Growth of science under the social influence in Arabic-Islamic and Western Civilisations, 700-1900 (Statistical Models)

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Abstract

A population of breakthrough scientists is considered to trace the development of science in both old Arabic-Islamic and Western civilisations. A statistical method is used to trace variation in the scientist population over several centuries. The analysis shows that the following: 1) There has been growth in Arabic-Islamic sciences for a period of three centuries (700-1000 AD), which was then followed by a period of decline. The decay time is approximately eight centuries. 2) The growth of science in Western civilisation started in approximately 1200 AD and continues to grow. The behaviour of the curve can be attributed to different historical events, particularly those events that may have affected scientific development.

Keywords: History of science, Science development, Statistical model.

Introduction

The modern natural sciences are based on scientific achievements and developments that have occurred over the last five centuries; however, the roots of knowledge extend deeper into history. One of the roots of science has an old Arabic-Islamic origin. Historically, the achievements of the Arabic-Islamic sciences are the closer to the achievements of modern science than are those of the Greco-Roman period. The achievements in modern science are mainly Western.

The present study is interested in the evolution of the natural sciences in two civilisations: the Arabic-Islamic and Western civilisations. The technique adopted in this work uses a quantitative (statistical) approach to study this evolution. Thus, scientific achievements, publications or the population of breakthrough scientists may be considered. Here, we choose to analyse the population of scientists.

Thus, the present work traces scientific development through the population of top scientists and analyses the pattern of that development in the two civilisations via a statistical technique. This technique may demonstrate the correlation between variations in scientific development and historical events.

Quantifying and modelling a historical phenomenon is similar in some respects to quantifying and modelling astronomical phenomena in astrophysical research. Here, we face the problem of a dearth of data from the period of AD 700-1900. The present work depends on the available data, which is from the distant past and reflects some of the missing facts. This work focuses on the development of the natural sciences (mathematics, geometry, medicine, astronomy, chemistry, biology

and physics), but the concept of natural science is rather new. In the west medieval period, it was called natural philosophy, whereas in the Middle East, it was part of knowledge. Philosophy in the Middle East has no historical foundations unlike philosophies in the West.

Scientific development is achieved by top or breakthrough scientists. Distinguishing between scientists and breakthrough scientists throughout older Arab-Muslim history is difficult. The word 'scientist' in the West refers to any person who works in science (i.e., science is his career), regardless of the value of his contribution or achievements; in Middle Eastern culture, however, 'scientist' is an adjective that confers value and relates an important role. The problem arises because all modern research into the history of science is performed by Western researchers; thus, their use of 'scientist' does not imply a breakthrough or top scientist as it does for some of the new Middle Eastern researchers. This difference in usage may lead some Middle Eastern researchers to misinterpret the word and thus infer an exaggeration when they study Western references.

There are many records that mention thousands of Arab-Muslim scientists. For example, the scientific historian Heinrich Suter gathered the names of a large number of mathematicians and astronomers throughout Islamic history. He managed to gather approximately 400 pages of the names and the works of those astronomers and mathematicians (Heinrich,1990) [1]. Many other historians also mentioned lists of many such scientists (Hockey, 2007, Selin, 1997) [2,3].

Of course, although large in number, not all of the scientists were top scientists. *The ratio of top or breakthrough scientists to the total scientist population is quite small.* The title of 'breakthrough scientist' is rather new. For old civilisations, the most suitable description is 'top' or 'well-known' scientist. In this direction of work, the sociologist Sorokin attempted to show the rise and fall of Islamic science during the period of 700-1300 AD by tabulating, over a fifty-year period, "the *comparative* importance of the contributions of Arabic-writing scientists and men of letters"(Sorokin,1935) [4] . Fifty years is an approximately average life span; thus, it is not suitable to demonstrate the accumulation of scientists.

Methods and analysis

Choosing the top or well-known scientists depends on their achievements. There are many references that are only interested in breakthrough and top scientists(Abdul Rahman, 1977; Badran & Faris, 1978; Mason, 1953; Benjamin, 1985; Faris, 1993)[5,6,7,8,9]. The present work depends on these types of references to collect data on top scientists. It should be mentioned that there is not a perfect consensus among the references concerning top scientists. These references do, however, provide a good estimation; many names were repeated in multiple references. As an example the present work depends on many references to collect data; in an encyclopaedia of Arab Muslim scientists (Faris, 1993)[9] the collection is less than what had been found.

The work has been conducted as follows:
1. The study concerns the period of 700-1900 AD. This period is about a century after the rise of Islam (610 AD).
2. The scientists who were included are those of mathematics, geometry, medicine, astronomy, chemistry, biology and physics. These scientists were

from different nations and of different religions, but they were working and living in either of the two main cultures.

3. There were 179 Arabic-Islamic top scientists and 572 western top scientists who were collected from this period. The scientists are grouped in classes according to the centuries in which they lived. Statistically, this process is called frequency distribution. The chosen class width is one century. Thus, there are a twelve class intervals.

