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ECOLOGIST UTOPIA FACING REALITY: MALTHUS AGAINST PRIGOGINE

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The world economy is experiencing the turbulence of the end of a long wave of development that precedes its entry into the new cycle, on which the 21st century will leave its mark. Two opposite economic logics are proposed to solve the challenges faced by the Earth: The first one is the conventional one based on the management of scarcity which corresponds to Malthusian ecologists. The second, the management of abundance, is a very non-academic answer with the Prigogine's thermodynamical approach of economics, and the inclusion of knowledge in the production function. The proof of the analogy between Shannon's definition of entropy and the Clausius's one opens the way to a new vision of Economy, abandoning the so-called politicaly correct approach of shortage management for the benefit of an Economy of abundance. The apply of Prigogine's concept of thermodynamic open system allows to break the deadlock of the green neo-Malthusianism ideology which is only able to make the poor even poorer and more numerous and to prophesy the end of the world.

Ключевые слова: управление дефицитом, управление изобилием, идеология неомальтузианства, подход Пригожина, энтропия, открытая система, знание

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INTRODUCTION

By exploitation of natural resources ever more intensively, the western economies have succeeded, so far as they are concerned, in banishing the specter of shortages which have bedevilled human societies from time immemorial. Both of these shortages have been overcome by the combined exploitation of suitable resources and ever more efficient technologies. The era of mass consumption became possible, and with it, very logically, the era of mass production. But they were also accompanied by the over-exploitation of natural resources, heedless of future generations, the accelerated degradation of the environment, and the deterioration of the ecosystems.

In 1972, believing that pollution and exhaustion of natural ressources are strictly linked, a multitude of purportedly experts demonstrated, with Meadows [1], that continued growth would lead the Earth to catastrophe. They concluded in the imperious need to stop economic growth, at the risk of letting humanity collapse under the blows of two connected plagues acting together: the generalized depletion of natural resources, and pollution which was bound to reach unbearable proportions. Whatever the inexactitude of their conclusions may be, it must be recognized the exactitude of the claim of these experts for a new way of development moving from quantity to quality.

Today, another band of experts, calling themselves "ecologists", somberly proclaim that the Earth will no longer be able to guarantee to all the inhabitants of the planet a standard of living comparable to the standard of living of the average American today. And these experts plead for a form of "*sustainable development*" that will mean the impoverishment of a large part of the presently industrialized countries, without providing any benefit to the most disadvantaged countries.

Two opposite economic logics are proposed to solve the challenges faced by the Earth:

The first logic, the "ecologically correct", is the Malthusian-ecologistic way of thinking: For it, only Nature is able of creating wealth; Man is a predator who can only develop at the cost of Nature. In this Malthusian ecologist way of economic growth, wealth is produced by the consumption and destruction of natural resources – for example, by burning oil, gas or coal.

As the world's material resources are limited, it is said, with increasing frequency, that it is impossible for everyone on earth to be able to have the same standard of living as that enjoyed by the people of America. One use to say that "*the future on earth would be jeopardized if 8 billions of human beings were to have the same life style as the billion of human beings living in developed countries*". It is rapidly acquiring the status of "revealed truth". No one would dare to dispute it. Conveniently forgetting the lessons of J.B. Say, B. Sauvy or W. Leontieff, this often repeated statement, these principles of the "sustainable development, are gradually taking over the collective subconscious. How cynical it would be to prevent the 9/10 of the planet from reaching one day this standard or even to let the world believe that wealth is forbidden for the impoverished countries!

The second logic rejects this approach and finds that wealth is accumulated by human labor and ingenuity.

1. PRELEGOMENA: SCARCITY, THE KEY – BUT MISUNDERSTOOD – ECONOMICS TOPIC

In his 1932 "*Essay on the Nature and Significance of Economic Science*", Lionel Robbins (1898–1984) defined Economics as the science to optimize the allocation and distribution of scare resources: "*Economics is the science which studies human behaviour as a relationship between ends and scarce means which have alternative uses*". Economics is the study of how society chooses to allocate its limited resources to the production of goods in order to satisfy unlimited wants. The very foundation of such permanent "anthropologically correct" feeling is the ancient humanity's ancient (and mistaken) view that scarcity is nature's plan and design which is based upon the assumption that there are not enough resources to meet the needs of the whole humanity. This concept of scarcity is essential to the field of all conventional economics theories which drive the world, whether inspired by Keynesian, neo-classic, liberal, Marxist, etc. ... We would be living in a closed and finite world.

