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Econophysics, Sociophysics & Other Multidisciplinary Sciences Journal (ESMSJ) Staff

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ECONOENGINEERING AND ECONOMIC BEHAVIOR: PARTICLE, ATOM, MOLECULE, OR AGENT MODELS?

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Abstract. *An introduction to the newly being talked about field of econophysics based 'econoengineering' is given with focus on the nature of economic behavior and the question of the correctness and utility of particle, electron, atom, and or molecule versus agent models of humans.*

Keywords: econoengineering, economic agent, human molecule, human atom, human particle

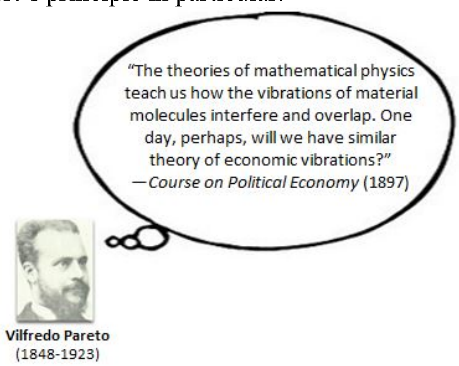
1. INTRODUCTION

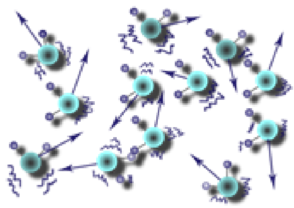
There's an old saying in medical school that every new third year always thinks their patient has what new disease they just learned about. In physical science and engineering, a parallel phenomenon exists according to which every new scientist, engineer, and or newly retired professor always thinks society can be modeled on what new scientific principle they just learned or what they did their thesis or dissertation on. Both, in hindsight, tend to be but the fault of not having had enough time to digest the big picture of the structure of science.

Italian philosopher polymath Francesco Algarotti in 1728 studied natural sciences and mathematics under Cartesian-turned-Newtonian follower Francesco Zanotti, at the University of Bologna, and so naturally enough, in his 1737 book *Newtonianism for the Ladies*, considering people as like celestial bodies, and employs the inverse square law to calculate the power of attraction between a pair of separated lovers, based on the logic of celestial mechanics:

$$\text{gravity} \propto \frac{1}{\text{distance}^2} \quad \text{(eq. 1)}$$

In 1870, French-Italian civil engineer Vilfredo Pareto did dissertation on 'The Fundamental Principles of Equilibrium in Bodies', and so naturally enough, two decades later, into the 1890s came be believe that people in socioeconomic systems are types of 'vibrating' molecules governed by rational mechanics, the study of forces of equilibrium and movement, d'Alembert's principle in particular:

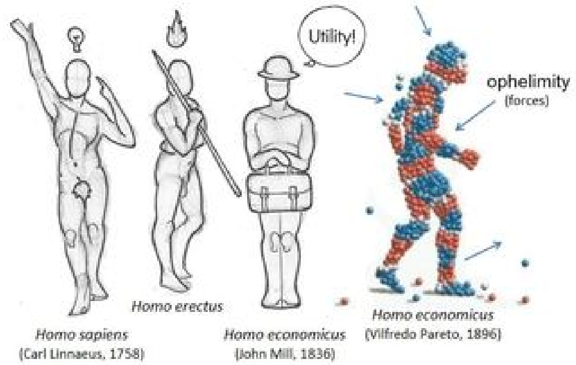




Molecules

Consumers & Producers

In the two decades to follow, Pareto went on to pen out an eight-volume collected work set in which he expanded on the premise that a person is a type of molecular economic agent acted on by the external forces of what he called *ophelimity* a type of utility defined by him as the ability of any object or service to satisfy a need or desire of an individual—a physical science upgrade, in a sense, to the older 1836 utilitarian model of English philosopher and political economist John Mill:[27]



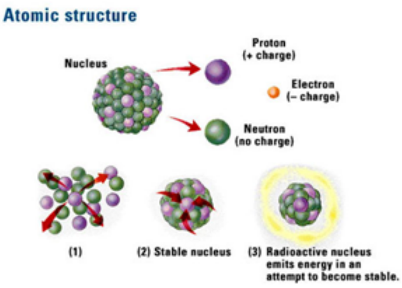
Economic agent = human molecule + external forces

In 1929, Italian engineer and theoretical physicist Ettore Majorana completed his MS in physics with a dissertation on 'The Quantum Theory of Radioactive Nuclei' at the Institute of Physics, University of Rome La Sapienza, under Italian theoretical physicist Enrico Fermi. Naturally enough, six years later, in circa 1935, three years before his mysterious disappearance, wrote his 'The Value of Statistical Laws in Physics and Social Sciences', wherein he derives a radioactivity and quantum mechanics based theory of sociology, the following passage being a representative example:

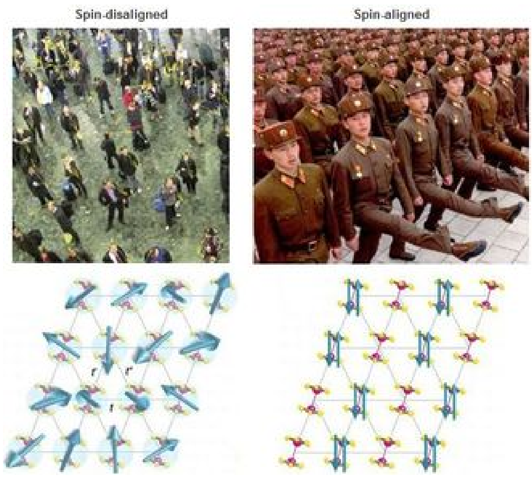
> "Quantum mechanics has taught us to see in the exponential law of radioactive transformations an elemental law which cannot be reduced to a simple causal mechanism. Naturally also the statistical laws recognized by classical mechanics and relative to complex systems keep their validity according to quantum mechanics. This modified on the other hand the rules for the determination of internal configurations and

does so in two different ways depending on the nature of the physical systems, thus given rise respectively to the statistical theories of Bose-Einstein, and of Fermi. However, the introduction in physics of a new type of statistical law, or simply a probabilistic one, which was hidden under the supposed determinism of ordinary statistical laws, obliges us to revise the bases of the analogy which we have previously established with the statistical laws in social sciences."

In short, Majorana, based on his recent graduate work in nuclear decay mechanisms, gleaned the tentative view that social theory is not the result of deterministic causal mechanism, but rather of indeterminism, a role of the dice so to speak, in the same way that the energy emission of radioactivity is unpredictable:[62]



In 1963, American physicist Eugene Stanley did his PhD dissertation at Harvard on critical phenomena in magnetic systems, so naturally enough into the 1990s came to believe that societal behavior is like a field of electrons in a metallic body that can be aligned or disaligned by an external force field—photo to the right being a 2012 photo a North Korean troops 'aligned' in accordance to the external field influence of leader Kim Jong-un in readiness for a war with South Korea:



While each of these physical models, has more or less merit to them, as will be discussed, the general pattern seen here that of scientists tending to philosophize about humanity and social behavior based on personal educational background, which in some ways is parallel to old truism that one's religious beliefs are but a product of one's birthplace. In both cases, whether scientific belief or religious belief, the inception of belief is root of action:

"A belief is a lever that, once pulled, moves almost everything else in a person's life. Are you a scientist? A liberal? A racist? These are merely species of belief in action. Your beliefs define your vision of the world; they dictate your behavior; they determine your emotional responses to other human beings."

— Sam Harris (2004), *The End of Faith: Religion, Terror, and the Future of Reason*

Each model of a person and model of human behavior has a certain ranking to it—we are, as modern physical science sees things, more vibrating molecule than rotating planet, radioactive nuclei, or spinning electron—and this ranking has much to do with the ranking of the various laws and branches of science, namely: chemistry, physics, and thermodynamics, in respect to each other, the foremost of which is the 'law which governs everything in the universe' (Rudolf Clausius, 1865), the 'supreme law' (Arthur Eddington, 1928), and 'law least likely to be ever be overthrown' (Albert Einstein, 1945), namely the second law of thermodynamics, otherwise known in its original formulation as the law of transformation content increase, defined by the following 1856 cycle integral:

$$N = -\int \frac{dQ}{T} \qquad \text{(eq. 2)}$$

where N is the equivalence value of all uncompensated transformation occurring in the system, whatever the system may be, otherwise known as entropy S increase, a term often misconstrued incorrectly, owing to the proliferation of simplified scientific folklore, as system disorder increase, dQ is a differential unit of heat imparted to the changeable body, a given society in our discussion, during a cyclical process, one earth surface day-night cycle, and T is the absolute temperature which the changing matter (society) has at the moment when it receives the element of heat.[31] Eq. 2 is the core equation of physical chemistry and in fact one that laces through the entire fabric of science.

The first to state that somewhere in the equations, symbols, and reactions of physical chemistry lies the foundation of ethics—the discipline dealing with what is good and bad and with moral duty and obligation—was German polyintellect Johann Goethe:

> The golden rule of ethics is ... a principle found in the "moral symbols" of physical chemistry.
> — Goethe (1809), Conversation with Friedrich Riemer, Jul 24

This is our starting point in any and all attempts at physical socioeconomics pure and or applied as in the form of socioeconomic engineering. The 24-volume collected works set, pure and applied, of Austrian psychologist Sigmund Freud, who in 1910 derived a thermodynamic based bound energy (TS) and free energy, i.e. system energy less bound energy, drive theory of human instincts, a theory tracing to above motto of Goethe along with Goethe's intellectual cohort German poet-philosopher Friedrich Schiller and his 1795 poem 'The World Ways' with its famous philosophical aphorism ending:[63]

"Hunger and love are what moves the world."

In more detail, a truncated main points of Schiller's poem are shown below:[64]

The rate by which all things
Receive inventory and shape,

But genius and heart has accomplished,
What *Lock 'and Des Cartes* never thought

In **moral systems**
Detail to be heard.

Man needs of the people very
To his great aims;
Only in the whole he **worketh**,
Many drops to give only the sea,
Plenty of water **drives** the mill.
Drum escapes of wild wolves as
Ties and the state band permanently.
To teach from the lectern

Mother *Nature* exerts the required
And ensures that the chain never breaks
And that the frost never Springet.
In the meantime, **the construction of the world**
Philosophy holds,
Receives its transmission
By **hunger and by love**.
— Friedrich Schiller (1795)

A water mill driven by waterpower, according to which the fall of the water "drives" the mechanical operation of the mill, which is to grind grain.

French physicist Sadi Carnot famously derived thermodynamics in 1824 on the model that the “fall of caloric (dQ)”, from the hot body (boiler) to the cold body (condenser), through the working substance [society], in the operation of the steam engine, is comparable, in principle, to the “fall of water”, from the higher location, through the rotary mechanism [social mechanism] of the water mill, to the lower location, in the machines operated by falling water, in the production of motive power, which is one third of the derivation roots of eq. 2; the others being: Euler reciprocity relation and the mechanical equivalent of heat.

In sum, baring prolonged digression into the Goethe-Schiller Freudian modified physical drive theory of human moral nature, as modern physical science stands every movement and phenomenon in the universe and every equation in science is subsidiary to overarching governance of eq. 2, the second law of thermodynamics:

> “If someone points out to you that your pet theory of the universe is in disagreement with Maxwell’s equations — then so much the worse for Maxwell's equations. If it is found to be contradicted by observation — well, these experimentalists do bungle things sometimes. But if your theory is found to be against the second law of thermodynamics [eq. 2] I can give you no hope; there is nothing for it but to collapse in deepest humiliation.”
> — Arthur Eddington, *The Nature of the Physical World* (1928)

Beyond eq. 2, however, science holds a vast sweep of equations, so much so that that many scientists, as outlined, unseasoned in physical science based humanities, will become, with equations and principles, like a kid in a candy store, when it comes to grand humanistic theorizing. In econophysics, the ubiquitous and random use powerful equations by physicists to construct and attempt solution to economic problems has recently been dubbed ‘toolism’ by German economist Egmont Kakarot-Handtke, as discussed in his interesting 2013 article ‘Toolism! A Critique of Econophysics’, wherein he compares the latest breed of econophysicists, or *toolists*, as he calls them, and their grabbing of equations and tools from physics to the overtypical Arnold Schwarzenegger role of being the hero who breaks into a gun store, grabs the most suitable device—such as the phase plasma rifle in 40 watt range—with the maximum fire power and thereafter relinquishes the enemy, after which in the sequel humankind will, supposedly, be better off:[65]

The latest toolist, according to Kakarot-Handtke, is French physicist Jean-Philippe Bouchard, who in his 2009 article ‘The (Unfortunate) Complexity of Economy’ argues that the powerful tool of the Curie-Weiss mean-field approximation, will soon revolutionize economics and the social sciences:[67]

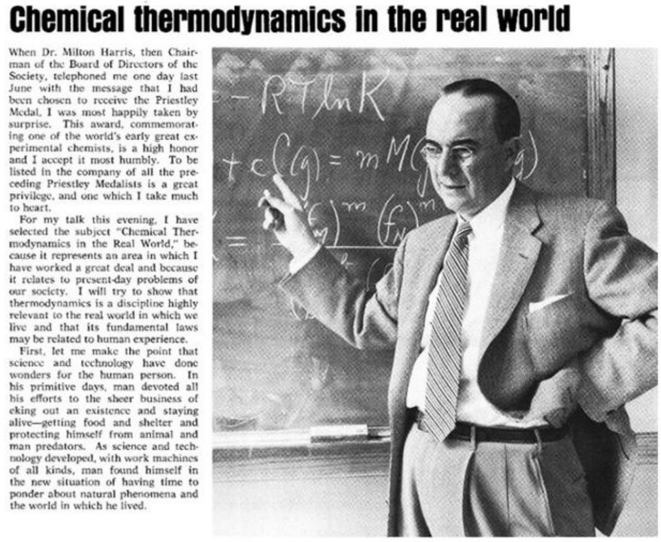
> “Whereas the simple Curie-Weiss mean-field approximation for homogenous systems is well known and accounts for interesting collective effects, its heterogeneous counterpart is far subtler and has only been worked out in detail in the last few years. It is a safe bet to predict that this **powerful analytical tool** will find many natural application in economics and social sciences in the years to come.”

The lesson to be learned from this ripe parody is that while ethical socioeconomic theory IS to be found in the powerful equations and symbols of physical science, at Goethe so acutely discerned, the solution is not simply to 'crush your enemies, see them driven before you, and to hear the lamentation of their women', as Conan would say, but rather to 'find a theory so indispensable to the whole structure that it has to be put in its place', as Freud said.[66]

This is our starting point in comparing the different theoretical models of humans behavior, used by econophysicists and sociophysicists, over the last three-hundred or so years and their correlated human conceptual models, such as: planet (Algarotti, 1737), vibrating molecule (Pareto, 1896), nuclei (Majorana, 1935), ferromagnetic body (Stanley, 1995), not to mention: particle, atom, electron, wave, Brownian particle in fluid suspension, molecule, gas molecule, and so on. More to the point, eq. 2., forms the basis for what American chemical thermodynamicist Frederick Rossini correctly refers to as the governing equations behind the 'real world' nature of freedom and security in social movement, whether in war or peace, which he deems as dictated by binding forces, energy, entropy, enthalpy, and free energy:

> "A simple description of energy is that the energy of a [social] system arises from the binding forces [exchange forces] that hold together the elementary particles—nuclei, ions, atoms, molecules, and macromolecules [people]—constituting the system. The greater the binding forces, the more tightly bound is the system, and the lower is its energy. This corresponds to a state of greater [socioeconomic] security. The smaller the binding forces, the less tightly bound is the system, and the higher is its energy. This corresponds to a system of lesser [socioeconomic] security."
>
> — Frederick Rossini (1971), "Chemical Thermodynamics in the Real World"[32]

The following is opening *Journal of Chemical & Engineer News* abstract of Rossini's famous 1971 Priestly medal address 'Chemical Thermodynamics in the Real World', wherein he gives a derivation to show how the second law (eq. 2), in reality, governs human freedom and human security in the course of reactionary existence:[32]


Chemical thermodynamics in the real world

When Dr. Milton Harris, then Chairman of the Board of Directors of the Society, telephoned me one day last June with the message that I had been chosen to receive the Priestley Medal, I was most happily taken by surprise. This award, commemorating one of the world's early great experimental chemists, is a high honor and I accept it most humbly. To be listed in the company of all the preceding Priestley Medalists is a great privilege, and one which I take much to heart.

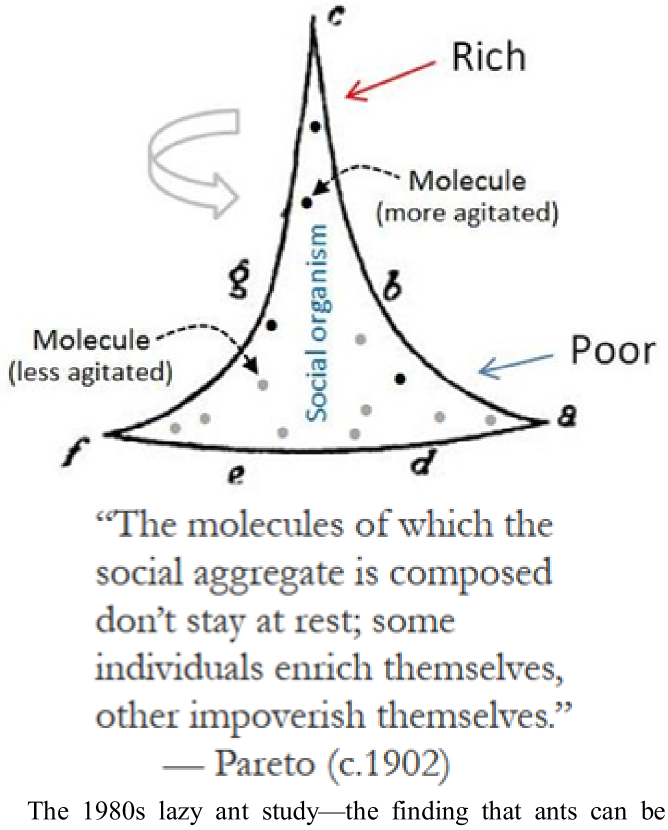
For my talk this evening, I have selected the subject "Chemical Thermodynamics in the Real World," because it represents an area in which I have worked a great deal and because it relates to present-day problems of our society. I will try to show that thermodynamics is a discipline highly relevant to the real world in which we live and that its fundamental laws may be related to human experience.

