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Watermarks Galore. Observations on the Number and Homogeneity of Papers Used in Manuscripts and Incunabula

It is common knowledge that all sheets of paper made by hand bear—on their left- or right-hand side—a watermark, which, from the 14th century onwards, was considered a trademark.[1] When sheets are folded to form an individual quire and a group of quires then assembled into a manuscript or a printed book, the position and integrity of the visible watermark will vary depending on the book's format. Accordingly, the entire watermark appears in half of the leaves of an in-folio manuscript, whereas it is divided in two by the quire's fold in half of the leaves of an in-quarto manuscript, and divided into four in one of the inside corners of half of the leaves of an in-octavo manuscript, and so on. Consequently, if N_f equals the number of leaves, the total number of whole watermarks appearing in books will be, respectively, $N_f/2, N_f/4, N_f/8$.

That being said, one can go on to pose a very simple question: how many *different* watermarks might one expect to find in a book? This question, which ostensibly seems simple enough, is actually rather ambiguous. What is meant, exactly, by the phrase 'different watermark'? The differences one meets with can be broken down into three essential types:

– The motifs encountered represent different objects (*scales*, *ox head*, etc.).
– The motif represents one and the same object, but the designs show obvious morphological differences (e.g. *scales* with round or triangular trays;

1 In his treatise *De insignis et armis*, the jurist Bartolus de Sassoferrato mentions the existence and function of the watermark: 'Et, ut vidimus, quodlibet folium carte suum habet signum propter quod significatur cuius edificii est carta. Dico ergo, quod isto casu apud illum remanebit signum in quo fit, sive iure proprietatis sive iure conductionis, sive quovis alio titulo…'. This text is often quoted by paper historians: see Rückert 2006, 10–11.

an unadorned *ox head*, or alternatively one wearing a *crown*; a plain *anchor*, or alternatively one contained within a circle, etc.). Therefore, from hereon in we shall speak of *types* to designate the categories that each design can be placed in.

– Watermarks of one and the same type are very similar, but they are not positioned on the same half of the paper sheet, and/or they are orientated differently (e.g. a *pot* with a handle turned towards the centre rather than towards the edge of the sheet), and/or they present minor differences of either a morphological or dimensional kind. In such cases, we can speak of *variants*.

Unfortunately, in the first two cases it is practically impossible to ascertain the original place of origin of sheets, and to know, in particular, whether or not they are all the product of the same paper mill: it is known, in fact, that one and the same mill could simultaneously produce sheets marked with different motifs (for quality differentiation purposes),[2] and that, conversely, two different paper mills could manufacture sheets bearing the same motif, but enhanced with differences in accessory elements so as to totally eliminate the possibility of counterfeiting.

In the third case, one is often, but not always, dealing with 'twin watermarks'. The optimisation of work cycles in paper mills involved the contemporaneous use of two moulds in the same vat of paper pulp. Twin watermarks, positioned on different halves of the two moulds, are never identical, so one can easily distinguish the difference between them. Given that the sheets produced by the two moulds were immediately added to the same heap—the so-called *post*—it follows that an entire document will normally contain at least two twin watermarks, provided that it is composed of a sufficient number of leaves.[3] However, in reality the situation is a little more complicated, since not infrequently, and above all in printed books, one can encounter multiple variants closely mixed together within one and the same document,

2 This function is stipulated as an obligation in the Bologna Ordinance of 1398, so as to make it possible to distinguish premium quality paper from second-rate product (known as *fioretto*) and wrapping paper. For the published text, see Gasparinetti 1963; for a critical analysis, see Ornato et al. 2001.

3 When there are more than ten leaves—which is to say five paper sheets in an in-folio folding—the probability that one of the twins will be missing does not exceed 1/32, which is to say approximately 3%. This estimate is not valid if the twins are randomly distributed in the paper stock. In actual fact, this is not true: cases in which the same twin appears more than once in a row occur more often than the law of probabilities predicts (see Bozzolo / Ornato 1980, 135–145).

and it is impossible to match them up without running the risk of making an error. One can nevertheless establish that the variants always originated from the same paper mill, whatever their place of origin might be.

Given the existence of some doubtful factors, for now it makes sense to simplify matters by assigning to the term 'different' its more widely understood and strictly visual connotation, without considering the nature of the differences observed and, above all, the historic substratum underlying them.

Now, if we pose the question 'How many different watermarks might we expect to find in a book?' to two different researchers—one who regularly examines manuscripts, the other incunabula—we will certainly be surprised by their respective answers. The first will complain of a paucity of watermarks, whereas the second will speak of an abundance of them. However, it is highly likely that both will express reservations about the pertinence of such a question, and will tend to limit the field of inquiry to that which they are most familiar with, namely the dating of written documents through watermarks. It is well known, in fact, that the dating of a document is far more accurate and reliable when it contains numerous watermarks. Yet the question posed is far from irrelevant to paper historians, since it relates to the composition of paper stocks and, indirectly, to the structure of markets.

1 Measuring the heterogeneity of paper stocks

First of all, can one place one's trust in two manifestly subjective and contrary points of view? The answer is yes, but at the same time, no. Yes, if one is prepared to settle for a rough estimation based on a concrete experience; no, if one wishes to understand the significance of any potential differences, and above all to explain the reasons lying behind them. It is plain to see that in the latter case a complete answer, prompted by the question posed, can only be arrived at by means of a systematic and quantitative approach. Here, the term 'systematic' is intended to mean the opposite of 'anecdotal' (i.e. limited to single cases). In fact, one cannot content oneself by simply tallying up the number of watermarks observed in a few books and pronounce the outcome as the result of a count. The term 'quantitative' means that one has to provide a quantified synthesis of the results in statistical terms that makes it possible to arrive at a reliable conclusion. Now, even when the statistical concept is reduced to its simplest terms, this type of approach is not lacking in problems. The term 'statistic' means calculation, and calculation means measurement, in the broadest sense of the word. Therefore, one has to establish whether or

not a simple count is the best measuring system for making a tally of the different watermarks present in a document and, if not, whether it can be replaced by another indicator.

In statistical terms, one can consider a document, whether it be handwritten or printed, as a sample drawn from a larger population of paper. It is therefore admissible to state in advance that, tendentially, a document that contains more different watermarks than the population from which it is drawn—i.e. the paper stock—is qualitatively heterogeneous. Intuitively, one can equally suppose that the number of watermarks detected will depend on the size of the sample, which is to say the number of paper sheets contained in the document. Can one likewise affirm that, the size of the sample being the same, the number of watermarks detected in it will depend on the size of the paper stock? If one is speaking of a direct influence, the answer is negative, but one can nonetheless state that a large stock of paper has a greater chance of being heterogeneous.

In addition, if the number of watermarks detected in a document depends on the number of paper sheets it contains, we need a unit of measurement which is independent of that parameter and makes it possible to compare documents of different 'thicknesses': so one automatically thinks of the relationship between the number of different watermarks revealed and the number of paper sheets in a document, which is to say the percentage of different watermarks, a figure that should provide a *heterogeneity index* for the stock. The maximum value of such an index is obviously 100, a figure which would indicate that all the watermarks in the document are different. Unfortunately, as we shall see, it is necessary to raise some questions about the operational character of the said index.

Now that the theoretical aspects of the problem have been defined in a fairly concise way, we must ask ourselves whether, in practice, we are really able to provide an answer to our question by means of systematic investigations. The answer depends on the existence of repertories that provide a census of all the watermarks contained in a corpus of documents and which at the same time furnish the necessary elements that will enable one to determine the number of paper sheets, the format and the number of leaves in each document. Happily, such repertories exist, because on the one hand Martin Wittek has carried out a census of all the watermarks appearing in dated manuscripts held in the Royal Belgium Library (this repertory has been sys-

tematically perused, and the information entered into a spreadsheet),[4] whilst on the other we have available to us on the Internet a complete repertory of the watermarks contained in incunabula produced in the Middle Ages in the Low Countries.[5] In both cases, information on the format and number of leaves in individual documents is readily accessible to researchers.

