–0.183 m) thick.[56] Thus French wood was estimated to be 0.994 m long and 0.17 m thick, for a volume of 0.029 m^3.

Clapboards (*klapholt*) were similarly defined as wood between 30 and 34 *tomme* (0.785–0.889 m) long, and five to six *tomme* (0.131–0.157 m) wide.[57] So again, middle measurements of 0.837 m long and 0.144 m thick were used in the estimate, giving clapboards a volume of 0.018 m^3.

Handspikes were sturdy pieces of wood used to turn windlasses or capstans and were thus very useful on ships. In the case of capstans, handspikes were very long, and squared in the centre, so that they could be placed all the way through the capstan and pushed

53. Steffy, *Wooden Ship Building*, 274.
54. Anderson, *London Commercial Dictionary*, 395.
55. Anderson, *London Commercial Dictionary*, 40.
56. Harboe, *Dansk Marine Ordbog*, 157.
57. Harboe, *Dansk Marine Ordbog*, 157.

from both sides. A single capstan might have four corresponding handspikes. Windlasses served the same purpose as a capstan, but were oriented horizontally, so an end of the handspike was placed into a slot rather than going all the way through the device.[58] It is therefore possible to determine the square dimensions of handspikes by looking at examples of capstans and windlasses.

According to Dutch dimensions, the openings for handspikes on the capstan should be one-sixth the thickness of the capstan, which was two and a half inches (0.064 m) per ten feet (2.831 m) of the length of the ship. For a ship of 100 feet (28.31 m) this yields handspikes that were 0.107 m thick.[59] The length, however, was more variable. The capstan on the same size ship would be 0.64 m thick, and assuming the handspikes would need to protrude about a metre on either side in order for men to push them effectively, this results in a handspike that is 2.64 m long. However, handspikes for windlasses would necessarily be about half as long. Therefore the length was estimated at two metres and the thickness at 0.1 m for a volume of 0.02 m^3.

Oars (*årer*) and boat-hook shafts (*baadshagestanger*) are common products in the STR, but only a few thousand of each arrived in Spain during the relevant time period.[60] In the eighteenth and nineteenth centuries, oars were used to propel boats, but also small ships in certain situations.[61] They therefore varied greatly in size. The *Dansk Marine Ordbog* specified oars of 25 feet for boats (7.81 m), and 32 or 44 feet for heavy-duty oars (10.02 or 13.78 m).[62] The middle measurement was used with a thickness of 0.1 metres, for an oar of 0.079 m^3. Boat hooks were long poles with a hook at the ends, which were used to push another boat away or pull it closer. These were a similar length to the oars on a boat, but were somewhat thinner. Boat hooks were given measurements of 7.81 m long and 0.076 m thick, for a volume of 0.035 m^3.[63]

Treenails were wooden dowels used to hold two pieces of wood together. These were shaped into multi-faceted cylindrical shapes, but 'are square when they come from the forest'.[64] A typical size for unshaped treenails in the eighteenth century was 0.61–1.122 m long and 0.032–0.508 m thick.[65] The average of these ranges yields a treenail that is 0.866 m long and 0.041 m thick, resulting in a volume of 0.001 m^3.

Pumps and pump wood (*pompe* or *pompetræ*) occasionally occur in the STR. There were only eight pieces sent to Spain between 1670 and 1806 so they were not researched in depth. The purpose of a pump was to bail water out from the bilge of the ship. Therefore they were

58. Steffy, *Wooden Ship Building*, 268 and 282.
59. Hoving, *Nicolaes Witsen*, 255.
60. 8898 boat hook shafts and 4316 oars.
61. Harboe, *Dansk Marine Ordbog*, 6.
62. Harboe, *Dansk Marine Ordbog*, 6.
63. Royal Museums Greenwich, http://collections.rmg.co.uk/collections/objects/66295.html [accessed 10 February 2016]. This example of a 1750 small craft model was scaled up to check the dimensions of oars and boathooks.
64. Quoted in Mike McCarthy, *Ships' Fastenings from Sewn Boat to Steamship* (College Station, TX, 2005), 98.
65. McCarthy, *Ships' Fastenings*, 98.
66. Thomas Oertling, *Ships' Bilge Pumps: A History of Their Development, 1500–1900* (College Station, TX, 1996), 23.

at least as long as the distance from the bilge of a ship to the first deck above the water level.[66] For most ships, this was probably between four to six metres.[67] Archaeological examples of pumps suggest that they were commonly around 0.3 m thick.[68] As such a pump five metres long and 0.3 m thick was used in the estimate, for a volume of 0.45 m^3.

