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# THE SHAKESPEARE AUTHORSHIP QUESTION

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## Abstract

Many in academic world accept as fact that William Shakespeare of Stratford-upon-Avon was the pen behind such works as *Romeo and Juliet*, *King Lear* etc. However there has been a debate dating back to the 18th century about whether the works attributed to the famed playwright were actually composed by another writer. The debate thus far has been focused on the lack of historic records concerning Shakespeare's life, as well as the evidence of a level of higher learning present in Shakespeare's works inconsistent with Shakespeare's background. This paper however will use modern text-analysis and datamining techniques to analyze the works attributed to Shakespeare and several leading alternative candidates in an attempt to provide a more concrete answer to the authorship question.

## 1 Introduction

The Shakespeare authorship question has mainly been approached from a historical point of view [11]. The work attributed to Shakespeare shows a knowledge of geography, foreign language, politics, and an immense vocabulary that many find inconsistent with what's known about Shakespeare's education. Shakespeare in his will also makes no mention of his shares in the Globe theatre, books, letters, or any of the 18 unpublished works at the time of his death. However, there is no one piece of concrete evidence that conclusively tips the argument either way. The arguments of many *Anti-Stratfordians* are simply based on a subjective impression of Shakespeare's work [12].

The purpose of this paper is then to apply modern text analysis techniques using the R statistical package to compare the works attributed to Shakespeare to those of leading alternate candidates such as Sir Frances Bacon, Christopher Marlow, and Edward de Vere. We compare writing styles by using quantifiable measures, that is character usage, word length, and percentage of unique words.

## 2 Data

Our data on Shakespeare's plays was pulled from MIT's online repository of Shakespeare's works [9]. The total of 37 works are available in HTML format which we then ran through a Ruby script to remove the HTML tags, stage directions, and character

names that precede spoken lines. The works were then loaded into R using the TM text mining library and run through a stemming and stopword removal algorithm as well as a conversion algorithm to map all characters to lowercase. A collection of five poems and a number of sonnets were taken from a different website [10], but were also normalized into a single text file in a similar manner.

The works of Sir Frances Bacon [8], Christopher Marlow [1], and Edward de Vere [6] are also available online and were also put through a similar normalizing procedure.

## 3 Christopher Marlowe

The first Shakespeare candidate we will examine is Christopher Marlowe. He was born in Canterbury in 1564. His father was a shoemaker, so he was fortunate to receive a scholarship to both King's School Canterbury, as well as Corpus Christi College, Cambridge. Here he practiced translations, poetry, and playwrighting. After school he entered the Queen's service instead of entering the Church [2]. He is said to have been killed in 1593, a fact denied by those who believe the *Marlovian* Theory (Shakespeare was Marlowe). Those who do not believe in this murder think he went off into some sort of exile and continued to write plays as Shakespeare. Fortunately, his works published before 1593 give us some room to test this hypothesis [3]. Plays by Marlowe used in our analysis include *Dido, Queen of Carthage*, *Tamburlaine part 1*, *Tamburlaine part 2*, *The Jew of Malta*, and

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Edward II [1].

### 3.1 Character Distribution

Our basic character distribution attempts to determine differences in style between authors by determining the probability that either author uses a given character. The basic algorithm is to first determine the relative probabilities that every unique character found in a work, then average those probabilities over each character for each work by a given author. The relative probabilities are plotted as shown in Figure[1] and a  $\chi^2$  test carried out.

A quick glance at Figure[1] shows that there are significant differences in the usage of certain letters. Marlowe tends to use the vowel "e" far more often than Shakespeare does. It also appears that Marlowe uses more spaces in his work, which could imply that Marlowe tends to use shorter words as we see in the next section. All this can be quantified with a  $\chi^2$  test.  $H_0$  in this case is that given the relative probabilities and variances of each character appearing in either author's work, what is the probability that both bodies of work share the same source? Table[1] shows the output of our R code, which includes the average probability of each character appearing in both Shakespeare's and Marlowe's works as well as the difference and the Z-score.

Before even looking at the P-value for the  $\chi^2$  test, we can see that for the vast majority of characters, the probability of both values coming from the same normal distribution is almost 0. The P-value on the  $\chi^2$  test confirms this suspicion, in that we soundly reject  $H_0$  in favor of  $H_A$ , that the works by Shakespeare and Marlowe do indeed come from different sources. Though there's a difference in the corpus size between the two authors, the amount of text we know was authored by Marlowe is fairly substantial so our results have some sway.

### 3.2 Word Length Analysis

We also chose to analyze the difference in word length distributions among the authors. For each author, we calculated the fraction of words that are a certain length. Specifically, we looked at words of length 1 to 19 because anything beyond that would not be significant. We then calculated the average proportions for each word length between each author's work. This is what is depicted on Figure[2].