4. The life spans of some scientists lie between two centuries. Each of these scientists is attributed to the century during which he lived most of his life. This may cause an average error of approximately 30 years, but there are a few such cases. Given that the time scale includes many centuries, the effect of this error is negligible.

5. The data are arranged in two series: one for Arabic-Islamic and one for Western scientists.

Figure 1 shows the results as a bar chart. The Y axis represents the number of scientists, and the X axis represents time (by century).
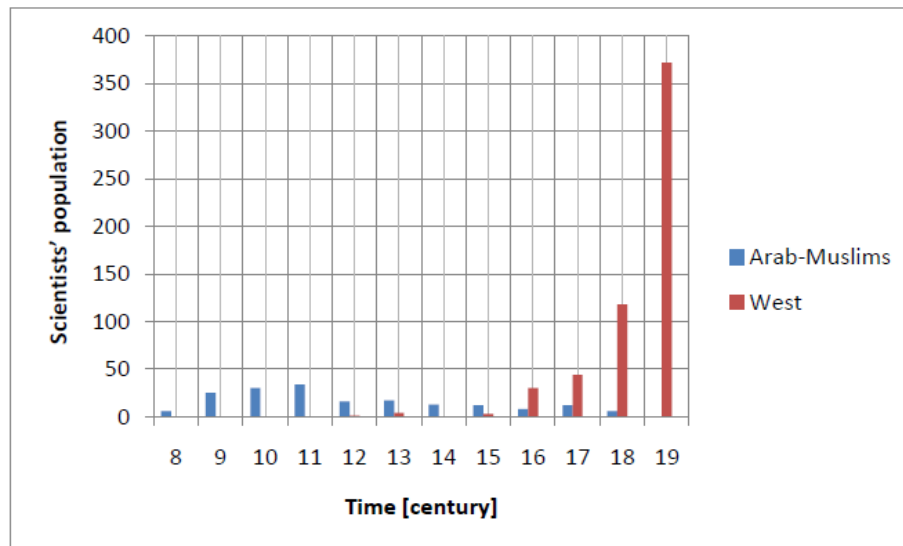

Figure 1. The bar chart of the top scientists' distribution.

The difference between the present work collection and that of the encyclopaedia of Arab Muslim scientists[9] is shown in Figure 2 . But the general behaviour of both distributions looks similar. Due to the continuity of time, we will deal with a continuous curve instead of bars; see Figure 3.
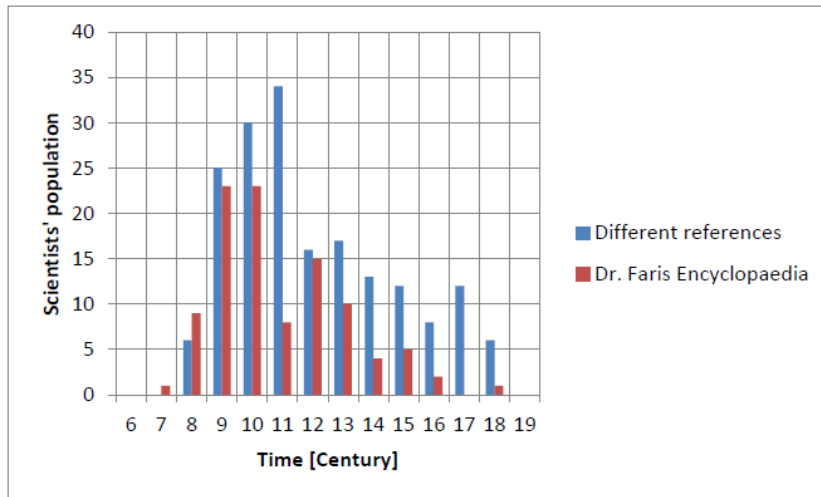
Figure 2. Comparison of Arab Muslim data

The variation in the curves behaviour is quite obvious. The variations in the behaviour may be related to the variation in scientific environments. Thus, the focus of this work is to explain the variation of the curve in terms of historical events likely to have affected the development of science.
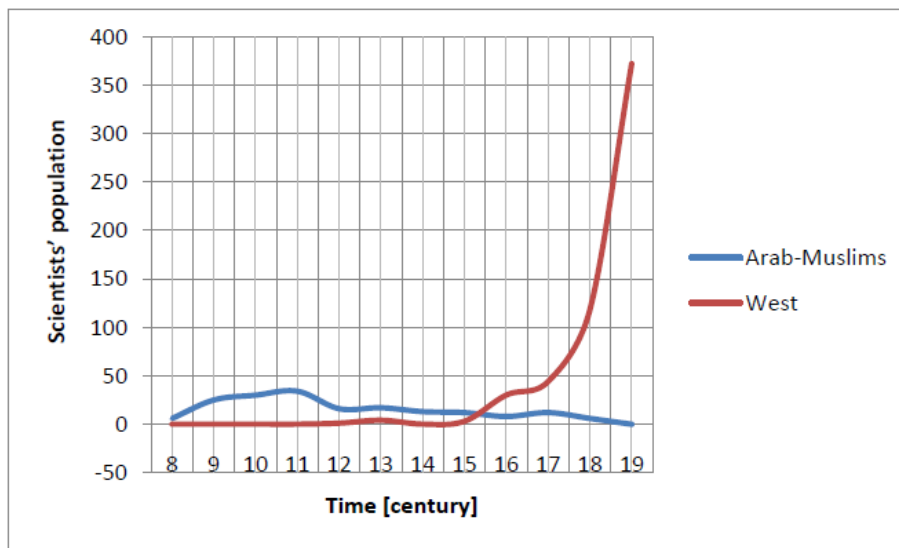

Figure 3. Top scientists' distribution.