Does the number of watermarks increase with the number of sheets contained in a book? Tab. 1, which concerns manuscripts, reveals that this is indeed the case (Tab. 1):

Manuscripts – Number of watermarks surveyed in relation to number of sheets				(tab. 1)
Format	**Number of paper sheets**			
	1–25	26–50	51–75	>75
In-folio	3	7	9	14
In-4°	3	6	(nd)	(nd)

Tab. 1: Manuscripts – Number of watermarks surveyed in relation to number of sheets

This result is not altogether surprising: if a ream of paper contains N different watermarks, the probability of seeing them appear at least once increases with the number of sheets used to make a book. Not surprisingly, one also observes that the result is the same for both of the formats most frequently employed.

Conversely, one finds (Tab. 2) that the heterogeneity index of the stock tends to decrease, which seems to contradict the previous result:

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4 Wittek 2003–2006. This repertory contains 1,183 reproductions (tracings). The systematic perusal was carried out by Anne Tournieroux within the framework of the European programme denominated 'Bernstein' (2003–2006), which culminated in the integration of four databases now available on the Internet (http://www.memoryofpaper:eu8080/Bernstein Portal/appl_start.disp). Last access 20/06/2020.
5 *Watermarks in Incunabula Printed in the Low Countries (WILC)*: http://watermark.kb.nl/ index.html (last access 20/06/2020). This repertory, created by Gerard van Thienen, contains more than 16,000 reproductions of watermarks (radiographs and rubbings) which are not all different, since the same watermark can appear in more than one edition.

Manuscripts – Heterogeneity index in relation to number of sheets				(tab. 2)
Format	**Number of paper sheets**			
	1–25	26–50	51–75	>75
In-folio	41.24	15.03	11.38	7.15
In-4°	32.13	16.16	(nd)	(nd)

Tab. 2: Manuscripts – Heterogeneity index in relation to number of sheets

The percentage of different watermarks, which exceeds 40% in the thinnest in-folio volumes, is no more than 7% in the thickest ones.[6] This is only an ostensible paradox, since if a stock of paper contains *N* different watermarks, once all those watermarks have appeared once, any introduction of a new sheet into the sample will not result in the introduction of a new watermark. Thus, the number of sheets in a document always increases faster than the number of new watermarks it contains, on condition, that is, that all the watermarks in the original stock of paper are different. In fact, statistical laws show that if a stock of paper contains four different watermarks in equal numbers, it will suffice to draw sixteen sheets in order for the observer to be certain of seeing all four watermarks emerge.[7] In such circumstances, if a book extracted from that stock is composed of fifty, or better yet one hundred sheets, the number of watermarks will never exceed four, and the percentage of different watermarks can only decrease.

In fact, this result makes it impossible to use the paper stock heterogeneity index as a universal estimation tool, because the comparisons are only reliable for volumes in which the number of sheets is more or less equal. For example, we notice that, within the same stock of completely homogeneous paper that contains only two twin watermarks, the index ranges from 20% for a volume that comprises ten sheets, to just 2% for a volume which comprises one hun-

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6 In the latter case, one is necessarily dealing with in-folio volumes, because there are too few in-quarto volumes in which the thickness exceeds 75 sheets: indeed, such a volume would have to be composed of more than 300 leaves.

7 To obtain this result, it is sufficient to calculate the probability of one watermark represented at a rate of 25% in a stock of paper never appearing in a sample of sixteen sheets. Binomial law tells us that that this probability is 1%; given that the stock contains four watermarks, the probability that at least one of them will not appear is 4%.

dred. It is plain to see that this index is just as biased as a full count of water-marks, and does not furnish any new information.

Actually, it would seem that there is no clear answer to the question 'How many different watermarks are there?' which is valid both in the general sense and in operational practice; indeed, all comparisons made between two documents of different thicknesses must necessarily be viewed with caution. Equally, we can see that, even if it were not biased, our index proves itself to be rather crude—as a matter of fact, it does not inform us on the degree of uniformity of the mixture of sheets. Indeed, one and the same result can conceal some very different situations: the frequency of the appearance of watermarks can be roughly the same or, conversely, one watermark might be massively represented whilst others only appear sporadically. Furthermore, we are no better informed on how 'close-knit' the mixture is: on the one hand, the same watermark can appear on a succession of consecutive sheets, but on the other changes might occur according to a sustained rhythm.

Estimates that take into account the various situations can certainly be envisaged, but they will run afoul of the fact that the requisite variables—the number of occurrences of each watermark, and the distribution of watermarks throughout the document—cannot be calculated by starting out from the data present in the specialised repertories. One should not, of course, blame their authors: it is not difficult to grasp how such surveys—which require a not negligible amount of additional work to compile—can be adjudged useless when the goal is to reproduce the greatest number possible of different watermarks. In fact, this process can only be put to work in targeted investigations.

Incunabula – Number of watermarks surveyed in relation to number of sheets				(tab. 3)
Format	**Number of paper sheets**			
	1–25	26–50	51–75	>75
In-folio	6	13	19	28
In-4°	6	14	18	19

Tab. 3: Incunabula – Number of watermarks surveyed in relation to number of sheets

Whatever the case may be, the same tendencies are observed in the corpus of incunabula of the Low Countries whose watermarks have been censused in *WILC* (Tab. 3 and 4). The tendencies are the same, but they are revealed on a different level. In addition, the highly divergent subjective estimates concerning the manuscripts and printed books are confirmed by statistical analysis: for books of the same thickness, roughly two times fewer watermarks are found for the manuscripts than for the incunabula:

Incunabula – Percentage of watermarks surveyed in relation to number of sheets				(tab. 4)
Format	Number of paper sheets			
	1–25	26–50	51–75	>75
In-folio	47.60%	35.07%	30.79%	20.29%
In-4°	70.98%	40.55%	29.39%	19.21%

Tab. 4: Incunabula –Percentage of watermarks surveyed in relation to number of sheets

Now that the difference between manuscripts and printed books has been confirmed, it seems only natural to ask what the reason behind it is, and to what extent it is representative of the composition of paper stocks.

If one disregards the reproduction technique, the manuscript document (book, register, etc.) and the incunabulum are two objects composed of bifolia assembled into quires, with clusters of such quires then being assembled into a book by means of a sewing process. From a structural point of view, they are similar objects in all ways; indeed, in both cases one is speaking of a *codex*. Even so, appearances can be deceptive, and where paper sheets are concerned, the difference is enormous.

By way of illustration, we can consider on the one hand an in-folio manuscript composed of 200 leaves—which is to say 100 sheets of paper (with the presumption that all the paper was purchased in one transaction)—and on the other hand a printed volume of the same format and with the same number of leaves, representing one copy of an edition of 500. In the hypothetical manuscript, any one of its constituent bifolia can be considered a sample which represents 1/500 of the ream of 500 sheets from which it was drawn. In turn, a bifolium in a quire of the hypothetical manuscript represents a 1/500 of the *same* ream, and so forth, so that the entire manuscript ultimately represents 20% of a *single* ream composed of 500 sheets.

In the hypothetical incunabulum, a bifolium always represents 1/500 of the ream. However, since our imaginary edition is composed of 500 copies, the immediately successive bifolium of the same quire represents 1/500 of a *second* ream, and so on, so that the total of 100 bifolia examined represents 0.2% of 100 reams, which is to say 50,000 sheets of paper. Therefore, each sheet of paper that forms the volume represents the tip of an iceberg, because in relative terms it is as small as the edition is large. Under these conditions, it should come as no surprise that in a less concentrated sampling a consistently larger number of different watermarks appears.

2 The composition of paper stocks: appearances and reality

Confronted with the disparity seen between the two types of document, can one argue, *ipso facto,* that the paper stocks used in the making of the manuscripts were more homogenous than those used to make the incunabula? Certainly not: such a hypothesis is quite simply not verifiable. Its verification is hindered by the fact that a manuscript document represents a *sequential* drawing of sheets from a *small* portion of stock, whilst an incunabulum is the product of a *systematic* drawing of sheets from a large portion of stock which, due to the fact that the printed sheets were not assembled into a volume strictly in accordance with the order in which they were drawn from the stock itself, can in practice equate to a random drawing of sheets.[8] Therefore, in the imaginary example described above, it will be sufficient for the paper stock to be composed of reams of strictly homogeneous content, with each ream carrying a different watermark, for our manuscript composed of 100 sheets to contain only one pair of twin watermarks, whilst all the sheets of the incunabulum, issuing from the same stock, should bear different watermarks. Consequently, all we can affirm is that the stocks of paper consumed in the manufacture incunabula were very far from being homogeneous.