First, let me make the point that science and technology have done wonders for the human person. In his primitive days, man devoted all his efforts to the sheer business of eking out an existence and staying alive—getting food and shelter and protecting himself from animal and man predators. As science and technology developed, with work machines of all kinds, man found himself in the new situation of having time to ponder about natural phenomena and the world in which he lived.

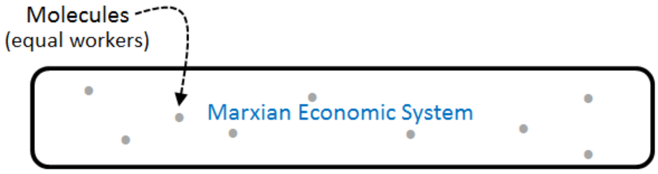
In short, Rossini goes through an example wherein he compares people to hydrogen molecules, according to which the association (H_2) and disassociation (H + H) reaction of hydrogen molecules into their atoms:

$$\mathrm{H{:}H} \rightleftharpoons \mathrm{H} + \mathrm{H} \quad \text{(eq. 3)}$$

has an equilibrium constant K the value of which determines the point when the reaction process stops and the forward and reverse reactions occur equally in both directions, which corresponds to time periods of socio-economic equilibrium or the 'end of a socioeconomic process' as Pareto saw it, or as British-French economist Alan Kirman put it in 1987 'Pareto regarded equilibrium as the termination point of a process … The time taken for this process is not specified but it certainly is not regarded as … as negligible.'[37] The following, to get a visual idea of Pareto and his socioeconomic reaction model, is a modified 1902 diagram by Pareto in respect to what considered to be a social pyramid spinning top, in which, over time, more agitated human molecules (active people) reactively move up the socioeconomic ladder, whereas less agitated human molecules (lazy people) reactively move down the socioeconomic ladder, and that over generations there occurs a circulation of elites as he saw things, i.e. the Rockefellers don't stay Rockefellers forever, one of the tenets of his so-called Pareto principle of wealth distribution:



The 1980s lazy ant study—the finding that ants can be divided into two categories: one consisting of hard workers, the other of inactive or 'lazy' ants, and that if the "system" is shattered by separating the two groups from one another, each in turn developed its own subgroups of hard workers and idlers; in other words, a significant percentage of the 'lazy' ants suddenly turned into hard working ants—corroborates with Pareto's model.[78] This might well be contrasted this with equal workers in a workers state social engineering model of Karl Marx and Friedrich Engels, which like Pareto employed people as molecule models and some thermodynamic thinking, but unlike Pareto does not corroborate with the lazy ant study, who concluded that a rectangular system like equal status system would be the ideal model for society:



In 1935, a Pareto-like chemical thermodynamic model was outlined by American physiologist Lawrence Henderson, wherein, building on the work of Pareto, mixed with the chemical thermodynamics work of American engineer Willard Gibbs, which in turn is based on eq. 2, goes through a comparison of the equilibrium properties of the following liquid phase chemical reaction, namely of reactants carbon acid H_2CO_3 with disodium phosphate Na_2HPO_4 to form the products of sodium bicarbonate $NaHCO_3$ and monosodium phosphate NaH_2PO_4:

$$H_2CO_3 + Na_2HPO_4 \rightleftharpoons NaHCO_3 + NaH_2PO_4$$
(eq. 4)

to that of the equilibrium properties of social systems, at the end of which Henderson states:[38]

> "This simple example illustrates [the] logical principles [physical chemistry] that find **universal application** in the physical, biological, and **social sciences**."

In other words, eq. 2 applies 'universally' to the social sciences and is in fact the foundation of future socioeconomics. A simple comparison would be the modelling of the two global power horses, China, symbol C, and America, symbol A, considered as a of the socioeconomic reaction:

$$C_i + A_i \rightleftharpoons C_f + A_f$$
(eq. 5)

The two socioeconomic systems will continue to equilibrate over time as mutual consumers and produces or coupled systems of molecular economic agents, being acted on by the force of *ophelimity*, which as we now know is the electromagnetic force, operated via the exchange of fields particles called photons, according to which goods and services are exchanged as a large scale function of the exchange force, until the termination point (equilibrium) of the process is reached, a point quantified by the socioeconomic equilibrium constant of the socioeconomic reaction.

Rossini goes on to state that from the second law (eq. 2) and the first law, namely energy can neither be created nor destroyed only transformed, or in equation form:

$$dU = dQ - dW$$
(eq. 7)

which states that the change in internal energy of a system will equate to the differential of the heat dQ added less the work dW done by the reacting system on the surroundings, we can derive the following two equations:

$$\Delta G^\circ = -RT \ln K$$ (eq. 8)

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$ (eq. 9)

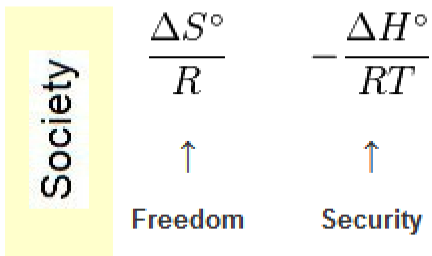
The first of which was derived in the *circa* 1884 so-called 'van't Hoff equilibrium box' experimental work of Dutch physical chemist Jacobus van't Hoff, the second of which was first derived in the 1923 'free energy table' work of American physical chemist Gilbert Lewis. Rossini then combines these two equations, eq. 5 and eq. 6, to arrive at the following governing equation for social systems:

$$\ln K = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{RT}$$
(eq. 10)

Rossini then concludes rather boldly:

> "The final state of equilibrium [Pareto equilibrium] is a compromise between the 'freedom' term, ΔS°/R, and the 'security' term, a –ΔH°/RT. To repeat, the final state of equilibrium, then, is a compromise between two more or less opposing factors: greater freedom or greater entropy, as measure by ΔS°/R; and grater security or lesser energy, as measured by – ΔH°/RT."

In short:



Stated another way:

> "Many economists and marketing executives would like to know what drives human behavior in the so-called marketplace. Thermodynamics explains what 'drives' inanimate behavior, that is, which processes will spontaneously occur and towards what equilibrium conditions they strive. Thus we might apply this theory also to economic behavior of humans. In thermodynamics the two quantities of greatest interest are the *energy* and the *entropy*."
>
> — Sture Nordholm (1997), "In Defense of Thermodynamics"[40]

To summarize, all previous equations, eq. 1 to eq. 10, can be shown to be related, in respect to the chemical thermodynamic theory of the socioeconomic behavior of humans, by the following relation:[46]

$$A = -\left(\frac{\partial G}{\partial \xi}\right)_{p,T} \qquad \text{(eq. 11)}$$

which is called the *affinity-free energy equation*, first derived in the above form by Belgian chemist Theophile de Donder in his 1936 *Thermodynamic Theory of Affinity*, though originally proved by German physicist Hermann Helmholtz in his 1882 ‘On the Thermodynamics of Chemical Processes’, where A is the driving force or the ‘elective affinities’ as Goethe envisioned things, otherwise considered as the ‘micro’ aspect of ophelimity force of socioeconomics, which acts on the individual molecular agent, in the mediation of its will and resultant desire for goods and services, ∂G is the partial derivative of the Gibbs free energy of the system, the system modeled as isothermal-isobaric, and $\partial \xi$ is the extent of the reaction, in other words the measure of the progress of the system reaction towards equilibrium. The recent works of German physicist Jurgen Mimkes (2006) and American physical chemist Thomas Wallace (2009) give some further derivation and guidance, respectively, in respect to eqns. 1-10 applied socioeconomically.[47]

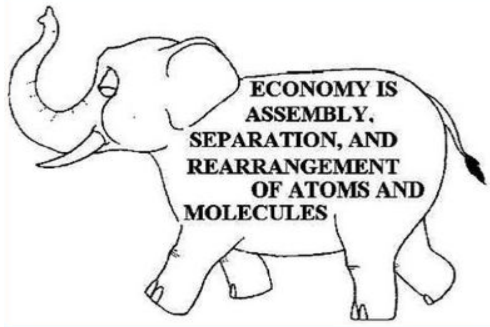
This controversial, to some, blasphemous, to others, assertion, that energy and entropy change govern the economy, the market place, and social freedom, naturally enough, in the post 9/11 era, has gone on to provoke quite a debate in the *Journal of Chemical Education*, with religious objection being the main resistance factor, a debate that continues up to the present day.[39] Barring further digression, the main point to take away here is that if one desires to do *real world* physical science based socioeconomic modelling, the ‘molecule’ or molecular agent model of the human is the correct mode of inquiry, surface-attached molecule model in particular, over that gas molecule models, being that humans are animate molecules attached to surface, as compared to other more remote models, such as spin models or subatomic particle models.

The approach tending to be employed in recent econophysics paper and books, conversely, tend not to be so near to reality as was would Rossini, Henderson, and Pareto advise us to employ. The following financial physics themed cartoon by American physicist and webcomic author Randall Munroe, used to mock the 2013 book *The Physics of Wall Street* book by American mathematician and physicist James Weatherall, is a remote example of this:[30]

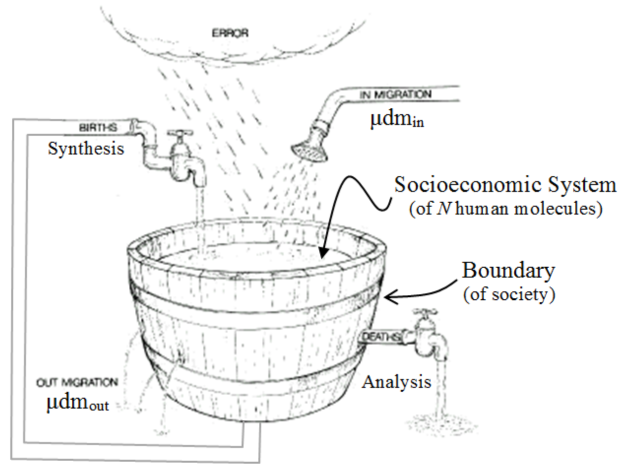
A case in point, of this cartoon parody, is Russian-born American physicist Victor Yakovenko and his graduate student Romanian-born American physicist Adrian Dragulescu’s popular 2000 article ‘Statistical Mechanics of Money’, wherein the open to the following ‘model it as a <simple object>’ approach:[41]

> “In a closed economic system, money is conserved. Thus, by analogy with energy, the equilibrium probability distribution of money must follow the exponential Boltzmann-Gibbs law characterized by an effective temperature equal to the average amount of money per economic agent.”

While there is no *Journal of Econophysics*, per se, the ‘just model it as a simple object’ approach, shown here is repeat with errors: firstly, socioeconomic systems are not closed, migrations and trade are two examples of matter (open system) crossing a socioeconomic system boundary:



The above image, to illustrate atomic-molecular nature of an economic system, is from Russian-born American organic chemist Yuri Tarnopolsky’s 2011 ebook *Introduction to Pattern Chemistry*, on the subject of what he calls ‘econochemistry’ or chemistry on the human-interaction scale model of society and economy.[48] The following diagram, to illustrate further is American physical sociologist Ed Stephen’s 1995 so-called semi-open thermodynamic territory rain barrel model of the boundary of society, given a comparative outline of how socioeconomic systems are assemblies of atoms and molecules (people) open to migrations of people, a factor quantified by chemical potential μ variables:[68]



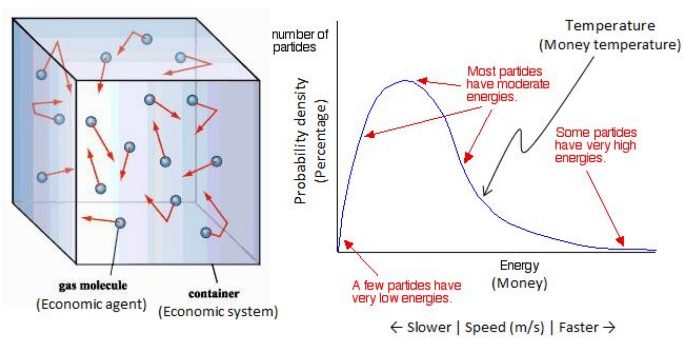
The model here of *in migrations* and *out migrations* quantified thermodynamically by the mass of the bodies or molecular agents, entering or leaving, respectively, the socioeconomic system, times the chemical potential of the agent, is a fairly advanced concept, about which very few people venture about. One example usage, however, is found in the 2003 article 'Money in Gas-Like Markets: Gibbs and Pareto Laws', by Indian econophysicists Arnab Chatterjee, Bikas Chakrabati, and S.S. Manna, who start out with a few simple assumptions, then derive a few equations, to reach the following conclusion:[28]

> "The possibility of adding and subtracting agents into/from the market, one similarly needs (negative) "chemical potential" which becomes zero at a finite temperature or money level in the market, when the "Bose condensed" fraction of the agents will fall out of the market distribution and might be identified as unemployed."

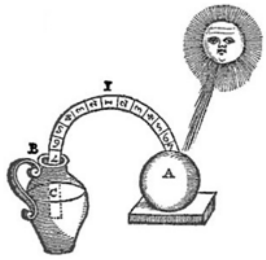
To continue, although the 'money = energy' model abounds, as has been historically well documented, money is not technically energy, in neither the mass-energy equivalence sense nor in the mechanical equivalent of heat internal energy transformed into work, nor in the conservation of kinetic energy sense—though English radiochemist Frederick Soddy might have something more to say about this—but rather, money is a function of the exchange force, operating such that the internal energy of the socioeconomic system as a whole is conserved and or transformed—and part of this, as Rossini points out, is found as bond energy in the form of socioeconomic chemical bonds and interaction energies, much of which does not have yet quantified monetary value. A simple case in point being the disappearance of billions of dollars every year lost in corporate misuse, another being the flipping of quarter into a wishing well, in hopes of an idealistic longing for a desire. Is the mechanical energy equivalency value of the quarter conserved in the wish?

Thirdly, the Boltzmann-Gibbs distribution, is a statistical mechanics based probability distribution particles, which, according to the Boltzmann chaos assumption, have non-correlated velocities—people have correlated velocities (if two people are driving toward each other head on in a game of chicken, one will swerve before impact)—of gas molecule speeds per degree of system temperature, people, however, are not gas molecules, neither are units of money:

Maxwell-Boltzmann Distribution | Money Model



Lastly, models of socioeconomic temperature have a long history of confusion, one of which owes to the fact that indicators for social temperature, measured in degrees kelvin, have not yet been invented, in the way that Philo of Byzantium in 240 BC made the first thermometer:



Philo thermometer (240BC)

Twitter social heat map (2013)

though there is no shortage of attempts—the above social heat map, based on tweets per location, being one example.[42]

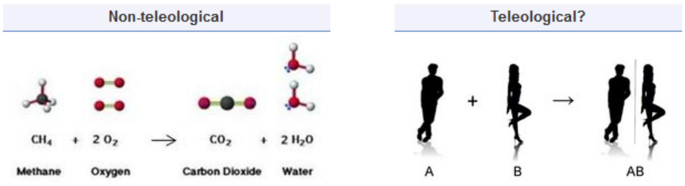
Our focus herein, in this comical light, will be to examine, in hindsight, the ubiquitous loaded term notion of the 'agent' model of the human, often used in econophysics and sociophysics, in which a person is defined as an abstract entity in possession of *agency* or thing with the capacity, condition, or state of acting, or exerting power, via physical operation, through which an end is achieved. While some uses of the term agent are fairly cogent:

> "We have begun to regard complex modes of human activity as collections of many interacting '**agents**'—somewhat analogous to a fluid of interacting atoms or molecules, but within which there is scope for decision-making, learning and adaptation."
>
> — Philip Ball (2003), "The Physics of Society"[29]

others are less so, often being laced with historical philosophical baggage not tending to be found or recognized in the molecular world of textbook chemical thermodynamics:

> "The question is what minimal agent can we conceive? I my *Investigations* (2000), I sought to answer this by proposing that a minimal **molecular agent** is a system that can reproduce itself and carry out one [thermodynamic] work cycle. On this account, a bacterium swimming up a glucose gradient and performing work cycles is an agent, and glucose has a value and meaning for the bacterium without assuming consciousness. Teleological language has to start somewhere, and I am willing to place it at the start of life."
>
> — Stuart Kauffman (2007), "Beyond Reductionism: Reinventing the Sacred"[43]

The term 'molecular agent' used here by American evolution theory chemist Stuart Kauffman, is cogent, but other addendum parts of his definition not so cogent. Self-reproducing system is code for perpetual motion. Chemical teleological is but recursive logic, implying that the final state of a reaction, or final cause (purpose) in the Aristotle sense, caused the motion:



TELOS – (from the Greek τελος): projected end, purpose, goal, achievement, realization. As in teleology, entelechy, …

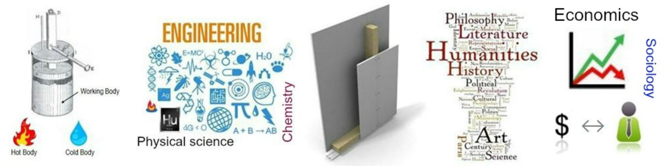
In other words, the following statement, found in actual college chemistry textbooks:[44]

> "Atoms [people] react in order to maintain stability."

Though subtle to notice on first pass, is teleological, because, as American psychologists Deborah Kelemen, Joshua Rottman, and Rebecca Seston explain, in their 2012 study on the use of purpose-based reasoning among professional physical scientists, because the statement 'violates temporal constraints by treating an entity's consequence as if it could be its own cause in a backward causal fashion.'