Converting volume to mass

Once a satisfactory estimate of volume has been determined, it is a theoretically simple to calculate tonnage by multiplying the cubic metre value by the wood density. However, this is complicated by several factors. First, the density of the wood depends on the tree from which it was made. Materials are often specified in the STR, but more commonly they are not, so it necessary to know what species of tree each product was most likely to be made of. In some cases, this is very clear in document evidence. For example, deals, masts, and spars were almost always made from pine. Other products, such as planks or balks, might be made from oak or pine, so one must either find out the most likely material, or to use an 'average' density between the two or more trees from which it may have been made. Multiplying the cubic metre value by its density yields a kilogram value, which can be divided by a thousand to arrive at tonnes.

Common species of trees that were exported from the Baltic area include *quercus robur* (English Oak), *pinus sylvestris* (Scots Pine), *abies alba* (European Silver Fir), *fagus sylvatica* (European Beech), and *fraxinus excelsior* (European Ash).[69] While these trees have average densities, these can vary by up to 85 kg/m^3 depending on whether the wood was shipped 'green', seasoned or dry.[70]

Unfortunately it is difficult to determine to what degree timber was allowed to dry or how long it might have been seasoned, as the reality of these practices often differed from the ideal.[71] Calculating mass was not a primary goal of this project, but it is necessary to fit timber into methodologies that estimate the volume of Baltic trade in mass. A rough estimate of the total tonnes of timber to Spain can be seen along with the volume estimate in Figure 2.

Results

Although they are not discussed in detail in this article, the results of the volume estimate for Spain are demonstrated in Figures 3 and 4. Figure 3 shows the total of individual pieces of certain timber products that were shipped to Spain, while Figure 4 shows these numbers converted to volume using the proposed methodology. It is clear that Figure 4 gives a much more accurate portrayal of the relative amount of wood used for each group. The most dramatic example is cask staves. These are the most

67. Hoving, *Nicolaes Witsen*, 250. Based on proportions for ships from 20–45 metres long, calculating the depth to the second deck.
68. Oertling, *Ships' Bilge Pumps*, 18 and 29.
69. Meier, *The Wood Database.*
70. Meier, *The Wood Database*; see also Steffy, *Wooden Ship Building*, 256–9.
71. David Goodman, *Spanish Naval Power, 1589–1665* (Cambridge, 1997), 112.

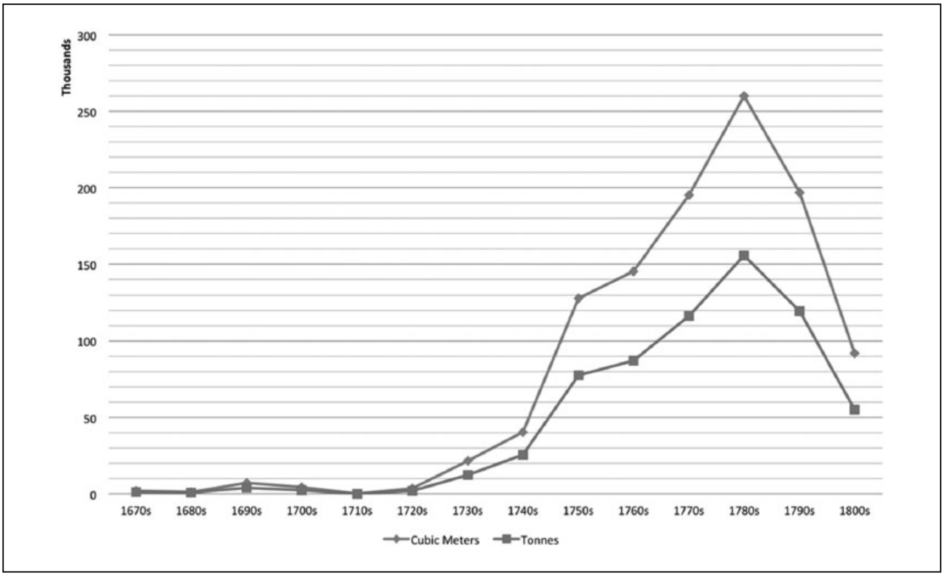

Figure 2. Estimated volume of timber to Spain via Danish Sound.