Arabic-Islamic civilisation

Figure 4 is the detailed curve of the Arab-Muslim part of Figure 3. The curve behaviour of Figure 4 may correspond to the following events:

1- The growth in the number of scientists begins after the conquest of Spain (711 **AD**) and at the beginning of the Abbasids caliphate (750 **AD**) in Baghdad. The data suggest that this period saw the rise of new attitudes toward all branches of culture and life.. Baghdad became one of the most important knowledge centres in the world and attracted many scientists from different countries.

2- The growth continues with the firm establishment of the Arab states. In 830 **AD** Bayt Al Hikma (House of Wisdom) was established in Baghdad as a research centre for the translation of Greek and Syriac works into Arabic. The University of Cordoba was founded in 970 **AD**; a similar university was established in Toledo. The translations of Greco-Roman and Syriac literature into Arabic were undertaken during this period. Arabs translated and developed the works of their predecessors. At the time Arabs possessed great acceptance for the cultures of others nations, and social freedom was quite widespread. The scientists were from different nationalities and religions. There was a wide range of Islamic ideas and active philosophical debates. The libertine (poetry) arts were acceptable. Social freedom was quite accepted, and Islam was not in opposition. Society included many types of beliefs, such as Christianity, Mandaeans (Sabian), and Judaism (Signer *et,al.*, 1993)[10]. These new dynamic activities appeared due to a sort of Arabic-Islamic renaissance. The growth is coincident with the period of Al Mu'tazili. Al Mu'tazili was a movement that was started during the Umayyad period and reached its height in the Abbasid. It was the earliest philosophical rational movement in Islam (Hourani, 1976) [11] . An example of the freedom in Baghdad at that time was Abu-Nuwas (756-814 **AD**), who was a great liberal poet (Figure 4).
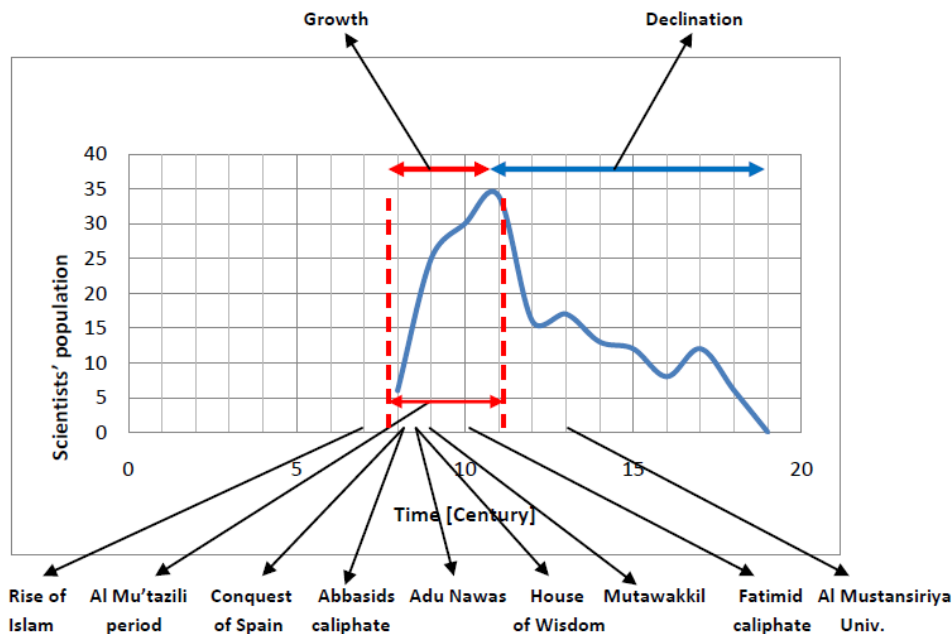

Figure 4. The Arab-Muslim scientists' distribution with respect to the relevant historical events.

3- The growth was expected to increase but became slower in the period 850-1000 **AD**. This period began with the caliph Al-Mutawakkil (821 – 861 **AD**), the tenth Abbasids caliph. Al-Mutawakkil was not as interested in knowledge as he was in religion; he opposed different groups of thinkers and especially opposed Al Mu'tazili. The interest in knowledge (science) decreased (Figure 5).