An agent, wherein a person is defined specifically as a molecule, correctly, whether gas molecule, fluid molecule, surface-attached molecule, will be defined herein, based in part of Kauffman's work cycle usage, as a 'molecular agent'. On this platform, a second focus will be to digress into the prospects of what some have been calling econoengineering or the application of econophysics pure. Throughout these discussions, our standing aim will be to facilitate the process of breaking down the long standing dividing way that separates the engineering, chemistry, and physical science departments from the humanities, economics, and sociology departments, because as Goethe so long ago put it:

> "There is, after all, only one nature."
> — Johann Goethe (1809), anonymous advert[56]



2. ECONOENGINEERING

An 'econo-engineer', as Robert Ekelund and Robert Hebert discuss in their 1999 *Secret Origins of Modern Microeconomics: Dipuit and the Engineers*, is a trained engineer who subsequently publishes on economic subjects, a term that traces to period following the French revolution and the period of the formation of the famous *École Polytechnique* the polytechnical school where thermodynamics was born, a group that includes: Jules Supuit (1804-1866), Achille Isnard (1748-1803), supposed progenitor of Leon Walras' general equilibrium model, a theory later expanded upon by Italian-French econoengineer Vilfredo Pareto in his economic force social mechanics theory, among about a dozen others.[69] While the work of Pareto, and the Lausanne school of physical economics, which includes: Leon Winiarski, Maffeo Pantaleoni, and Emanuele Sella—a group which utilized both eq. 2 and human molecule theory—are seen as the exemplar par excellence econoengineering models, the art of econoengineering, *per se*, has seemed to have fallen out of practice into the 20th century. This is evidenced by the following 1989 retrospect commentary by American economist Paul Samuelson on makeshift retired engineers-turned-econoengineers:[70]

> "As will become apparent, I have limited tolerance for the perpetual attempts to fabricate for economics concepts of 'entropy' imported from the physical sciences or constructed by analogy to Clausius-Boltzmann magnitudes. The monthly mail still brings grandiose schemes to replace the dollar as a unit of value by energy or entropy units. Superficial knowledge of thermodynamics, brought into contact with ignorance of economics, cannot even in the presence of the catalyst of noble intentions beget stable equilibrium of useful of useful products. This is not a tautology, merely a finding of fifty-five years of reading the morning mail."

No doubt there is much truth to this 'superficial knowledge of thermodynamics, brought into contact with ignorance of economics' mentality of the weekend econoengineer. The author frequently comes into contact with these weekend types as well in his yearly email communications. Samuelson, to his discredit, while a second generation student of American engineer Willard Gibbs, via Edwin Wilson, lacked the thermodynamic ability to be able to see the big forest amid the trees picture.[36] While Samuelson, in his 'Gibbs in Economics' symposium contribution, is quick to parody the situations with his 'I could trace some farfetched elements of economics connected to Gibbs', he seems to be himself ignorant of the fact that the entire basis for formulating a reactionary equilibrium economic model is spelled out clearly in the pioneering 1876 work of Gibbs, which Samuelson cites:[71]

> "Little has been done to develop the principle [of entropy] as a **foundation** for the general theory of [economic] thermodynamic equilibrium, which may be reformulated as follows: for the equilibrium of any isolated [socioeconomic] system it is necessary and sufficient that in all possible **variations** of the state of the system which do not alter its energy, the variation [δ] of its entropy shall either vanish or be negative."

The method of how this is accomplished, in terms of formulating a theory of thermodynamic equilibrium of socioeconomics, is via eqns. 10 and 11. While Samuelson, to his credit, in his PhD dissertation turned book *Foundations of Economic Analysis*, suggest that the variation of the demand for a factor with a change in its price was analytically similar to thermodynamic variation in the pressure, volume, and temperature of an ideal gas, he does little beyond this, his 1972 discussions of an economic Le Chatelier principle aside, to develop the principle of entropy as a foundation for a general theory of economic equilibrium.

On this platform, we can now define modern *econo-engineering* as the study of the principles of physical socioeconomic pure and applied, applied in the form of engineered socioeconomic actuations—with focus on correctness of basic concepts and the notion of applicability of chemical, physical, and thermodynamic theory to humans, socially and economically.

The two pure physical humanities fields seeing the most activity in recent years, as evidenced by their recent inclusion in German, Polish, and to some extent American physical societies, are sociophysics and econophysics, where, in the latter of which—econophysics—in particular, there are two schools of thought: firstly, the mainstream view according to which tools of physics, such as the Boltzmann distribution, random walk theory, Ising model, fractal analysis, statistical mechanics, etc., are applied to the study not humans directly and individually but their bulk peripheral indicators such as financial patterns, market trends, money, and other sociological gauges, a point of view which seems to be well captured by the following statement:

> "Econophysics **does NOT** literally apply laws of physics, such as Newton's laws or quantum mechanics, to humans. It uses mathematical methods developed in statistic physics to study statistical properties of complex economic systems consisting of a large number of humans."
>
> — Victor Yakovenko and Barkley Rosser (2009), "Statistical Mechanics of Money, Wealth, and Income"[5]

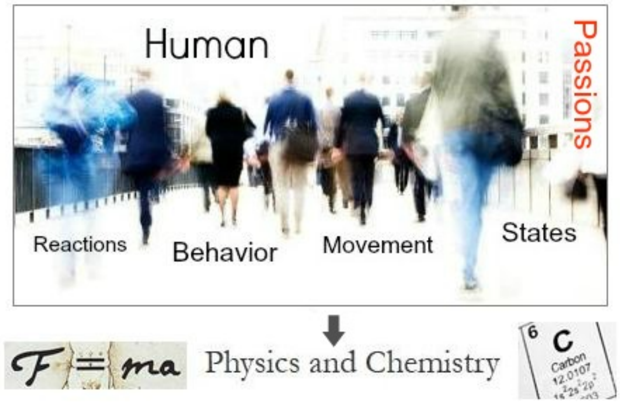
This school of thought, being opposed to the line of argument held herein, namely that eq. 2 does apply literally to humans and social behavior, naturally enough, tends to produce less fruitful results, being that it has cordially distanced itself from the 'real world' of chemical thermodynamic governed reactionary reality.

The alternative more avant-garde and according to some controversial view applies physics 'literally' to humans, a point of view well captured by the following two statements:

> "Sociophysics uses some methods and concepts coming from physics to describe certain social and political behaviors. Galam's sociophysics study the existing knowledge thanks to methods borrowed from statistical physics. Because sociophysics [**DOES**] compare the behavior of people with the behavior of atomic particles, it is not an exact science."
>
> — Christophe Thovex and Francky Trichet (2012), *Social Networks Analysis*[6]

> "Econophysics was from the beginning the application of the principles of physics to the study of financial markets, under the hypothesis that economic world [**DOES**] behave like a collection of electrons or a group of water molecules that interact with each other, and the econophysicists are always considered that, with new tools of statistical physics, and the recent breakthroughs in understanding chaotic systems, they are making a controversial start at tearing up some perplexing economics and reducing them to a few elegant general principles with the help of some serious mathematics borrowed from the study of disordered materials."
>
> — Gheorghe Savoiu and Ion Siman (2008), "Some Relevant Econophysics Moments"[4]

The essential difference between the two schools of thought is that one does not speculate on the nature of human behavior—chemically, physically, or thermodynamically—whereas the other does, in the form of what is known as reduction, human behavior reduced to physico-chemical description:



A point of issue, however, in these latter real world schools of thought speculations on the physical nature of human behavior, we see humans being compared to atomic particles, electrons, and water molecules, respectively, and in some cases subatomic particles:

> "Are humans fermions or bosons?"
>
> — Ed Stephan (1977), speculative discussions with physicist Louis Barrett[33]

> "All entities, whether fermions or humans, need some mediating agency to interconnect them into systems. This indispensable interrelating and interacting role is ultimately played by different field particles named bosons. Unlike fermions, which are characterized by a significant mass and charge, bosons do not take partake of these to attributes. Rather, they only have spins and provide connections as they are exchanged among fermions."
>
> — Paris Arnopoulos (2005), *Sociophysics*[34]

Many of these comparisons, in this real world school of thought, are quite explicit about the comparison, employing the human comparison in the titles of articles, books, and book chapters: 'Human Molecules' (Mary Mesny, 1910), *We Human Chemicals* (Thomas Dreier, 1948), 'Human Molecules' (Alan Nelson, 1989), 'When Humans Interact Like Atoms' (Serge Galam, 1996), *The Molecular Relationship* (Joseph Dewey, 1999), 'Particles or Humans? Econometric Quarrels on Newtonian Mechanics and the Social Realm' (Francisco Louca, 2001), *The Little Fun Book of Human Molecules* (John Hodgson, 2002), 'I Am Not A Molecule' (Steve Fuller, 2005), *The Social Atom* (Mark Buchanan, 2007), *The Human Molecule* (Libb Thims, 2008), 'Atom and Individual: the Trajectory of a Metaphor' (Kristian Camilleri, 2011), and so on. Here we see a proliferation of confusion as to what exactly a human is: fermion, boson, electron, particle, atom, chemical, and or molecule—a question that only becomes compounded with the dominate usage of the agent model in economics.

The first school of thought, which literally does NOT apply the laws of physics to humans, a group which more often than not tends to cite American physicist Eugene Stanley's 1995 conception of *econophysics* as the use of physics tools to study financial markets, will be classified herein as *surface* socioeconomic physics, or more generally as financial physics, in that it tends to employ physics tools to look at indicators of socioeconomic problems on the surface, e.g. the use of chaos theory to study the rise and fall of the price of tea in china or the Ising spin model to theorize about tax evasion, and so on.

This real world school of thought will be classified herein as *fundamental* socioeconomic physics, in that it employs universal physics principles, such as the standard model of physics, the conservation of energy, atomic theory, etc., in aims to discern the fundamental nature of human economic and social behavior in a unified or rather universal one-nature point of view, e.g. the use of the second law to study the transformation of a society over time or the application of quantum mechanics explain or speculate on determinism or indeterminism in the humanities.[35] Thinkers keen to real world point of view will argue, for instance, that the electromagnetic field governs the movement of people, as it does the movement of ions, atoms, and molecules and that socioeconomic theory needs to be structured around this uniform point of view. The former *surface* point of view, conversely, will strictly avoid such speculation—and may even go so far as to call such speculation crackpottery, often doing so with gleeful chuckle, though more often than not such thinkers tend to be what is called *forest blind*, able to see the trees (a few equations or principles) but not the forest (the one nature perspective).[36] Iranian mechanical engineer Mehdi Bazargan, the 75th prime minister of Iran, a well-rounded represented of the *fundamental* view, is a ripe example of someone in possession of view that the electromagnetic field governs human movement:

> "In general, an object in a given force field will, of necessity, **behave** in a calculable and predictable way. For any object, whether a stone, a plant, or a human society, force means movement."
> — Mehdi Bazargan (c.1980), "Cause of Movement and Life"[8]

Here we see the hypothesis, which we might readily call, for lack of an official statement of the fact that humans move in force fields, the Bazargan hypothesis—though, to note, he is not the first to apply field theory to the study of human movement, American physical historian Morris Zucker (1945), discussed below, being one example. Human societies, socially and economically, owing to their situation in a force field, according to Bazargan, will always 'behave' in a calculable and predictable way. Hence, if this is true, namely that economic behavior and social behavior can be quantified, calculated, and predicted, owing to the nature of the given force field, then the intuitive *socioeconomic engineer* should be able to formulate physical science based theories of economic behavior and on these theories make calculated predictions.

> "It is just because the application of the every-day principles of **engineering** to the animate engine [humans] offers such a powerful corrective to the make-believes of the economic systems of society that I have ventured to address you on the subject."
> — Frederick Soddy (1921), "Cartesian Economics Lectures"[1]

> "It is the possible development of theory (e.g., kinetic theory or sociophysics) and practice (e.g., **social engineering**) that may be useful for men."
> — Arthur Iberall (1974), *Bridges in Science: from Physics to Social Science*[7]

> "Early views of [Bertalanffy] systems approaches saw them as prologue to **social engineering** where individual choice is abstracted and human beings are relegated to the role of *molecules* bouncing around in a social petri dish."
> — Debra Straussfogel (2000), "World-Systems Theory in the Context of Systems Theory"[2]

Subsequently, to use a comparatively simple example, just as weather forecasters are able to use the equations and methods of meteorology to forecast into the future about 'predicted' phenomena such as rainfall, hurricanes, or earthquakes—knowledge which people can use to prepare for forecasted times of distress, such as by stocking up on food and supplies or taking shelter—so to, in the future, will the physical socioeconomist or physical historian be able to use the equations and science behind the nature of the force field and the Gibbs based socioeconomic 'variational principles' Samuelson speaks of, which in this case is the electromagnetic force, the same force behind light, magnetism, electricity, and chemical reactivity, and Gibbs free energy differentials, respectively, to forecast into the future about predictable socioeconomic phenomena, such as points of equilibrium or socioeconomic process termination. This was outlined in 1978 by Russian physical chemist Georgi Gladyshev as follows:[72]

> "In considering the thermodynamics of biological evolution it is convenient to examine subsystems where different processes of reaching corresponding quasi-equilibrium take place: molecular processes, chemical evolutions, supramolecular evolutions, and evolutions of higher orders such as genera, families, associations, and ecological evolutions, etc. Assuming that the corresponding quasi-equilibria are reached in the processes of general and particular evolutions of the biosphere and its subsystems one can use the Gibbs free energy criteria of equilibrium to predict the degree of evolutionary development of each process."

The details of how this is done, however, is where the current problem lies, but one that is but an engineering problem, that will needs solution help from both sides of the two cultures working together. Hence, in respect actual engineered applications, it will be some time before the actual subject of physical socioeconomics matures enough into the form of a solidified established program of research, one that is actually taught in universities as standard thoroughfare before one makes the tumultuous jump to actual socioeconomic engineering. Some, however, will be quick to believe that maturity has been reached:

> "Physics fields which have matured enough to allow reliable applications are called engineering and thus I mention shortly some successes of **econo-engineering**. This difference is the same as teaching the efficiency of a Carnot process in lectures in thermal physics, versus building an efficient car engine: both aspects are needed."
>
> — Dietrich Stauffer (2000), "Econophysics: a New Area for Computational Statistical Physics?"[3]

> "After 2000, econophysics has matured enough to allow generalized applications, their field being called sometimes **econo-engineering**."
>
> — Gheorghe Savoiu and Ion Siman (2008), "Some Relevant Econophysics Moments"[4]

Maturity, however, has not been reached and we are now more than two hundred years and counting since the subject and practice of econo-engineering, at the time of the 1794 founding of the French engineering school École Polytechnique founded by French engineer Lazare Carnot, father of thermodynamics initiator Sadi Carnot, and French mathematician Gaspard Monge, began to take root. Hence, the 'generalized applications' mentioned here are immature and mostly baseless—akin alchemy before it became chemistry. The Schulenberg and Associates so called 'Maxwell-Boltzmann Stock Market Timing Model' is one example of what seems to be a vacuous econoengineering result:[48]

SAI **Schulenberg and Associates (since 1981): Originators of the *Thermodynamic Approach* to Stock Market Timing and the Stock Strategist™ Newsletter**

This type of thermodynamic stock market picking method is certainly not taught in any engineering program the author is aware? This model, similar to the Yakovenko-Dragulescu's money mechanics model, an example of a type of economic alchemy, some green in fruit of application, others lost in search of the philosopher's stone. These are what are called thermodynamic sounding models, theories that use thermodynamic terms in namesake, like Shannon entropy, but not ones that employ the actual science of thermodynamics, meaning that they don't employ the terms work, heat, and temperature, in SI units:

> "Indeed, it may sound philistine, but a scientist *must* be clear, as clear as he can be, and avoid wanton obfuscation at all cost. For level-headed physicists, entropy (or order and disorder) is nothing by itself. It has to be seen and discussed in conjunction with temperature and heat, and energy and work. And, if there is to be an extrapolation of entropy to a foreign field, it must be accompanied by the appropriate extrapolations of temperature, heat, and work."
>
> — Ingo Muller (2007), *A History of Thermodynamics*[50]

The following is a good rule of thumb to tell if something is thermodynamic or not:

> "[Blank]'s discussion of thermodynamics is vague and superficial to an extent that should not be tolerated even in a popular lecture. In the discussion of thermodynamic quantities it is important to define the system. When [Blank] is writing about a change in entropy of the system, [Blank] never even defines the system. Sometimes [Blank] seems to consider that the system is a living organism with no interaction whatever with the environment; and sometimes it is a living organism in thermal equilibrium with the environment; and sometimes it is the living organism plus the environment, that is the universe as a whole."
>
> —Linus Pauling (1989), American chemical engineer[51]

Another example of a thermodynamic sounding applied socioeconomic engineering boasting comes from the 2009-launched consulting firm Social Thermodynamics Applied Research, founded by Spanish telecommunications engineer Gregory Botanes, claiming be applying the laws of social thermodynamics to model social network behaviors and make predictions of business paths, needs, and issues:

SThAR
Social Thermodynamics Applied Research

> "Sthar is the first company in the word to apply the revolutionary and recently discovered social thermodynamics universal laws to model social networks behavior and predict social changes, based on a mathematical model instead of existing statistics-based models."

While it is not our intention here to entrepreneur bash, it is imperative to point out, to new researchers, that the shortcut quick to make a dollar 'model it as a <simple object>' approach is like eating wonder bread: it tastes good at first, but does not fill the appetite for long.