One can immediately notice that Shakespeare uses significantly more 4 letter words than 3 letter words whereas Marlowe uses more 3 letter words than any

other. We found that Shakespeare was one of the few authors that used more 4 letter words than any other size. The graph is a good way to understand data, but the  $\chi^2$  test for independence can tell us if the word length distribution between Shakespeare and Marlowe is actually significantly different. This test is shown below in Table[2].

After running the test between the average word length distribution in 37 Shakespeare works and 5 Marlowe works, we got a P-value of 0.256. We decided that we should go with the standard 0.05 cutoff so this clearly shows that the distribution of Marlowe's word length usage is not significantly different from Shakespeare's.

### 3.3 Proportion of Unique Words

The vocabulary is used in written works often varies from author to author. We decided to look at ratio of unique words in a work to the total number of words used. We averaged the ratios for each of 5 works for Marlowe and got an average ratio of 0.2073 with a variance of 0.0005. The extremely low variance tells us that Marlowe was quite consistent in how many unique words he used in his works relative to the total number of words. We did the same thing with a set of Shakespeare's works. It is important to note here that we had 37 works for Shakespeare, which is significantly more than our corpus for Marlowe. The average ratio of unique words to total words for Shakespeare was 0.16 with a variance of 0.0002. Once again we see a very low variance which gives us hope in using our calculated ratio to distinguish between Shakespeare, the 'real' Shakespeare, and other contemporaries. We clearly see that Marlowe and Shakespeare have a significantly different writing style when it comes to vocabulary usage. These results are summarized in Table[3].

## 4 Frances Bacon

The second Shakespeare candidate we examine is Francis Bacon. Francis Bacon was born on 1561 to Sir Nicholas Bacon who held the title of Lord Keeper of the Seal. Francis Bacon had a good education, attending Trinity College Cambridge at the age of 12. Francis Bacon was an ambassador, and then a member of the House of Commons. After the ascension of James VI he was knighted and moved to higher political positions. Francis Bacon remains a noted philosopher who took an interest in learning and scientific discovery. Francis Bacon died in 1626, making him

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the only 'suspect' we are investigating to have lived throughout the entire lifetime of William Shakespeare [7]. Works by Francis Bacon we use for comparison to Shakespeare's plays include, The Great Instauration, Preparative toward a Natural and Experimental History, and New Atlantis [8].

#### 4.1 Character Distribution

We used the same character distribution test as with Marlowe. The results are given in Figure[3] with the  $\chi^2$  test displayed in Table[4].

A quick look confirms gives us the same conclusion as with Marlowe. Bacon seems to use longer words (ie fewer spaces) than Shakespeare as well as significantly more usages of the letters "t", "i", and "e".

It's not surprising that the P-value = 0 for the  $\chi^2$  test given the differences illustrated by Figure[3]. That means based on this one test, it's unlikely the works attributed to Bacon and Shakespeare came from the same source. However this result also suffers from the same flaw as in the previous section. Marlow did not have many published works so our character probabilities are only based on the three we could find.

#### 4.2 Word Length Analysis

The comparison of word length distribution between Shakespeare and Bacon produced significantly different results compared to the Marlowe comparison. The graph of the word length distributions can be found in Figure[4].

The P-value from our  $\chi^2$  test for independence shown in Table[5] is 2.25E-7. This is an extremely low P-value and leads us to conclude that the word length distribution is significantly different between Shakespeare and Bacon. From this result, and others in our project, we decided that it is unlikely that Francis Bacon ever wrote under Shakespeare's name.

#### 4.3 Proportion of Unique Words

Analyzing Bacon's unique word usage compared to total word usage yielded very similar results to that of the Marlowe analysis as shown in Table[3]. Bacon's average ratio was 0.2044 with a slightly greater value of 0.0012. However, these values are still significantly far away from Shakespeare's 0.16 average ratio with a variance of 0.0002.

## 5 Edward de Vere, 17th Earl of Oxford

The final Shakespeare candidate we investigate is Edward de Vere. Edward de Vere was born in 1550 to the Earl of Oxford, John de Vere. Edward was educated at Queen's College Cambridge and also studied law at Gray's Inn. At a young age, de Vere traveled around Europe, visiting France, Germany, and Italy [4]. Oxfordians, those who believe Edward de Vere wrote Shakespeare's plays, point to these travels as evidence of de Vere's potential for writing plays which show worldly education, as well as an acute interest in things Italian. Other evidence often attested to is the amount of literary praise given to de Vere, despite only a few number of his poems surviving [5]. It is these poems that we compare to William Shakespeare's poems.

