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The Main Effects of Space Weather on the Earth´s Economy

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Abstract: *The work examines space weather phenomena that affect the transfer of mass, momentum, jerk, energy and charge of heliospheric magnetized plasma into the geosphere and its sub-spheres. In addition to phenomena involving transfers between individual parts of the geosphere, space weather also affects biological and technological systems found both in the heliosphere and below the Kármán line, as well as biological and technological systems on the ground. The economic implications of the transfer mechanisms for space business are also discussed.*

Key words: Cognitive Informatics · Physical Economics · Space Economics · Space Geodesy · Space Weather

JEL Classification: A12 · B41 · D12

1 Introduction

The current age of the Sun is estimated on 4.6 billion Earth´s years (Bonanno, Schlattl & Paternò, 2002), while its lifetime in the main sequence of the Hertzsprung-Russell diagram is estimated at 10 billion Earth´s years (Adams, Bodenheimer & Laughlin, 2005). In a time interval of five billion Earth´s years it will be necessary for people to find a new home on another body of the Solar System or outside the Solar System. The Apollo Research Program has created the conditions for launching intensive preparatory work for the colonization of the Moon and other bodies of the Solar System.

Analysis of satellite data and remote sensing of the Moon have provided indications of the presence of water on lunar surface (e.g. in lunar pyroclastic deposits) (Milliken & Shuai Li, 2017), (Pieters, C. M. & 28 coauthors, 2009). The lunar crust is composed primarily of oxygen, silicon, magnesium, iron, calcium, and aluminium, but important minor and trace elements such as titanium, uranium, thorium, potassium, and hydrogen are present as well. Based on geophysical techniques, the crust is estimated to be on average about 50 km thick (Wieczorek & 15 coauthors, 2006). It means for example from the chemical point of view that the combination of chemical elements mentined above will allow the production of fuel directly on the Moon.

2 Informal background of finitary relations theory

In this paper a relational concept is expressed as the set. An n –ary finitary relation ρ over the sets $S_1, S_2, \ldots, S_n$ is a subset P of their Cartesian product, i.e. $P \subseteq S_1 \times S_2 \times \ldots \times S_n$. Finitary relations are classified according to the number of sets in the Cartesian product, i.e. ρx_1 denotes a unary relation, where $x_1 \in S_1$; $\rho x_1 x_2$; or $x_1 \rho x_2$ denote a binary relation, where $x_1 \in S_1, x_2 \in S_2$; $\rho x_1 x_2 x_3$ denotes a ternary relation, where $x_1 \in S_1, x_2 \in S_2, x_3 \in S_3$; $\rho x_1 x_2 x_3 x_4$ denotes quaternary relation, where $x_1 \in S_1, x_2 \in S_2, x_3 \in S_3, x_4 \in S_4$.Finitary relations with more than four terms are usually referred to as n –ary (e.g. 7 –ary relation). It means that a n –ary finitary relation is simply a set of n –tuples (Fraissé, 2000).

The principle of correspondence that for two different scientific fields may also be called the binary principle of correspondence is a simple representation that assigns quantifiable variables from one scientific field to a quantifiable variable of a second scientific field based on the same qualitative importance of mechanisms of transfer of mass, momentum, jerk, energy and charge describing the development of systems states in two different scientific fields. Finding a principle of correspondence requires a high degree of understanding of the two different scientific fields. If a principle of correspondence is derived between n scientific fields, then this principle of correspondence is called the n – ary principle of correspondence.

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3 Results

3.1 Binary principle of correspondence in space weather

The Lausanne School of Economics and the Cambridge School of Economics were among the first schools of economics to systematically describe and analyze economic processes using methods and models of non-relativistic theoretical physics, especially those of mechanics and thermodynamics (Zeithamer 2012, a), (Zeithamer 2012, b). Both of these schools of economics laid the foundations for a new field of science that incorporates the current state of knowledge of basic research in the areas of physics, economics, sociology, neurophysiology, biophysics and cognitive informatics and is known as physical economics. The term physical economics is used in the book title "Econophysics and Physical Economics", authored by Peter Richmond, Jürgen Mimkes and Stefan Hutzler (Richmond, Mimkes & Hutzler, 2013).