Scarcity refers to a gap between limited resources and limitless humanwants. The notion of scarcity is that there is never enough goods to satisfy all human wants. Scarcity involves by the way, scarcity is the root of conflict. So, the ancient views of Thomas Robert Malthus (1766–1834) with his 1798 book "*An Essay on the Principle of Population*" still dominates the scarcity debate. The strong drive for reproduction in relation to the weak expansion of goods possibilities drive to Malthusian catastrophe: population reaches or exceeds the capacity of the shared supply.

Politically correct economic theories are derived in large part from the concept of relative scarcity. Enlarged theories of production, distribution, consumption, business fluctuations, and other economic elements have been introduced and continually reconsidered from a variety of viewpoints, to optimize the necessary management of scarce resources to avoid any "societal malfunctioning".

In such framework of economic concepts, due to increased pollution and exploding demography, facing the reckless exploitation of natural resources lead to their depletion following the Ricardo law of diminishing returns in an entropic process, It would be only possible to retard the final catastrophe.

In Malthus's time, there were "nonscarce" goods, which goods didn't need to be valueless, even if some can even be indispensable for one's existence. Because of their abundance these "nonscarce" goods fail to be objects of desire and of choice; They may also be called "free goods". They seems to have no value in the sense in which the economist uses that term. They exist in superfluity; that is, in quantities sufficient not only to gratify but also to satisfy all the desires on them. Some one may use nonscarce goods, without preventing anyone else from using it. Nonscarce goods are looked to have an infinite existence, no sense of possession, or it could be infinitely replicated.

Modern pollution challenged this concept. There are no more nonscarce goods. Take air, for example. From an individual's perspective, breathing is completely free. In a number of cities today, poor air quality has been associated with high rates of disease and death. In order to avoid it, cleaner processes have to be developed. These costs fall on the citizens in one way or another, that means air is not "free", which arise a number of economical (and technological) questions bringing up many questions about how to efficiently allocate resources. And come the very first dogma of the economy that the world has limited – or scarce – resources. World would be "a closed system", opposing the Prigogine's concept of "thermodynamic open system".

Such perception of scarcity gave rise to competition for resources—success in the competition went to those most cunning, diligent and/or ruthless. Winning conferred power and status—the winners gained control of the resources. Those most useful to the winners were granted access to a greater measure, or share, in the resources—those successively further removed, less useful, received proportionately less—until they were so far removed that they received no share and no access. Thusly, hierarchies of access to resources were "born", and the now familiar drawing of the pyramid to represent those hierarchies was developed—with the winners, the richest, at or near the top, of the pyramidal diagram, and the losers, the poorest, distributed at the bottom along the pyramidal base. Social disease is there, with future conflicts and wars.

Competition for those scarce resources evolved as a survival strategy. Humankind learned quickly enough that complacency does not assure today's and tomorrow's survival. Those who "won" the competition for resources may survive, those who "lost" surely would not. Scarcity, or its threat, rules the struggle for daily life. Aggression, oppression, conflict, power and war became "winning" strategies for coping with the scarcity game. Aggressive and competitive cultures overcame those which were not; and established in ever-expanding "spheres of influence" born of winning, the rules by which the "game of life" was to be played.

As we are supposed to live in a closed system, scarcity is based on the idea that oftentimes a limited supply of goods or services comes up against an ever increasing demand for it and that, as such, every effort must be made to ensure its proper utilization and distribution so as to avoid inefficiency. Scarcity is managed by making choices regarding value so that individuals can exchange resources in a system of trade. In ideal circumstances, pricing systems adjust accordingly, thereby maintaining the balance between supply and demand.

2. CHALLENGING ECONOMICAL DOGMAS [2–11]

The conventional economic theories, with varying degrees, are inspired by the principles of conventional physics applied to a conservative system. Even the Marxist system, which allocates its role to technical progress, only does this reductively, they implicitly presume the existence of a Hamiltonian between capital and labor, usually called "production function" running within a *closed* system. For these theories, Economics is a "*system at once vast and simple which resembles the astronomic universe in its pure beauty*" (Walras).

These concepts which found the standard models of economic growth and conventional economic theories are based on postulates transformed into dogmas, most of which cannot withstand scrutiny. Enlarged theories of production, distribution, consumption, business fluctuations, and other economic elements have been introduced and continually reconsidered from a variety of viewpoints, are based upon the dogmatic assumption that there are not enough resources to meet the needs of the whole population.