That being said, from a historical perspective, it is legitimate to suppose that, prior to the rise of printing, small stocks of paper sold retail by a *cartolaio* ('paper merchant') were intrinsically more homogeneous than they were later on when massive stocks were purchased by wholesalers from paper mills and

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8 In other words, in the theoretical case under consideration, the sheet marked *a1* is the first of the first ream, with no guarantee that the sheet marked *a2* represents the first of the second ream.

subsequently resold to printers, because in the absence of the ravenous monster that the printing industry represented, the market was undoubtedly much less open and the supply sources more concentrated. Nevertheless, precisely towards the end of the 15th century, when the consumption of paper had greatly increased, the number of watermarks one can detect in manuscripts and chancery registers is still rather low, and so the quandary remains: one cannot be sure whether this dearth can be accounted for by a greater homogeneity of stocks, or by the sampling characteristics that hinder carrying out a deeper analysis.[9]

If one is prepared to trust the data presented in the repertories, a printed volume contains, on average, two times more watermarks than a manuscript volume of the same thickness. However, this observation is a little too simplistic, because the term 'volume', although being formally correct in both cases, does not reflect the same reality. Here, a concrete example provides proof that the situation is rather more complicated than one might first imagine. In 1481, the printer Johann von Paderborn[10] published in Louvain an in-folio volume composed of 132 leaves containing the treatise *Epitoma primae partis Dialogi de haereticis a Guilielmo de Ockam compositi*, compiled by Henri de Zoemeren, of which there are today 50 surviving copies (*ISTC*: ih00053000). The watermarks in this edition have been thoroughly surveyed and reproduced in *WILC*, but if one consults another repertory—Piccard on line (*POL*), which collects the reproductions made by the paper historian Gerhard Piccard[11]—one can see that certain watermarks originate from somewhere other than the 1481 edition.[12] *WILC* inventories

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9 This problem is far from being of little importance, because if the stocks were of different types, the existence of separate markets could quite reasonably be postulated, and by extension also that of different manufacturing standards in relation to the expected use.

10 Also called Johannes de Westphalia in repertories of incunabula.

11 This database, which contains more than 90,000 watermark reproductions, the majority of which are different, is not a simple duplication of the printed repertory (Piccard 1961–1997, 23 tomes collected in 17 volumes). On the one hand, the latter is not complete, whilst on the other it is not possible to establish a term-to-term correspondence between the two repertories, on account of the identification system being different (and parallel). Recently, *POL* has been merged with a much larger catalogue: *WZIS* (*Wasserzeichen—Informationssystem*: http://www.wasserzeichen-online.de /wzis/; last access 07/09/2021), which also contains a census of watermarks originating from a certain number of German libraries. Today, the number of watermarks reproduced in this new database totals 103,033.

12 Entered in Piccard's card index as 'Joh. De Westphalia 1481' and/or by the shelf number of the copy held in Stuttgart's Landesbibliothek: 8435.

29 different watermarks, and *POL* 30.[13] In strictly quantitative terms, the concordance between the two sources is excellent and the heterogeneity index of the stock (45%, as opposed to 31% for volumes of the same thickness) seems to be quite remarkable for an incunabulum composed of 66 paper sheets.

However, we are in for a bit of a surprise, because when one superimposes the images originating from the two watermark repertories, one notices that this pleasing concordance vanishes. To be sure, the list of motifs remains precisely the same: the letter *C*,[14] the letter *Y*, the letter *P*, the *pot*, the *crown*, the *wheel*, and *heraldic coats of arms*, and one can say the same of the types, with one exception,[15] but as soon as one 'drills down' to the level of variants, one notices that there are only 14 watermarks shared by the two sources; 16 watermarks do not appear in the *POL* catalogue, and 15 are not found in *WILC*.[16]

Is it the case, then, that the authors of the repertories were rather careless when it came to making reproductions of the watermarks? This hypothesis is certainly plausible: quite simply, it turns out that the copies examined were not the same, since one is kept in The Hague, and the other in Stuttgart. If one considers the total number of watermarks in one and/or the other copy, the number of variants reaches 45, and the disparity between the printed volume and manuscript increases by a considerable amount. This result is particularly impressive, but at the same time it serves to underline the futility of drawing a comparison between objects when the processes used to generate them have nothing in common: in one case a unique example, and in the other a vast ensemble composed of many hundreds of examples. What is important is the fact that the examination of a single copy is far from providing an exhaustive panorama of the paper stock used to manufacture an entire edition. It is this aspect of the problem that we shall examine in greater depth from now on.

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13 In fact, *POL* provides 50 reproductions drawn from this incunabulum, in which about twenty are in all likelihood duplicates.

14 Classed as the letter *D* in *POL*.

15 KB1721: a heraldic *coat of arms* containing a *fleur-de-lis surmounted by a cross*.

16 These numbers are necessarily somewhat subjective; in fact, when the watermarks are not definitively identified, it is not always possible to know whether one is dealing with different objects, or deformed versions of the same object.

3 The paper stock used in two Venetian editions

If the examination of a second copy implies a not inconsiderable enrichment of the watermarks surveyed, it is only reasonable to ask what would happen if the examination were carried out on a greater number of copies. Unfortunately, there are no other surveys of the Johann von Paderborn edition available to us. Nevertheless, we can still attempt to answer the question thanks to a specific investigation carried out 15 years ago on two editions, as part of the research project *Progetto Carta*[17] (the results of which have never been published).[18] The project consisted in surveying all the watermarks present in multiple copies of two incunabula published in Venice:[19]

BOCCACCIO, Giovanni, *Genealogiae decorum; De montibus, silvis, fontibus, lacubus, fluminibus, stagnis seupaludibus, de noniminibus maris*. Venice: Bonetus Locatellus for Octavianus Scotus, February 23rd, 1495 (*ISTC*: ib00753000). Six copies examined.

APULEIUS MADAURENSIS, Lucius. *Opera*. Ed: Johannes Andreas, Bishop of Aleria. Venice: Philippus Pincius, April 30th, 1495 (*ISTC*: ac00936000). Eight copies examined.

The two editions are in-folio format. The first is composed of 162 leaves, the second of 118. Since the volumes are in-folio, it follows that the printing of each volume required, respectively, 81 and 59 sheets of *reçute* or 'chancery' format paper, which was by far the most common size used throughout Eu-

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[17] Concerning this work, which was carried out under the aegis of Carlo Federici, the former director of the Istituto centrale per la patologia del libro (now known as the Istituto Centrale per il restauro e la conservazione del patrimonio archivistico e librario), see Ornato et al. 2001.

[18] An anticipated second publication, focused this time on the watermark-related aspects of the research project, foresaw further collaboration with the abovementioned institute, but sadly never materialised due to the unforeseen premature departure of its director. The data harvested from the edition of Boccaccio cited below were nevertheless used in a different perspective: (a) the validation of instrumental measurements (thickness, whiteness) carried out within the framework of *Progetto Carta* (could it be that the variability of the results, inevitably linked to states of preservation, more or less positively in relation to the history of each copy, compromises the measurements carried out on individual specimens? [see Ornato et al. 2001, II, 3–38]); and (b) an investigation of the systematic reduction of the whiteness observed in the second half of the edition (Ornato et al. 2001, II, 255–259).

[19] The survey was carried out by Paola Franca Munafò and Maria Speranza Storace.

rope. A copy of the edition of Boccaccio is therefore approximately 28% thicker than a copy of the work by Apuleius.