Real econoengineering theorists are those such as Vilfredo Pareto who from 1890 to 1912 penning out theoretical ramifications, in the form of eight volumes, or American physical historian and chemistry of human molecules theorist Henry Adams, who, while not an engineer, from 1865 to 1918 penned out a dozen volume collected work set on a prolonged effort to find solution to the following view, stated by Adams in the early 1860s, are the is where the respect lies, not in quick to the gun shown-n-tell baseless derivations:

> "Everything in this universe has its regular waves and tides. Electricity, sound, the wind, and I believe every part of organic nature will be brought someday within this law. The laws which govern animated beings will be ultimately found to be at bottom the same with those which rule inanimate nature, and as I entertain a profound conviction of the littleness of our kind, and of

the curious enormity of creation, I am quite ready to receive with pleasure any basis for a systematic conception of it all. I look for regular tides in the affairs of man, and, of course, in our own affairs. In ever progression, somehow or other, the nations move by the same process which has never been explained but is evident in the oceans and the air. On this theory I should expect at about this time, a turn which would carry us backward."

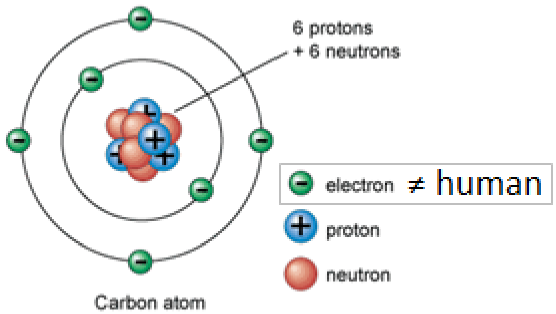
Likewise, American physical historian Morris Zucker, in his 1945 two-volume *Historical Field Theory*, is another example of respect due when makes a prolonged effort to apply bedrock physics principles, such as electromagnetic field theory, relativity, and quantum mechanics, etc., to the study of cause and effect in human history and from these resultant findings and principles, developed therefrom, initiates reasoned socioeconomic and historical predictions—predictions that could be used in engineering application if so desired.[9]

Our objective herein, however, will not be to go into a detailed analysis of these types of *fundamental* socioeconomic theories, of which there are many, numbering in the hundreds, but rather to give some seasoned direction to newcomers in the field of attempting to extend econophysics and or sociophysics into the form of an engineering discipline, such as econo-engineering or socio-engineering.

3. WHAT IS A HUMAN | PHYSICAL SCIENCE?

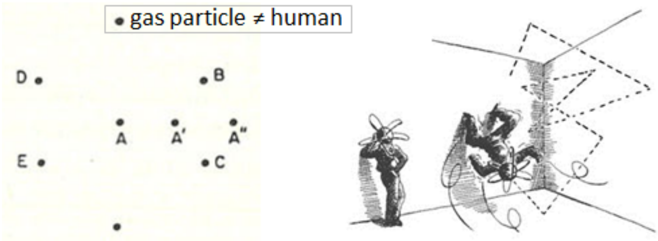
The above cited proliferate usages of the various 'electron, particle, atom, chemical, or molecule' models of humans, as well as generic 'agent' model of the economic entity, seem to give indication that this is the first issue of confusion that needs to be clarified prior to the development of any sort of socioeconomic engineering. In other words, what exactly is an individual human from the correct physical science point of view. Term clarification and definition would seem prudent at this point.

Firstly, an electron, symbol e^-, is a lepton with a rest mass of 9.11E-31 kg (0.511 MeV), an electric charge of -1.60E-19 coulombs, a spin of ½, is considered an elementary particle, and characterized as obeying Fermi-Dirac statistics. The following diagram, of a carbon atom, shows the basic visual conception of an electron, specifically the six negatively-charged particles, colored green, orbiting the nucleus, which is comprised of six protons and six neutrons:



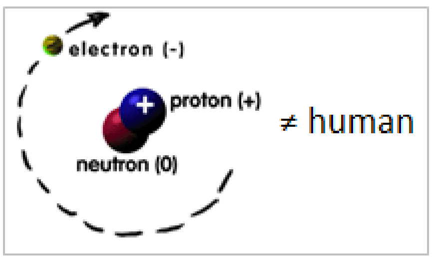
To cite one example comparison of humans to electrons, in *circa* 1986 American business executive Steve McMenamin defined self-motivated super-achievers of corporations, who define their own job, as 'free electrons' since 'they have a strong role in choosing their own orbits', as McMenamin put it. This business model became the chapter 'Free Electrons' of the 1987 book *Productive Projects and Teams* by Americans electrical engineer and consultant Tom DeMarco and business consultant Timothy Lister.[10] While interesting, and no doubt there is fruit to be reaped from this comparison, e.g. in the development of human molecular orbital theory, a human, to explicitly clarify, is NOT an electron.

Secondly, a particle, whether a Newtonian mechanics billiard ball particle, statistical mechanical particle, or atomic particle, is an entity generally defined as having no internal structure, one that has the property of having perfectly elastic collisions, meaning kinetic energy is conserved, and one that obeys the Boltzmann chaos assumption, which means that it has non-correlated velocities with other particles, and in short has a chaotic nature. Below left is Austrian physicist Ludwig Boltzmann's 1895 drawing of gas 'particles' in the 'rest position', as he conceived things; below right, is a 1999 parody rendition of a human as a particle bouncing off walls:[11]



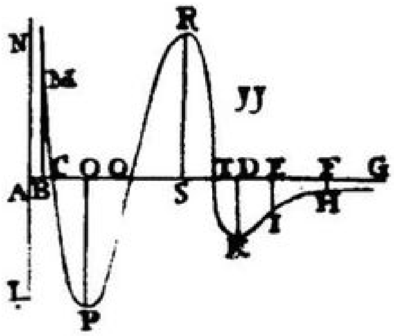
To cite one example comparison of humans to particles, in the 2004 book *Critical Mass: How One Things Leads to Another,* English chemist and physicist Philip Ball argues that 'to develop a physics of society' one must use the model that 'particles will become people', a conceptual model view where in computer simulations he discusses how he uses the term *peoploids* to designate human particles. While interesting, and while likewise there is fruit to be reaped from this ideal physics model conception, e.g. in power law theory distributions of wealth, a human, to explicitly clarify, is NOT a particle.

Thirdly, an atom is a bound state of matter consisting of a specific number of protons, from 1 to 92, as occurs naturally in earth-bound standard temperature and pressure conditions, tightly bound to about the same number of neutrons, and surrounded by typically the same number of electrons, depending on atom type, which are called elements, of which, again, there are 92 naturally occurring varieties, hydrogen to uranium. The following is the basic depiction of the atom:

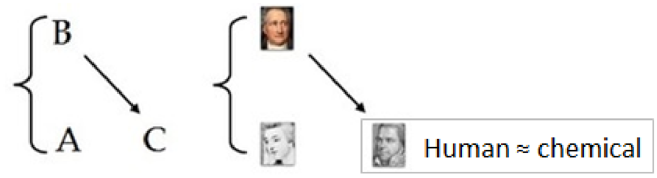


One of the earliest models of a human as an 'atom' comes from English chemist Humphry Davy who in 1813, building on the earlier 1758 work of Croatian mathematical physicist Roger Boscovich and his *Theory of Natural Philosophy*, wherein he outlines a stationary point atom theory, viewing atoms a 'centers of force', that are quantified by force–distance curves, such as found in his earlier 1745 dissertation *De viribus vivis*, where letters identify 'limit points' where attraction turns into repulsion and *vice versa*, inflection points, maxima and minima and so on—a complicated model to say the least—stated the following:[12]

> "The true chemical philosopher sees **man** an **atom** amidst atoms fixed upon a point in space and yet modifying the laws that are around him by understanding them; and gaining, as it were, a kind of dominion over time, and an empire in material space, and exerting on a scale infinitely small a power seeming a sort of shadow or reflection of a creative energy, and which entitles him to the distinction of being made in the image of God and **animated** by a **spark** of the divine mind."



The Boscovich model of the atom, in turn, would go on to influence a number of other humanistic philosophers including German philosopher Friedrich Nietzsche, who in 1865 discovered the work of German philosopher Arthur Schopenhauer, noted Goethean-Schiller humans-as-chemicals theory protégé, and his emphasis on 'will', i.e. the chemical will = human will model, and the concept of 'will to live', and, the following year, through a reading of Friedrich Lange's 1865 *History of Materialism*, discovered the work of Boscovich and his *Theory of Natural Philosophy*, and through these went on to develop a 'centers of force' theory of 'will to power' as the embodiment of what Nietzsche believed was the main driving force in man.[53] Digression, at this point, will not be possible, being that all of this Nietzsche-Schopenhauer will theory connect back to the rather involved and intricate 1796-1809 human chemical theory work of German polyintellect Johann Goethe, who conceived of relationships as affinity reactions, the nature of which being governed by the force *A,* of eq. 11, or the reaction forces of 'elective affinities' as they were called:[54]



Chemical Behavior [=] Human Behavior

Here, to quickly conclude, not only do we see Davy's argument riddled with religious conjectures, which was common in his era—but also, conjectures about how man as a special type of atom is able to 'modify the laws' about him, this being a common pitfall even in modern times—and one that is 'animated by a spark', which is good physics logic, but again one soaked with religion, namely a special type of spark guided by the divine mind.

Another example is French physical chemist Pierre Teilhard's 1938 *The Phenomena of Man*, and his surrounding corpus of publications written between 1916 and 1955, wherein he employs atom, molecule, and element models of the human. Certainly, Davy and Teilhard, like other authors who employ the term 'atom' to describe the behavior of humans in bulk, may being using this term in a figurative sense, metaphor, or analogy in aims to describe collective phenomena in a chemical or physical way? Whatever the case, it is now the 21st century and terminology clarification is a must—hence, whatever fruit the atom model of the human may have yielded in the past, to explicitly clarify, a human is NOT an atom.

Moreover, a human is MADE of atoms, some 26 varieties to be specific, not an atom. That this seems to be continuously confused, even in modern days, some two centuries after Davy, is puzzling? To cite one example, American physicist, in his 2007 *The Social Atom*, gives us the following advice:

> "We should think of people as if they were **atoms** or **molecules**."

This makes no sense, whatsoever? Are we both an atom and a molecule? An atom, by definition, is one single element, in possession of one single nucleus, though the size of this nucleus will vary, depending on element type. A molecule, conversely, by definition, is a structure comprised of two or more atoms. This definitional distinction, between an atom and a molecule, was established in 1649 by French thinker Pierre Gassendi, in his *Arrangement of the Philosophy of Epicurus*. In respect to evolution and atomic theory, Gassendi gave us the following logic:[13]

> "While [the **atoms**] are moving in various ways and meeting, interweaving, intermingling, unrolling, uniting, and being fitted together, **molecules** or small structures similar to molecules are created, from which the actual seeds are constructed and fashioned."

The distinction should be clear at this point: atoms are the material building blocks of chemistry, that move about in various ways, and humans are 'fitted together atoms', as Gassendi explains, to which he assigns the term 'molecule', which is French for 'small mass' or 'extremely minute particle'.[14] In short, a molecule is a bound geometry of two or more atoms. More advanced terminology, beyond this basic definition, can be also be employed. German-born American physical organic chemist Ernest Grunwald, in the opening section 'Formal Components', to his 1997 book *Thermodynamics of Molecular Species*, for example, defines the term molecular species, as follows:[15]

> "In general, a **molecular species** is a macroscopic or near-macroscopic ensemble of molecules that are characterized by a definite molecular formula, a definite and distinctive equilibrium geometry, and a distinctive set of molecular modes of motion and spectral properties. For example, the actors in chemical reaction mechanism—the reactants, products, substrates,

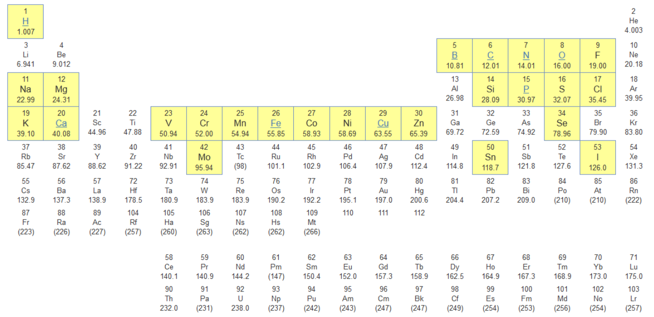
catalysts, reactive intermediates, and even the mechanically unstable transition states—all represent separate molecular species, as do any sets of molecules that become distinguishable in physical interaction mechanisms.”

Individual humans, as we will see, are indeed characterized by a ‘definite molecular formula’, hence, in a thermodynamic sense, one can also employ the term molecular species to describe a human, in terms of modern physical science. That Buchanan, a trained physicist, should confuse the two definitions, atom and molecule, in respect to what exactly is a human, is puzzling?

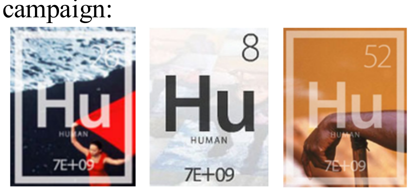
Fourthly, as mentioned in the Pierre Teilhard example usages, sometimes one will come across the ‘element’ definition of a human. English-born American chemical engineer William Fairburn, in his 1914 book *Human Chemist*, for instance, outlined a theory of human chemistry based on the following logic:

> “All men are like **chemical elements** in a well-stocked laboratory, and the manager, foreman, or handler of men, in his daily work, may be considered as the chemist.”

An element, however, to clarify, is an atom characterized by a nucleus containing a specific number of protons, numbering from 1 (hydrogen) to 92 (uranium), for naturally occurring elements, of which 26, as shown highlighted below, are found to comprise the definite molecular formula of a human:



The following likewise, are examples of the human element icon logs from the noted 2006 Dow Chemical advertising campaign:

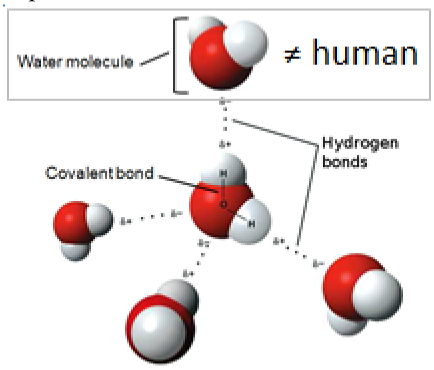


according to which the symbol Hu is the element symbol for a human, just as H is the element symbol for hydrogen, and where the number 7E+09 is the current human population of 7 billion people, themed on a combination of the mass number notation, found at the bottom of each element on the periodic table, and Avogadro’s number 10E+24, the number of atoms in a twelve gram sample of carbon twelve. The person behind this ‘human element’ creative idea was science and human behavior reader John Claxton, creative director of Draftfcp Chicago, who at the request of Andrew Liveris, the newly established Dow CEO, who was looking for a new philosophical motto for Dow, possibly akin to how Google’s informal corporate motto is ‘don’t be evil’, came up with the idea, which he explains as follows:

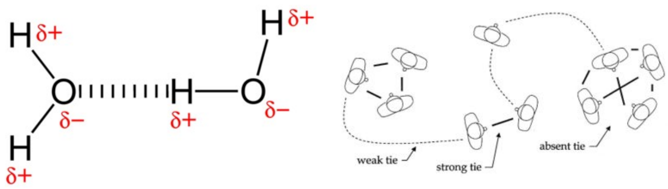
> “One of the first steps was a creative meeting at our agency during the “pitch process.” I walked into the meeting with a new element for the Periodic Table. . . not carbon, hydrogen or oxygen, but the **Human Element**. That pretty much put everything in motion. Including the Human Element on the Periodic Table of the Elements changed the way Dow looked at the world and the way the world looked at Dow. Every creative decision we made from that point on was filtered through the lens of the Human Element, and that’s what took us down a very non-science approach to science advertising.”

While this is certainly an interesting philosophy, the Hu logo in fact worn commonly by the author on his golf shirts as representative of his general periodic table chemical philosophy of human existence and experience, to explicitly clarify, a human is NOT an element, but rather a animate structure COMPRISED of elements.

Fifthly, and lastly, in respect to physiochemical science models of humans, we come to the chemical or molecule model of the human. The following is a depiction of molecules, five water molecules held in a group by hydrogen bonds to be specific:



The classic usage of the comparison of people to water molecules, of course, is the famous 1969 ‘weak ties’ hydrogen bonding based association model of American sociologist Mark Granovetter, a job finding study based theory that resulted in his 1973 article ‘The Strength of the Weak Ties’, the gist of which is that weak social ties, similar to weak hydrogen bonds, as compared strong social ties, similar to covalent bonds, is the primary method though which people tend to find jobs—the visual comparison of which is outlined below:[16]



Granovetter’s weak ties paper, of interesting curiosity, was initially rejected—specifically by the *American Sociological Review*—Granovetter soon, however, resubmitted a shortened version to *American Journal of*

Sociology, where it was accepted and it has since gone on to become the most-cited sociology paper of all time; cited in over 24,000 publications at present. Granovetter's model is a subject germane to the human chemical bonding theory, a subject beyond the scope of the present article, but a subject touched on herein in the Rossini model of internal energy of social systems.[17] To quickly point out one area of confusion, however, in respect to human chemical bonding, that often tends to erupt when molecule or chemical reaction models are used to explain human behavior, when, for instance, an author states explicitly that an individual single unattached human is a molecule and that when a pairing occurs a chemical bond will accrue through the following type of combination reaction:

$$A + B \rightarrow AB \qquad \text{(eq. 12)}$$

The person new to the field of human chemical reaction theory, a subject that dates back to the 1796 work of German polyintellect Johann Goethe, and his human chemical theory, will often times quickly object to the supposition that two people, A and B, defined as molecules, are held in an actual chemical bond, AB, on the objection that the actual bond '≡' of the union A≡B or AB for short is not a covalent bond, and hence not a real chemical bond, but rather the use of the term bond in respect to human unions is only metaphor, or something along these lines. This objection comes up so frequently, that clarification would seem prudent at this point.