For conventional economics, human are predators who can only develop at the cost of Nature. Wealth is produced by the consumption and destruction of natural resources. Then comes the notion of "rationing" scarce resources, or "allocating" or "managing" scarce resources. This acquires rapidly the status of a "revealed truth", as an "economic dogma".

The prerequisites of war are embodied in the definition itself of conventional economics theories which are not compatible the concept of Sustainable Peace. These principles of the csustainable development" are gradually taking over the collective subconscious. This traditional "mechanistic" approach is embodied in the framework of a "fatality" of all human activity which is necessarily included within a thermodynamic context from which any escape is impossible.

2.1. The false dogma of the reversibility of economical processes

One dogma is the reversibility of economic processes. A very large number of mathematical developments carried out in economics implicitly assume the following condition:

$$F(-t) = -F(t)(!) \qquad (2.1)$$

This assumption means – we beg the reader to excuse the perhaps overwrought image – that after having crashed a car against a wall, it would suffice to back up to return it to its previous condition!

All the mechanisms are presumed to be reversible, occurring endlessly, for example in Keynesian cycles, which are immutable, imperturbable, governed by the sole laws of savings and investment. At equilibrium, the system functions "perfectly", and the "Golden Age" is finally regained. The existence of reversible processes, enabling a generous Nature spontaneously to correct the excesses of human activity. By this reasoning, for example water and air are qualitatively invariable, between the time when they enter into the production and consumption cycle, and the time when they exit the cycle as "external outputs". If, by some mistake, degradation occurs, this is gratuitously corrected by a generous Nature by mechanisms which are never questioned because they are presumed to function correctly without human intervention. Similarly, in this approach, wastes do not have to be considered. They are ignored.

Evidently, and as demonstrated by Prigogine, with a few rare exceptions, the processes governing the functioning and evolution of humanity, are irreversible processes.

2.2. One more false dogma: The mythical existence of a general equilibrium

The concept of general equilibrium is directly related to the concepts of reversible processes, linear or not, spontaneously giving rise to the postulate of an economic evolution that must necessarily tend towards an ultimate state of "the general equilibrium". A few passages at the limit would allow the interpretation of turbulences hindering or slowing the march towards this equilibrium. Equilibrium appears as limiting cases and not as representative models of real economic behaviour.

2.3. Another false dogma: the Adam Smith's "invisible hand power"

The "invisible hand" is a metaphor for how, in free market economy, self-interested individuals operate through a system of mutual shorttermist interdependence. Each free exchange creates signals about which goods and services are valuable and how difficult they are to bring to market. Adam Smith introduced the concept in his book 1759 book "The Theory of Moral Sentiments" and later in his 1776 book "An Inquiry into the Nature and Causes of the Wealth of Nations". The market would be an element with corrective influence over ecological malfunctions, an answer belonging to a functionally entropic society inefficient on the long term.

"Dysfunctions would be corrected due to the existence "somewhere" of mysterious mechanisms. Some hidden "laws" operating on the free market", would "spontaneously" ensure the correction of all malfunctions, as long as nothing comes to prevent their free operation. Hence a virtually mystical belief in the benefits of an absolutely free market in which the forces that govern it, are spontaneously and permanently adjusted.

The solution to the problem of the protection of the environment, the reduction of pollution and waste, the more economic use of natural resources are naturally in line with a rationale composed of bans and incentives. With the damage caused to the environment being, in this rationale, linked to dysfunctions, the corrective mechanisms should, when nothing opposes their functioning, be able to break the vicious cycle: growth ⇒ pollution ⇒ exhaustion of natural resources.

We may, first of all, note that this call on market mechanisms to correct any dysfunction has an unfortunate twist. It prioritises the short term. It ignores the well-being of future generations which will be affected by the decisions taken today under the influence of short-term descriptive mechanisms. It conceals the future price of the decisions born of these opportunities. It introduces a bias in favour of goods for which the prices are relatively transparent, contrary to those for which transparency does not exist, first among which, specifically, is environment.

It should also be noted (Barre, 1964), that the allocation of resources resulting from adjustment mechanisms using prices is not necessarily and obligatorily the best (or what would be best) for community. This allocation of resources is the result of compromises prioritising the short term and which we now recognise, can reveal themselves to be harmful or dangerous in the long term. We can also ask about the validity of mechanisms that shrug off all responsibility with regard to the protection of the environment onto others for payment.