### 5.1 Character Distribution

Our test for character distribution is identical to that used in the previous sections. There is a difference though in our corpus of data: Edward de Vere was a noble man and thus it is conjectured that he did not publish plays (such an act was not considered slightly for a man of his status). Thus the only readily available works we could find were 25 attributed short poems for a total of around 600 lines. Because poetry tends to have a different structure and style than prose (ie plays), we did not deem it fair to compare de Vere's poems with Shakespeares plays. The input to our character distribution test is then a collection of Shakespeare's poems and sonnets totaling around 1100 lines. The results are presented below with Figure[5] plotting the relative probabilities and Table[6] showing the  $\chi^2$  test.

There are significant difference in the character usage between the two poets. Shakespeare tends to uses fewer spaces (and thus longer words) than does de Vere, and seems to use a lot more punctuation.

The  $\chi^2$  test shows fairly conclusively that the poems attributed to de Vere and Shakespeare came from different sources based on the character distribution test. But this test suffers the most in terms of corpus size. We only had some 600 lines of poetry from de Vere; compare that to the 9000 lines of prose (which tends to be longer) which we analyzed for Marlowe and you see the heart of the problem. Until more surviving works from de Vere surface, there's really nothing we can do to improve accuracy.

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## 5.2 Word Length Analysis

Lastly, we ran an analysis on the word length distributions between Shakespeare's poems and Edward de Vere's poems. In general, poems are significantly shorter than dramatic pieces, histories, and comedies. It is also well known that only approximately 25 of de Vere's works survive. However, we still decided to run this test because we found a plethora of information online leading us to believe that de Vere may have written as Shakespeare. The graph of our comparison is shown in Figure[6].

The results of our  $\chi^2$  test does not distinguish the works of the two authors very well. In this regard there's strong evidence that de Vere remains a viable candidate as the true author of Shakespeare's plays. Our P-value was 0.40, a shockingly high number compared to the results from the previous section. Even though we didn't have many works by de Vere, this result, along with other statistics comparing Shakespeare to de Vere, lead us to believe that the two may have written under the same name.

## 5.3 Proportion of Unique Words

The real surprise came when we used our uniq word ratio to compare Edward de Vere's works with Shakespeare's plays, the results of which are summarized in Table[8]. It is important to note again here that there is not a significant amount of work available that was written by de Vere. We used a concatenation of a set of Shakespeare's works that totalled approximately 8300 words and a concatenation of de Vere's works that totalled approximately 3700 words. We got that de Vere had a ratio of 0.31 and Shakespeare had a ratio of 0.30. These values are extremely close to each other and work well to backup our result from the word length distribution comparison between Shakespeare and de Vere. Perhaps de Vere was Shakespeare.

## 6 Conclusion

Based on our studies, it appears extremely improbable that the works attributed to William Shakespeare were written by either Marlowe or Francis Bacon. However, the results of the Shakespeare-Edward de Vere tests indicate that the Oxfordian camp may have some veracity. We are particularly intrigued by the connections between events in Shakespeare's plays and events in Edward de Vere's life that abound online. Though such personal connections cannot be

scrutinized in a text-mining experiment, they do give greater weight to statistical similarities. Given more time we would like to conduct a more extensive study of the vocabularies of Shakespeare's plays and Edward de Vere's letters. Though indications exist online that such work has been done, it is hard to easily acquire solid research about this subject. In short, our research leads us to believe that out of the suspects, Edward de Vere is the only candidate who shows serious potential. After noticing that Edward de Vere also holds the most followers currently ascribing to the non-Shakespeare philosophy, the authors of this paper are very doubtful that Shakespeare did in fact write his plays.