This observation is not sufficient to evaluate the thickness of the entire stock used for the printing, as this feature depends not only on the number of sheets in an edition, but also on the number of copies printed, that is to say the overall edition. Now, the latter datum remains unknown for almost all editions dating from this period. Nevertheless, we are not completely helpless when faced with a lack of this information. The two international repertories of incunabula—the *Incunabula Short Title Catalogue* (*ISTC*), and the *Gesamtkatalog der Wiegendrucke* (*GW*)—in effect provide the most complete list possible of the surviving copies.[20] Accordingly, one can count 215 conserved copies of the edition of Boccaccio, and 103 of the work by Apuleius.[21] In both cases, the numbers are very high, but the disparity observed between our two editions—a twofold difference—is too great to be the product of mere chance. Given that the two volumes were most likely targeted at the same readership, and that this factor to a large extent influenced the survival rate of the copies,[22] it is quite reasonable to suppose that the disparity observed reflects a significant difference in the number of copies printed of each edition, in a ratio of about two to one in favour of Boccaccio's work. As the edition of Boccaccio contains a greater number of leaves, the relationship between the thickness of the paper stocks should in fact be approximately 2.75/1.

Given that the paper stock used for the printing of the Boccaccio is much thicker, one would expect to find a greater number of different watermarks in it than in the edition of Apuleius. However, precisely the opposite turns out to be the case (Tab. 5).

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20 The two catalogues can be consulted online (http://www.bl.uk/catalogues/istc/index.html; http://www.gesamtkatalogderwiegendrucke.de/; last access 07/09/2021).

21 The number of surviving copies is probably not definitive. However, the possible future discovery of a few more copies which have not been surveyed up till now would not change the situation in a significant way.

22 Within the framework of the present contribution, it would take too long to examine in-depth the question of edition numbers and the survival of copies. For a list of editions for which the original number of copies is known, see Neddermeyer 1998, II, 753–762; for a diachronic overview of average edition numbers, see Neddermeyer 1996; for some more recent insights, see Ornato 2012, 178–187.

23 Although the examination of the edition of Apuleius was carried out on eight copies, the figures presented in the table relate to the first six, and therefore allow for an immediate comparison with the edition of Boccaccio.

Watermark	Boccaccio	Apuleius
Number of motifs, types and variants in six copies of editions of Boccaccio and Apuleius[23]		(tab. 5)
Motifs	5	7
Types	14	29
Variants	39	101

Tab. 5: Number of motifs, types and variants in six copies of editions of Boccaccio and Apuleius

Overall, the paper stock used for the printing of the Apuleius is 2.7 times more varied than the stock used to print the Boccaccio, even if, as we have seen, the stock used for the Apuleius is thinner. The greater heterogeneity of the paper stock in the edition of Apuleius manifests itself elsewhere at all levels: indeed, one counts 4.1 types per motif, as opposed to 2.8 in the edition of Boccaccio, and 3.5 variants per type, as opposed to 2.8.

Due to the rather particular characteristics of the paper making cycle, variants of one and the same type tended to be thoroughly mixed into all the stocks, because the watermarks originated from the same mill. Since the moulds were used in pairs, one should only count two variants per type: indeed, this is what one almost always observes in manuscripts. Conversely, in the incunabula one often encounters multiple variants of a type, because for a single stock of very important paper multiple pairs of moulds were produced which were used alternately or successively and could become muddled up over time.[24] Although the total number of variants is not without interest, if the aim is to evaluate the heterogeneity of the stock as a blend of papers of different origins, in the first place it is the melange of different types of watermark that we must pay attention to. Viewed from this standpoint, it is undeniable that the stock used for the Boccaccio printing is more homogeneous than that used for the Apuleius.

If one examines, sheet-by-sheet, the paper in six copies of the Boccaccio edition, one finds that, whilst not being entirely homogeneous, the succession of watermarks nevertheless exhibits a certain degree of consistency (Tab. 6).

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24 The superabundance of variants of the same type in one paper stock cannot be accounted for by the presence of moulds used in two or more pulp vats at the same mill, because at the end of the 15th century paper mills were equipped with only one vat.

Edition of Boccaccio: distribution of watermark types within the volume				(tab. 6)

Motif	Type	Quires		
		a–g	h–o	p–u
Scales	A1	54	18	6
	A2	6	6	14
	A3	18	96	2
	A4	–	5	7
	A5	–	–	10
	A6	–	–	7
	A7	–	–	18
Crown	B1	51	–	–
Ox head	C1	37	1	4
Hat	D1	1	42	61
	D2	–	–	2
Bell	E1	–	–	18

Tab. 6: Edition of Boccaccio: distribution of watermark types within the volume

This is the case, above all, for the composition of the stock. In fact, one observes that certain types are massively represented in the 484 sheets examined (Tab. 6): the *scales A3* (116 occurrences, equating to 24%), the *hat D1* (103, equating to 21%), and the *scales A1* (78, equating to 16%). Thus, three types alone monopolise 60% of all occurrences. If one considers each copy taken alone, the *scales A3* presents in a minimum of 18 occurrences, and the *hat D1* 15. This situation is stable: the hierarchy among the types remains the same, irrespective of the copy examined. Additionally, 70 sheets of the 81 that constitute the edition, equating to 86% of the total, present with the same type of watermark in the six volumes examined. What is more, the 'invariable' sheets (or, stated more precisely, those carrying the same watermarks) often succeed one another without a continuity solution. It is worth noting that this is the case with the *hat D1* and *scales A3* types: the former appears in two

blocks, one of seven and the other of five consecutive sheets;[25] the latter in a block of four sheets and in two blocks of three.

In addition, with the exception of the *scales A2* (which is actually rather sparsely represented), one observes that none of the types is equally distributed throughout the volume: the *scales A1*, the *crown B1*, and the *ox head C1* appear above all in the first third, the *scales A3* in the second, and the *hat D1* in the second and third, with the other types surveyed only appearing in the third, which therefore presents the most varied configuration (twelve types are present, as opposed to six in the first part, and five in the central part). In essence, we can confirm that the stock used for the edition was composed of fairly homogeneous blocks that succeed one another in a more or less orderly progression. The homogeneity of blocks is seldom disrupted, since only eleven sheets are not 'invariable', and in this instance they never involve more than two types of watermark.

The picture that the edition of Apuleius provides us with is altogether different. The most represented type (*hat C1*) only registers 32 occurrences in total (at best seven per copy), equating to 10%, and in order to reach 60% of the total one has to add the occurrences of nine types, even if three suffice for the edition of Boccaccio. More than anything, though, it seems that the mixture of types within the stock is much more 'intimate' than in the edition of Boccaccio: the proportion of 'invariable' sheets in the six copies does not exceed 41% (as opposed to 86%), and in fifteen sheets, equating to 25%, one finds three or four different types of watermark (Tab. 7).

Edition of Apuleius. Distribution of watermark types within a volume		(tab. 7)
Homogeneity	**Occurrences**	**Percentage**
Invariable sheets	24	41%
2 types per sheet	20	34%
3 types per sheet	6	10%
4 types per sheet	9	15%

Tab. 7: Edition of Apuleius. Distribution of watermark types within a volume

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25 Sheets *n2-o4* and *s2-t1*. Leaf *n2* is the second in the quire marked *n*, and so on, following the same pattern. Each volume is composed of quaternions.

The degree of heterogeneity is all the more remarkable given that, in the edition of Apuleius, the paper stock used to print one sheet represents, as we have seen, almost half that which was required to print one sheet of the Boccaccio. If we suppose that one sheet of the edition represents a sample of 600 to 1,000 paper sheets, the presence in one such sheet of three or four types of watermark in the six copies examined implies that the reams themselves contained more than one type of watermark, and therefore must have been 're-constituted' at some point or another whilst *en route* from the paper mill to the producer, and ultimately to the consumer.

All the above having been said, just like in the edition of Boccaccio, the most represented types of watermark appear successively in a consistent way within each copy (Tab. 8).