The reference to corrective mechanisms regulating the "good" functioning of market has displayed all its effectiveness with regard to what relates to the extrants of the productive act: *marketable goods*. But it does not seem that these mechanisms could be relied upon to be effective in ensuring the healthy management of the resources at mankind's disposal, that is to say, a management capable of distinguishing between short-term constraints and long-term requirements.

Price reflects not only the value of the goods, but also their rarity. Veritable "rarity tensions", price's function is thus, according to Barre (1964), "*to orient goods and resources towards the uses that appear to be the most necessary and where their use will be the most efficient*". The price system functions for Massé as a warning signal whose profound significance is "*Economise me because I am dear, take care of me because I am rare*". Alas, being incapable of reversing the entropicity of the processes that preside over the functioning and evolution of economic paradigm, considered closed, all these corrective mechanisms, however efficient they are in the short term, will be able only to act as temporary palliatives that merely delay the final collapse. These palliatives, can on no account constitute the foundations of a policy responsible for the future and long-term survival of the planet.

2.4. Another false dogma: a conservative system

This dogma conveys the idea that identical production factors would be found at the end of processes of production and consumption. This dogma cannot withstand the simple observation of the reality of an economic system, which produces scrap, waste and pollution.

Owing to the manner in which it functions, humanity, transforms its environment by producing and consuming goods and services. The general rule is of a dissipative system. The Laplacian point of view of a universal differential system parametering all economic states are no longer admissible as a fundamental postulate of Economics. Energy and matter are not invariant. The economic system is a dissipative system in which the processes animating it and enabling it to function are mostly irreversible. As an immediate corollary, the implicit hypothesis of the existence of a Hamiltonian presumed to describe the system must be abandoned.

Companies, human, human community are "*open thermodynamic systems*" whose functioning is based on irreversible processes, exploiting inputs, and generating outputs which have a dual form: evolved and degraded. They function by exchanges with their environment, from which they procure their needs, which they alter, and from which they suffer the consequences. There is feedback, and there is backlash. "*The organisation transforms, pollutes and enriches*" (E. Morin).

2.5. Another false dogma: a closed system with limited resources

In the closed universe of planet Earth, the mere consideration of limited resources necessarily leads to the hypothesis of a closed economic system. By incorporating in the production and consumption process an ever increasing quantity of elements whose added value displays an entropic balance, the societal systems that have followed each other through history have succeeded in offering the economic agents merchant goods and services enabling them to improve their standards of living. The reckless exploitation of natural resources lead to their depletion in a process – the law of diminishing returns – described by Ricardo: "*The return is not the withdrawal*" (E. Morin).

The neo-malthusian-ecologists rightly criticize this functioning mode. But by limiting their view of the world to that of a *closed* system with *limited* resources, by refusing to question the underlying dogmas of Economics, the solutions they propose are based on a false interpretation of the second principle of thermodynamics, which assimilates waste with entropy. To reduce entropy to waste would be to assume that an "*economic*" management of natural resources could cancel the overall entropic balance of the system. This is a fundamental misunderstanding of the concept of entropy and of its related mechanisms.

In these attempts, economic thought tends to reduce the number of production factors to Capital and Labor. These associations reduced to two production factors are the expression of an economic thought that excludes man's inventive activity from its field of analysis and from its preoccupations. De Jouvenel pointed out that these production functions "*incorporate neither the contribution of human ingenuity, nor the contribution of the forces of Nature*". The use of knowledge as an input of the production function helps to overturn these hypotheses: since knowledge is inherently limitless, the resources available to humanity are hence limitless. Since knowledge comes from an unclosed universe, the human creativity. Any system based on the use of knowledge is not a thermodynamic closed system.

3. INTRODUCING KNOWLEDGE AS A PRODUCTION FACTOR

3.1. Objecting labor to production factor

Economic activity is traditionally described with the help of a production function, connecting the inputs, the production factors, to the outputs, the merchant goods and services produced and marketed. The production function expresses the relationship that exists, for a particular status of technology, between the quantities of factors utilised and the quantities of products obtained.

