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Space Weather, Cosmic Ray and Price' storms

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We study for possible manifestations of the influence of space weather, through cosmic rays and earth weather, on agricultural and consumables' prices. We present a possible connection scheme that includes nonlinear transition elements with a threshold type of sensitivity. We show that two types of manifestations can be observed and identified: 1) Distributions of time intervals between price bursts and for corresponding unfavorable phases of sunspot cycle must have the same statistical parameters; 2) Price asymmetry with systematic differences between prices in favorable and unfavorable states of solar activity (for example: Maximum/Minimum) can be detected. We show that in Medieval England and in the modern USA this effects of space weather influence had place.

1. Introduction

The problem of the possible response of prices of agriculture products (wheat, for example) to solar activity state (through influence of space weather on the earth weather) has a long history, and was an object of interest and discussion for many famous personas among European science and culture (J. Swift, W. Herschel, W. S. Jevons). Last results on cosmic ray influence on cloudiness and North Atlantic Oscillation dependence on magnetospheric activity indexes "aa" and "Pc" restored a physical base for possible solar-terrestrial connections, and stimulated a search for other manifestations of this relation, which may work as an effective proxy, more sensitive to space weather effects.

2. Price bursts as possible proxy of space weather abnormalities.

In the previous part of our research [1] (PY 2004), we reconsidered possible causal connections between space weather and wheat prices. It was shown that a complex causal chain can be placed between them. This chain includes a number of elements, while its basis is the influence of the solar activity on the weather state, caused by modulation of galactic cosmic rays propagated into the Solar System to the Earth and penetrated into the earth atmosphere. Ions and radicals in the air formed by cosmic rays are essential factors of vapor condensation and cloud formation; their modulation can lead to corresponding variations of the earth weather. Another way for space weather to influence the Earth weather is to change the Atlantic storm propagation caused by North Atlantic Oscillation, modulated by magnetospheric deformation caused by solar wind. From the other side, these weather abnormalities can lead to drops of agricultural production in regions of high risk agriculture, with corresponding market reactions on deficit in the form of price bursts. As a result, a causal chain between solar activity and prices of agricultural products can be presented as a sequence of a number of elements (Fig. 1).

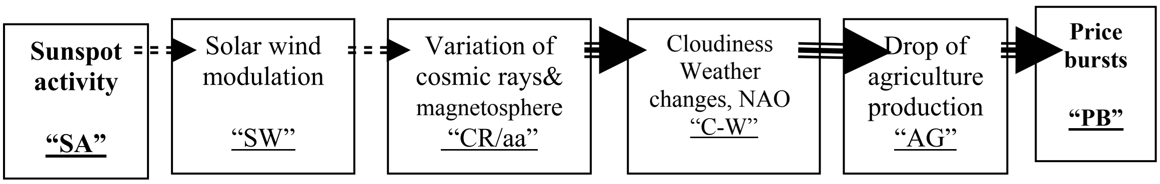

Figure 1. *A possible causal connection between space weather and price bursts.*

As the result, the multi-element chain of the causal connection (Fig. 1) can not be described by "hard type" models with univocal relations like $Y = kX + Noise$, or more generally, $Y^{(n)} = \sum k_i X^i + Noise$, where X_i - input variables (space weather parameters, conditions in the Earth atmosphere, market characteristics,…), Y - the output reaction (market prices, social outcomes, famines), k_i - the coefficients of connections, $^{(n)}$ - the order of derivatives. On the opposite, this multi-element chain requires "soft type" models for its description when the coefficients of connections k_i depend on the input variables X_i and the output reaction Y: $Y^{(n)} = \sum k_i(X,Y) * X^i + Noise$.

This situation is typical for "catastrophe theory" (Arnold 1992) and requires including into consideration hidden parameters of the system. The system's behavior is very sensitive to its location in the multi-dimensional space of X_i. For situation, when all four control parameters are near critical state, market behavior expected according to the presented scheme (Fig. 1) has to show the following two types of reactions on the space weather abnormalities:

a. The burst-like price reaction on the crucial combination of the above-considered control parameters. These price bursts are most probable in specific phases of solar activity (minimal or maximal sunspot number) that lead to the most unfavorable states of weather for concrete agricultural crops in the concrete region/state and under concrete local market conditions. Possible types of market reactions were discussed in details in PY 2004 and presented in Fig. 2,3 in that work.