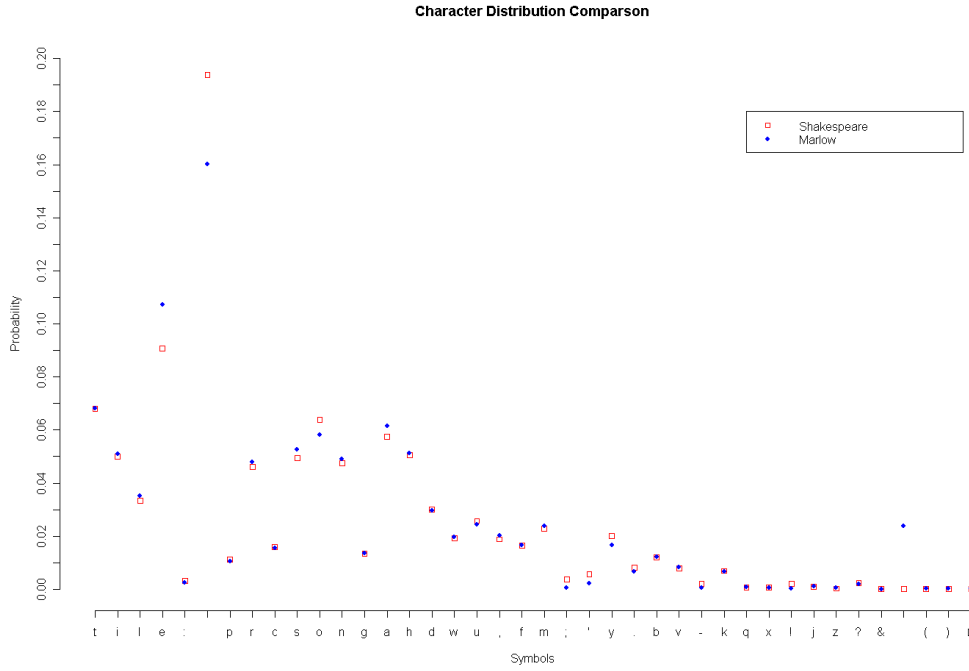


Figure 1: Character Probabilities: Shakespeare and Marlowe

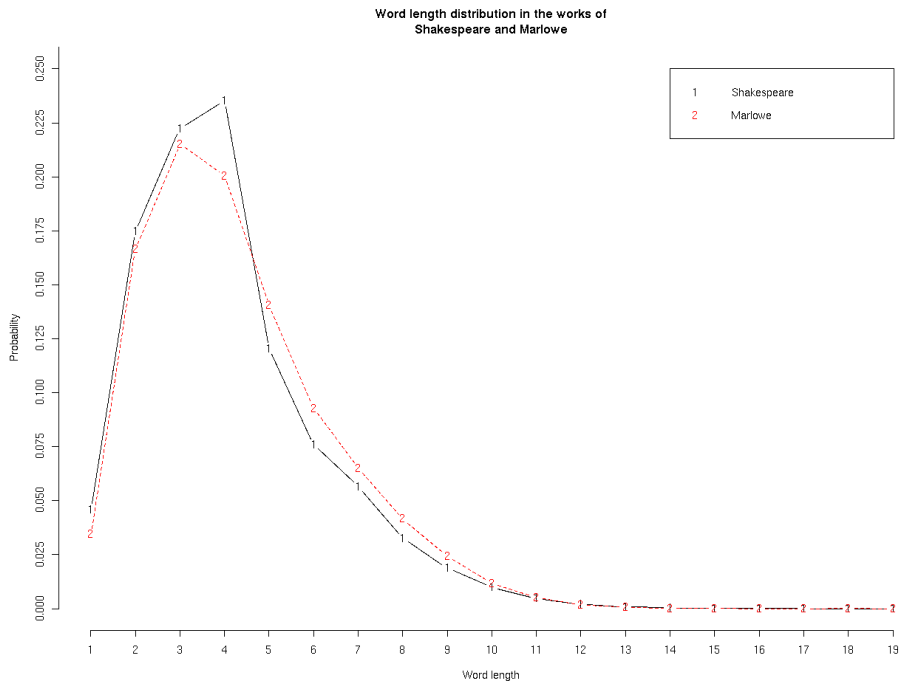


Figure 2: Average Word Length Probabilities: Shakespeare and Marlowe

Table 1: Character Probability Averages: Shakespeare and Marlowe

<i>Symbol</i>	<i>Shakespeare</i>	<i>Marlowe</i>	<i>Difference</i>	<i>Z-score</i>
t	6.79E-02	6.80E-02	-0.00012	-28.20449
i	5.00E-02	5.09E-02	-0.00087	-22.81445
l	3.34E-02	3.50E-02	-0.0016	-16.22445
e	9.06E-02	1.07E-01	-0.01656	-20.05603
:	3.19E-03	2.52E-03	0.00068	-2.70089
	1.94E-01	1.60E-01	0.03362	-26.86132
p	1.12E-02	1.06E-02	0.00055	-7.40764
r	4.61E-02	4.78E-02	-0.00172	-11.52948
c	1.58E-02	1.54E-02	0.0004	-8.96711
s	4.94E-02	5.25E-02	-0.00313	-13.85843
o	6.39E-02	5.81E-02	0.00579	-31.02457
n	4.75E-02	4.91E-02	-0.00158	-25.96769
g	1.34E-02	1.35E-02	-0.00012	-10.43488
a	5.74E-02	6.16E-02	-0.00414	-16.34992
h	5.06E-02	5.12E-02	-0.00056	-21.93819
d	3.00E-02	2.97E-02	0.00036	-12.50583
w	1.93E-02	1.96E-02	-0.00031	-9.80106
u	2.57E-02	2.42E-02	0.00154	-16.56256
,	1.88E-02	2.01E-02	-0.00125	-8.67774
f	1.64E-02	1.65E-02	-0.00012	-7.80556
m	2.27E-02	2.37E-02	-0.00097	-11.19167
;	3.62E-03	5.40E-04	0.00308	-0.42509
'	5.65E-03	2.04E-03	0.00361	-0.79073
y	2.01E-02	1.66E-02	0.00352	-9.43229
.	8.03E-03	6.51E-03	0.00152	-3.12498