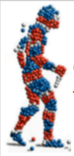
Firstly, a covalent bond, simply means that that two atoms share valence electrons, nothing more, nothing less, or in quantum chemistry terms, as described in 1927 by German physicist Walter Heitler, as the joining together of electron wavefunctions, with plus, minus, and exchange terms.[18] Human bonding is much more complicated than this. While both, covalent bond and human bond, involve the interaction of photons with valence shell electrons, i.e. quantum electrodynamics, in the language of American physicist Richard Feynman, the former involves only two electrons, while the latter involves some 10^{27} electron and photon quantum electrodynamic interactions at a rate of 1,000 billion per second, in daylight hours, interacting per surface area the size of a pinhead. For lack of a better word, some will refer to human interactions, chemically speaking, as non-covalent interactions. One example comes from French chemist Jean-Marie Lehn who in 1995 stated the following, in an unwritten reference to Goethe's human chemical theory:[19]

> "Supramolecular chemistry is a sort of molecular sociology! **Non-covalent interactions** define the inter-component bond, the action and reaction, in brief, the behavior of the molecular individuals and populations: their social structure as an ensemble of individuals having its own organization; their stability and their fragility; their tendency to associate or to isolate themselves; their selectivity, their 'elective affinities' and class structure, their ability to recognize each other; their dynamics, fluidity or rigidity or arrangements and of castes, tensions, motions, and reorientations; their mutual action and their transformation by each other."

Lehn is alluding here to the idea that humans are like 'molecular individuals' whose sociological nature is mediated by non-covalent interactions. In any event, while there is much fruit indeed in the molecular model of humans, to explicitly clarify, a human is NOT a water molecule. A human IS, however, a molecule, just not a water molecule, which is only made of two elements, and is non-animate. The definition of a human as a molecule was first proclaimed in 1789 by French philosopher Jean Sales, in his *Treatise on Moral Human Nature*, as follows:[55]

> "We conclude that there exists a principle of the human body which comes from the great process in which so many millions of atoms of the earth become many millions of **human molecules**."

This is correct: a human is a molecule, specifically a surface attached motile carbon-centric animate molecule—specifically, an individual human is a 26-element, CHNOPS-based, surface-attached, animate, turn-overrate, freely-going molecule or molecular species, with the following average human molecular formula:



$$C_{10^{27}} H_{10^{27}} O_{10^{27}} N_{10^{26}} P_{10^{25}} S_{10^{24}} Ca_{10^{25}} K_{10^{24}} Cl_{10^{24}} Na_{10^{24}} Mg_{10^{24}} Fe_{10^{23}} F_{10^{23}} Zn_{10^{22}} Si_{10^{22}} Cu_{10^{21}} B_{10^{21}} I_{10^{20}} Sn_{10^{20}} Mn_{10^{20}} Se_{10^{20}} Cr_{10^{20}} Ni_{10^{20}} Mo_{10^{19}} Co_{10^{19}} V_{10^{18}} = \text{human}$$

This formula definition of a human, as of 2011, is now the standard thermodynamics textbook definition of a human. Specifically, as Indian-born American mechanical engineers Kalyan Annamalai, Ishwar Puri, and Milind Jog, in their 2011 *Advanced Thermodynamics Engineering*, define things:[21]

> "A human [is] a 26-element energy/heat driven dynamic atomic structure."

Alternative definitions of a human as a 22-element molecule, based on American limnologists Robert Sterner and James Elser's human molecular formula, published in their 2002 *Ecological Stoichiometry* textbook, likewise, can be found several recent ecology textbooks and encyclopedias.[22] Sterner and Elser define a human as follows:[23]

> "This formula combines all compounds in a human into single abstract 'molecule'. The stoichiometric approach considers whole organisms as if they were single abstract molecules. Organisms can be thought of as complex evolved chemical substances that interact with each other and the abiotic world in a way that resembles a complex, composite, chemical reaction. This formula for the '**human molecule**' [allows one] to think about how every human represents the coming together of atoms in proportions that are, if not constant, at least bounded and obeying some rules."

At this point, to clarify explicitly, a human IS a molecule, but one of a very specific type—and to clarify again a human is NOT a water molecule, nor an atom, particle, electron, or element, but a surface attached animate molecule that reacts with other human molecules, and the surrounding system, in the form of large scale mechanism-based surface attached human chemical reactions. This logic in physical economics was long ago point out by Dutch-born American mathematician, theoretical physicist, and economist Tjalling Koopmans, who in 1947, seems to have been the first, in the 20th century, to state something along the lines of what is called the human molecular hypothesis:[24]

> "While it was long possible and sometimes tempting for physicists to deny the usefulness of the molecular hypothesis, we economists have the good luck of being some of the 'molecules' of economic life ourselves, and of having the possibility through human contacts to study the behavior of other 'molecules'."

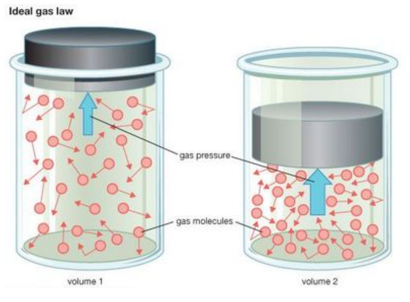
The study of economic behavior, according to Koopmans—notable co-recipient of the 1975 Nobel Prize in economics—is thus the study of molecular behavior. This is the theoretical starting point for any and all sound econophysics or physical economics research. Those who, in sociophysics and econophysics, would deny that humans behave molecularly, an example of which being the following grossly incorrect 1996 statement by Austrian-born American physicist Fritjof Capra:[25]

> "Humans can choose whether and how to obey a social rule; molecules cannot choose whether or not they should interact."

are from the get-go starting on incorrect intellectual footing. Humans, according to modern 21st century physical science are indeed molecules, and as Capra correctly points out 'molecules cannot choose' how or whether or not they should interact—the choice is but the 'result of the process' as Mexican-born American chemist Vicente Talanquer would say.[26]

4. HUMANS: GAS OR SURFACE MOLECULES?

A seemingly obvious question is are humans gas molecules or surface attached molecules? To give some hints to this question, the following, below right, shows a prototype, i.e. a Guericke vacuum pump and vacuum bulb, to the famous 1858 pneumatical engine invented by Robert Boyle and Robert Hooke, with which the first ideal gas law, namely that pressure, of an ideal gas, is inversely proportional to its volume, aka Boyle's law, was formulated, and below left shows the generic conception of what 'behavior' ideal gas molecules supposedly have, namely that the move around in the gas phase at speeds of 500-meters per second or 1200-mph seemingly unaware of each other's motion—an approximation known as the Boltzmann chaos assumption:[73]



To answer this question via illustrative comparison, many of us have heard the story of the 18-wheeler semi tractor-trailer that gets stuck under a bridge, after which the city calls in a team of civil engineers, several tow trucks, and a helicopter to figure out how to get the semi unstuck, and out from under the bridge. After dozen hours of deliberation among the team of 20 people, including discussions to use, oil, soap, to dig up the ground, take the semi apart, destroy the bridge, call in the national guard, and so on, a small boy on the outskirts of the crowd raises his hand and exclaims: 'couldn't you just let the air out the tires?', after which everyone's mouth stood agape, realizing the boy was correct.

The same issue exists in socioeconomic physics, namely every year, dozens if not hundreds of papers and books are written by teams of physicists, replete with hundreds of recalled from memory toolism derivations and equations, and all sorts of methods to get the problem of how to solve socioeconomic problems using physics unstuck. After several decades of deliberation in scientific journals, a small boy passing by an open door of an econophysics conference raises his hand and proclaims: 'aren't humans surface-attached molecules and not gas molecules?', after which everyone pauses for a moment and realizes the boy was correct. Humans are indeed molecules attached to a surface. Hence, it would deem prudent to employ surface chemistry, surface physics, and surface thermodynamics models, articles and books about which there is no shortage of, in attacking socioeconomic problems. To exemplify, the following diagram, from Gabor Somorjai and Yimin Li's 2010 *Introduction to Surface Chemistry and Catalysis*, gives a visual conceptual model of molecules, in this case reactants CO and O_2 and product CO_2, first unattached, then attached, at the surface catalyzed collision reaction point, then unattached again as gas molecules, in the product end of the reaction process:

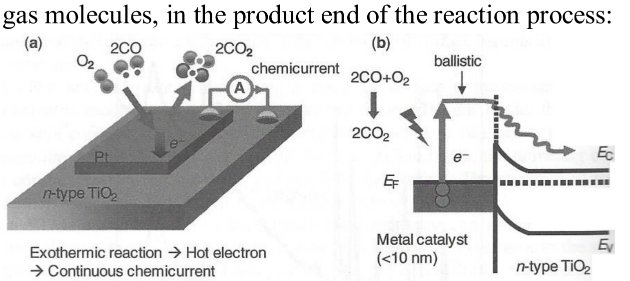


Diagram (a) shows the detection of ballistic charged carriers in the catalytic metal-semiconductor Schottky diode (Pt-TiO_2) and (b) is an energy diagram of the generation process of hot electrons during the exothermic reaction:[57] While a 1-element and 2-element molecule reacting on a surface is still a ways off from a pair of 26-element molecules (two humans) reacting on a surface, such as in the process of reproduction, a double displacement reaction, we are at least getting away from the even more remote ideal gas models commonly seen employed in 21st century physical socioeconomic publications. One quick example of the former, to illustrate, comes from American physicist John Q. Stewart, head of the 1950s Princeton school of social physics, who in his 1947 'Suggested Principles of 'Social Physics', attempted to outline, formulaically, what he called a 'human gas' model of population demographics, in which he viewed each person as a 'molecule' (or human molecule, in the modern sense of the term) and used the following shorthand version of ideal gas law:

$$pa = NT \quad \text{(eq. 13)}$$

where p is demographic pressure, a is an area of land occupied by N individuals (human molecules), and T is the demographic temperature, combined with population census data, to derive concepts such as demographic energy, demographic force, and demographic gravitation, among others.[74] Other *human gas* based models include: C.G. Darwin (1952), John Bryant (2009), Agnes Kovacs (2009), and Mohsen Mohsen-Nia (2013).[75] The point here is that humans do not have ideal gas behavior, humans have surface molecule behavior.

Beyond this issue, is the so-called boundary issue. Ideal human gas based econoengineering models are boundary 'closed', a term which means that molecules, human molecules or otherwise, e.g. trade goods, cannot pass socioeconomic boundaries. An 'open' socioeconomic system, conversely, is one where humans and trade good are allowed to pass the socioeconomic boundary, albeit in an energy regulated way, such that the first law of thermodynamics is not violated, aka the change in the internal energy dU of eq. 10 is accounted for in the act of crossing, typically accounted for via 1961 chemiosmotic theory of membrane energy transduction developed by English chnops-chemist (bio-chemist) Peter Mitchell or in a more complicated manner through use of the Pfaffian form:

$$\sum_{k=1}^{n} X_i(x_1, \ldots x_n)dx_i \quad \text{(eq. 14)}$$

where X is an intensive property, and x is an extensive property, of the socioeconomic system, respectively, the logic of which were developed by German mathematician Johann Pfaff in circa 1805.

A simple visual molecules reactively crossing a semi-permeable energy regulated boundary is the so-called 'equilibrium box' invented by Danish physical chemist Jacobus van't Hoff in *circa 1*886 and supposedly is the basis for the equation that relates free energy change (ΔG or ΔF) to the equilibrium constant (k) of a chemical reaction (eq. 10), which Rossini says governs the nature of our conflicting inner desires to be both free and secure:[76]

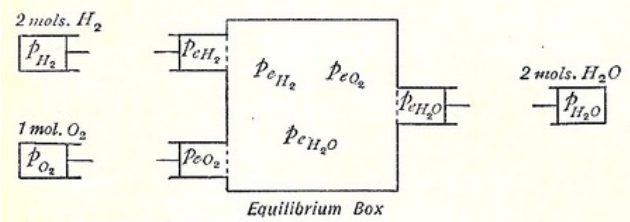


Figure: Maximum work of a gaseous reaction.

The model, wherein we can begin to see how to go about calculating the maximum work of a given open socioeconomic reaction process, is a first step towards 'real world' socioeconomic modeling, as Rossini would say.

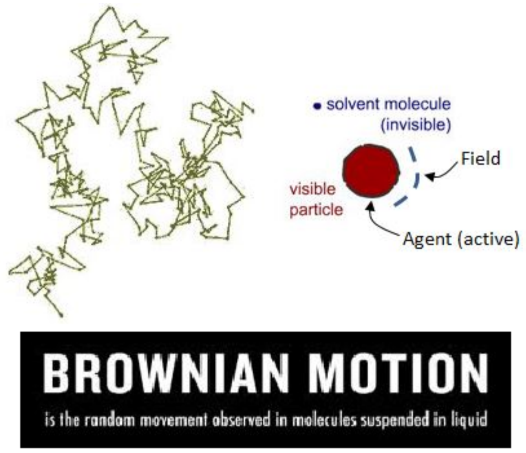
4. MOLECULAR AGENTS

The original agent model employed in economics is said to be traced to the older theories of Adam Smith, Thomas Malthus, and Karl Marx who viewed workers, capitalists, and landowners as the three main types of economic agents. In modern physical socioeconomic terms, the previous surface reaction visual of the O_2 and CO molecules colliding on a certain region of catalytic surface in order to break their existing bonds to form new bonds, is a doorway into the modelling of humans as ballistic charged *molecular agents* that collide at certain catalytic earth surface locations, e.g. a new house or a school, in order to break their existing, e.g. family bonds, in order to form new bonds, e.g. matrimonial bonds. Some of this type of modeling can be found in the author's 2007 two-volume *Human Chemistry* textbook.[59]

The older Adam Smith economic agent perspective model differs from the newer molecular agent model in terms of how land and resources are conceptualized in the new surface reaction point of view, as aspects of catalyst and or exchange force mediators, which is a subject barely in infancy, but one with great potential.

One recent semi-surface like model of the molecular economic agent is that of the Brownian motion, aka random walk model of the economic agent, wherein people macroscopically are modeled as pollen grains suspended in water—the term 'Brownian motion' named after Scottish botanist Robert Brown who, in 1827, studied the movement of pollen grains suspended in water microscopically, which became a physics topic when in 1905 German-born American physicist Albert Einstein explained Brownian motion in terms of molecular collisions between the visible particles with the invisible solvent molecules, whereby owing to constant and random bombardment, sometimes a particle is pushed one way, sometimes another, smaller particles move more than larger ones, and motions increase with increasing temperature.

The recent econophysics term *active Brownian agent*, or Brownian agent, is agent conceived as a point-like particle that has active Brownian motion, the term 'active' meaning the ability of an individual unit to move actively by gaining kinetic energy from the environment, active particles or agents assumed to have an internal propulsion mechanism (motor) and may use energy from an external source and transform it under non-equilibrium conditions into directed accelerated motion.



The actual term 'active Brownian motion' was introduced in 1995 by German theoretical physicists Lutz Schimansky-Geier, Michaela Mieth, Helge Rose, and Horst Malchow as follows:

> "We call Brownian particles with the ability to generate a field **active Brownian particles** if the produced field self-consistently determines the motion of the particles or defines their rates of chemical reactions."

Since this introduction, the idea of 'active' agents has taken on an expanded or alternative meaning, depending. Werner Ebeling, Lutz Schimansky-Geier, et al, in 2012 gave the following history:[60]

> "The concept of '**Active Brownian Particles**' introduced more than a decade ago. The term was first introduced by [Schimansky-Geier, et al] [61], referring to Brownian particles with the ability to generate a field, which in turn can influence their motion. In the following Ebeling, Schweitzer and others used this term in the context of self-propelled particles far from equilibrium. In general we will refer to "Active Brownian Particles" in the latter context as Brownian particles performing active motion, which may be accounted for by an internal energy depot and/or a (nonlinear) velocity-dependent friction function."

Here, like the other models, we see both good and bad theory formulation. Agitated moving molecules surrounded by and bumping into other moving and agitated molecules in a fluid-like surface system sounds remotely like human society. Beyond this, we see a good deal of chemically-coded baggage for older anthropomorphic historical ideals. A particle that generates its own field which determines its own motion is but code for perpetual motion—as is the term 'self-propelled'. The mention of far-from-equilibrium, is but code for Prigogine-based indeterminism emerging passed the bifurcation, aka free will.

5. SOCIAL MPEMBA EFFECT

One quick example of socioeconomic engineering prototype is the use of the scientific understanding of the Mpemba effect or Aristotle-Mpemba effect, the paradoxical phenomenon that hot water will freeze faster than cold water, the reasoning being that in hot water the geometrical ties and bonds of the water molecules are more loosened up and hence are able to solidify into the new order faster than the colder water molecules, which are confined to the old ties and bonds and thus not able to get to the new order as fast to socioeconomic modeling and theorizing in respect to war time consultancy.

Historically, French anthropologist Claude Levi-Strauss was the first to distinction between 'cold' and 'hot' societies; though it is doubtful that he ever considered the Mpemba effect in this respect. As applied to social affairs, the Mpemba effect, in regards to orderings of human molecules (people) in societies, should predict that a 'hot society' should cool or solidify faster into the new social order as compared to a 'cool society. This physical science based hypothesis is evidenced by the fact that the 'Cold War', between Russia and America, lasted 44 years, from 1947 to 1991, whereas traditional 'Hot Wars', such as WWI (1914-1918) or WWII (1939-1945), tend to last on average about 5.5 years, in other words the 'cooling process' to the new social order (frozen water) from the old social order, occurs much faster if the collective societies are heated (liquid water) first.

The repercussions of this, if tested via socioeconomic-engineered wartime formula stratagem, while Machiavellian, would be that a hot war, theoretically, would, in the long term, result in solidified social order or a state of stable peace faster than would a cold war. While some might object, on moral grounds, to such speculation, the following 1903 statement by Austrian philosopher Otto Weininger, noted Goethean human chemical theory follower, would seem to well put the situation into perspective:[77]

> "If iron sulphate and caustic potash are brought together, the SO_4 ions leave the iron to unite with the potassium. When in nature an adjustment of such differences of potential is about to take place, he who would approve or disapprove of the process form the moral point of view would appear to most to play a ridiculous part."

Indeed, rather than play a ridiculous part, it is best to search for the golden rule of ethics in the physical sciences, but to do so, as Freud would say, by slow cautious deliberation.