Edition of Apuleius. Distribution of watermark types within a volume				(tab. 8)
Motif	**Type** [26]	**Quires**		
		a–g	h–n	o–t
Scales	A4	27	1	1
Hat	C1	20	12	0
Scales	A6	16	1	0
Scales	A2	15	1	1
Ox head	B2	14	0	0
Hat	C2	13	8	0
Scales	A5	11	0	0
Scales	A8	0	4	31
Ox head	B5	0	0	19
Scales	A3	0	0	18
Ox head	B1	0 [27]	3	18

Tab. 8: Edition of Apuleius. Distribution of watermark types within a volume

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26 These occurrences appear in an initial binion lacking a signature that contains the preface by Jean André, Bishop of Aleria and the editor of the text, which could have been printed last.

4 Watermarks galore

How reliable are the results, then? Put another way, to what extent can a survey carried out on just six copies provide a complete picture of the composition of a stock (i.e. motifs, type and variants) used to print hundreds of copies?

In the first place, one can measure the input of variants collected through the analysis of six copies compared to the data one would obtain if one were to settle for one or two copies (Tab. 9).

Number of variants surveyed in relation to the number of copies examined								(tab. 9)		
Edition	**1 copy**			**2 copies**			**6 copies**	**Gain realised from 1 to 6 copies (%)**		
	min.	max.	av.	min.	max.	av.	total	min.	max.	av.
Boccaccio	19	26	24	24	34	27	39	50%	105%	63%
Apuleius	37	42	40	58	67	62	101	140%	173%	153%

Tab. 9: Number of variants surveyed in relation to the number of copies examined

The average gain[28] (Tab. 9) is not negligible, but one can immediately see that it is much greater for the edition of Apuleius than for that of Boccaccio. Furthermore, Chart 1 shows that if one were to examine a greater number of copies, the number of variants would very likely continue to increase; this is the case for the edition of Apuleius in particular, where the addition of two new copies to the six already examined results in an increase of 20% of the number of variants already recorded.

Is it possible, then, to predict the extent to which the examination of additional copies might be worthwhile? In practice, the number of different watermarks found in a single copy can certainly provide a useful indication in

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27 It goes without saying that these types are all different from those surveyed in the edition of Boccaccio, even if they bear the same names.

28 When one examines six copies, the average number of different watermarks per copy is obtained, quite obviously, by calculating the average for the six copies. The average number when one examines two copies is obtained by calculating all the pairs that can be made starting out from six copies (in this case 15, according to the general formula *N (N-10/2)*.

the first instance: the larger the stock, the more likely it is, in fact, that it will be heterogeneous.[29]
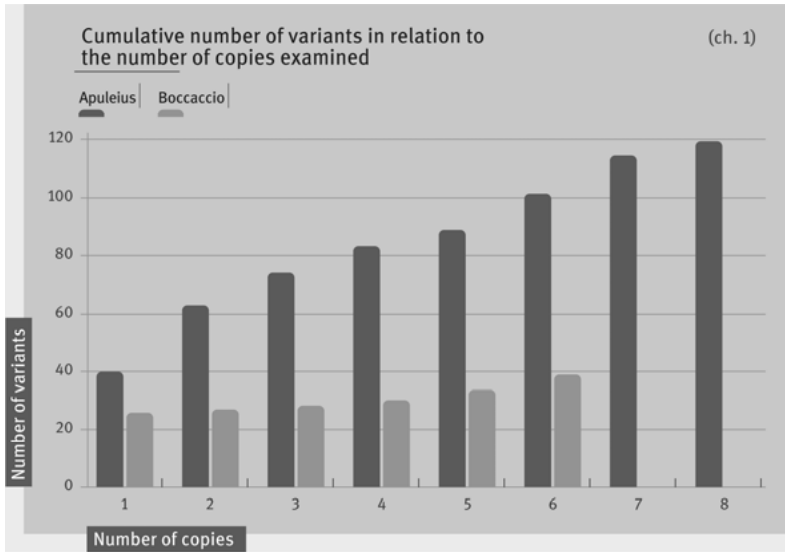

Chart 1: Cumulative number of variants in relation to the number of copies examined

Starting immediately from the first copy, one can see that the paper stock of the edition of Apuleius appears more varied that that used for the Boccaccio, and this remains the case when one examines the new copies. Nevertheless, the edition of Henri de Zoemeren discussed above (p. 158 ff.) contradicts what common sense would normally suggest: it carries more motifs (10) than the other two editions (Apuleius 7; Boccaccio 5), but considerably fewer types (10, as opposed to 29 and 14), and both of the two copies examined present 30 different variants, in contrast to 40 and 24 on average for the edition of Apuleius and that of Boccaccio respectively. Thus, one can see that, in absolute terms,

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29 This is not so in theory: one can well imagine a volume composed of 100 sheets in an edition of 500—the printing of each sheet would thus require one ream of paper—where the paper of each ream would bear a different watermark, but the contents of each ream would be perfectly homogeneous. In this case, one would survey 100 different watermarks in one copy, but the gain made by examining other copies would be strictly nil.

the edition of Zoemeren finds its place between the two other editions, although it is closer to the that of Boccaccio than that of Apuleius.[30]

However, this situation changes when one considers two copies; indeed, the gain made when a second copy is examined is only 13% on average for the edition of Boccaccio, whereas it increases to 55% for that of Apuleius. For the edition of Zoemeren, the gain is 50%, a figure which is much closer to the Apuleius than to the Boccaccio. One can therefore reasonably assume that the examination of several copies of the Zoemeren would be more profitable in terms of the acquisition of new watermarks, whereas the same operation would be much less rewarding for the edition of Boccaccio.

In fact, the foreseeable gain can be estimated by measuring the degree of similarity between two copies. This can be calculated by using a simple formula[31] (Tab. 10): a weak resemblance presages a heterogeneous stock, and vice versa.

Coefficient of similarity between two copies[32]			(tab. 10)
Editions	**Resemblance coefficient between two copies**		
	min.	max.	average
Boccaccio	47%	75%	64%
Apuleius	24%	43%	32%
Zoemeren			31%

Tab. 10: Coefficient of similarity between two copies

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30 We note that the number of paper sheets is not very different in the three editions (Zoemeren: 66; Apuleius: 59; Boccaccio: 89). It follows that this parameter cannot exert an influence on the number of watermarks surveyed.
31 Statistical literature offers several formulae which make it possible to measure this kind of resemblance. For our purposes, it seems to me that the most relevant among these is Jaccard's Index: *NFC/NFT*, where *NFC* is the number of watermarks shared by the two editions, and *NFT* the number of different watermarks surveyed in both of the copies.
32 The coefficient is calculated for each of the pairs of copies, which can be obtained using the formula *N.(N-1)/2*—in our case, 15 pairs. The value of the coefficient is variable, as the copies do not all resemble each other to the same extent. The table presents the largest and smallest degrees of similarity observed between two pairs, as well as the average value of all the coefficients obtained.

In essence, if one takes into account the fact that the edition of Zoemeren, of which 50 copies are conserved, was without doubt smaller than those of the other two works, which would imply that a smaller amount of paper was consumed, one can reasonably suppose that the stock used by Johann von Paderborn was less heterogeneous than that used for the Apuleius. This kind of estimate therefore seems to be fairly good, but it presupposes that the watermarks in two copies are surveyed. Now, this happens to be the case for a good number of editions whose watermarks have been surveyed by *WILC*, which therefore clears the way for a systematic investigation of the nature and structure of the stocks of paper imported by the Low Countries.

Once it has been established that stocks of paper delivered to the printer were as often as not heterogeneous to varying degrees, a question naturally comes to mind: how many copies would have to be examined in order to arrive at a more or less exhaustive picture of a stock of paper? Common sense provides an initial answer: the more a stock is heterogeneous, the more the number of copies to examine becomes important—which means, in fact, that the number of copies to examine is negatively correlated to the frequency with which a particular watermark appears in a stock. Thus, a watermark that only appears a few times in a hundred reams of paper would very likely pass unnoticed if one were only to examine a few copies. To this obvious objective criterion, we can add another (which depends on the exigencies of the observer), namely the number of copies to examine depends equally on the level of certainty one wishes to attain. In the sphere of the human sciences, a threshold of certitude which is considered acceptable for statistical purposes is broadly speaking 95%.[33]

This problem is easy enough to model: one has only to apply the binomial probability law. Thanks to this law, we can know in advance the probability of an occurrence of a *P* probability—called a 'success'—occurring *N* times (or at least *N* times, or none at all) in a series of repeated tests. Thus, we can know in advance the probability of the tails side of a coin coming up ten times in a series of fifteen coin tosses, given that the probability of tails appearing with each coin toss is 50%. Now, one can liken the examination of a sheet of paper in a copy of a book to a test in which a variant of a watermark has a *P* probability of appearing in accordance with its frequency in the stock, and pose the following question: how many copies must one examine for a particular variant of *F* frequency in the stock to appear at least once with a 95% degree of certitude?