b	1.20E-02	1.21E-02	-0.00016	-9.29055
v	7.79E-03	8.32E-03	-0.00053	-9.09473
-	1.98E-03	6.10E-04	0.00138	-0.75325
k	6.91E-03	6.69E-03	0.00022	-5.95808
q	6.30E-04	8.40E-04	-0.00021	-3.15638
x	5.60E-04	5.40E-04	0.00002	-2.37869
!	2.07E-03	1.00E-04	0.00198	-0.1594
j	8.40E-04	1.08E-03	-0.00025	-2.35293
z	2.40E-04	5.50E-04	-0.00031	-1.97961
?	2.39E-03	2.00E-03	0.00039	-2.05162

$\chi^2$ -value = 26431.80

95% Critical Value = 54.57

P-value = 0

Table 2: Word Length Probability Averages: Shakespeare and Marlowe

<i>Length</i>	<i>Shakespeare</i>	<i>Marlowe</i>	<i>Difference</i>	<i>Z-score</i>
1	0.0459	0.0344	0.0115	1.1627
2	0.1747	0.1665	0.0082	0.7032
3	0.2223	0.2152	0.007	0.5302
4	0.2352	0.2005	0.0347	2.6684
5	0.1203	0.1404	-0.0201	-1.7334
6	0.0759	0.0928	-0.0169	-1.5402
7	0.0565	0.0651	-0.0086	-1.1033
8	0.0325	0.0416	-0.0091	-1.317
9	0.0187	0.0244	-0.0057	-0.997
10	0.01	0.0115	-0.0016	-0.3423
11	0.0046	0.005	-0.0004	-0.1284
12	0.0019	0.0017	0.0003	0.302
13	0.0008	0.0008	0.0001	0.2094
14	0.0003	0.0001	0.0002	0.8328
15	0.0002	0	0.0001	1.0076

$\chi^2$ -value = 21.48  
 95% Critical Value = 28.87  
 P-value = 0.26

Table 3: Probability of Unique Words in Prose

	<i>Shakespeare</i>	<i>Marlowe</i>	<i>Bacon</i>
<b>Variance</b>	0.0002	0.00005	0.0012
<b>Mean</b>	0.16	0.20	0.20