Economic analysis traditionally considers three production factors: capital, labor and natural resources. This distinction derives from the analysis of resources exploited to produce goods and services. Some of the great authors have preferred different forms of association in their analyses. Association between Labor and Nature (Smith, Ricardo, Marx etc.), between Labor, Capital and Nature (J.B. Say, Marshall etc.). A. Marshall refined this distinction: "*There is really no clear distinction between Labor that is productive and that which is not*" For him, there were only "*two production factors: Nature and man".* The distinction drawn between the associations privileging Nature over Labor stems from the distinction drawn between the soil, natural resources and capital: "*Labor is the father, and Nature is the mother of all wealth*" (W. Petty): "*Labor is primarily an act that takes place between man and Nature*" (Marx). Production results from the combination of Labor and Nature, or the combination between Capital, Labor and Nature: "*The productive faculty of natural agents mixes and merges with that of capital*" (Marx). Company activity is sometimes considered as an additional production factor, although difficult to isolate and quantify. Marshall considered including organisation as a production factor. An attempt was also made to introduce technical progress by means of an additional variable assuming the form of time (Solow etc.).

Labor as a production factor has frequently been a controversial subject. A. Smith already distinguished two types of Labor: productive Labor "*which adds value to the object on which it is exerted*", and unproductive Labor "*which concerns natural agents*". Karl Marx suggested as a measure of Labor, to use an "average" value corresponding to the "average" skill of an "average" worker. Such "average" values are defined in some vague manner, but whereof the importance resides in the fact that these concepts involve an a-temporal concept: skill. This sparked even further debate.

3.2. Splitting of "labor" in two different production factors: energy and knowledge

The Greeks and Romans used two terms to designate labor: "ergos" and "ponens", "opus" and "labor". For the Romans, "labor" meant arduous work, the expression of physical strength, reserved for slaves. Conversely, "opus" represented the creative work drawing on intellectual skills, intelligence, erudition and knowledge. If we refer to these ancient definitions of labor, it must be broken down into two parts: one corresponding to the exercise of strength: energy; and the second to the exercise of intelligence and skill. Labor, a social act, thus stands as a combination of two production factors of opposite entropic natures [3], energy and knowledge, proceeding in a temporal process. (Let us denote knowledge by the letter E, from "Erkenntnis" [3], the German word for knowledge as well as know-how, the initial knowledge gained by initial training and the know-how gained by experience).

The equation of state, let say the production function, of any economic system is accordingly described by the combination for four production factors: Capital, K (tangible assets); Matter: M; Energy: U and Knowledge: E (untangible assets)

$$Y = f(K, M, U, E,). \tag{3.1}$$

This model was implicit in the Cleveland et al. or Georgescu-Roegen's fund-flow model which describes production as a transformation process in which a flow of materials, energy, and information is transformed by two agents of transformation human Labor and manufactured capital. The flow of energy, materials and services from natural capital is what is being transformed (the material cause), while manufactured capital effects the transformation (the efficient cause).

We will see below that Matter and Energy are entropic, Knowledge is negentropic. Capital, as a synergistic aggregate of matter, energy and knowledge, has a dual nature, entropic or negentropic, depending on the relative part of knowledge.

Time accordingly appears as an indication of chronologies during which these four production factors are put into play in the productive act. The efficiency of a production factor will very probably depend on the production factor itself, but also on the temporal processes through which it is made available to the economic agents. The production function would then very likely include as additional variables: insofar as K, M, U, E are continuous, derivable, and which can be written:

$$Y = f(K, M, U, E, t) \quad \text{or} \quad Y = g[K(t), M(t), U(t), E(t)]. \tag{3.2}$$

Time, in line with the ideas of Prigogine, must be regarded as a measure of the irreversibility of human processes.

The productive process as any human activity is submitted to universal laws. Among those laws, one is inevitable for humanity: the second principle of thermodynamics. Applied to economics, this second principle says that besides goods and marketable products, human products waste, consequence of the energy and matter degradations it exploits. Waste stands for all residues, scraps, pollution, all the "externalities" of the enterprise. The entropic nature of human activities implies that the yield of any transformation had to be lower than the unity. Any productive process implies its symmetry. It generates pollution and waste.

To meet his needs and to answer his many concerns, man has progressively structured his relationships with his environment, by making himself master of a quantity, a quality and a growing number of resources. These relationships of man with his environment define societal paradigms [12] having the structure of a system if one refers to the definition provided by J. Delattre [13]: "*as corresponding to a set of interacting elements*", or as "*a dynamic totality of elements whose interaction produces new properties of integration, not reducible to those of its components considered separately*" (Mshvenieradze quoted by B. Walliser [14]). This system is organized around and by socio-technico-economic mechanisms which account for its functioning (that is to say its activity), and its morphogenesis, (namely its evolution).

Due to these differences accorded to entropy, the function of production cannot be homogeneous and substitution between factors is not possible.