6. CONCLUSION

Herein we have contrasted, compared, and critiqued the various physical 'models' of the human seen used, throughout history. Modern hard physical science now sees humans as substrate-attached animate motile 26-element molecules. In this view, to keep one's socioeconomic physics models anchored in the *real world*, as Rossini famous put it, it would seem prudent to begin with the thermodynamic approach, first and foremost in the newly developing fields of econophysics and sociophysics.

> "The curious history of the economic agent reveals some important aspects of our conception of ourselves as social beings with the passage of time and the spread of capitalist social relations."
> — Duncan Foley (2002), "The Strange History of the Economic Agent"[58]

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(c) eoht.info/page/Strong+tie

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ENERGY METAPHORS FOR KNOWLEDGE DYNAMICS

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Abstract. *The purpose of this paper is to present a new perspective in understanding knowledge by using energy metaphors. Most of the research conducted so far is based on using metaphors based on tangible objects and linear metrics. The new perspective introduces the concept of knowledge field and knowledge dynamics based on energy metaphors. Thus, instead of using the old dyad of explicit and tacit knowledge, we introduce a new dyad containing cognitive and emotional knowledge, and the reciprocal transformation of one form of knowledge into the other one. The energy metaphors can be extended to developing an entropic model for the intellectual capital, too, where knowledge is the main constituent.*

Keywords: explicit knowledge, tacit knowledge, cognitive knowledge, emotional knowledge, metaphor, thermodynamics

1. INTRODUCTION

We are living in a complex and infinite world. However, our mind is limited in its capacity of representing and understanding this infinity in time, space and complexity. In order to understand this world, our mind developed in its millennial existence *thinking models*, as cognitive and emotional representations of it [1-5]. As Senge remarks, our "*mental models determine not only how we make sense of the world, but how we take action*" [2, p. 175]. Among many such mental models, *metaphors* play an important role in understanding new phenomena, structuring our thinking and developing new concepts [6]. A metaphor is not just a semantic similarity between two concepts, but an instrument to develop a new cognitive approximation using a well known concept [7-9]. In this case, we refer to a conceptual metaphor [10, pp. 181-182], "*which can be defined as conventionalized and systematic mappings (sets of correspondences) between distinct conceptual domains.*" As Andriessen remaks [7], choosing uncounsciously a metaphor has an important impact on how we reason about knowledge, what could be seen and what remains hidden within an organization, and what could be an appropriate solution of a given problem.

For more than two millennia, reason has been taken for granted as being the defining characteristic of human beings. Reason means processing cognitive knowledge and making decisions in any environment of our life. Recent developments of cognitive sciences demonstrated that reason is not disembodied, as tradition considered so far, but it arises from the nature of our brains, bodies, and bodily experience. "*Reason is not completely conscious, but mostly unconscious. Reason is not purely literal, but largely metaphorical and imaginative. Reason is not dispassionate, but emotionally engaged. This shift in our understanding of reason is of vast proportions, and it entails a corresponding shift in our understanding of what we are as human beings*" [6, pp. 4-5].

The purpose of this paper is to shed light on knowledge understanding by using energy metaphors, that means a completely new perspective of the knowledge meanings spectrum. The next sections of this papers are structured as follows: first, we shall discuss the most used metaphors for knowledge developed so far, and then we shall introduce our energy metaphors and their contribution to the knowledge debate.

2. KNOWLEDGE AS STOCKS AND FLOWS

Conceptual metaphors work in the following way: they contain two semantic domains, one of which is well known and onother one which is unknown. The known domain is called the *source domain*, since we extract from it a series of meanings and semantic relations. The unknown domain is called the *target domain*, since we transferred to it what can be transferred from the known domain (see Fig.1). However, the transferred meanings and relations constitute only a part of the source domain. Thus, in the source domain there will remain a good part of what is not used, while in the target domain there will remain some unknown semantics what the metaphor cannot disclose. The power of a metaphor is given by what it can transfer from the source domain to the target domain [7, 8, 11, 12]. Thus, "*Metaphors not only enable the reflection and communication of complex topics and the anticipation of new situations, the use of different metaphor models also affects further perception, interpretation of experiences and possibly also subsequent actions*" [13, p. 4].

In Knowledge Management, knowledge is considered a resource, and thus the simple analogy with tangible resources created the first metaphor: *knowledge as an object*. Thus, knowledge can be

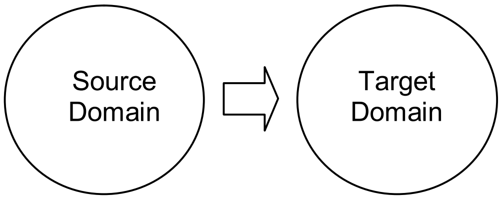

Fig. 1 The conceptual metaphor structure

accumulated, acquired, delivered, held, located, moved, exchanged, packaged, sold, stored, and so on. In this perspective, knowledge behaves in organizations like tangible objects, and it can be evaluated using linear metrics. The generic meaning of this type of metaphors is understanding knowledge as a *stock*. It is a quite limitative metaphor, but unfortunately used extensively due to its attractive simplicity.

Knowledge as an object is a static metaphor, and it cannot explain knowledge transformation from explicit into tacit forms, as it is conceived in the SECI model of knowledge dynamics developed by Nonaka and his colleagues [14-17]. The SECI model is based on the dyad of explicit and tacit knowledge, and contains four major knowledge processes of transfer or transformation: socialization, externalization, combination, and internalization.

Socialization is the process of transferring tacit knowledge from one person to the other when they are working together. Nonaka considers that socialization is the most important process in Japanese companies since it involves the hidden and sticky part of all knowledge created at individual level, that is tacit knowledge. In his view, tacit knowledge is "*personal knowledge embedded in individual experience and involves intangible factors such as personal belief, perspective and the value system*" [16, p. VIII]. Tacit knowledge is a result of direct experience of an individual within a given *Ba*, where *Ba* is a dynamic and complex context where knowledge is created and transferred.

Externalization is an individual process of transformation of tacit knowledge into explicit knowledge. That means to transform something we got through direct experience, that is in our unconscious, into something we are aware of since it is present in our conscious. The advantage of explicit knowledge is that it can be articulated and transferred to other people using the formal language, and formal channels of communication.

Combination is the transfer of explicit knowledge from one person to another by using the natural language. It is "*the process of creating new network structures of explicit knowledge by integrating individual explicit knowledge into organizational knowledge structures. Unlike externalization that is purely individual process, combination is a social process based on the communication property of explicit knowledge*" [18, p. 162].

Internalization is an individual process of transforming explicit knowledge into tacit knowledge. It is the reverse process of externalization. It is closely related to learning-by-doing. Internalization means that new acquired knowledge through combination is integrated into the matrix of known knowledge, and then transformed into tacit knowledge.

As Nonaka remarks, "*The most prominent feature of knowledge, compared with physical resources and information, is that it is born of human interaction. It is not a self-contained substance waiting to be discovered and collected. Knowledge is created by people in their interactions with each other and the environment*" [17, p. 7].

In developing this model for knowledge dynamics, Nonaka used mostly the metaphor *knowledge as flow*. This metaphor has been used frequently also by Davenport & Prusak [19], and by Nissen [20]. The metaphor is based on the Newtonian mechanics applied to fluid flows. Actually, it is a composed metaphor, since it involves the fact that knowledge is like a fluid, and it can flow when the fluid is under a pressure field. This mechanical model has inspired Nissen [20, p. XX] to imagine knowledge as a fluid flowing within an organization: "*To the extent that organizational knowledge does not exist in the form needed for application or at the place and time required to enable work performance, then it must flow from how it exists and where it is located to how and where it is needed. This is the concept of knowledge flows*."

However, this metaphor is rather incomplete since in fluid dynamics a flow is defined with respect to a field of forces, and a pressure difference between two points or two limits. For instance, water flows in rivers from a higher level to a lower level with respect to the see level. In industry, water flows through a pipe due to the pressure difference between the entrance and the exit of the pipe. This kind of specification lacks entirely in the metaphor *knowledge as flow*, which constitutes a severe limitation.

Considering together *knowledge as stock* metaphor, and *knowledge as flow* metaphor, many researchers use, for organizational knowledge, the composed metaphor *knowledge as stocks and flows.* That means catching the meaning of knowledge accumulation and storage within an organization, and the meaning of flow throughout the organization. Although it is a better representation of organizational knowledge, it still has many limitations coming especially from the perspective of Newtonian fluid mechanics. The most important one is the linearity property. As demonstrated by Bratianu [21], knowledge is highly non-linear and it cannot accommodate linear metrics for its evaluation. Also, in any organizationa knowledge is distributed non-uniformly, and as a result of that we may talk about knowledge flows.

3. KNOWLEDGE AS ENERGY

The metaphor *knowledge as energy* is a very complex one since it changes the paradigm of representing and understanding knowledge. In this metaphor, the source domain is represented by the semantic field of the *energy* concept, while the target domain is represented by the semantic field of the *knowledge* concept (see Fig. 2).

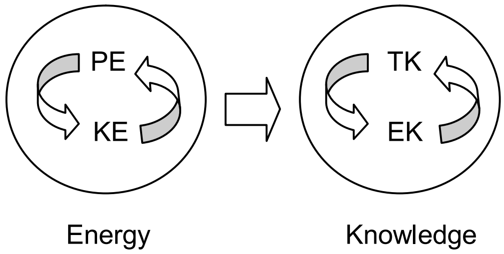

Fig. 2 Mechanical energy metaphor structure

Energy is not a substance, rather a field of forces. It is spread in space and time, and it can be found in different forms: mechanical energy, thermal energy, gravitational energy, electric energy, magnetic energy, nuclear energy and so on. The main characteristic of energy is that it cannot be created, it cannot be destroyed, but it can be transformed from one form into another form, in accordance with the energy conservation law. For the first stage of our metaphorical analysis we shall consider only the mechanical energy. Thus, in the energy domain we distinguish two forms of mechanical energy: potential energy (PE), and kinetic energy (KE). Potential energy reflects the position of a given body with respect to the gravity field, while kinetic energy is the form able to generate mechanical work. According to the energy conservation law, potential energy can be transformed into kinetic energy, such that value of their sum to remain constant. Also, kinetic energy can be transformed into potential energy by consuming some mechanical work.

The first property that can be transferred to the knowledge domain is that of the field existence. Thus, knowledge is not anymore considered as an object, but as *a field of forces*. This field is nonlinear and distributed nonuniformly in space and time. That means that the field is capable of generating variation of knowledge in time and fluxes of knowledge in space. That means a completely new perspective on representing knowledge a a nonsubstance entity, and in a dynamic conceptual model [8, 18]. At the organizational level, the knowledge field is conceived as an entity able to integrate all individual knowledge contributions from a certain organization, and to map the whole organizational knowledge as a continuum in time and space.

Knowledge as energy is a very powerful metaphor since it allows to conceive new characteristics for knowledge that were not possible with the previous metaphors. In the knowledge domain we distinguish between two forms of knowledge: tacit knowledge (TK), and explicit knowledge (EK). Tacit knowledge represents our unconscious knowledge obtained mostly from direct experience. It is similar to the potential energy. While potential energy of a body varies in space and time with respect to its position in the gravity field, tacit knowledge varies in space and time with respect to the experience gained by an individual. Explicit knowledge is a result of our conscious mind, and it is decisive in understanding the world we are living in, and in making decisions and initiating actions. From this point of view explicit knowledge is similar to kinetic energy.

The most important feature of this metaphor comes from the fact that potential energy can be transformed into kinetic energy and vice versa. That means that we may consider also the transformation of tacit knowledge into explicit knowledge and vice versa. The transformation in itself has been postulated by Nonaka in his SECI model, through externalization and internalization processes. This metaphor validate actually the postulated transformation, and allows for new interpretations of knowledge dynamics. From a mathematical point of view, for the energy domain it is known that the total energy (E) results as a sum of the potential energy (PE) and kinetic energy (KE), and it is constant:

$$E = PE + KE \qquad (1)$$

Similarly, for the knowledge domain we may write that total knowledge at the individual level (K) represents the sum of the tacit knowledge (TK), and explicit knowledge (EK). However, unlike energy, knowledge can be created and destroyed. That means that for the knowledge domain we cannot apply the conservation law. Relation (1) can be written only as a qualitative relation as:

$$K = TK + EK \qquad (2)$$

The above metaphor is based on the Nonaka's dyad composed of tacit knowledge and explicit knowledge. Since we do not know how much tacit knowledge we have, and what is its actual composition, it is very difficult to operate with it.

Bratianu introduced a new dyad composed of *cognitive knowledge* (CK) and *emotional knowledge* (EK), which represents the nature of knowledge much better [22, 23]. Cognitive knowledge represents the rational knowledge that can be expressed as explicit knowledge. Thus, cognitive knowledge can be shared with other people and can be processed by the rational intelligence, i.e. mathematical and logical intelligences in the Gardner's framework of multiple intelligences [24]. Cognitive knowledge can be through codification into documents or data bases, stored and retrieved, and transferred to other people or organizations. Codification means to transform knowledge into some specific formats and then make them available to the whole organization [19, 25, 26].

While rational knowledge is a product of European philosophy, *emotional knowledge* is a product of Japanese philosophy [14-17]. However, cognitive sciences and brain sciences demonstrated its importance and te role it plays in making decisions [27-30]. Recognizing that emotional knowledge was neglected within the realm of research and practice, Le Doux demonstrates that human brain is both cognitive and emotional: "*But now it is time to put cognition back into its mental context – to reunite cognition and emotion in the mind. Minds have thoughts as well as emotions and the study of either without the other will never be fully satisfying*" [30, p. 39].

Cognitive knowledge has only got one dimension that allows measuring knowledge based on its quantitative characteristic. Emotional knowledge has got two dimensions: an extensive dimension that is quantitative, and an intensive dimension that is qualitative. By analogy with thermodynamics, we may call the intensive property *emotional temperature*.

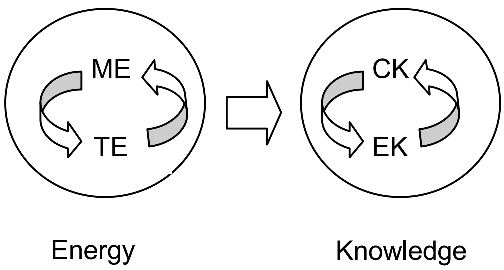

Fig. 3 Thermal energy metaphor structure

It is interesting to underline the fact that the same emotion may have different temperature values for different people, and different emotions may have different temperature values for the same individual. However, at this stage of research we do not know how to measure the emotional temperature, but that is not an argument for not considering this new dimension of knowledge. We have to remember the fact that even the temperature of a body immersed in a thermal field could not be measured in the beginning. It took some time for scientists to develop the thermometer as a practical instrument of measuring the temperature of a body. Finding a similar instrument and method to measure the intensity of a ceratin emotion is just a challenge at this moment.

In figure 3 we illustrate the structure of the thermal energy metaphor for knowledge. In this metaphor we change the mechanical perspective for the thermodynamics perspective. In the energy domain we consider two forms of energy: mechanical energy (ME), and thermal energy (TE). Energy can be transformed from one form into another form in concordance with the second law of thermodynamics. In the knowledge domain we consider two forms of knowledge: cognitive knowledge (CK), and emotional knowledge (EK). As a result of this metaphor, we may consider that cognitive knowledge can be transformed into emotional knowledge and vice versa. This is an important result of our analysis since it reveals new aspects of knowledge dynamics, which could not be seen in the previous metaphors. Actually, this transformation of cognitive knowledge into emotional knowledge and vice versa is so spectacular that some people cannot understand and accept it. For many of them that is a pure speculation. However, many scientific discoveries and theories started as pure speculations.

The metaphor illustrated in figure 3 is a complex one, containing actually four interacting metaphors:

- Metaphor #1: Knowledge as Energy.
- Metaphor #2: Cognitive knowledge as Mechanical energy.
- Metaphor #3: Emotional knowledge as thermal energy.
- Metaphor #4: Knowledge dynamics as energy thermodynamics.

The last two metaphors are completely new by comparison with any other metaphor developed so far. The thermodynamic approach opens new windows of understanding of knowledge and its dynamics, such as knowledge management, can be much more effective. Now we can understand much better why emotional knowledge plays such an important role in decision making. As Hill remarks, "*Breakthrough in brain science have revealed that people are primarily emotional decision makers*" [31, p. 2].

4. CONCLUSIONS

The purpose of this paper is to develop a new type of metaphors for understanding the concept of *knowledge* based on thermodynamics principles. That means to go beyond the Newtonian mechanics, where knowledge has been interpreted as a stock or a flow, which means tangible objects. Also, to go beyond the linear metrics applied to the tangible resources and to accept that one of the most important characteristic of knowledge is the property of non-linearity. That means to think in terms of synergy, when the result of interaction of several elements within a system is higher then their arithmetic sum. Synergy is very important in management and leadership since they are domains where motivating people is essential, and where organizational knowledge and intelligence is not a result of summing up the knowledge and intelligence of all employees.

In order to deal with these managerial processes it is necessary to find new metaphors for knowledge, going beyond that of *stocks and flows*, which is mostly used today. Stocks reflect accumulation of knowledge like accumulation of water in a certain reservoir, and flows suggesting the transfer and sharing of knowledge within an organization.

The first advantage of using energy metaphors for knowledge is that of interpreting knowledge as a field of forces, and no longer as a mere substance. This new paradigm allows us to develop a new theory of knowledge dynamics based on the multifield structure of the organizational knowledge. We may consider that in any organization there are several fields of knowledge, the most important being: cognitive knowledge, emotional knowledge, and spiritual knowledge. Cognitive knowledge represents rational knowledge and it is important in working with analytics and sets of data. Emotional knowledge reflects the feelings and emotions of employees, in different working contexts. Their motivation is essential in creating new knowledge and in realizing a competitive advantage of the company on the market. Spiritual knowledge reflects the individual and organizational values. Although we discussed only about cognitive and emotional knowledge in our metaphors, spiritual knowledge plays a guiding role in the process of decision making.