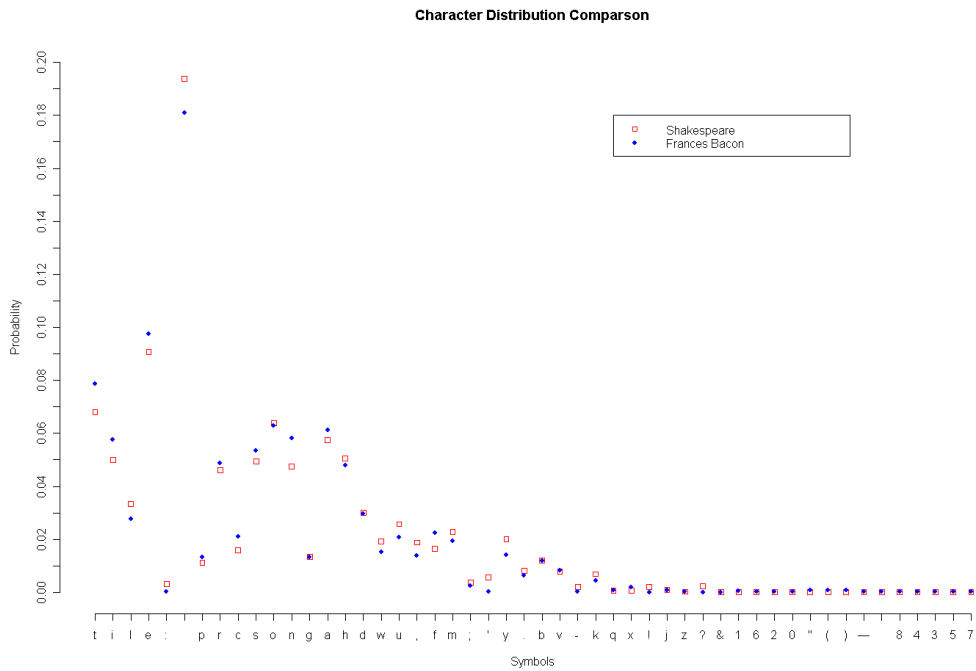


Figure 3: Character Probabilities: Shakespeare and Bacon

Table 4: Character Probability Averages: Shakespeare and Bacon

<i>Symbol</i>	<i>Shakespeare</i>	<i>Bacon</i>	<i>Difference</i>	<i>Z-score</i>
t	0.06791	0.0787	-0.01079	-18.92844
i	0.04998	0.0576	-0.00762	-10.30105
l	0.03342	0.0276	0.00582	-13.43811
e	0.09064	0.09751	-0.00687	-24.49717
:	0.00319	0.00025	0.00294	-0.494
	0.19374	0.18079	0.01295	-42.86218
p	0.01115	0.01338	-0.00223	-9.23132
r	0.04611	0.0487	-0.00258	-14.56877
c	0.0158	0.02088	-0.00508	-6.93951
s	0.04941	0.05339	-0.00397	-18.0288
o	0.06392	0.06275	0.00117	-32.14914
n	0.04752	0.05808	-0.01055	-10.66828
g	0.01342	0.0133	0.00012	-10.8877
a	0.05744	0.06128	-0.00384	-14.41545
h	0.05061	0.04787	0.00275	-18.46369
d	0.03003	0.0297	0.00034	-9.47193
w	0.01925	0.01528	0.00397	-4.04217
u	0.02574	0.02066	0.00509	-13.91337
,	0.01881	0.01391	0.0049	-4.88274
f	0.01638	0.02242	-0.00604	-16.3671
m	0.02274	0.01938	0.00336	-13.0568
;	0.00362	0.00234	0.00129	-2.62851
'	0.00565	0.00035	0.00529	-0.3412
y	0.02008	0.0142	0.00588	-6.65896
.	0.00803	0.00643	0.00161	-2.1982
b	0.01196	0.01182	0.00013	-8.94862
v	0.00779	0.00818	-0.00039	-6.50818
-	0.00198	0.00032	0.00166	-0.47871
k	0.00691	0.00445	0.00246	-3.86776
q	0.00063	0.00076	-0.00013	-2.35421
x	0.00056	0.0019	-0.00134	-2.87749
!	0.00207	0.00001	0.00206	-0.01833
j	0.00084	0.00076	0.00008	-1.80369
z	0.00024	0.00013	0.00011	-1.24812