b. Min/Max price asymmetry - systematical differences between prices in minimum and maximum states of solar activity, caused by the opposite sign of space weather influence on the market in these opposite states of solar activity. For analysis of concrete situations we have to take into account that global atmospheric circulation that transfers air masses with clouds from their birth region to thousands kilometers away (for example, from North Atlantic to East Siberia) may lead to a time lag in weather sensitivity to cosmic ray/sunspot activity, in spite of vapor state being far from critical in these distanced regions. Another factor of possible increase in system sensitivity to space weather is compactness of agricultural production zones. Clearly, regional sensitivity of crops to weather conditions is much stronger for those of them that are localized in small and compact regions (hundreds kilometers) than for those dispersed on thousands of kilometers (where average weather variations are much smaller).

On the base of this description we can conclude that standard methods of statistical inference (regression/correlation, Fourier analysis) may be ineffective for the search of the "space weather-price level" connection. Identification of space weather manifestations through Earth markets requires application of another approach based on the event statistics. As it was shown in the previous part of our work (PY, 2004a), adequate methods for this purpose can include (a) statistical study of time intervals between prices bursts and (b) search of price asymmetry. Application of this approach to the isolated wheat market of Mediaeval England has shown the existence of space weather influence on prices both for price bursts statistics and for price asymmetry. At the same time, for more reliability we need to test this fact on other independent samples of prices for the same historical period. Another side of the problem is possible manifestations of the "space weather - market state" connection for modern conditions, when market globalization and increased agriculture resistance to unfavorable weather conditions obviously can diminish the weather influence on prices.

3. Sources of Data

To test our assumptions about the influence of solar activity on prices we used the following two additional databases of prices: (a) The first is the Composite Unit of Consumables (CUC) in England for seven centuries, 1264-1954 [3]. (b) As the second data set for testing efficacy of the proposed scheme in condition of the modern wheat market we used the USDA-2004 database [4], that contains average yearly prices in US$ per bushel received by farmers in the USA for wheat (durum, spring, winter, other kinds, total).

4. Results and Discussion

Effects of sunspot activity on the CUC

The dynamics of CUC for about 700 years is shown in the upper part in Fig. 2. of our second article Pistul'nik and Yom Din [5]. We chose to analyze only part of the available CUC prices, namely 1260-1720 as that was the basis for the first part of our research (PY 2004). We repeated data analysis, as it was made in the first part of our research for wheat prices: restoration of slow trend component with the following normalization of CUC prices by this slow component gave us relative variations of CUC prices; the noise component was filtered from the burst component by amplitude discrimination (the level of 27.5% was used); the largest CUC price bursts were identified for each 11-year period. Means, medians and standard deviations of inter-burst time intervals were calculated (Table 1). As it is seen from the Table 1., statistical parameters for these three used interval distributions (Composite Unit of Consumables, wheat prices, and "minimum sunspot" states) are very similar and the hypothesis that all three samples have the same nature (are taken from the same statistical population) cannot be rejected on a 0.01 significance level.

Table1. Comparison of statistical parameters for 3 studied samples: burst-burst intervals for prices of Consumables, burst-burst sample for Wheat Prices, Minimum-Minimum intervals for Sunspot Cycle.

Sample	**Median (years)**	**Average (years)**	**Standard deviation (years)**
Price burst to burst interval according to:			
Composite Unit of Consumables	10.0	10.65	1.57
Wheat prices (1259-1702)	11.0	11.14	1.44
Min-Min sunspot intervals (1700-2000)	10.7	11.02	1.53

