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THE IMPACT OF SUNSPOT CYCLES ON TOURISTS ARRIVALS DURING 1948 AND 2012

Abstract: This article presents a historical research of sunspot cycles and sea salt production, followed by a study of a correlation between sunspot cycles and foreign tourists' arrivals in Slovenia. The study identifies a linear correlation coefficient ($\rho = - 0.30$), which provides evidence of a correlation between arrivals of foreign tourists to Slovenia and sunspot cycles.

Keywords: Sea Salt Production, The Maunder Minimum, Sunspot Cycles, Foreign Tourist Arrivals

1. INTRODUCTION

The theoretical assumptions underlying this study stem from the results of data, operating in a reverse fashion when compared with traditional research. Our assumptions, based on these data, used inductive reasoning ([1],[2]). With inductive reasoning, the theory should more or less match the data, be relevant to it and it should be possible to work with and modify the theory according to new data or newly organised data sets. As with all scientific research, any theoretical assumptions derived from data should be provable and repeatable [3]. From the outset, such assumptions should be internally consistent, coherent and without error. In the process of building a theory, additional research on similar examples helps in the formulation and validation of the theory, and in the identification of any contradictions that might otherwise lead to unrealistic results.

Such a treatment enables mathematical modelling and the use of scientific methods. It is a form of epistemology, which is the theory of knowledge ([4], [5]). The research described in this article bases on data from various archives. As the phenomena occurred in the past, they are unique, and any repetition is impossible. We extracted periodic events from these phenomena, which occurred in twelve-year cycles. From these results, we established a theory that seasonal economic activities, which are influenced by changes in the weather, are also affected by sunspot cycles.

The basic research idea arouses from the curiosity and the wish for greater

understanding. The cause for long-term changes in the Earth's climate researched Milanković [6], who developed astronomical theory of climatic change.

Following his work in the past and leading our contemporary research, we anticipate that the results of the research will provide useful knowledge on how to make long-term predictions for seasonal economic activities. These long-term predictions are more convenient for managing processes and their regulation than providing a complete analysis of all the factors that contribute to the success of these economic activities ([7],[8]). The most important processes comprise key decisions at the highest level of management (e.g. financial investments) together with staff education and experience.

2. PROBLEM STATEMENT

2.1 Basic assumptions

The existence of spots on the sun and their variation knew the scholars in the antique time. Sunspots had been observed and described more than two thousand years before the invention of the telescope. Their appearance correlated with changes in the weather [8]. The introduction of the telescope to astronomy at the beginning of the seventeenth century changed astronomical observations forever and also accelerated the development of optics and epistemology. The telescope was used to observe and describe the heavenly bodies, the moon, the sun and its sunspots.

The discovery of sunspot cycles at the beginning of the nineteenth century was one of the most important discoveries in astronomy [10]. All our knowledge about the nature of the sun, which directly affects the earth and life on it, is a result of that discovery. From a combination of sunspot numbers and their distribution on the solar disc in the past 150 years, it follows that the maximum number of solar activities repeated between every 9.5 and 11 years. Wolf's number is another name for this repeating period [11]. These cycles take too long to impinge directly on our everyday life. As a result, we either fail to notice their influence or simply forget it.

The identification of the nature of sunspots started at the beginning of the twentieth century. They appear because of an anomaly in the sun's magnetic field [12]. At the time of the Maunder Minimum, the observation of the sun was 68% ($\pm 7\%$) of available days [13]. During that period appeared the sunspots notification and the observation of few polar lights, which reinforces the existence of the Maunder Minimum. Radioactive isotopes produced by cosmic rays in the upper layers of the atmosphere are a confirmation of its existence in the past. Deposits of cosmogenic carbon-14 and beryllium-10 were particles in the remains of living bodies in Antarctic ice [14].

In this article, we used yearly sunspot numbers from two different sources: the estimated numbers for the period from 1610 to 1700 [14] and the average numbers of sunspots since the year 1700 [16]. These verified and systematically arranged data sets were used to calculate a linear correlation coefficient with data sets from two local commercial activities that are seasonally affected: sea salt production in Piran during the time of the Maunder Minimum and arrivals of foreign tourists to Slovenia between 1948 and 2012.

3. SEA SALT PRODUCTION IN PIRAN DURING THE MAUNDER MINIMUM

The Republic of Venice (*Serenissima Repubblica di Venezia*) lasted from the 7th century until 1797. Initially, fishing and salt production were the main sectors of its economy. The development of the shipping trade led indirectly to the development of other activities. A typical characteristic of Venetian

economic policy was the unacceptability of a market surplus for any goods. State monopolies were carefully maintained to ensure steady prices. The state prohibited the import of goods or their production to prevent any reductions in price [17].