$\chi^2$ -value = 6606.74

95% Critical Value = 66.34

P-value = 0



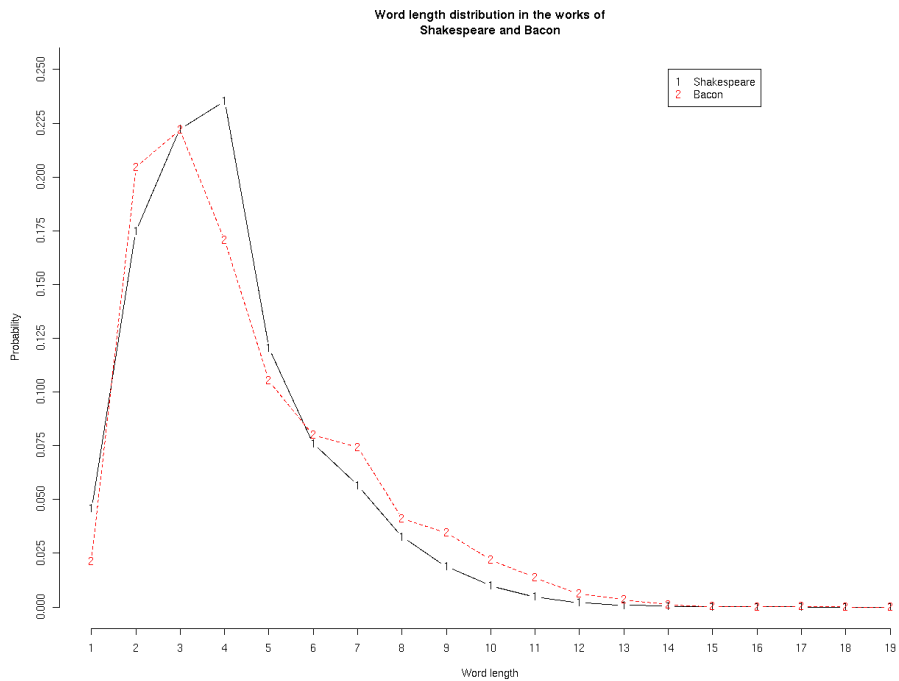


Figure 4: Average Word Length Probabilities: Shakespeare and Bacon

Table 5: Word Length Probability Averages: Shakespeare and Bacon

<i>Length</i>	<i>Shakespeare</i>	<i>Marlowe</i>	<i>Difference</i>	<i>Z-score</i>
1	0.0459	0.0213	0.0246	3.3783
2	0.1747	0.2046	-0.0299	-2.7564
3	0.2223	0.2219	0.0004	0.0284
4	0.2352	0.1707	0.0646	2.5493
5	0.1203	0.1052	0.0151	1.3481
6	0.0759	0.08	-0.0041	-0.7713
7	0.0565	0.0741	-0.0176	-0.9183
8	0.0325	0.0411	-0.0086	-1.937
9	0.0187	0.0345	-0.0159	-2.966
10	0.01	0.0219	-0.0119	-2.2019
11	0.0046	0.0137	-0.009	-2.6368
12	0.0019	0.0061	-0.0042	-2.1959
13	0.0008	0.0034	-0.0026	-1.9021
14	0.0003	0.0011	-0.0007	-1.468
15	0.0002	0.0002	-0.0001	-0.3665