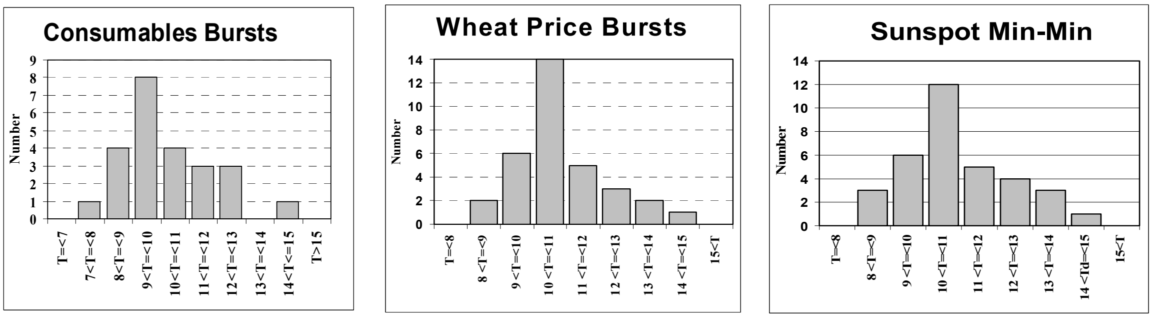

Fig.2. Another indication on the common nature of CUC price bursts, wheat prices bursts and sunspot minimum states is illustrated above where three histograms of the interval distributions for the considered samples are shown.

5. Possible manifestation of the solar activity in the modern USA wheat market

To test of the applicability of our approach to modern times, we investigated wheat prices in the USA in 1908-1993 [4] (Fig. 3). In this situation of small sample, we can test only maximum-minimum price asymmetry, such as that discovered for wheat prices in medieval England during the Maunder minimum century in 1600-1700 (PY 2004).To test the Max-Min price asymmetry, we examined wheat price variations in the USA in 1908-1993 (Fig. 3), marked the moments of sunspot minimum and maximum (white triangles and black squares) and price transition from state of minimal activity to the maximal one (arrows, white for raising of price and black for fall down). In the upper chart in Fig. 4 the differences $\mathbf{\Delta Price}$ between prices observed in maximum and succeeding minimum states of solar activity are shown for every sunspot cycle. The sample means were estimated as $\overline{\mathbf{\Delta Price}} = \mathbf{0.29}$ and the standard deviation as $s(\overline{\mathbf{\Delta Price}}) = \mathbf{0.12}$. This allowed rejecting the one-tailed zero hypotheses about the non-positive mean value of the price difference on a significance level $\alpha < 0.05$.

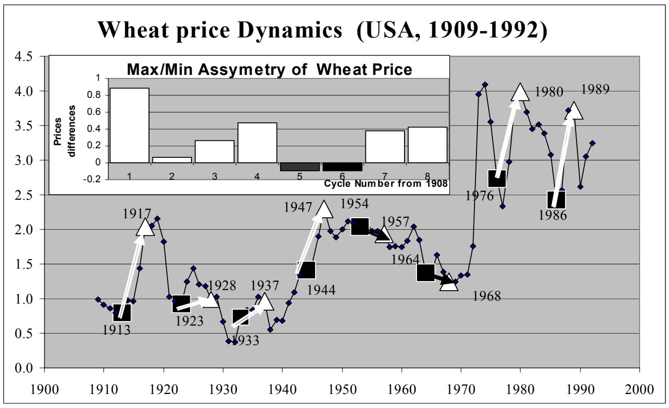

Fig. 3. Maximum-minimum price asymmetry for USA wheat prices, 1909-1992. White triangles are prices during periods of maximum sunspots; black squares are prices during periods of minimum sunspots. White arrows indicate rise in price from minimum to maximum sunspot periods; black arrows indicate drop in price. Inset shows the price difference for each of the eight sunspot cycles.

It mean that space weather influence in 20-th century US had place, in spite globalization' suppression. A possible explanation of this surprised result is the extremely compact localization of wheat production in USA (especially, durum and spring wheat) with 70% of all USA durum produced in a part of North Dakota whose area is less than 2% of the USA. Clearly, a high concentration of the crop area in so small a region increases sensitivity of wheat production to weather abnormalities and, among them, abnormalities caused by space weather.

6. Conclusions

1. The test of the interval distribution of the prices of consumables for Medieval England shows a good consistency with the interval distribution of sunspot minimum-minimum. I
2. The test of the maximum/minimum price asymmetry for wheat in the USA in the 20-th century shows that the effect of the influence of solar activity had a place, too, but its amplitude and its significance level were lower than that for Medieval England in Maunder Minimum.
3. In present times the problem is not in testing of principal possibilities of space weather – price storm relation, but in identification of zones where necessary requirements to critical state of local weather status (sensitive to CR and magnetospheric variations), to agriculture production (high risk zone and compactness) and to market condition (limited external supply) are realized, and where sensitivity to space weather must be high. For this aim we started a study of wheat price bursts for 100 wheat markets of Europe from 1200 to 1900 years.

References

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