The most important contribution of the energy metaphors comes from the dynamics transfer from the energy domain towards the source domain. This dynamics reflects the possibility of transforming one form of knowledge into another form of knowledge, a feature that other metaphors do not have so far. This transformation can explain how people make decisions, especially when they act as customers. Many decisions are completely irrational due to the powerful influence of emotions, and they cannot be explained based on the known linear and rational metaphors used so far in economics and management.

Finally, the energy metaphors and the law of entropy open new directions of research for knowledge management and intellectual capital management in organizations.

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FRACTALS AND HEAVY TAILS IN THE ROMANIAN STOCK MARKET

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Abstract. *The Fractal Market Hypothesis and the existence of fat tails are investigated for the BET Index of Bucharest Stock Exchange. In addition to this, an uncertainty index is defined in order to explain large deviations in stock market returns.*

Keywords: fractals, heavy tails, uncertainty.

1. INTRODUCTION

This Fractal Market Hypothesis (FMH) was first introduced by Peters (1989) as a response to the Efficient Market Hypothesis (EMH).

The Fractal Market Hypothesis is based on four essential elements describing the stock market:

- The market is stable and liquid enough when investors have different time horizons;
- Investors maintain the time horizon of the investments independently of informational changes;
- Available information are not automatically reflected by prices;
- The evolution of trading prices is reflected in the evolution of anticipated earnings.

Mathematically, FMH is equivalent to is the fact that the logprice $p_t = \ln P_t$ is a fractional Brownian motion with the following properties:

- $E(p_t) = 0, \forall t$.
- $E(p_t p_s) = \frac{1}{2}(t^{2H} + s^{2H} - |t-s|^{2H}), \ \forall t, s$.

In the above notations H is the Hurst coefficient, $H \in (0,1)$, which defines the behaviour of the returns series.

- *H=0.5* - prices follow a random walk process, and returns are not correlated;
- *H<0.5* - the series of returns presents positive autocorrelation (persistent series);
- *H>0.5* - the series of returns presents negative autocorrelation (anti-persistent series).

The fractional Brownian motion has the property of auto-similarity of a fractal, because in distribution terms, we have:

$$p_{at} \sim |a|^{2H} p_t .$$

Stable distributions have a remarquable property: they allow for skewness and heavy tails and more, any linear combination of stable independent variables is also stable. In other words, the shape of distribution is preserved under linear transformation.

In the literature there are several parameterizations of stable distributions. For this paper we have chosen the parameterisation S0, in Nolan (2003)'s variant.

Thus, a variable X follow a stable distribution $S(\alpha, \beta, \gamma, \delta; 0)$ if its characteristic function has the form:

$$\phi(t) = \begin{cases} \exp(-\gamma^{\alpha}|t|^{\alpha}[1 + \\ + i\beta \tan(\frac{\pi\alpha}{2}) sign(t)(|\gamma t|^{1-\alpha} - 1)] + i\delta t, \alpha \neq 1 \\ \exp(-\gamma|t|[1 + i\beta t \frac{2}{\pi} sign(t)(\ln(\gamma|t|)] + \\ + i\delta t, \alpha = 1 \end{cases} .$$

In the above notation $\alpha \in (0.2]$ is the characteristic parameter (tail index), $\beta \in [-1,1]$ is the skewness parameter, $\gamma \in (0, \infty)$ is the scale parameter and $\delta \in \mathbf{R}$ is the location parameter.

The behavior of stable distributions is driven by the values of stability index α : small values are associated to higher probabilities in the tails of the distribution.

2. DATA ANALYSIS

The sample used in analysis consists in daily data for BET Index from Bucharest Stock Exchange (3357 observations, covering the interval 2007-2011).

Starting from the observed price p_t, we compute the logreturns as

$$r_t = \log p_t - \log p_{t-1} .$$

For time series of logreturns, we estimate the stability index α for stable distribution and the Hurst exponent, using a rolling window of 250 trading days.

The Hurst exponent was estimated using the R/S analysis, while the tail index α was estimated using the time series regression method (Kutrouvelis, 1980).

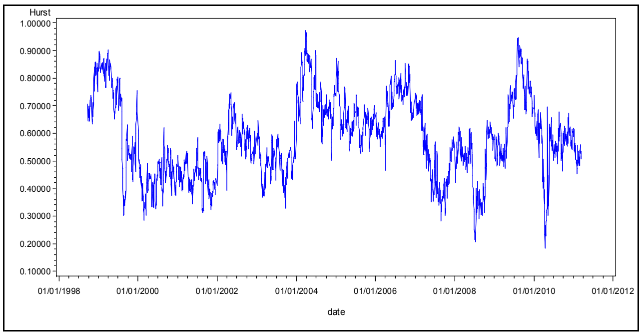

Figure 1. The Hurst exponent - 250 trading days rolling window

The behaviour of the Hurst exponent is not stable over time: starting 2008, when the financial crisis hit Romanian stock market, the time series returns present a very irregular pattern in terms of autocorrelation structure. The value of the Hurst exponent goes from 0.18 (positive autocorrelation) to 0.5 (random walk), having a maximum of 0.97 (negative autocorrelation).

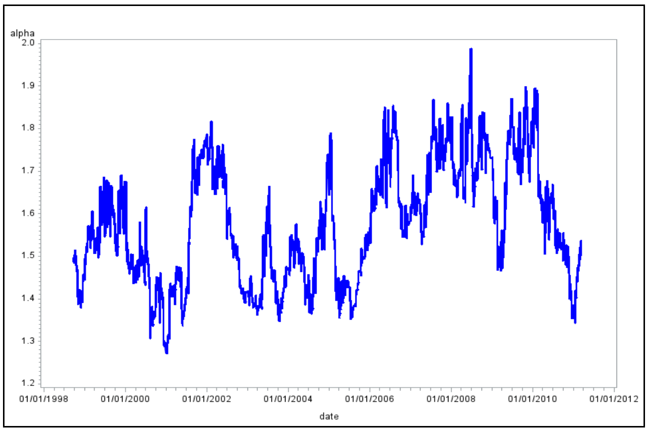

Figure 2. The tail index α - 250 trading days rolling window

The estimated values of the tail index for the returns of the BET Index show a clear departure from normality. The tail index has a maximum value of 1.98 on 30 June 2008, before the financial crisis in October 2008.

Our working hypothesis is that the likelihood of large negative returns could be explained by extreme values of the Hurst exponent or of the tail index. To verify this hypothesis we estimate the following binary logistic regression model:

$$P(Y_t^* = 1) = \frac{\exp(\beta_0 + \beta_1 dH_t + \beta_2 d\alpha_t)}{1 + \exp(\beta_0 + \beta_1 H_t + \beta_2 \alpha_t)}. \quad (1)$$

In the above equation, we have:

- $Y_t^* = 1$, where $Y_t^* = \{1 \mid r_t < r_t^-, P(r_t < r_t^-) = 0.05\}$ (lower tail of returns distribution);

- $dH_t = H_t - 0.5$ is the deviation of the Hurst exponent at time *t* from the value corresponding to a random walk ;

- $d\alpha_t$ is the relative change of the tail index from the time *t-1* to *t*.

Table 3. Analysis of Maximum Likelihood Estimates for model (1)

Parameter	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	-2.86	0.09	1029.22	<.0001
dHurst	-1.50	0.58	6.70	0.01
dalpha	-12.78	6.14	4.34	0.04

Table 4. Odds Ratio Estimates for model (1)

Effect	Point Estimate	95% Wald Confidence Limits	
dHurst	0.22	0.07	0.69
dalpha	<0.001	<0.001	0.47

Analysing the results of the estimation, we can extract some facts regarding the relationship between the fractal nature of returns, heavy tailness and the probability of large negative returns:

- The likelihood of extreme negative returns decreases as the value of Hurst exponent is higher than 0.5, the characteristic value of a random walk. In other words, if the local trends on the market are likely to invert, i.e. the time series of returns is anti-persistent, then the probability of a stock market crash diminishes. By contrast, if the market has a persistent trend, then the likelihood of a stock market crash increases.
- If the market stability index increases (the tail index converges to Gaussianity), then the likelihood of a stock market crash decreases. By contrary, if the tail index has a negative trend, then the likelihood of a stock market crash increases.

In order to evaluate the impact of both fractal dimension and probability in the tails of the returns distribution, we set up an uncertainty index, as follows:

$$UI_t = \frac{H_t}{\alpha_t}.$$

For this uncertainty index we have the following situations:

- For a constant Hurst exponent, the Uncertainty Index is negatively correlated to departure from normality of returns distribution;
- For a constant tail index, high values of UI_t correspond to high values of Hurst exponent, meaning reversions in local trends.

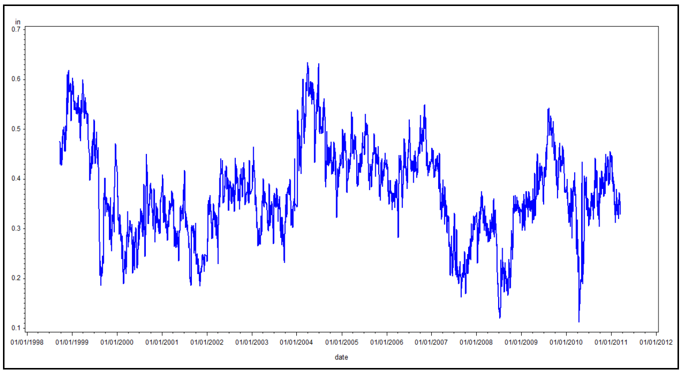

Figure 3. Uncertainty index for BET Index

The following binary logistic regression model

$$P(Y_t^* = 1) = \frac{\exp(\beta_0 + \beta_1 UI_t)}{1 + \exp(\beta_0 + \beta_1 UI_t)} \quad (2)$$

was estimated and the results are presented in the following table.

Table 5. Analysis of Maximum Likelihood Estimates for model (2)

Parameter	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	-1.69	0.32	27.40	<.0001
Index	-3.54	0.90	15.35	<.0001

Table 6. Odds Ratio Estimates for model (2)

Effect	Point Estimate	95% Wald Confidence Limits	
Index	0.03	0.01	0.17

Analysing the results of the estimation, we can see that the Uncertainty Index is negatively correlated to the likelihood of extreme negative daily returns. Thus, if the Uncertainty Index increases by 1, then the odds of occurrence of extreme negative values of BET returns drops by around 97%.

3. CONCLUSIONS

In this paper we propose a method for defining a measure of stock market uncertainty, using the Hurst exponent and the tail index associated stable distributions. The statistical tests applied to the daily BET index returns series indicate that this measure of uncertainty is correlated to probability of large negative returns. In our future researches we intend to develop this uncertainty index in order to capture both fractal dimension and heavy tailness of returns distribution.

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APPENDIX

A SAS code for estimating the Hurst exponent

This SAS code uses a dataset called *date*, with two variables: t is the time index and logreturn is the variable containing the returns of a financial asset.

The value of the Hurst exponent is saved in the dataset *hurst*.

```
proc iml;
use date;

READ all var {t logreturn} into y;
n=nrow(y);
p=int(log2(n/16));
pp=2**p;

rsp=j(pp,p,0);
nmare=j(p,1,0);

do q=0 to p;
      k=2**q;

      delta=int(n/k);
      xt=j(delta,1,0);
      st= j(delta,1,0);
      gt=j(delta,1,0);
      do i=1 to k;
            do j=1 to delta;

            xt[j]=y[(i-1)*delta+j,2];
            end;
              mean = mean(xt);

            std = sqrt(var(xt));


                  st=xt-mean;
                  gt[1]=st[1];
                  do l=2 to delta;
                  gt[l]=gt[l-1]+st[l];
      end;
                  gmax=max(gt);
                  gmin=min(gt);
                  rrs=(gmax-gmin)/std;
                        rsp[i,q+1]=rrs;
```

```
      nmare[q+1,1]=delta;

      end;

end;

nonzero=j(pp,p,0);


do i=1 to pp;
do j=1 to p;
if rsp[i,j]>0 then nonzero[i,j]=1;
end;
 end;

s=j(p,1,0);
nr=j(p,1,0);
rs=j(p,1,0);
do i=1 to p;
s[i]=sum(rsp[,i]);
nr[i]=sum(nonzero[,i]);
rs[i]=s[i]/nr[i];
end;
hurst=rs||nmare;
y=log(rs);
x1=log(nmare);

x0t=j(1,p,1);
/* x0t is a row vector of ones */
x=(x0t//x1`)`; /* xt is the transposed
design matrix for a simple linear
regression */
b=inv(x`*x)*x`*y; /* b is a vector of
estimated regression coefficients*/
hurst=b[2,1];
      create hurst from hurst;append from
hurst;
quit;
```

EXPLAINING THE DYNAMICS OF EUROISATION USING ELECTRIC CIRCUITS MODELS WITH EMPIRICAL EVIDENCE*

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Abstract

This paper aims to explain the process of euroisation using the models of electric circuits. The factors that are affecting the dynamics of euroisation of deposits are analyzed using mathematical models from the field of electrical engineering. The results obtained from the model of electric circuits suggest that changes in the currency structure of deposits as a consequence of changes in the interest rate differential can be compared to the electricity flow. The speed of adjustments is defined by the time constant. The theoretical findings are then econometrically tested based on the samples for Serbia in the period from January 2004 to December 2012. the results obtained using the VAR methodology suggest that euroisation of deposits reacts to the change in interest rate differential set in favor of euro-deposits, and this effect diminishes after four months.

Keywords: *euroisation, financial system, foreign exchange rate, depreciation, interest rate spread, R-L circuits, electricity flow, VAR methodology.*

1. INTRODUCTION

Laws from the field of physics have been widely used in explaining different economic phenomena (Săvoiu, 2009). The purpose of this paper is to show the connection between the dynamics of financial euroisation and the rules in electrotechnical science. The flow of local and foreign currency in the financial system is linked to the electricity flow in R-L circuits. Theoretical background covers 8 countries from Central and South-Eastern Europe, while the empirical model is derived on the basis of Serbian data, from January 2004 to May 2012.

Highly euroised countries often suffer from the high dependence on exchange rate movements, since sudden depreciations may jeopardize financial stability as well as the overall economic environment. Probably the most important problem connected with the high euroisation is the fact that liabilities are mainly denominated in the foreign currency and that high depreciations increase the costs of servicing that liabilities expressed in the local currency. In order to act in a way apt to promote macroeconomic stability, and lower the impact of the exchange rate movements on the financial stability, it is necessary to define the strategy that will result in a reduced level of financial euroisation.

Financial euroisation (asset substitution) is an informal form of euroisation which assumes that foreign currency dominates local currency in its function as a store of value. This form of euroisation assumes the euroisation of interest-bearing assets and liabilities. Euroisation of deposits and loans is a problem that concerns many Central and South-Eastern European countries outside the euro area. The level of euroisation varies among the countries from very high levels in Serbia, Croatia, Romania, to lower levels in Poland and the Czech Republic (Table no. 1). What all these countries have in common is the fact that all of them suffered from the macroeconomic crisis in the early 1990s, which resulted in the loss of a confidence into a local currency. High inflation rates from this period eroded the value of local-currency deposits but also resulted in a loss of confidence into local banking sector, which means that savings were placed not only in foreign currency, but also outside the banking sector ("under the mattresses") instead of in bank deposits. Some important changes occurred in 2000s, when the banking sector in these countries started to develop increasingly. Increased competition in the market has played a key role in restoring confidence in the banking sector. After many years, lending activity revived, and the presence of foreign banks made foreign loans more accessible and less expensive, which only intensified further financial euroisation. Although significant progress was made, confidence in the local currency is still not fully regained. This resulted is increase in banking deposits as well as in increased lending activity, but in the first place it intensified the process of euroisation in these countries. Evidence from the recent literature suggests that as long as euroisation promotes financial depth it is considered as positive (De Nicolo, Honohan and Ize, 2005). On the other hand, there is much more evidence in favor of the negative sides of euroisation, such as balance sheet mismatches, fear of floating, weakened interest rate transmission channels. Among those who point to the negative effects of this phenomenon, the most important is the exaggerated impact of exchange rate on monetary and economic trends, which suggests that countries with high levels of financial euroisation become "hostages to fear of floating" (Honohan, 2007), since exchange rate depreciations may threaten the financial stability of the country. Also, the interest rate transmission mechanism becomes weakened due to the fact that the key policy rate has no effect on loans denominated in foreign currency, but only to those in the local (Aleksić, Palić, Đurđević and Tasić, 2008). In this sense, the research is mainly conducted in the way of defining strategies that will result in de-euroisation of the financial system. When defining the optimal strategy, one should take into account the specific issues of the region and the respective country due to the fact that the process of de-euroisation requires a long period of time.

The rest of the paper is organized as follows: the first section deals with problems that countries in the Central and South-Eastern Europe are exposed to due to high levels of euroisation, and historical factors that caused euroisation. In the second part of the paper the model of the dynamics of euroisation based on a model of RL circuit is presented. The third section presents the empirical evidence on the dynamics of euroisation for the case of Serbia, based on the results of the VAR models and impulse response functions. The last part deals with the conclusions and the implications for the monetary policy of euroised country, as well as the possible areas for further researches.

2. THE PROBLEM OF EUROISATION IN CESEE COUNTRIES

Countries from Central and South-Eastern Europe that are not members of the euro zone are suffering from the problem of eurosiation. The data on the level of euroisation of interest bearing deposits and loans for Poland, the Czech Republic, Serbia, Croatia, Romania, Bulgaria, Albania and Turkey are collected from the respective National Banks' statistics and are presented in Table no. 1. Countries that exhibit lower levels of deposit euroisation mostly also exhibit lower levels of loan euroisation and vice versa. This suggests that banks are trying to match the currency structure of deposits and loans in order to hedge against currency risks.