4- Fatimid Caliphate had risen in North Africa in 909 **AD**, and there was great interest in knowledge. In the eleventh century, growth reached its maximum. This peak may be attributed to the cumulative effects of the renaissance periods of the Abbasid, Andalusia, and Fatimid Caliphates. Fatimid was not opposed to Al Mu'tazili or rationalism.
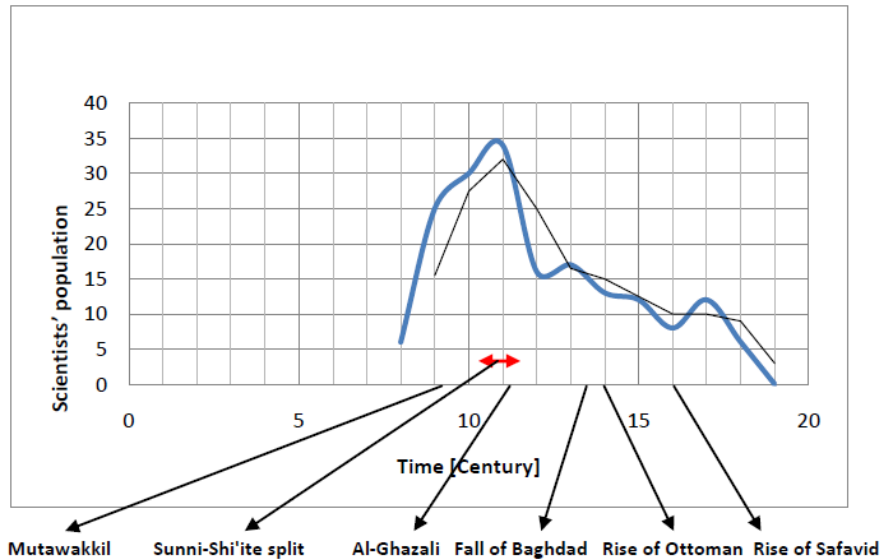

Figure 5. Decay comparison with relevant historical events. Note the 2-moving average.

In the tenth century, many small states tried to gain independence from the Abbasid caliphate. In Andalusia, the state was divided into petty emirates. Each of those fragmented tiny states tried to develop and encourage scientists. At the same time, however, the systems of their societies were weakened by internal and external wars and by many types of political and religious problems. In the period of 945-1055 **AD**, the Sunni-Shi'ite divide in Islam became fully established (Stearns, 2001)[12] (Figure 6). Arabs then lost Sicily (1072 **AD**) and Toledo (1085 **AD**).

In this century, Al-Ghazali (1058-1111 **AD**), one of the most famous Muslim thinkers had turned the direction of thought against rational philosophy and thus obstructed free thought. Moreover, the first Crusade began in 1095 **AD**.

The 11th century clearly shows a decline in scientific activities. This period is when Arabic-Islamic sciences truly began to decline.

5- By 1227, the Al Mustansiriya School had been constructed in Baghdad. It was the first school that was featured by the university in Baghdad (Figure 4). The Mongol sack of Baghdad in 1258 **AD** ended the Abbasid caliphate. This invasion was a consequence of the decline. The eighth Crusade occurred in 1270 **AD**. The restricted teachings of the scholar Ibn Taymiyyah (1263–1328 **AD**) began to dominate in the thirteenth century.

6- The moving average method (Figure 6) shows a small growth that may be attributed to the rise of Ottoman Empire in 1288 **AD** and the Safavids dynasty in Persia (1501–1722 **AD**). However, the decline in the scientists' population continued.
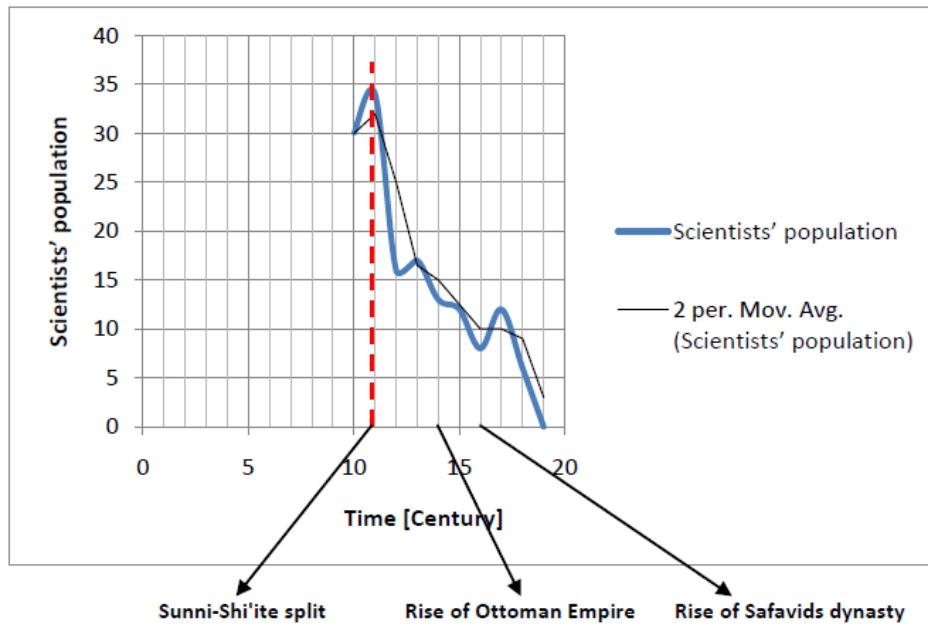
Figure 6. The 2-moving average of declination part of the Figure 4.