3.3. Properties of Knowledge

Knowledge, understood in its broadest form, that is to say, "savoir", "savoir-faire" and "savoir-être", and their availability represent the keystone of the functioning and the evolution of a socio-technico-economic system which is concerned with economic peaceful growth that creates increased wealth and respects the quality of the environment.

3.3.1. Knowledge's generating processes

The corpus of knowledge is accordingly defined as a complex of interacting elements, or culturemes. The p culturemes making up the corpus of knowledge are interlinked by R relationships. The behaviour of a cultureme p_i in the relationship R_j differs from its behaviour in another relationship R_k. The whole is defined by a system of non-linear, integro-differential equations, which are generally impossible to process.

The primary dimension of knowledge is its extension, namely the number of elements making it up, the "culturemes". Its second dimension is its "fecundity", namely the probability of existing, or potential, associations, combining the culturemes with each other to produce new ones. A first attempt to measure knowledge could be given by applying Zipf's formula in linguistics:

$$E = ALogn.T + K_1\Sigma_i\Sigma_j p_{i,j} + K_2\Sigma_i\Sigma_j\Sigma_k\, p_{i,j,k} + \ldots \tag{3.3}$$

where n is the number of culturemes, T the temperature in Mandelbrot's meaning characterizing with $p_{i,\,j}$ the probability of occurrence and potential associativity, i.e. the "fecundity" of the culturemes. A, K_1 and K_2 are constants.

The first term, $A\log n.T$, could be used to quantify the extent of knowledge, namely the number of culturemes present in the corpus of knowledge. The second term, K_1 (formula), could be used to measure the density of inter-culturemes relationships and can be assimilated with their "fecundity". This term could be considered as an attempt to measure the 'quality' of knowledge.

A second attempt to quantify knowledge can be made by using the formalism of the General Theory of Systems.

In the corpus of knowledge, certain rules govern the combination and organization of the culturemes between each other. At the higher level, meta rules govern these elementary rules between each other, modify them or transform them. At an even higher level, meta-meta rules in turn help to codify and modify the meta rules, and so on and so forth. This multitude of rules at different levels is enriched and modified as they are used in a network that Hofstadter [9] has called "strange loops", and whose incompleteness was demonstrated by Gödel. There are two types of mechanism for the exploitation and utilization of the corpus of knowledge and its transformation into flows of technical intelligence.

The first mechanism consists of the use of the flows of information as they exist. This is the behaviour of "Mr. Everyman" who uses these flows without questioning, contesting or modifying them. Their use is strictly passive.

Creators' act differently. Having observed a combination of culturemes as the definition of any knowledge, the creative person will modify the message contained in this combination of culturemes to create another message, to create a new knowledge. To do this, he can either delete a cultureme, or add another, always attempting to create a different message. He can also continue his work of questioning the previous order by proposing new rules, new meta rules permitting the genesis of new inter-cultureme combinations, in other words new knowledge. And these new flows of knowledge are the seeds of discoveries, innovations and inventions.

These creative approaches are sometimes logical and can be inferred from the rules and meta rules already known. They may also be *infra-logical*, enabling the creator to identify, against all logic, the new knowledge, the knowledge whose existence is denied by the initial rules, but which will permit the emergence of flows of knowledge which augur breakthrough innovations.

Creation is based on three distinct mechanisms, which may be complementary to each other.

– Rearrangement, in a new form, of the existing flows of knowledge: this process of technological creation is logical.

– The exploitation of the flows of knowledge in new forms (exploitation of new combination rules of culturemes, or the definition of new meta rules).

– The genesis of new culturemes, entailing the definition and application of new rules, indeed new meta rules. This creative process eludes any logical form. It is uncertain. Its duration, cost and probable results cannot be determined in advance. The resulting technological innovations are generally breakthrough innovations.

3.3.2. The synergic/antagonistic property of knowledge

Knowledge can be compared with a gigantic puzzle in which each part, each cultureme, has its own place, its individuality, its specificity. Every part, every cultureme, is unique, different from all the others, and hence irreplaceable.

Since each new cultureme is different from all the others, it cannot supplant the older culturemes, which preceded it in this logic of continuous creation. No new cultureme can take the place of an older cultureme by destroying it. On the contrary, it aggregates with the culturemes already present in the existing knowledge corpus, in a synergic combination whose total value is never equal to the sum of its parts. The aggregation of a new cultureme, the discovery of a new rule, of a new meta rule, do not cause the older rules or culturemes to disappear, but, to the contrary, leads to their embellishment. There is no disappearance, but rather mutual enrichment, and a perpetual expansion of the stock of knowledge. Depending on the aptitudes of each, the combination of culturemes could yield possibly nothing, or a few, or could bring about new flows of knowledge.