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33 This threshold can only increase to the extent that the making of an error will not result in any serious consequences. Most people would not board an aircraft if they knew the risk of it crashing was 5%, though!

The answer to this question is rather surprising: if one examines six copies, to be almost certain that one variant will appear at least once in a given sheet,[34] the frequency in the stock has to be at least 40% (32% if one examines eight copies, as we did in the case of the edition of Apuleius). Clearly, the variant can also appear when the frequency is lower, but not with a level of certitude of 95%. Likewise, the calculation demonstrates that one would have to examine at least 26 copies in order to be practically certain of seeing a variant appear at least once should its frequency in the stock used to print a sheet be 10%, and 59 copies should its frequency be 5%. One might object that a rate of 10% is not very high, but despite this, in an edition of one thousand copies one is speaking of one hundred sheets of paper that would be far more likely to escape detection if one were limited to six copies—indeed, the probability of detecting their presence in a stock would only be 47%. Finally, the fact that six attested specimens of the same sheet all carry the same watermark almost guarantees that the frequency of the latter in the stock will not be lower than 60% (70% if one examines eight copies), but it will not guarantee that it will reach 100%. To be 95% certain, one would have to examine at least 50 copies.

All this leads us to make a simple observation: in many cases, taking into account the fact that the number of known copies is very seldom sufficiently high, it would be impossible to know with a satisfactory degree of certitude the full composition of a stock of paper, even if one could examine all the surviving copies. In any event, given that (practically speaking) it is not feasible to examine a large number of copies of each edition, it is pointless to dig any deeper, since one would only lose one's breath (as it were) in an impossible quest to achieve an exhaustiveness whose benefits are far from being clear. All that one must remember is that in certain cases, such as the edition of Apuleius, the examination of one copy alone will only provide access to a little more than a third of the number of variants represented in the stock, and without doubt fewer if one considers that the addition of each new copy will be accompanied by its share of new variants.

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34 One must be beware of the fact that this probabilistic reasoning should not be applied to the entire copy, but instead to individual sheets, because the examination is performed sheet-by-sheet. Indeed, let us consider the imaginary case of a volume composed of 100 sheets printed in an edition of five hundred copies, where each ream would bear a different and unique watermark. Each watermark would therefore have an overall frequency of 1/100, and so (in theory) would have very little chance of appearing if one were not to examine a large number of copies. However, the theory is only valid if the watermarks are distributed uniformly throughout the stock. Now, since its frequency varies, depending on the sheets, from 0 to 100%, from a logical standpoint it is a sure thing that it will appear as soon as the first copy is examined.

That being said, the examination of just one copy is already sufficient to allow one to form an idea of the fundamental structure of the stock, and to know the motifs and types of watermark that form its 'backbone'. In fact, the paper stock cannot be likened to a pack of cards which is perfectly shuffled: observation shows that it is 'structured', in that a certain number of motifs and types predominate, whereas others only appear sporadically, and the same is true of the variants; for each type of watermark there is always a pair of twins whose frequency of appearance is overwhelmingly in the majority. In fact, the stock is almost always composed of 'blocks', namely reams containing a predominant watermark which are used in succession in accordance with the progress of the work (assuming that the work proceeded in tune with the natural sequence of the text). Thus, certain types of watermarks appear at the beginning of a volume and then disappear, to be replaced by others.

Accordingly, the degree of heterogeneity of the stock can be broadly understood and approximated by examining just one copy. The examination of several copies serves to determine how 'close-knit' the mixture is within the blocks. All the data can be presented in a matrix that can be read both vertically (the succession of watermarks within one and the same copy) and horizontally (an overview of the watermarks in the same sheet in the copies examined). In this way, one can clearly apprehend the high degree of fragmentation of the stock used in the edition of Apuleius (Tab. 11).

Edition of Apuleius. Survey of the types of watermark in eight copies (excerpt) (tab. 11)

Sheets	Copies 1	2	3	4	5	6	7	8
i1	C1	C1	B6	B6	C1	C2	B3	B6
i2	C1	C1	C1	C1	C1	B3	C1	B3
i3	E1	E1	C2	C2	C2	C2	C2	C2
k1	A2	B1	C2	B4	C2	B4	B4	C2
k2	B4	B1	B1	B7	B4	B4	B4	B4
k3	B3	B3	B3	B3	B3	C1	B3	B6
l1	A7	A7	B6	B6	B8	B6	A7	B6
l2	F1	B6	B6	B8	A7	F1	B6	B8
l3	F2	E1	E1	E1	A7	B9	F2	E1

Tab. 11: Edition of Apuleius. Survey of the types of watermark in eight copies (excerpt)

5 Heterogeneity of stocks, paper quality, publishers' strategies

Once it has been established that the stocks used in the incunabula were practically always heterogeneous, and above all to some extent varied, one should enquire what the underlying logic of the phenomenon might be (if, indeed, one exists).

The heterogeneity of the stocks is not the result of a strategy employed by printers who, by scattering their financial outlay, preferred to purchase relatively small amounts of paper in accordance with their needs. This hypothesis does not hold water, for a simple reason: the division of labour was highly developed in the printshops; several editions could be in production on multiple presses at the same time, and two or more parts of one and the same edition were often distributed among two or more teams that worked in concert. On the other hand, archive documents confirm that printers planned in advance the amount of paper that would be required to realise a publishing project, as well as procurement methods. In fact, the work of a printing shop of any importance never ceased, so an uninterrupted flow of paper was required.

Heterogeneity is therefore an intrinsic characteristic of stocks assembled in advance, without doubt by wholesale merchants. The production of a single mill—which was not reserved for an individual customer, a fact shown, in the repertories, by the wide geographical distribution of documented usages of identical sheets—was insufficient to satisfy significant needs in a very short period of time. Additionally, it was essential to harness the output of several mills.

Nevertheless, as we have seen, certain stocks exhibit a closer-knit mix than others. Why? To answer this question, we will have to examine the overall composition of the stock used in the editions of Boccaccio and Apuleius. If one considers the motifs represented, a good number of them are shared by both editions: *scales within a circle*, *ox head*, *cardinal's hat*, *crown*. In both cases, the *scales* motif is sweepingly predominant. This should come as no surprise: the bulk of Venetian incunabula produced in the last decades of the 15th century present with the same design (to which one must add, albeit rarely, the *anchor within a circle*). All the motifs are widely documented in the output of mills located on Lake Garda,[35] which not only supplied Venice, but also Austria, southern Germany, Dalmatia and the Ottoman Empire (Tab. 12).

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[35] The watermarks originating from this region have been catalogued by Leonardo Mazzoldi (Mazzoldi 1990–1991).

Watermark content of Venetian incunabula (over the period spanning from 1491–1500) compared with editions of Boccaccio and Apuleius   (tab. 12)

Motifs	Editions 1490–1500	Apuleius	Boccaccio
Scales	53%	46%	55%
Ox head	13%	26%	9%
Hat	14%	15%	22%
Anchor	4%	0%	0%
Crown	3%	4%	10%
Other motifs	13%	8%	0%

Tab. 12: Watermark content of Venetian incunabula (over the period spanning from 1491–1500) compared with editions of Boccaccio and Apuleius

Even if the basic trends roughly correspond to the physical make-up of the Venetian market, one nevertheless observes that the structure of the stock in the two editions is not exactly the same. The frequency of the *ox head* is higher, on average, in the edition of Apuleius, and lower in that of the Boccaccio; similarly, the frequency of the *hat* and the *crown* is higher, on average, in the edition of Boccaccio. Can this be the product of pure chance? Perhaps not.