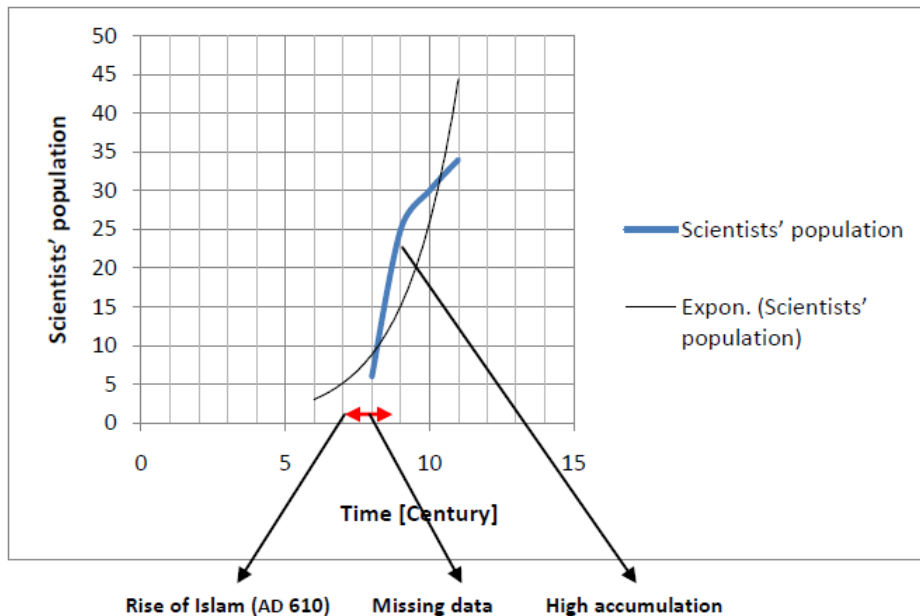The normal growth has a cumulative nature and experiences exponential growth behaviour.

Figure 7. Growth comparison with exponential growth.

However, it is obvious that the actual population growth rises sharply and is not normal; see Figure 7. This behaviour may be attributed to the following theories:

1- The accumulation in this period (between 700-800 **AD**) was due to previous scientific achievements, which were scattered throughout different countries in the region before gathering in Baghdad and Andalusia and thus appeared as a phenomenon. In other words, it is not an era of natural growth.

2- This simple peak may be related to premature growth due to the lack of a suitable environment to grow continuously.

West civilisation
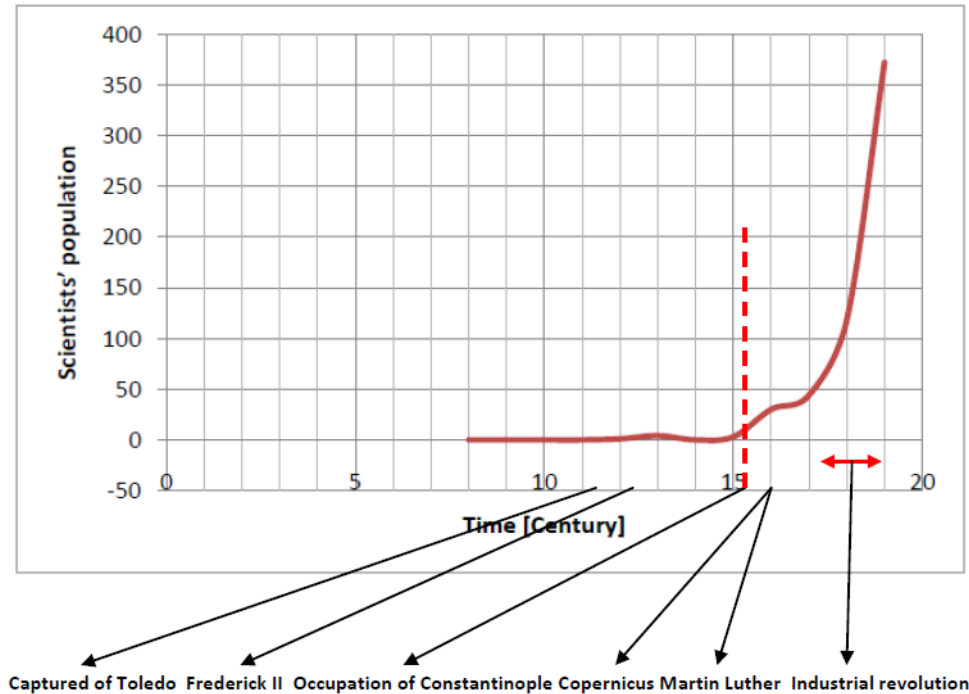Scientific development in the West has a different pattern of development.

Figure 8. The Western scientists' distribution with respect to relevant historical events.