As the addition of identic culturemes has no sense. The mode of composition of culturemes is not additive. It is synergic or antagonistic. Knowledge has no additivity property. The non-additivity property of knowledge as a production factor, invalidates any economic analyses which, implicitly or explicitly, perform with this mathematical property. The use of mathematical operators such as addition, subtraction, multiplication, division mathematical to perform any "object", which postulates that these objects, is impossible. Many econometric models must thus be rejected.

In the gigantic puzzle formed by the knowledge corpus, every part, every cultureme is unique and cannot be replaced by another. Each gap, each missing part, may be crucial for the one which does not possess it. The absence of a tiny missing cultureme would make the whole incomprehensible.

An old proverb that states "nobody is irreplaceable" is not quite right: we shall never know the end of Schubert's Unfinished 8° Symphony. By dying too soon, Stendhal deprived us of the end of his novel "Lucien Leuwen". And how did Karl Marx want to conclude "Capital"? etc.

Knowledge suffers no deterioration during its uses. On the contrary, owing to learning mechanisms, knowledge could become richer with use. Their potential of application grows as it is used, what is called the "experience curve".

Knowledge do not wear out. It is not deteriorated, depleted or altered by consumption. It can be repeated as often as necessary. This use can be repeated indefinitely without any degradation. Knowledge accumulate and recombine indefinitely. This process of perpetual growth can take place without any degradation of the other production factors. It can only be imperilled knowledge which make them obsolete. Yet even this obsolescence is never total, since new knowledge never completely substitutes for old knowledge.

Its consumption does not alter it, but, far to the contrary, can result in an increase in quantity and quality. Its exchange takes place without any misappropriation. It can be stored without deterioration. It can be increased without any deterioration of the other production factors, capital, energy and matter. The same knowledge can be used simultaneously in several different places, without any effect on quality. The use of knowledge knows no limits, and its use can be infinite.

While the uses of the other production factors and other tangible goods are fixed spatially and while their uses are exclusive of any other simultaneous use, the same does not apply to knowledge. Knowledge is intangible. It is the fruit of human creativity. It comes from nowhere and everywhere. Knowledge has no limits, and its use can be infinite.

3.3.3. Knowledge is negentropic

The application of the Bose–Einstein formalism and Planck's Law demonstrates easely the negentropic property of Knowledge [3, 15, 16].

That is, all the knowledge in the world compiled in a huge corpus. Let quantify it in bytes.

That is N_i, a knowledge byte, at time t. The total of knowledge byte of the human corpus at time "t" is:

$$N = \sum_i N_i. \quad (3.4)$$

Any variation of the "volume" of the humanity knowledge corpus is equal to

$$dN = \sum_i dN_i \neq 0. \quad (3.5)$$

For $\sum_i dN_i = 0$, would means knowledge corpus would be constant, that ought to happen for no progess.

Regarding a creative shock with an other knowledge byte.

Any knowledge byte is able to generate an addtional knowledge byte, but any creative shock is not necessarily able to generate such additional knowledge byte. For it happens, it must have some synergetic effects between the two shocked knowledge bytes.

Two parameters can describe the creative quality of a byte. The first parameter, Q_i, quantifies the intrinsic quality of creativity of byte N_i, Q_i is independent of its environment and of the events that may occur in it. Creative shocks do not affect the value of the intrinsic quality of creativity of the byte.

At time t, the total value of the creativity's intrinsic quality of the humanity knowledege corpus is equal to:

$$U = \sum_i Q_i N_i. \quad (3.6)$$

The increase of the intrinsic creativity of humanity knowledge is equal to:

$$dU = \sum_i Q_i \delta N_i + \sum_i N_i \delta Q_i. \quad (3.7)$$

As Q_i is immutable and unalterable, $\delta Q_i = 0$, there is:

$$dU = \sum_i Q_i \delta N_i. \quad (3.8)$$

The intrinsic creativity of creativity does not give a the real societal value of the knowledge corpus. The same amount of knowledge in the brain of Henri Poincaré, Beethoven, Hittler or Monet will not have the same result.