Within the framework of *Progetto Carta*, the examination protocol for papers involved two measurements which were carried out with precision instruments: thickness and degree of whiteness.[36] Now, concerning the latter parameter, it appears that watermarks are not all on an equal footing. Indeed, one notices that the sheets bearing the *hat* and the *crown* are, on average, whiter than those bearing the scales motif and, above all, the *ox head* (Tab. 13). At a global level, then, there exists a correlation between the watermark motif and the whiteness of sheets. To be sure, this is a statistical trend: one cannot expect that every sheet bearing the *crown* will be whiter than every sheet bearing the *ox head*.

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36 For details of the instrumentation and the measuring protocol employed, see Ornato et al. 2001, I, 39–61.

Venetian editions (1491–1500). Whiteness of sheets in relation to watermark motifs[37]   (tab. 13)

Watermark	Whiteness
Scales	71.83
Ox head	70.39
Hat	73.79
Crown	72.24

Tab. 13: Venetian editions (1491–1500). Whiteness of sheets in relation to watermark motifs

Now, one will notice that in the edition of Boccaccio the watermarks linked to the whitest papers are better represented. Likewise, one notices that, irrespective of the number of each watermark in a copy, the paper of that edition is whiter overall (75.57 as opposed to 73.39, the difference being 1.78). If one calculates the weighted average, which takes into account the effect of each watermark, the difference increases to 3.45 (75.98 as opposed to 72.53). There is therefore clearly a form of synergy at play between the two phenomena: in the stock of the two editions, the watermarks represented are roughly the same, but the quality is consistently better in the Boccaccio (see Tab. 14), which furthermore favours the watermarks linked overall to the whitest paper.

Editions of Boccaccio and Apuleius: average whiteness of paper in the most frequent motifs   (tab. 14)

Watermark	Boccaccio	Apuleius
Scales	76.18	73.22
Ox head	77.02	69.93
Hat	74.93	74.55
Crown	77.19	73.86

Tab. 14: Editions of Boccaccio and Apuleius: average whiteness of paper in the most frequent motifs

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37 The data concern the period covered by our two editions. However, the same trend is seen in the preceding years.

The sole exception is represented by the paper bearing the *hat* motif, whose quality in the edition of Boccaccio seems rather mediocre compared with the papers bearing the other motifs. This contrasts with what one observes in the edition of Apuleius, and in the production in general. This exception is, however, easily explained: indeed, starting from quire *n*, which corresponds to the second half of the edition, the *hat* motif ceases to appear. In this second half, the whiteness of the paper is markedly lower. This decrease affects all the copies examined, and above all affects the watermarks that were already present in the first half (Tab. 14).[38]

One must therefore conclude that the quality hierarchy applies just as much, if not more so, within each watermark motif as it does between the motifs themselves. In other words, the printer of the edition of Boccaccio chose, for each watermark motif, the superior quality product and used more paper whose watermarks are normally associated with better quality.

Now, even though the watermark content is not all that different in the two editions, given that the quality gap is so obvious, one must ask oneself whether or not the degree of homogeneity of stocks, which is different in the two editions, is linked to the whiteness of the paper.

In Chart 2, which relates to the Venetian editions examined during the course of *Progetto Carta*, the curves have been plotted by separating the editions into two categories: those in which the relationship between the number of watermarks (motifs and types, without taking into account the variants) and the number of sheets of paper is less than 15% (homogeneous stocks), and those in which the percentage is higher (heterogeneous stocks).[39] The qualitative difference between the stocks is quite clear.

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38 Concerning this issue, see Ornato et al. 2001, I, 255–261. The cause of the phenomenon cannot be identified, but there can be no doubt that it is not related to the intrinsic quality of the paper stock.

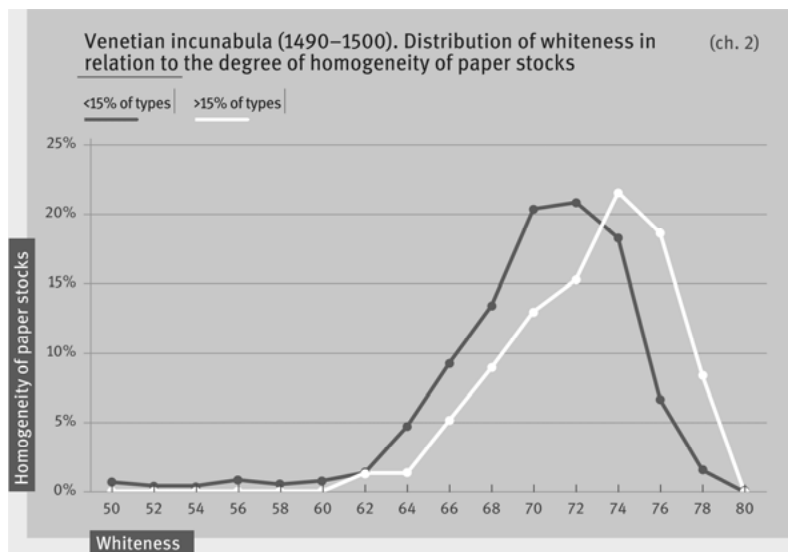**39** These percentages only relate to the sole copy that was examined.

Chart 2: Venetian incunabula (1490–1500). Distribution of whiteness in relation to the degree of homogeneity of paper stocks

Tab. 15 helps us to better understand the way in which the phenomenon operates. One notices that the effect of the variable 'homogeneity/ heterogeneity' manifests itself in all cases, irrespective of watermark motif, and irrespective of the quality of the edition:[40] the *ox head*, whose whiteness is lower than the average, is far more frequent in the heterogeneous stocks, as in the edition of Apuleius, whereas the *hat*, whose whiteness is superior, is above all frequently seen in the homogeneous stocks, as in the edition of Boccaccio. Likewise, the stocks are a lot more heterogeneous in the 'standard' editions than in the 'ambitious' editions. Finally, one notes that the effect of the 'heterogeneity' factor does not eliminate the impact of the other factors, but instead constitutes a sort of aggravating circumstance: the 'ambitious' editions always exhibit the best whiteness values,

40 The two categories—'ambitious editions' and 'standard editions' (editions of lesser quality being absent from the corpus examined)—were defined on the basis of four 'editorial parameters'. Judged to be 'ambitious' are Venetian editions which present at least three of the following characteristics: more than 80 surviving copies (disseminated); less than 48% of the copies currently situated in Northern Italy (exportation); pages holding fewer than 50 lines (line density); space reserved for opening initial that occupies vertically more than 15% of the number of lines per page (overt sumptuousness). The editions of Boccaccio and Apuleius both belong to the 'ambitious' category, albeit according to different parameters and to varying extents.

regardless of the homogeneity of the stocks. Concerning the qualitative hierarchy of the watermarks, namely the gap between the watermark motif which is on average the whitest (*hat*) and the least white (*ox head*), this is far more pronounced when the stocks are heterogeneous (gap = 1.06, as opposed to 3.06). This would seem to indicate that the quality loss mainly affects the watermarks usually associated with 'good paper', which was mixed with 'second class' product with the aim of creating roughly uniform stocks.