The curve behaviour of Figure 8 may correlate with the following events:
1- No distinguished scientists during the Middle Ages (700-1100 **AD**) were found.
2- After the capture of Toledo (1085 **AD**) by King Alfonso VI, the great and unlimited acceptance of the Arabic-Islamic culture had begun, and waves of translations from Arabic literature were started. The archbishop of Toledo began the translation efforts during the period 1125 to 1151 (Goddard, 2001)[13]. The whole translation period took approximately 155 years. During the period of Roger II (1111-1154 **AD**), "Sicily function as a kind of cultural melting-pot" (Goddard, 2001)[13].
3- The Holy Roman Emperor Frederick II (1194-1250 **AD**) spoke fluent German, French, Italian and Arabic (Wright, 1985)[14], and he supported the translation efforts. In the 13th century, the establishment of universities spread to Europe, with the establishment of Paris University in 1200 **AD**, Oxford University in 1214 **AD**, Padua University in 1222 **AD**, Naples University in 1224, and Cambridge University in 1231. In this century, many Western scientists, such as Roger Bacon (1214-1292 **AD**), mentioned Arab scientists in their works. Despite the domination of theological studies, science found a suitable place to grow at these universities.
4- In the 15th century and after the occupation of Constantinople by the Ottoman Empire (**AD** 1453), the renaissance that may have began in

Florence was supported by the emigration of Constantinople's scholars and scientists. The influence of the renaissance began to spread across Europe, and "Renaissance Italy was not cut off from the rest of Europe"(Wright, 1985)[15] . In this century, the growth of the population of scientists is quite obvious.

5- The Medieval Inquisition began around 1184 and extended to many European countries (Lea, 1887)[16]. This effect on science may be evident in Figure 9 as a fluctuation. Major advances took place and supported the freedom of thought. One such advance was the separation of church and state during the period of Martin Luther in 1517 and Henry VIII in AD 1530.
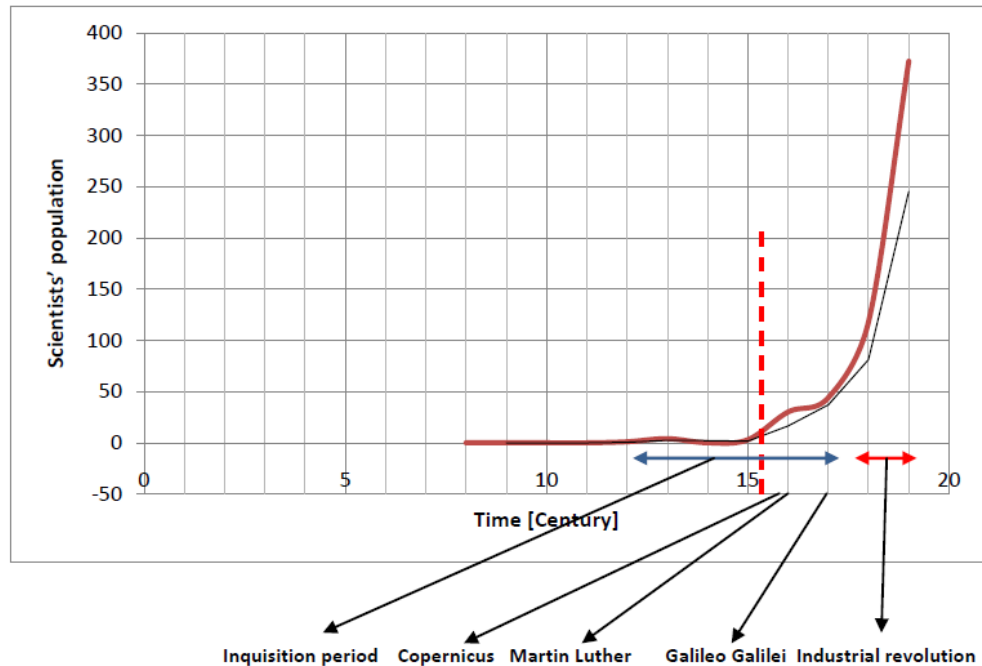

Figure 9. The Western scientists' distribution with a 2-moving average curve.

6- The growth continued nonlinearly due to the effect of the industrial revolution, and a great number of scientists appeared in 19th century. Smoothing the data using a moving average shows the growth trend; see Figure 9.

Conclusions

In a previous study (Sanduk,2000)[17] , the growth of human activities were considered to be a sort of growth of instability in social activities, similar to the instability of magnetohydrodynamics (MHD).

Accordingly, the revolutions may be regarded as a sort of instability in terms of social change and scientific activity. In physics (fluid dynamics, for example), the growth of instability has an exponential form.

The form of growth or decay in a physical system can be represented mathematically by an exponential form,

$$N = N_{\circ} \exp \pm \gamma T ,$$

where N is the number of growing units after time T (year), $N_\circ$ is the initial number, positive γ is a growth rate and negative γ is a decay rate. This form can be applied to social models (Fedorovich, 1977)[18] and can thus also be applied to the growth of science. Growth of the population of top scientists in Western civilisation (Figure 9) appears to approximately follow that form.