In heliosphere the Sun generates space weather phenomena that physically involve the transfer of mass, momentum, jerk, energy and charge in heliospheric magnetized plasma that interacts with the geosphere and its sub-spheres. Quantifying future states of magnetized heliospheric plasma sub-systems in space weather is analogous to developing methods for meteorological forecasts (Siscoe, 2007). One approach to quantifying the size of storm systems in terrestrial meteorology is to classify them into three basic categories in descending order based on the extent of the Earth's surface that is affected: extratropic cyclones, hurricanes and tornadoes. Storms in cosmic weather can also be classified in descending order into three basic sizes: M-region storm, coronal mass ejection, super auroral electrojet. The correspondence principle for forecasting space weather and terrestrial weather can be formulated as follows: extratropical cyclone (corresponds with) ↔ M-region storm; hurricane ↔ coronal mass ejection; tornado ↔ super auroral electrojet (Siscoe, 2007).

3.2 Binary principle of correspondence in price theory

A comparison of the analytical structure of economics and the analytical structure of non-relativistic theoretical mechanics has led to the following conclusion: path s traveled by a body over time t corresponds with price n of the commodity at time t, i.e. n(t) ↔ s(t) for $t \in \langle 0, +\infty)$. There is a fundamental difference between the real functions of real variable t "commodity price" n(t) and "the path traveled by the body" s(t). The path traveled by the body is a non-decreasing real function of time, but the commodity price may over certain time intervals increase or decrease as a function of time. The first derivative of path s according to time t, i.e. $\frac{ds}{dt}(t)$, is the path traveled by the body over a unit of time, called the instantaneous magnitude of velocity of the body. A change in commodity price over a unit of time is the first derivative of commodity price n over time t, i.e. $\frac{dn}{dt}(t)$. For the time being in this work, a change in commodity price over a unit of time is called the "tempo of commodity price change" or "price tempo". The change in commodity price over a unit of time may be positive, zero or negative, while a change in the path per unit of time is nonnegative (positive or zero). The second derivative of the path of the body over time means the first derivative of the velocity of the body is a change in the velocity of the body over a unit of time, called the acceleration of the body. The second derivative of commodity price over time means the first derivative of price tempo over time and in this work is called "acceleration of commodity price", or price acceleration, or "velocity of price tempo". The third derivative of the path of the body over time, i.e. the first derivative of the acceleration of the body over time is the instantaneous magnitude of jerk of the body (body jerk). The third derivative of the commodity price over time means the first derivative of the price acceleration, or price jerk (Zeithamer, 2015 a). The economic significance of price jerk is the change of price acceleration over a unit of time. The fourth derivative of the path of the body over time is,from a physical perspective, the change in magnitude of jerk of the body over a unit of time (i.e. also the speed with which body jerk changes). There is no established Czech term for this, but in electrical engineering the fourth derivative of a signal is often called the signal vibration. The fourth derivative of commodity price over time, $\frac{d^4 n}{dt^4}(t)$, that expresses the change in commodity price jerk over a unit of time is the tempo of price jerk, or price vibration (quake) or commodity pricequake. The fifth derivative of the path of the body over time means the physical change in speed of body jerk over a unit of time, or the acceleration of the body jerk. The fifth derivative of commodity price over time is the economic change in tempo of commodity price jerk over a unit of time, or price crackle.

In this section of the work it is necessary to mention the following notes:

1) In physics the quantities of velocity, acceleration and jerk are vector quantities. For example this pertains to railway engineering, construction of machinery, civil engineering and aviation engineering.

2) This work uses the scalar meaning of price. An article devoted to the vector meaning of price is being prepared for publication.

3.3 Axiomatic approach to the stationary field of retail gravitation

This work assumes that preferences exhibit the characteristics given by the following axioms: I.1. Axiom of reflexivity; I.2. Axiom of completeness; I.3. Axiom of transitivity; I.4. Axiom of continuity; I.5. Axiom of convexity; II. 1. Axiom of non-satiation (Never Get Enough); III: 1. Axiom of continuity of the retail gravitation field.

This work uses an ECEF Cartesian frame of reference $\sum_3$, the origin of which is located at the gravitational center of the Earth with axes fixed to the geoid (Earth-Centered, Earth-Fixed frame of reference). For the description of retail gravitation this coordinate system is a sufficiently accurate approximation of the inertial coordinate system (see references (Burša & Kostelecký, 1999), (Leick, 2004).