$\chi^2$ -value = 65.85

95% Critical Value = 28.89

P-value = 2.25E-07

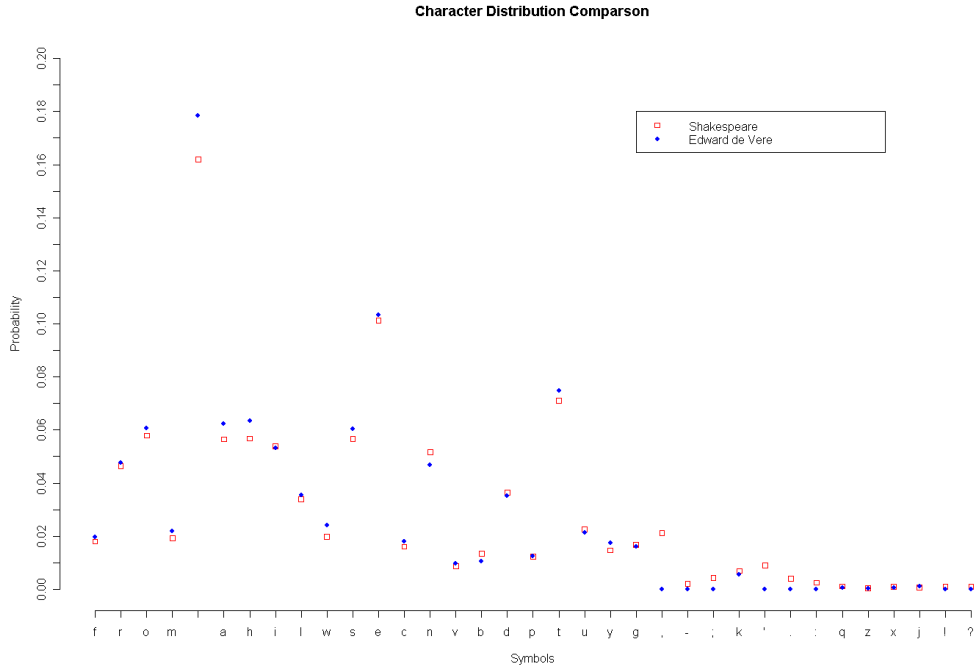


Figure 5: Character Probabilities: Shakespeare and Edward de Vere

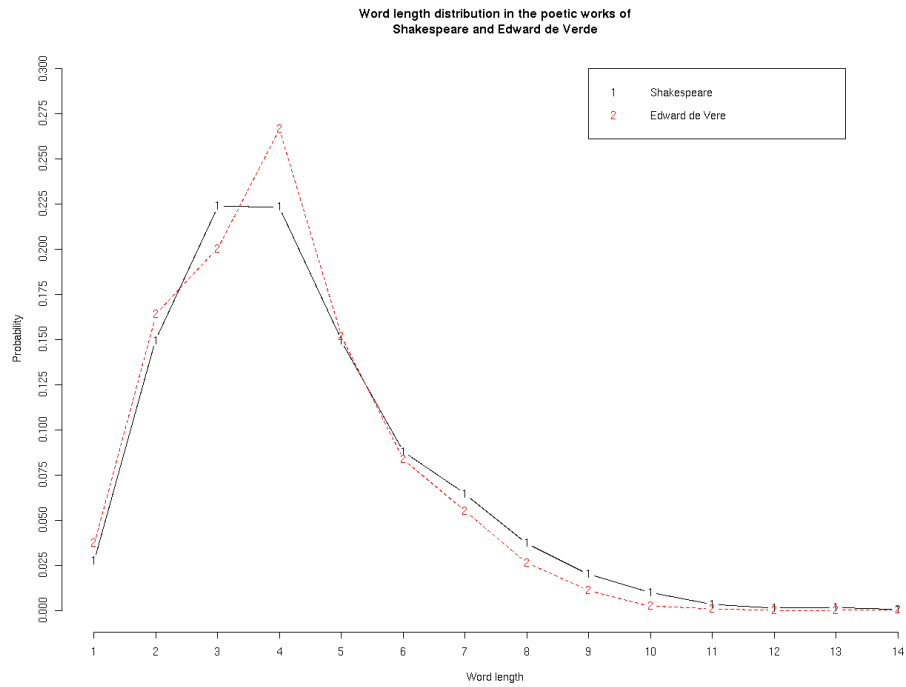


Figure 6: Average Word Length Probabilities: Shakespeare and Bacon

Table 6: Character Probability Averages: Shakespeare and Edward de Vere

<i>Symbol</i>	<i>Shakespeare</i>	<i>de Vere</i>	<i>Difference</i>	<i>Z-score</i>
f	0.01797	0.01967	-0.0017	-1.40985
r	0.04644	0.04749	-0.00105	-0.56543
o	0.05789	0.06071	-0.00282	-1.35334
m	0.01926	0.02191	-0.00265	-2.0999
	0.16202	0.17853	-0.01652	-4.9629
a	0.05647	0.06224	-0.00577	-2.75457
h	0.05674	0.06339	-0.00665	-3.15152
i	0.05383	0.05323	0.00061	0.30668
l	0.0339	0.03552	-0.00162	-1.00551
w	0.01987	0.0241	-0.00423	-3.2219
s	0.05661	0.06033	-0.00372	-1.79557
e	0.10117	0.10328	-0.00211	-0.79264
c	0.01606	0.01792	-0.00187	-1.62616
n	0.05165	0.04683	0.00481	2.55611
v	0.00866	0.00967	-0.00101	-1.19566
b	0.01342	0.01038	0.00304	3.27326
d	0.03642	0.03514	0.00128	0.78945
p	0.01231	0.01246	-0.00015	-0.15009
t	0.071	0.07465	-0.00365	-1.59271
u	0.02255	0.02126	0.00129	1.01264
y	0.01464	0.01732	-0.00269	-2.39782
g	0.01676	0.01601	0.00074	0.67077
,	0.02122	0	0.02122	31.0065
-	0.00201	0	0.00201	9.44346
;	0.00431	0	0.00431	13.85014
k	0.00686	0.00563	0.00123	1.81059
'	0.00895	0	0.00895	20.01466
.	0.0039	0	0.0039	13.17868
:	0.00244	0	0.00244	10.40498
q	0.00104	0.00055	0.00049	2.12809
z	0.00041	0.00022	0.00019	1.28997
x	0.00088	0.00049	0.00039	1.79447
j	0.00068	0.00104	-0.00036	-1.34875
!	0.00086	0	0.00086	6.16706
?	0.00083	0	0.00083	6.0853

$\chi^2$ -value = 2112.28

95% Critical Value = 48.60

P-value = 0

Table 7: Word Length Probability Averages: Shakespeare and de Vere

<i>Length</i>	<i>Shakespeare</i>	<i>Marlowe</i>	<i>Difference</i>	<i>Z-score</i>
1	0.0276	0.0372	-0.0096	-2.6887
2	0.1495	0.1642	-0.0147	-2.0425
3	0.2239	0.2004	0.0235	2.9478
4	0.2235	0.2668	-0.0433	-5.0714
5	0.1495	0.1519	-0.0024	-0.3409
6	0.0878	0.0836	0.0042	0.7665
7	0.0646	0.0552	0.0094	2.0438
8	0.0372	0.0263	0.0109	3.2668
9	0.02	0.011	0.009	3.9235
10	0.0097	0.0024	0.0073	5.4404
11	0.0034	0.0008	0.0026	3.2937
12	0.0013	0	0.0013	3.2747
13	0.0015	0	0.0015	3.5179
14	0.0005	0.0003	0.0002	0.5343

$\chi^2$ -value = 18.87

95% Critical Value = 28.87

P-value = 0.40

Table 8: Probability of Unique Words in Poetry

	<i>Shakespeare</i>	<i>de Vere</i>
<b>Variance</b>	2.53E-05	0.31
<b>Mean</b>	5.71E-05	0.31

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