Table no. 1 Euroisation of deposits and loans in some CESEE countries

Country	Euroisation of deposits	Euroisation of loans
Poland	8.0	34.0
Czech Republic	5.4	8.3
Serbia	88.7	72.4
Croatia	85.3	70.0
Romania	36.5	64.0
Bulgaria	52.7	63.9
Albania	45.0	64.9
Turkey	39.3	32.5

Source: **PNB, CZNB, NBS, HNB RNB, BNB, ANB, TNB and author's calculations**

The data in Table no. 1 also suggest that in these countries the problem of euroisation is not causing the currency mismatch problem to banks, since the currency structure of loans is matched to those of sources of financing, but it may have as a result that in a cases when clients go default, banks become unable to service their liabilities. Many studies have confirmed (Ivkovic, 2008; Luca and Petrova, 2005) that banks match the currency structure of loans with the currency structure of the sources of funding (dominantly savings) in order to hedge against the currency risk. Banks are not exposed to the risk that they will be unable to repay interest on deposits due to different currency structure of active and passive interest rates. The problem for the banks, and consequently for the whole economy, lies in the fact that currency structure of the residents' income and liabilities is not matched. The residents' income is largely denominated in the local currency (in many countries this is regulated by law), while the currency structure of the loans is largely set in favor of the euro (Table no. 1). If residents' liabilities are denominated in foreign currency, the pace of repayment will largely be determined by movements in exchange rates. The increased significance of this phenomenon is obtained in cases of sudden depreciation shocks, resulting in increased local-currency debt payments related to foreign currency. In such cases, the problem for the banking system, as well as for the whole economy, is that in cases of high depreciations, debtors are unable to repay bank debt, which may have banking crisis as a result.

From the data on deposit and loan euroisation, we can conclude that the above-mentioned countries differ in the level of euroisation. Since all these countries started from the high levels of euroisation in 1990s, we can conclude that they experienced different dynamics in de-euroisation. Deposit euroisation in Poland fell from about 80% in 1990s to below 10% in 2012, while euroisation in Serbia remained persistent and is still moving around the level of above 80%. The common factor for all these countries, except for Croatia and Bulgaria, is inflation targeting (IT) framework and managed floating exchange rate regime (Bulgaria adopted the currency board in 2003 and Croatia's exchange rate regime is tightly managed). According to the most prominent literature in this field, inflation targeting combined with freely floating exchange rate should lead to decrease in euroisation levels (Ize and Yeyati, 2003). The intuition behind this is quite clear, since the agents decide to save in a less risky currency. As long as home-currency savings are less risky relative to foreign-currency savings, the increase in home-currency savings will come as a result. The evidence from the Central and South-Eastern European countries suggests that there exist some other factors that drive the dynamics of euroisation.

This paper tries to explain that there are other factors that determine the dynamic of euroisation/de-euroisation of deposits. The model presented in this paper is based on the model from Rajković and Rajković (2013) and deals with empirical findings for the case of Serbia. This model differs from the above mentioned in the fact that it deals only with the euroisation of interest bearing deposits.

The subject of this paper is the dynamics of de-euroisation as a result of changes in interest rate differential in favor of one of the currencies. Bearing in mind that the interest rate differential is a cost for borrowers and an income for those who save, we tried to explain the dynamics of de-euroisation using the model of RL circuit assuming that incentives come in the form of interest rate differential.

3. MODEL R-L CIRCUIT

As long as interest rates in the short run follow uncovered interest rate parity (UIP), higher depreciation rates will result in higher levels of deposit euroisation in the short term, and due to the high persistence, this trend is likely to continue in the future. Uncovered interest rate parity assumes that the spread between local-currency deposits interest rates and foreign currency deposits interest rates is set to be equal to the expected depreciation. If the interest rate on domestic deposits is higher than that on foreign currency deposits, home currency must depreciate in the following period, otherwise, there would exist the possibility for arbitrage.

Assuming that the economic activity is carried out in the bi-currency system, and since the euro is dominant foreign currency in the currency structure of deposits and loans, we refer to euro as a foreign currency. This assumption is reasonable given that more than 70% of loans and deposits in foreign currencies are denominated or indexed in euros.

Agents' decisions on the currency structure of savings or borrowings are based on the real interest rates. Real interest rates on home-currency or foreign-currency deposits and loans are given by the following expressions:

$$r_{t+1}^{H} = i^{H} - \pi_{t+1} \quad (1)$$

$$r_{t+1}^{F} = i^{F} + e_{t+1} - \pi_{t+1} \quad (2)$$

where r^H and r^F are the real interest rates on home-currency and foreign-currency deposits (loans), respectively, i^H and i^F stand for the nominal interest rates, e for the rate of change of the nominal exchange rate and π for the rate of inflation. Nominal interest rates are assumed to be fixed during the life of the contract. If we assume that at the beginning of the period nominal interest rates are determined to satisfy the uncovered interest parity condition, any deviation from this parity comes from the difference in the rates of depreciation.

The real interest rate differential is defined as expected difference between real interest rates on deposits in foreign currency and those in local currency ($E_t(r_{t+1}^F - r_{t+1}^H)$). If uncovered interest rate parity holds than $E_t(r_{t+1}^F - r_{t+1}^H)=0$ and agents are indifferent between savings or borrowings in home or foreign currency, because they will earn the same interest. On the other hand, whenever the UIP condition is violated, one of the options will be more profitable. The deviations from the UIP come from the unexpected depreciations of the local currency. For example, if in period t+1, depreciation rate is higher than the one predicted by UIP condition, than interest rate differential will be in favor of foreign currency deposits.

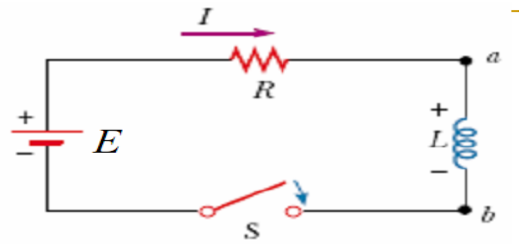
This model assumes that at the beginning of the period, UIP holds, and that agents make their decisions based on other factors. At the end of the first period, they can observe the interest rates, as well as realized depreciation rate and then make decisions on the reallocation of their savings. In this setup, the interest rate differential is what drives the process of euroisaiton (de-euroisation).

We used the RL circuit for the modelling of the dynamics of the financial euroisation (de-euroisation). The increase in domestic-currency savings, or a decrease in financial euroisation will occur if over some period of time real interest on domestic-currency savings is higher than that for foreign currency savings.

Savings in local currency will be more profitable than savings in the foreign currency if the differential between the interest rates on the local and foreign currency deposit higher than depreciation. This means that the depreciation of the dinar, which is above that accrued in the nominal interest rate according to the uncovered interest parity, increases the euroisation of deposits, while depreciation below the expected level reduces the euroisation of deposits.

The assumption of fixed nominal interest rates is in accordance to the fact that interest rates are mostly determined by the contract, and do not change until the termination of the contract, and on the other side exchange rates are changing on a daily basis. Periods in which the exchange rate is growing rapidly are alternating periods when the rate may fluctuate or decline slightly.

The model of RL circuit is presented in the Figure no. 1.



(1)

Figure no. 1 The model of RL circuit.
Source: Authors' illustrations

The same form of the circuit is used to explain the dynamics of financial euroisation depending on the movements of interest rate parity and exchange rate changes. The parameters R and L in electretechnics stand for resistance and inductance, and have their physical units: R_u is measured in Ω (ohm) and L_u is expressed in H (henry). Parameters R and L determine the time constant τ.

In the model of financial euroisation, *E* (Expression no. 3) is an incentive for borrowing in local currency and in foreign currency (voltage in electrical circuits). In this model, E is the differential in real interest rates on savings deposits in home currency and foreign currency deposits in the event of deposit euroisation. It is given by the following expression:

$$E = r_{t+1}^{H} - r_{t+1}^{F} \quad (3)$$

The incentives for changes in the currency composition of savings and loans occur if the uncovered interest rate parity condition is violated, or if the interest rate differential is such that favors one of the currencies. Expression E stands for the interest in investing in home-currency or foreign currency savings to achieve interest or to preserve the value of money. E can be thought of as "financial force" that in the "financial circuit" is driving the money flow.

When E <0, the deposit euroisation rate increases, (euros are flowing through the circuit). When E> 0, euroisation rate decreases (local currency is flowing through the circuit).

Periods in which home-currency savings are more profitable than foreign-currency savings alternate with the periods in which foreign-currency savings are more profitable, and so on. We expect that agents will react on the change in interest rate differential by switching from home-currency deposits to foreign-currency deposits depending on the sign of interest rate differential.

Reactions of the euroisation share may be presented by different models of RL circuits with different values of time constant τ (Figure no. 2). This figure shows two different RL circuits depending on the time constant τ. When the time constant is low, the shock in independent variable will be spilled over the dependent variable in very short period of time, while in the case of high time constant, this process will last for a longer time.

Both of these circuits are of the same shape, the only thing they differ in are parameters R and L, and the time constant they determine τ = R / L

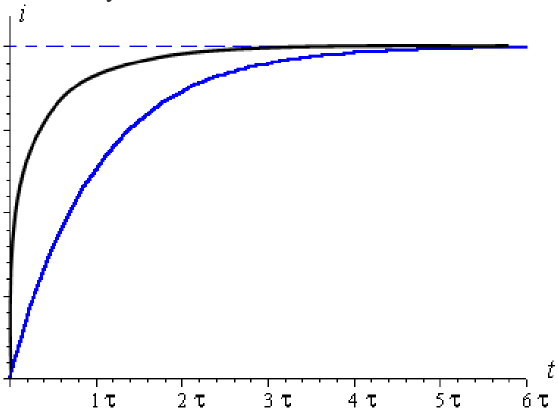


Figure no. 2 Graphic I = f (t) in the time constant τ1- reduction dinar savings and τ2 - time constant increases dinar savings

Source: Authors' illustrations

In the electric circuit, I stands for the electric power, the amount of electrical charge per unit of time elapsed through the circuit. It is explained by the following expression:

$I=dQ/dt$ (4)

In this model, I is actually the amount of the units of local currency or euros, which is placed as savings, or raised from the bank in the unit of time.

In addition to the graphic representation of the model in the form of an electric circuit (Figure no. 2), the model can also be displayed in a mathematical form, and solved by the rules and fundamentals the theory of electrical circuits.

According to Ohm's law for the transition process, which occurs in the circuit, after turning the switch S (Figure no. 1), the following differential equation can be written:

$$E = RI + L\frac{dI}{dt} \quad (5)$$

Differential equation (5) can be written in the form:

$$E - IR - L\frac{dI}{dt} = 0 \quad (6)$$

The equation will be solved by introducing the following:

$$x = \frac{E}{R} - I \qquad dx = -dI \quad (7)$$

$$x + \frac{L}{R}\cdot\frac{dx}{dt} = 0 \quad (8)$$

$$\frac{dx}{x} = -\frac{R}{L}dt \quad (9)$$

$$\ln\left(\frac{x}{x_0}\right) = -\frac{R}{L}t \quad (10)$$

$$x = x_0 \cdot e^{-\frac{Rt}{L}} \quad (11)$$

Based on the initial conditions: I = 0, at time t = 0, x_0 is calculated:

$$x_0 = \frac{E}{R} \quad (12)$$

$$x = \frac{E}{R}\cdot e^{-\frac{R}{L}t} \quad (13)$$

$$\frac{E}{R} - I = \frac{E}{R}\cdot e^{-\frac{R}{L}t} \quad (14)$$

$$I = \frac{E}{R}\cdot\left(1 - e^{-\frac{R}{L}t}\right) \quad (15)$$

The time constant τ is defined as follows:

τ = L / R (16)

and Equation (14) can be written as:

$I=E/R(1-e^{-\tau t})$ (17)

4. EMPIRICAL EVIDENCE

The results from the model presented in the previous section are econometrically tested on the data set for Serba from January 2004 to May 2012. We considered only interest-bearing deposits of households and entreprises (transaction deposits are excluded from the analysis). Since the time series on the currency structure of interest rates on deposits is very short (from September 2010), we estimated the real interest rate spread by depreciation rates (Rajković, 2012). The euroisation share is approximated by the share of interest-bearing deposits denominated or indexed in euros in total interest bearing deposits. In Serbia this ratio varied within the range of 81% to 89% which is a very high level.

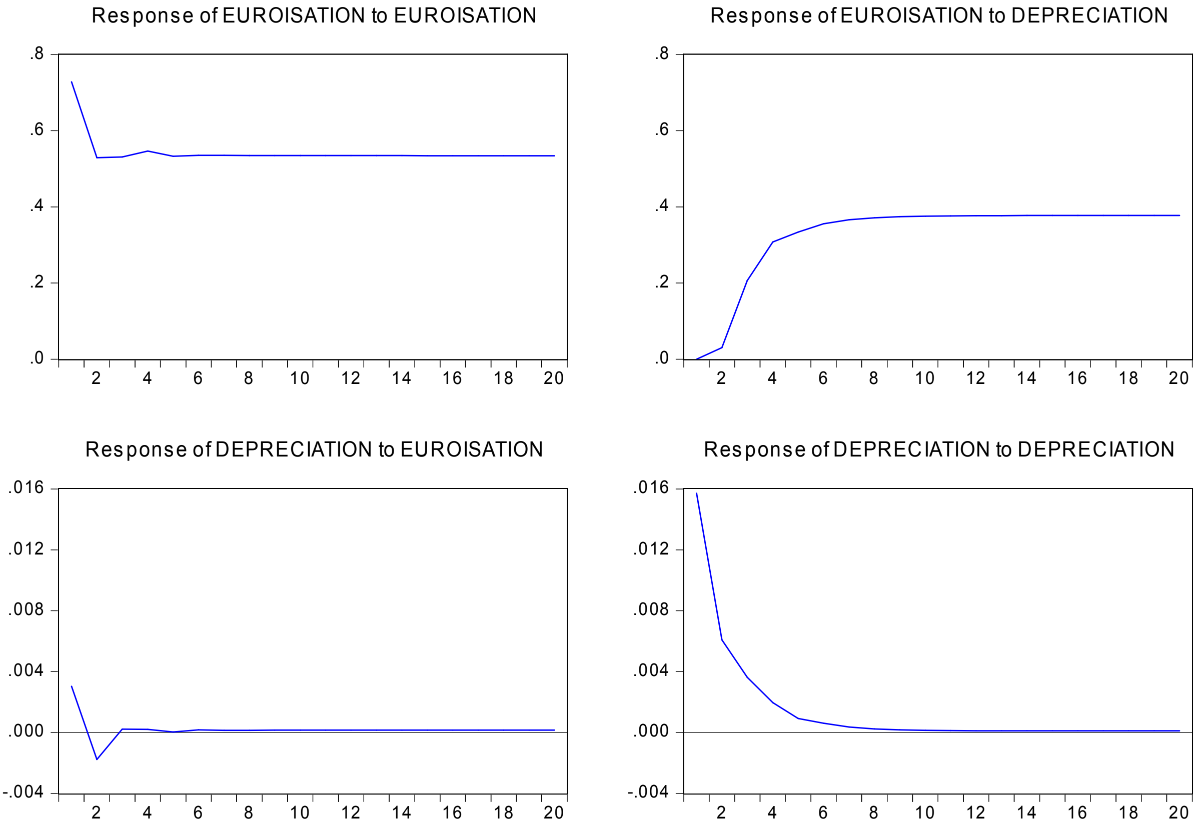
In this model, depreciation rates stand for E, which is actually the driver of changes in the currency structure of depostis. We expect that higher depreciation rates will lead to changes in the currency structure of deposits towards the foreign-currency depostis. We also do not expect that the whole amount of depostis will be converted to foreign-currency deposits, since there are other factors different from the profit-maximization that drive the dynamics of euroisation.

In order to econometrically test the findings from the theoretical model, we estimated VAR model for deposit euroisation and then estimated the impulse response function. The graphical representation of impulse response function is given by Figure no. 3. As expected, estimated coefficient for the depreciation rates is statistically significant and possitive, which suggest that increases in relative value of euro increase euroisation share. If agents maximize the profit expressed through interest rates, they will react on depreciaiton of the dinar by switching their depostis to euro-denominated deposits.

Figure no. 3. presents how the euroisation share reacts to the shock of depreciation rates. The shape of the impulse response function looks like the function from the Figure no. 2 with the low time constant. This means that, for the case of Serbia, the currency structure of deposits is very sensitive to the changes in interest rate differential. This analysis proves the relationship between the increase in euroisation as a consequence of sudden depreciation.

Econometrical analysis suggests that the number of periods after whics effects of depreciation on euroisation share will diminish will dissapear is 4. This confirms the statement that the proces for Serbia may be defined by the low time constant. What is not formally tested in this paper is what determines the value of time constant, and this may be the topic for the further research.

Figure no. 3. Impulse response function from the regression of deposit euroisation to depreciation rates



Source: Authors' calculations

5. CONCLUSION

The results of this study may be important in explaining the dynamics of deposit euroisation. The analogy observed between the motion of electrons under the influence of electromotive force in the electric circuit and the cash flow under the influence of interest rates, explains why the interest rate differential set in favor of the foreign currency leads to an increase in euroisation.

For the financial circuits we applied the equations for Kirchhoff's laws and Ohm's law and the electric circuit.

The model derived in this paper points to the importance of confidence in the local currency when determining the dynamics of de-euroisation.

In the process of euroisation, what matters is the time constant. In the case of Serbia it is estimated at 4, which means that after four periods (in this case four months) the effects of depreciation to euroisation share will disappear. By increasing the time constant, the dynamics of euroisation would change and the deposits would not be converted from local-currency to foreign currency that quickly. The value of the time constant is determined by the level of confidence in the currency. With the growth of confidence in the local currency, the time constant would be increased, and incentives for de-euroisation in the form of interest differentials would be relatively quickly resulted in the overflow of the euro-deposits in the local-currency deposits.

The theoretical model presented in this paper provide a good basis for further research on this topic, as well as space for empirical work to determine the numerical values of the coefficients that determine the dynamics of dinarisation.

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*The views expressed in this paper are those of the authors, and do not represent the official view of the National Bank of Serbia, or of other universities.