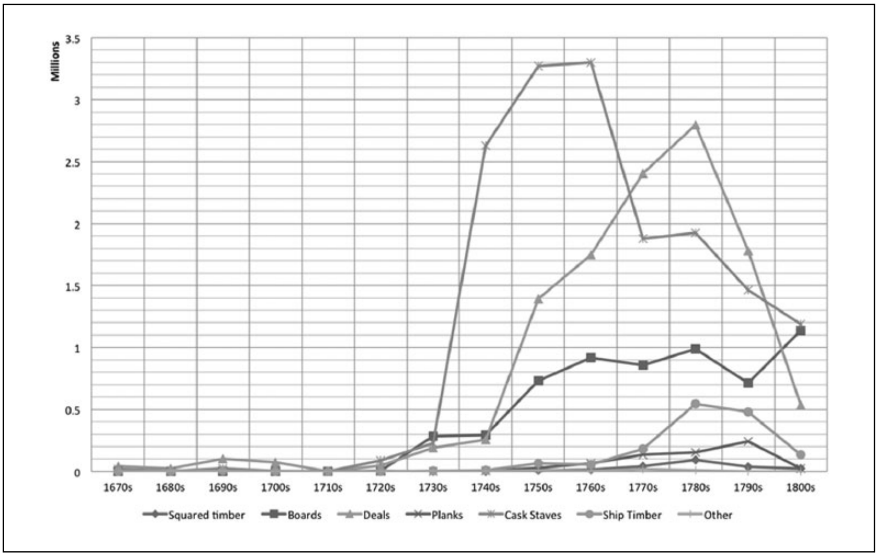

Figure 3. Pieces of timber to Spain via Danish Sound 1670–1806.

significant product by number of pieces, but they consumed far less wood than other product groups. On the other hand, products that seem very insignificant by number gain much more relative importance when considered by volume. This is most obvious

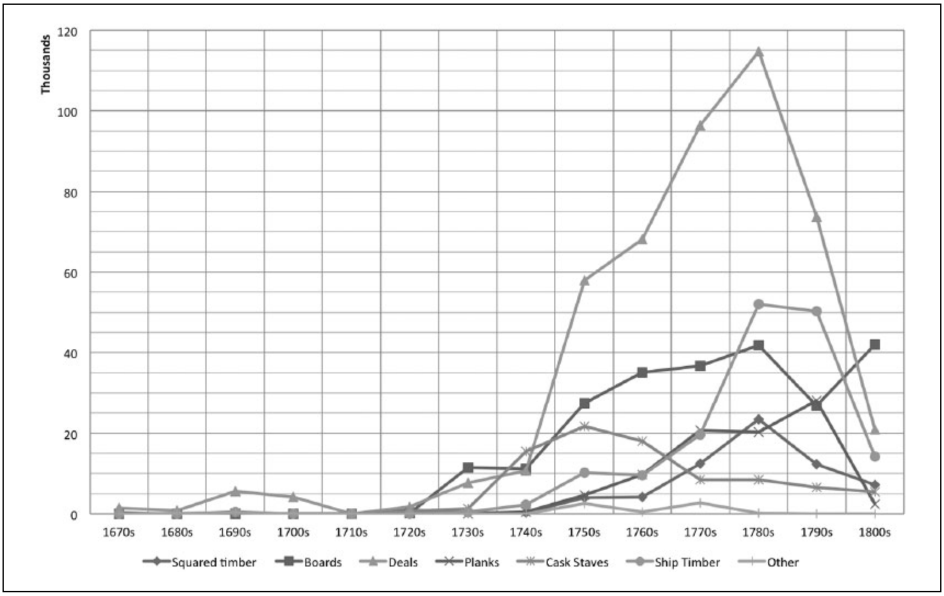

Figure 4. Timber volume to Spain via Danish Sound (cubic metres) 1670–1806.

with squared timber, which often came in large pieces compared to products in the other groups, as per Figures 3 and 4.

Problems and limitations

There are several problems that remain with the proposed methodology. The first is the question of chronological changes. The methodology does not take into consideration whether the understood dimensions of certain products changed over time. Furthermore, since this case study examines Iberia from 1670 to 1806, there is potential that some products were completely left out due to the time period examined. Many of the best primary sources for determining the dimensions of timber products come from the nineteenth century, and risk being somewhat removed from the reality of the eighteenth century, especially if products became more and more standardized over time. It is also possible that there were certain regional differences in products that have not been taken into consideration. In some cases, they have been taken into consideration, but are difficult to interpret, as is the case with the previously discussed 'Prussian' deals.

Another potential problem is that this case study only considers the Iberian Peninsula, and more specifically Spain, which may have had different interests than other major timber consumers such as England, the Netherlands, and France. While the timber products taken to Iberia represent the most common products in the STR, there is a risk that some lesser products may have been excluded. However, if a study includes a product that is not explored here, the same methods can be applied.

Although the author has made every effort to estimate the dimensions for certain products, these ultimately varied, sometimes significantly among different shipments of the same product. It was decided that it was better to underestimate than to overestimate, so when in doubt estimates were kept low. As a result, the methodology presented in this article remains purely a way of estimating the volume of timber products that passed through the Danish Sound and should not be taken as empirical fact.

Perhaps the greatest strength of this methodology is its flexibility. Products can be added or removed, and dimensions for calculating volumes can easily be changed. The best effort was made to make this estimate as accurate as possible since the author's study focuses solely on timber. Nevertheless, due to the spatial and temporal generalizations it involves, it should be considered more effective for larger datasets than for smaller ones where more precision is required.