The data fluctuate, but smoothing by the 2-moving average technique clearly shows the two contradictory aspects of scientific evolution (Figure 5) in Arabic-Islamic science. In only three centuries, there was a period of growth of Arabic-Islamic science. The exponential form is not clear in this period. The decline period has a long period of decay.

Abu Nuwas (Figure 4) has been mentioned as an example of freedom during the growth period. Abu Nuwas was a free poet and expressed many ideas that are forbidden in Islam, but he was also socially accepted.

The decline in Arabic-Islamic science may be attributed to the domination of theological thought and the domination of clerical influence on the society. Such domination occurred around 850 **AD** and opposed the rationalism of Al Mu'tazili. Thus, interest in science and philosophy decreased compared to theological interests. Many science historians focus on Al-Ghazali in their explanation of the decline of science (Glick, 2005)[19] . This focus is due to Al-Ghazali's restricted teachings against the freedom of thought and rationalism (Huff, 2003) [20] ; what modern Muslim scholars call the Islamisation of science (Al-Attas, 1978)[21]. One of these science historians is F. Sezgin. Sezgin (Sezgin, 1975)[22] collected the names and works of the scientists, in separate volumes, in fields such as mathematics and astronomy but stopped around the middle of the eleventh century because he stopped studying Al-Ghazali. He was under the influence of Al-Ghazali, who was responsible for the halt in scientific development (Saliba private communication).

In the present work, we found that the developmental slowdown began during the period of Al-Mutawakkil (821 – 861 **AD**) and before Al Ghazali (1058-1111 **AD**); see figure (10). The type of thought that led to the decline has been strongly supported extremely by Al-Ghazali's teachings and other scholars, such as Ibn Taymiyyah [20]. Thus, Al-Ghazali may be considered to be one of the factors that caused the *continuous* decline; Al Ghazali himself and other scholars were a social product of the decline of science. The results show that there were still some fluctuations in scientific achievements after Al-Ghazali. G. Saliba (Saliba, 2007)[23] comes to rather different conclusions. For Saliba, there was no decline in the fifteenth and even sixteenth centuries. Saliba is interested in astronomy development. Considering the population of astronomers and mathematicians, Figure 10 shows that there is a small peak in the fifteenth century, and this peak might be related to the influence of the rise of Ottoman Empire and the Safavids dynasty in Persia. However, the decline in the population of scientists continued. Saliba did not consider the top scientists but instead relied on the number of scientists irrespective of their contributions.
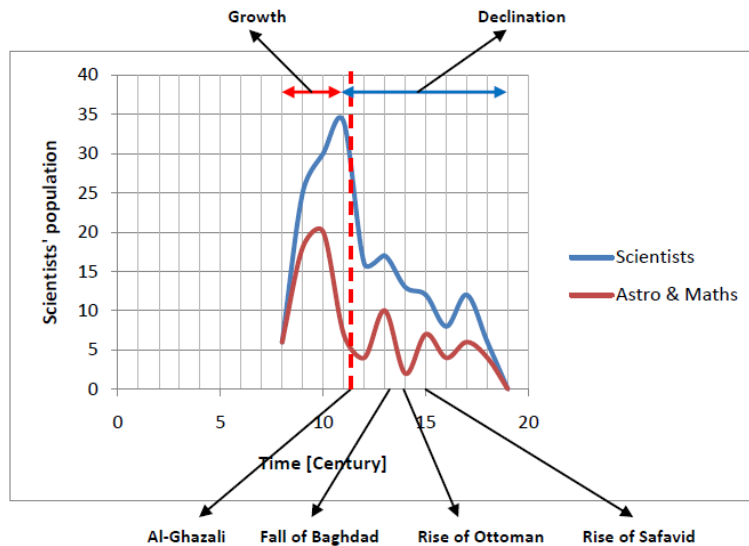
Figure 10. Comparison of the population of astronomers and mathematicians.