In the thirteenth century, the Senate of the Venetian Republic appointed a large number of magistrates, which restricted the authority of the Doge. An administrative body for salt was also established (*Magistrato sopra i sali*). This body had four overseers, political appointees held by noblemen for two years and later 18 months. They issued salt contracts for the production and trading of salt for every salt field in the territory of the Republic. These contracts ensured a state monopoly over salt in the domain of the Adriatic Sea. Despite the administrative restrictions, significant levels of salt smuggling happened. The overseers received reports on smuggling, which increased, especially in those periods when the price of salt was high [18]. Salt was one of the most important additions to food since people used it for food preservation.

The city of Piran, which now lies in Slovenian Istria, was part of the Venetian Republic from the end of the thirteenth century until its decline. The first known salt contract between the Venetian Republic and the Municipality of Piran dates from 1375 [19]. Venetian government, represented by the administrative body for salt, and the Municipality of Piran, represented by the Council of Twenty for Salt (*Colleggio dei XX del sal*) signed salt contracts. The Council consisted of twenty representatives of salt field owners in Piran. At first, these contracts were valid for five years. At the beginning of the eighteenth century, however, this period was extended to twelve and later increased to fifteen years. The last salt contract between the Venetian Republic and Piran, dating from 1780, was made for 20 years. The main part of these contracts was the price of salt. In a salt contract set up in 1636, the yearly limit of sea salt to be produced in Piran was 5200 *modi* (a *modio* is equivalent to 801 kg). This quantity remained stable for a further 113 years. During this entire period, the amount of salt produced in Piran changed very little.

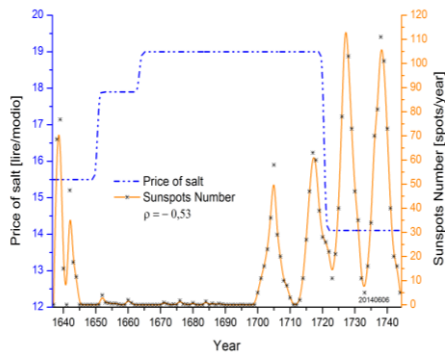


Figure 1: Correlation between the price of sea salt in the Republic of Venice and the number of sunspots during the Maunder Minimum

The Piran Archives include data relating to the quantities of salt harvested in Piran ([18],[19]). The earliest data about salt production are from 1637. The data were regularly recorded until 1685 when their systematic registration stopped. During this entire period of 48 years, only the data for 1657, 1658, 1663 and 1672 are not available. For the following 70 years, until 1744, there are data for five separate years and a further two 5-year periods (1730–1734 (21,170 modi) and 1735–1739 (21,327 modi)).

In Piran, salt contracts determined the price of salt per modio in *lire* (1 *lira veneziana* = 1/2 *ducato d'oro* = 20 *soldi* = 240 *denari*) from 1637 until 1744 (Figure 1). The linear coefficient of correlation between ([20],[21]) the price of salt and the average number of sunspots in the observed period is $\rho = -0.53$. The anti-correlation between these two groups of data means that the price of salt went up when the number of sunspots was lower.

4. FOREIGN TOURISTS ARRIVALS TO SLOVENIA DURING 1948 – 2012

In the past 65 years, annual data relating to the arrivals of foreign tourists have been taken from different sources and then arranged by year ([22], [23], [24]) Slovenian Department of Statistics recorded extreme events in the data for the period between 1948 and 2012.



Figure 2: Arrivals of foreign tourists to Slovenia from 1948 to 2012

In 1973, a steady increase in the number of tourists stopped abruptly and, in 1991, there was a dramatic decrease in the number of foreign tourists (Figure 2). These events derived from the political situation in Slovenia at the time, namely, the result of political instability in 1973 and the breakup of Yugoslavia in 1991. The time distance between these two events is $16 \pm$ one year. Throughout the entire observed period of 65 years, there were shorter periods of change with lower amplitudes, with periods of three to five years and from six to eight years. The shortest periods of decrease occurred in 1999 and 2009. The data relating to arrivals of foreign tourists are not as reliable statistically as data relating to overnight stays. The political events at that time influenced the data relating to overnight stays.

A linear correlation coefficient between the annual numbers of foreign tourists and annual sunspot numbers in the past seven sun cycles is $\rho = -0.30$ (anti-correlation). As for the numbers of these cycles in the past 65 years, there is a very probable correlation in anti-phase.

A detailed analysis of the graph in Figure 3 shows that during the most rapid increase of sunspot numbers, the number of arrivals of foreign tourists decreased, and vice versa. These roughly seven-year cycles had a lower amplitude between 1948 and 1973 when arrivals of foreign tourists increased steadily.