Conclusion

Calculating the volume of timber products has been a great challenge for historians trying to interpret the data in the STRO. Most products were recorded in weights or volumes. These values have their own challenges, particularly regional differences in weights and measures. Timber does not fit in with other products because it was usually recorded in pieces and is therefore often left on the fringes of historical studies of the STR. However, the majority of timber products in the Sound Toll Registers implied certain cuts of wood with a predictable range of dimensions, so careful identification and research of these products yields a feasible estimate of volume that can be backed by historical and archaeological evidence. Using a good volume estimate, one can also arrive at weight, which allows timber to be combined with estimates of other products that have been proposed by authors such as Werner Scheltjens. While there are still issues with the methodology proposed in this article, it is likely the best way to estimate the volume of the timber trade represented in the Sound Toll Registers, and may therefore interest historians studying this traffic as well as environmental historians concerned with the impact of human demand on the world's forests.

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Nathan Gallagher has a BA in History from Indiana University and a Masters of Arts in Nautical Archaeology from Texas A&M University. He is currently engaged in a pre-doctoral Marie Curie fellowship in early modern history, which forms part of the European Union FP7 project 'Forest Resources for Iberian Empires: Ecology and Globalization in the Age of Discovery (ForSEAdiscovery)'.

Appendix. List of timber products sent to Iberia via Danish Sound 1670–1806 with estimated dimensions, volume, density, and mass per piece.

Product	length (m)	width (m)	thickness (m)	volume (m^3)	density (kg/m^3)*	mass (kg)
Balks	8.000	0.257	0.257	0.528	640	337.92
Boards, specified	4.896	0.343	0.026	0.044	575	25.300
Boards, unspecified or ordinary	4.115	0.343	0.026	0.037	575	21.275
Boat-hook shafts	7.810	NA	0.076	0.035	575	20.125
Clapboards	0.837	0.144	0.144	0.017	575	9.775
Compass timber and knees	2	0.2	0.2	0.080	700	56.000
Deals, Norwegian	3.35	0.229	0.038	0.029	575	16.675
Deals, ordinary or unspecified	3.658	0.279	0.038	0.039	575	22.425
Deals, Prussian	8.23	0.25	0.06	0.123	575	70.725
Deals, specified lengths	5.285	0.279	0.038	0.056	575	32.200
Deals, Swedish	4.115	0.343	0.026	0.037	575	21.275
French wood	0.994	0.17	0.17	0.029	575	16.675
Handspikes	2.600	0.1	0.1	0.020	575	11.500
Laths	1.400	0.038	0.03	0.002	575	1.150
Ledges	8.000	0.086	0.086	0.059	640	37.760
Masts	12.970	NA	0.320	1.040	575	598.000
Boat masts	6.290	NA	0.155	0.120	575	69.000
Oars	10.020	NA	0.075	0.044	700	30.800
Other ship timber	NA	NA	NA	1.471	700	1029.700
Planks and ship's planks	5.300	0.284	0.076	0.114	640	72.960
Planks, thick-stuff and wales	5.300	0.284	0.137	0.206	640	131.840
Pumps and pump wood	5.000	0.300	0.300	0.450	700	315.000
Quartered timber	8.000	0.129	0.129	0.133	575	76.475
Rafters	8.000	0.131	0.131	0.137	575	78.775
Spars	13.206	NA	0.223	0.520	575	299.000
Small spars and rods	4.720	NA	0.080	0.024	515	12.360
Staves, hogshead	1.212	0.118	0.042	0.006	700	4.200
Staves, pipe	1.585	0.118	0.042	0.008	700	5.600
Staves, barrel or unspecified	0.990	0.118	0.038	0.004	700	2.800
Treenails	0.866	0.041	0.041	0.001	700	0.700
Unidentified timber* **	4.115	0.343	0.026	0.037	575	21.275
Unprocessed or semi-processed timber**	8.685	0.332	0.332	1.471	640	941.440
Wainscot	3.658	0.279	0.026	0.027	700	18.900

*Density is approximate based on the wood a product is most likely made of. Pine: 575. Oak, beech, or ash: 700. Pine or oak: 640. Spruce: 515. *Sources*: Meier, *The Wood Database*, and Steffy, *Wooden Ship Building*, 256–9.

**Volume is estimated from figures in Boudriot, *The Seventy-Four Gun Ship*, 54. See explanation in text.

***Dataset contains a total of 3374 unidentified pieces; 3300 of these were listed as '*bonde bræder*', which literally translates to 'peasant boards' or 'farmer boards'. No historical references to this item were found. For this reason, unidentified timber was given the same dimensions as an ordinary board.