The growth in Western civilisation began around 1200 AD after the capture of Toledo and continued to grow after the occupation of Constantinople (Figure 11). The 13th century was the century of the universities (see Figure 11), and the first growth began after the capture of Toledo.
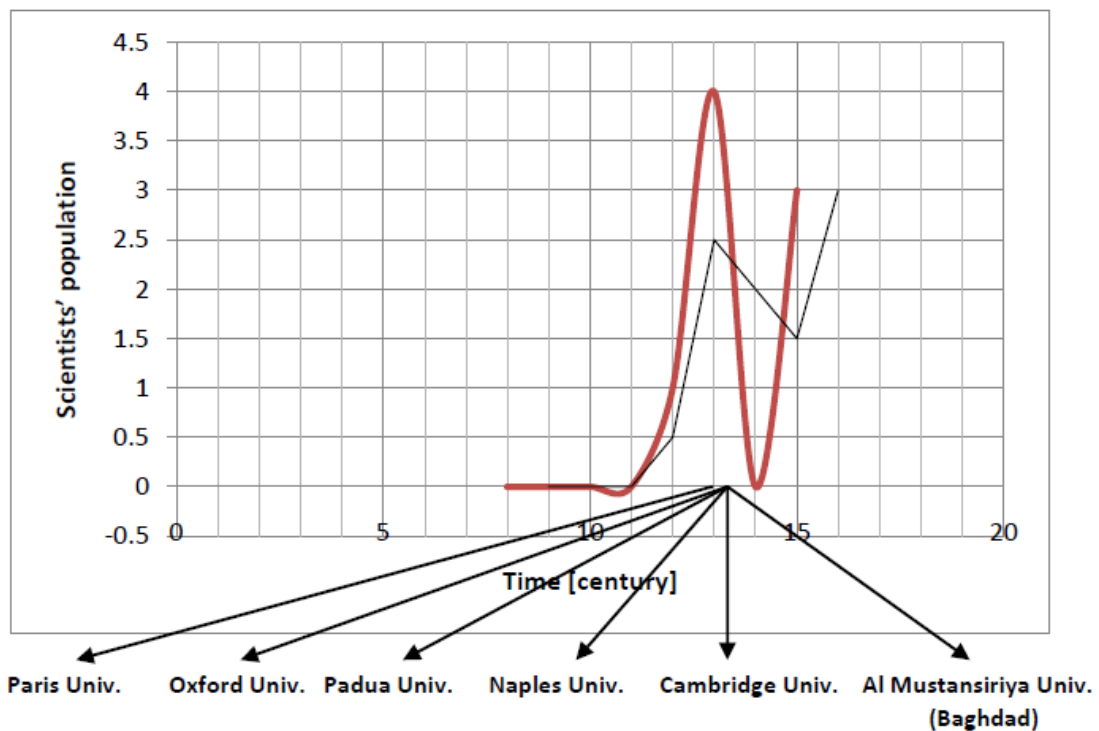

Figure 11. The century of the universities.

The effect of the inquisition period is clear but did not cause as much damage as the theological restrictions of the Arab-Muslim civilisations. Figures 9 and 12 of the 2-moving average show two different types of growth.
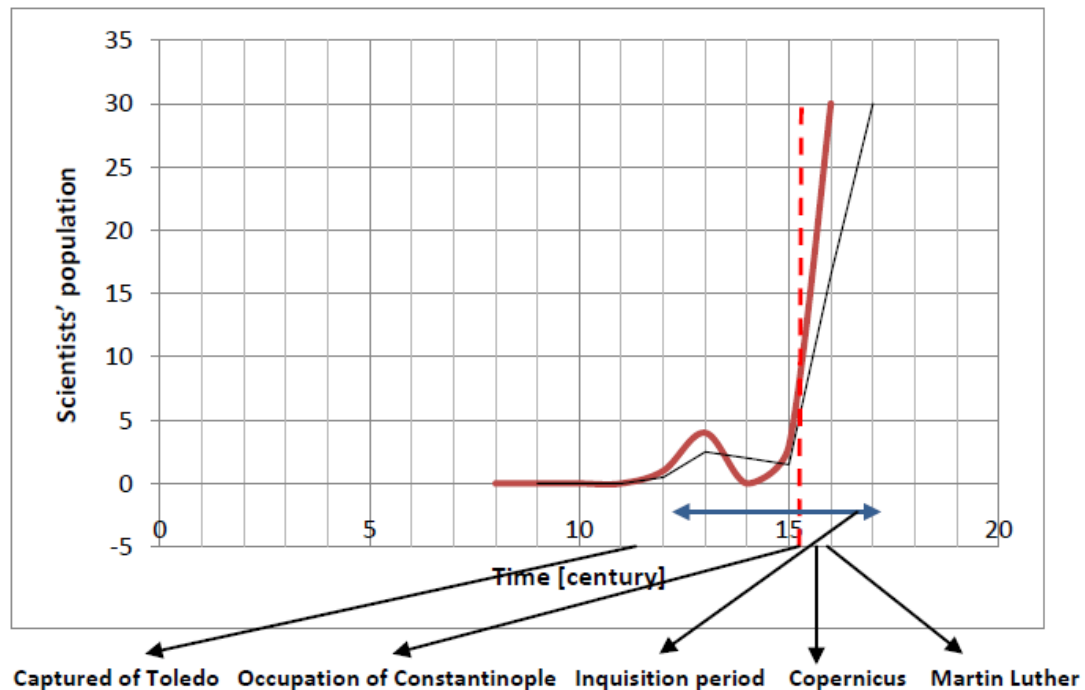
Figure 12. The growth before the 16th century in the West.

The first type of growth is influenced by the inquisition and political and social instabilities; the second is under the influence of the industrial revolution and the new wave of humanitarian freedom. The fast growth appears to have started between the 17th and 18th centuries during the age of enlightenment.

Science is a complicated social product; it is affected by many social factors Science is quite sensitive to the effects of financial support and social freedom of thought. The effect of social freedom of thought may be the main factor in the decline of Arab-Muslim science. The causes of the decline of Arab-Muslim science may be different than the causes of decline in other parts of the world. However, the effect of the social freedom of thought is detected in this analysis.

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