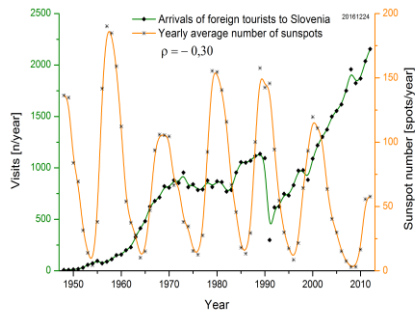


Figure 3: Correlation between the annual numbers of arrivals of foreign tourists to Slovenia and sunspot numbers from the eighteenth to the twenty-fourth sunspot cycle

We carried out an FFT frequency analysis ([25], [26]) of the available data for the annual numbers of arrivals of foreign tourist for the period between 1948 and 2012.

The cyclical events at the 10.83 and 13 year period points have nearly the same level of power and coincide with well-known natural cycles, namely, sunspot and geomagnetic storm cycles [27].

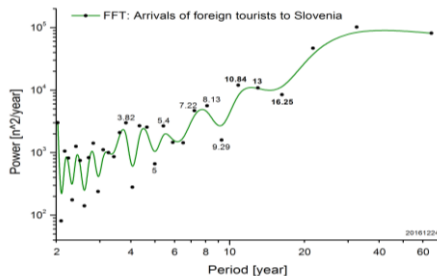


Figure 4: Results of frequency analysis (FFT) of annual arrivals of foreign tourists' data in Slovenia from 1948 to 2012

Each has greater power than the 16.25 year period point, caused by the political events in Slovenia at the time (Figure 4). The 10.84 year period point is little higher than the average value of 10.78 year periods for the sunspot cycles numbered 19 to 23. Sunspot cycle 19 started in April 1954, and sunspot cycle number 23 ended in January 2008 ([16], [28]).

5. CONCLUSION

Comparison of the available data of sea salt production in the Piran Municipality during the time of Maunder Minimum with the

estimated data of sunspot numbers during the same time did not give the expected results [19]. The raised price of salt at the time in Venetian Republic shows a great shortage of this commodity on the market at that time.

The linear correlation between the salt production in the Piran Municipality and the sunspot numbers during the time of Maunder Minimum does not exist. Also, other types of correlations did not give any useful results [29] mainly for the lack of continuous data. Behind the deficiency of adequate data, the same question crops up as it appears to the collector of data of production: Are the data of salt production in the Piran Municipality at the time of Maunder Minimum correct? Between 1994 and 1997 the salt production was organized in the Piran salt pans of the same dimensions as those during the seventeenth century. The harvest of sea salt was from 3.1 modi per salt pan in the rainy year to 6.2 modi per salt pan in the year with good weather conditions. However, during the time of Maunder Minimum, this production was limited by a Salt Contract to 2 modi per salt pan [18].

To obtain the expected results and to check the data sets more easily we used the data relating to the arrival of foreign tourists in Slovenia for the past sixty-five years (1948-2012) for additional verification of linear correlation with annual sunspot numbers. The result of this mathematical operation is a linear anti-correlation coefficient $\rho = -0.30$.

In parallel measurements with the same type of magnetometers, but with different serial numbers, in two neighboring observatories on four successive geomagnetic very calm days, the reckoning linear correlation coefficients are ranging from $\rho = 0.81$ to $\rho = 0.93$ with the average value of $\rho = 0.85$ [30]. The value of this correlation significantly drops if the observatories are on different geographic latitudes and longitudes, and they can also reach negative values. These measurements have something in common; they represent the flux of energy from the Sun to the Earth's magnetosphere.

After the frequency analysis during the sixty-five year period, we also see that the power of influence of solar cycles on the tourist industry in Slovenia is comparable with the power of political events. This industry is in major part a long-term investment, especially in hotels. For a long-term planning of this industry, it would also be very useful to study

the influence of solar cycles on it. Therefore, it would also be necessary to use adequate data sets from other tourism-orientated countries. Moreover, the standard verification of economic efficiency of the tourist industry in those countries would help in decision-making to take seriously into concern the influence of sunspot cycles upon tourist arrivals and consequently to rethink investments to tourism.

There is not only the cycle of sunspot numbers which the Sun creates. In the time of its minimum, the circumstances in the space

around the Earth are not calm; they are only changed [31]. In that time the flux of cosmic rays are bigger which influence the formation of the clouds ([32], [33]). The Sun with its activity also directly influence on the health of the people [34] and the nowadays technology [35]. All these phenomena change our way of life and also change the direction and intensity of tourist's currents flow.

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