Let A be a city on the geoid with population P_a. Because retail flows are realized in three-dimensional space and time, we define the stationary potential of retail gravitation of city A by the relation

$$\varphi(x,y,z)=\varphi(D_a)=\alpha(A,E_A)\frac{N_a}{D_a}, \tag{1}$$

where D_a is the distance of the observation point from city A measured along the geoid. If the distance measured along the geoid is such that the geoid curvature can be neglected, then the distance of the observation point from city A is given by the relation $D_a=\sqrt{(x-x_A)^2+(y-y_A)^2+(z-z_A)^2}$, where x,y,z are the coordinates of the observation point and x_A, y_A and Z_A are the coordinates of city A; $\vec{D}_a=(x-x_A,y-y_A,z-z_A)$, i.e. $\vec{D}_a=(x-x_A)\vec{\imath}+(y-y_A)\vec{\jmath}+(z-z_A)\vec{k}$ is the position vector of the observation point, from which retail trade is attracted along the geoid in the direction of city A, or to mass point A; $\vec{\imath}$, $\vec{\jmath}$ and $\vec{k}$ are orthogonal unit vectors. Proportionality constant $\alpha(A,E_A)$ is expressed in units $[\alpha]=c.u.\ m^2\ pers.^{-2}$, where $c.u.$ = currency unit, m^2 = square meter, pers.= person; A is mass point with coordinates x_A, y_A and z_A, i.e. mass point $A=[x_A,y_A,z_A]$ depicts city A; E_A– is an economic facility of city A; N_a– is the number of long-term economically active adult inhabitants in city A at time t. Vector field $\vec{K}_a$ of the intensity of retail gravitation is determined by the negative gradient of potential of retail gravitation φ, i.e.

$$\vec{K}_a=\left(-\frac{\partial\varphi}{\partial x}(D_a),-\frac{\partial\varphi}{\partial y}(D_a),-\frac{\partial\varphi}{\partial z}(D_a)\right). \tag{2}$$

This means that the magnitude K_a of the intensity vector of retail gravitation is given by the relation $K_a=|\vec{K}_a|=\alpha(A,E_A)\frac{N_{Aa}}{D_a^2}$. For the intensity vector of retail gravitation the following relations apply $iv\,\vec{K}_a=0$, $rot\,\vec{K}_a=\vec{0}$, and the potential of retail gravitation is obtained by solving the Laplace homogeneous partial differential equation $\Delta\varphi=0$. Any vector field of retail gravitation $\vec{M}_a$ can be considered the superposition of two fields, one of which is determined by scalar potential while the second is determined by vector potential $\vec{A}$. Let us designate the field of retail gravitation determined by scalar potential φ as $\vec{K}_a$ and the field of retail gravitation determined by vector potential $\vec{A}$ as $\vec{L}_a$, then $\vec{M}_a=\vec{K}_a+\vec{L}_a$, it means that the vector of retail gravitation at the observation point is expressed by the relation

$$\vec{M}_a=-grad\,\varphi+rot\,\vec{A} \tag{3}$$

The first summand in relation (3) determines the amount of retail trade that can be attracted to city A by a single inhabitant who is at the observation point. The second summand in relation (3) determines the amount of retail trade that can be relocated from city A to the observation point per single inhabitant found at the observation point. The presented theory of a stationary field of retail gravitation implicitly contains axiom III: 1, which concerns the continuity of the field of retail gravitation, i.e. the scalar and vector stationary potentials are continuous functions of spatial coordinates and time.

4 Conclusion

Basic Czech research into the principle of correspondence between physics and economics began in the early 1970s. Pioneers of this basic research in the Czech school of economics included prof. Dr. Ing. Pavel Hrubý and his co-worker Ing. Jaromír Kálal. With periodic breaks of varying length, the research have continued to the present day and is steadily incorporating current findings obtained in the field of Sun-Earth relations. The experimental work has resulting in numerous studies, the most important of which are cited in this work; study authors are prof. Dr. Ing. Pavel Hrubý, Ing. Jaromír Kálal, doc. Ing. František Drozen, CSc. (VŠE in Prague), prof. Ing. Jiří Pospíšil, CSc. (ČVUT in Prague), Ing. Tomáš Zeithamer, Ph.D. (VŠE in Prague) (Hrubý & Kálal, 1974), (Drozen, 2008), (Pospíšil, 2013), (Zeithamer, 1986, 1988, 1990, 2012 a, 2012 b, 2013, 2014 a, 2014 b, 2015 a, 2015 b, 2016 a, 2016 b), (Zeithamer & Pospíšil, 2015, 2016 a, 2016 b).

The transfer of mass, momentum, jerk, energy and charge in Sun-Earth relations is the fundamental process that affects the majority of communication technologies we encounter on dynamically changing markets. Therefore, it is essential for the scientific community to understand the axioms of market dynamics in its basic research, and based on this understanding play an active and independent role in the changing business environment.

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