Venetian incunabula (1490–1500). Whiteness variation in relation to the homogeneity of paper stocks				(tab. 15)
	Frequence in the stocks		**Whiteness**	
	Homogeneous stocks	Heterogeneous stocks	Homogeneous stocks	Heterogeneous stocks
Total sheets	39.59	60.41	74.12	71.19
Scales	38.10	61.90	74.21	70.84
Ox head	32.89	67.11	72.01	70.79
Hat	49.44	50.56	75.07	71.85
'Ambitious' editions	40.38	59.62	73.62	72.53
'Current' editions	29.84	70.16	71.19	69.88

Tab. 15: Venetian incunabula (1490–1500). Whiteness variation in relation to the homogeneity of paper stocks

All of these observations point towards the same finding: whilst being rendered necessary by the difficulty of procuring paper from a sole local supplier, the mixing of different papers in stocks also provided a way of standardising the characteristics of sheets, although the end result was in any event inferior (even if it should be remembered that we are speaking of Venice, the domain of high end products). Mixing was in all ways the rule: of the few dozen editions printed in Venice from 1490 to 1500 and examined during *Progetto Carta*, only three were printed on a paper stock which, in the section of the volume examined, proved to be entirely homogeneous.[41] It should come as no surprise that these volumes score

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41 *Etymologicum magnum* (in Greek). Venice, Zacharias Calierges, 1499 (*ISTC*: ie00112000), *fleur de lis*; Albertus Magnus, *Summa de creaturis*. Venice, Simon de Luere, February 16th, 1499

the best values with respect to whiteness. However, in the majority of cases the stocks show a rate of fragmentation higher than 15% and, from this standpoint, the edition of Apuleius sits at the top of the scale, with 23 types on 59 sheets, equal to 39%.[42] Given that the examination of this edition revealed that the same sheet could be marked by two or more types of watermark, and taking into account that it can be safely estimated that between 600 and 1000 copies were printed,[43] there can be no doubt that the reams themselves did not always contain a unique watermark type, which suggests that they were repackaged (partially, at least) subsequent to leaving the paper mill.

How, then, was the mixing process carried out? Obviously, it is impossible for us to know, because we are completely ignorant of what actually took place between the moment when the paper left its place of manufacture and the moment it arrived at the printers. Furthermore, we do not know what happened within the paper mill prior to the product being delivered to the buyer. To be sure, we know that one and the same mill could produce writing paper, intermediate quality paper (known as *fioretto* in Italy), and packing paper,[44] all in at least two formats. However, within the 'writing paper' category, production quality was far from homogeneous, even within one and the same paper mill; indeed, business contracts of the period show us that, for sheets of the same dimensions, variations in the weight of reams—the only objective parameter that could be measured at the time—and therefore also of price, could be considerable.[45] Furthermore, it was likewise difficult to guarantee a highly standardised output, since numerous factors could exert an influence on the whiteness of sheets, such as the quality of rags, water purity, sizing and drying. Seasonal factors in particular must have played an important role.[46] It is therefore quite reasonable to suppose that the output emanating from the same pair of moulds could have been hierarchically hand-selected by the paper maker in accordance with a pre-determined quality standard which had to be met. If the sheets bearing the mark of the *hat* or the *crown* were generally whiter than those bearing the *scales* and, above all, the *ox head*—since that was the aim—the least successful of the *scale* sheets could be

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(*ISTC*: ia00334000), *scales*; Theodorus de Gaza, *Grammatica introductiva* (in Greek), Venice, Aldus Manutius, December 25th, 1495 (*ISTC*: id00426000), *hat*.

42 In the first copy examined. Only four editions fared worse.

43 Taking into account the likely rate of conservation for this type of edition; the rate lies towards the top end of the scale.

44 As well as more specific products, such as packing boxes, playing cards, and window paper.

45 For the variations observed in the Salò region—which supplied Venetian printers with paper—see Ornato et al. 2001, I, 388–389.

46 See Ornato et al. 2001, II, 205–212.

less white than the best *ox head* sheets (Chart 3). This is exactly what one observes in the two editions under discussion in the present contribution.

From the printers' perspective, more than anything it was necessary to offer paper whose overall quality was well adapted to the needs and financial capacity of readers. That being said, it was of equal importance to prevent readers from being disappointed by visible differences in the quality of sheets within one and the same edition.[47]
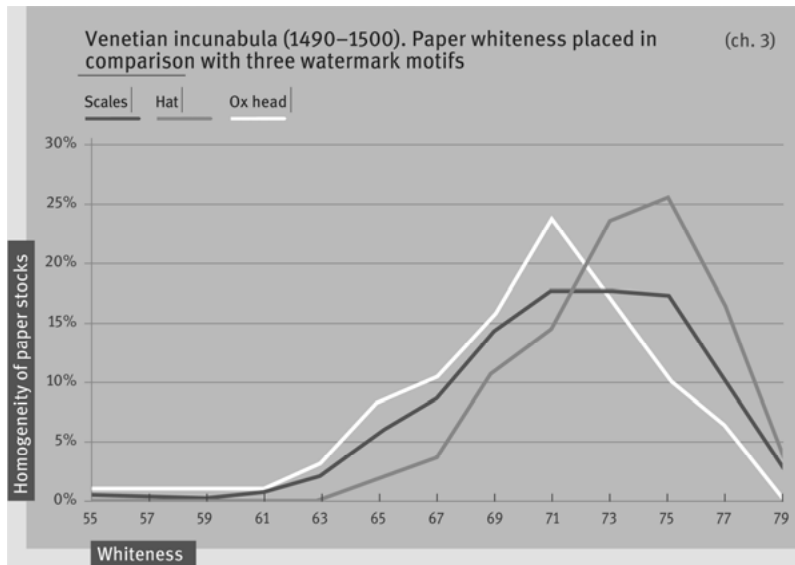

Chart 3: Venetian incunabula (1490–1500). Paper whiteness placed in comparison with three watermark motifs

To achieve this end, there were only two possible solutions available: (a) to set about buying a good number of reams of homogeneous paper, or (b) to have access to a stock of paper which had been mixed beforehand and consisted in sheets

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47 In any event, a selection was carried out so as to eliminate waste material (scrap paper) which, proscriptions notwithstanding, people tried to introduce to the marketplace. The introduction of a certain amount of scrap paper into reams of good quality product—strictly prohibited in the 14th century in Bologna—was a common practice starting from the 16th century. The phenomenon was also recognised and regulated in the 18th century in the Grand Duchy of Tuscany. Concerning this matter, see Ornato et al. 2001, I, 200–204.

originating from different sources. The second solution was not available to printers, but it could be implemented by wholesalers who obtained their supplies from mills located in the Garda region.

The first solution was not easy to achieve, on account of the fact that it was difficult to monopolise the entire output of a mill over a not inconsiderable length of time. This solution was therefore only practicable when a project made it worthwhile: namely when pursuing very ambitious editorial goals, which was the case, in particular, for volumes in Greek. Therefore, the printer's investment in paper could be very heavy, which explains the rarity of homogeneous stocks in the corpus assembled for *Progetto Carta*. In fact, in the majority of cases, printers had to settle for essentially heterogeneous stocks, available as and when they were required, whose quality decreases with the degree of intimacy of the mix.

So, the printers procured their paper supplies from a marketplace that was adapted to their needs. It is for this reason that, the origin of the paper being the same, roughly the same watermarks were present in all the printing ateliers—*scales*, *ox head*, *hat*, and sometimes a small complement of the *crown* and the *anchor*—but with an overall predominance of the *scales* which, as can be seen on the chart, covers a quality range which also extended to that covered by the *hat* and the *ox head* combined. In the stocks assembled by the wholesalers, calibrated in accordance with the quality standards sought by the printers, the only variation was the diversity of the mixture and the respective share of the principal watermark motifs, as we have seen in the editions of Boccaccio and Apuleius.

In conclusion, the tally of different watermarks in the manuscripts, owing to the small quantity of paper used and in the absence of economic considerations, is only of secondary interest. On the other hand, the same issue is in an entirely different league of interest when it comes to printed books, where the financial outlay negotiated was always considerable and three parties were involved: the papermaker, the middleman and the printer (the readers being the ultimate judges). Therefore, this qualitative parameter should be considered an accurate source of information both for the history of paper and for that of the book. Even though the analysis provided in the present study focuses on Venice, there can be no doubt that the practice of mixing different papers was not restricted to that city alone—indeed, given that the same problem requires the same solution no matter where it is encountered, this approach without doubt represented the rule in all the important printing cities whose production was fed by the chief papermaking centres. Consequently, it is easy to notice at first glance the existence of the same phenomenon in the *WILC* repertory. The whiteness of sheets is not included among the data collected, but since we have established that the degree of intimacy of the mix is partly correlated to this pa-

rameter, we could use it as an indirect indicator to serve as a starting point to conduct a wide-reaching enquiry into the qualitative characteristics of the paper used in various cities and within different printing ateliers, both synchronically and diachronically. Despite being less detailed than the study conducted during *Progetto Carta*, such a research project would have the advantage of addressing a much larger number of volumes.

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