The societal context is also a determining factor. Leonard de Vinci described the principles of helicopter, but he was unable to build it in the Renaissance period as the required technologies were not available. It is necessary to add at every byte of knowledge corpus a second parameter which will describe the effective creative potential. Let's call "creative degeneration", g_i such parameter. g_i may varies according to the time, the era and the brain of the individual.

The number of state g_i for any byte of knowledge is very high. It is directly related to the societal and technological environment, to the cultural patrimony, which are dynamic and interactive. It is also related to the number of individual actors of cultural, scientific and economic life and more generally to the total population. As a result:

$$g_i \gg N_i. \quad (3.9)$$

So, the intrinsic creativity of knowledege, its societal "value" can be described as a function of the type:

$$E = f(N_i, Q_i, g_i). \quad (3.10)$$

The measurement of knowledge, E, is equal to the totality of the possible combinations of the knowledge bytes, taking into account their number and their creative degeneration which are decisive for the fertility of creative shocks able to generate more knowledge bytes. Any knowledge byte is unique; it is different from all others. Consequently, the number of possible combinations is given by the formula describing the distribution of bosons:

$$C = (N_i + g_i - 1)!/N_i!(g_i - 1)! \quad (3.11)$$

At time t, the total of creative shocks, describing the possible value of knowledge is equal to the product of the combinations for each level of creative degeneration. For Bose–Einstein statistics, that can be used in this case:

$$E = \Pi_i \, (N_i + g_i - 1)!/N_i!(g_i - 1)! \quad (3.12)$$

$$\textit{with} \quad g_i \gg N_i \quad \textit{and} \quad g_i \gg N_i \gg 1. \quad (3.13)$$

so

$$E = \Pi_i \, (N_i + g_i)!/N_i! g_i! \quad (3.14)$$

and

$$LogE = \Sigma_i (\log(N_i + g_i)! - \log(N_i)! - \log(g_i)!).$$

Applying Stirling's formula:

$$\log E = \\ = \Sigma_i \left[(N_i + g_i)\log(N_i + g_i) - N_i \log N_i - g_i \log g_i \right], \quad (3.15)$$

as

$$\Sigma_i N_i = c^{te}, \quad \text{so} \quad \delta N_i \neq 0. \quad (3.16)$$

By applying the method of Lagrange multipicaters, it comes a law of distribution of the form:

$$N_i = g_i / e^{\beta Q i} - 1, \quad (3.17)$$

with β are status parameters.

Which gives for E, the knowledge:

$$\log E = \beta \Sigma_i g_i Q_i e^{-\beta Q i}, \quad (3.18)$$

where:

Q_i – measures the intrinsic creative value of cultureme i,

g_i – measures the state of creative degeneration of culteme i,

β – a parameter of state, obtained by the resolution of the equation describing log E by application of the method of Lagrange multipliers,

i – is the total number of culturemes.

This result is homolog to the Clausius entropy formula.

But due to the presence of the sign "–" into exponential, this formula is therefore characteristic of negentropy. Knowledge has negentropy properties.

3.3.4. Thermodynamics and Information Theory

The entropic neo-malthusian ecologist fatality

For neomalthusian economists, as Economy would fit into the framework of a thermodynamic closed system, its total balance would be entropic. This inevitably means a regressive evolution to the final collapse. This is the narrow framework surrounding the neomalthusian-ecologist dogma, that of a closed system whose resources are limited.

"*This image of the inexorable death of the universe suggested by the second principle ..., this idea that, because of the very nature of things, the only possible and ultimate future for man is the annihilation of things, has infiltrated like paralysis through our entire occidental culture*" leads L. Brillouin [17] to wonder "*How is it possible to understand life if the whole world is governed by a law like the second principle of thermodynamics, which points towards death and annihilation?"*

This is based on a false interpretation of the second principle of thermodynamics, which, schematically speaking, assimilates the concept of waste and pollution with entropy. Its assume that an "*economical*" management of natural resources could cancel the overall entropic balance of our world, isolated in the universe. In so far as this can be treated as an isolated, indeed closed, system, its total entropic balance would be positive, regardless of the "*economies*" which can be realized. Its regression would be inevitable. This is a fundamental misunderstanding about the neomalthusian concept of entropy and its related mechanisms.

MAXWELL'S DAEMON ENIGMA AND SHANNON APPROACH

A second approach to the concept of evolution has developed in line with a view opposed to the Carnot/Clausius principle. In biology, as in sociology, the concept of evolution appears to be closely associated with a process of organization which can lead to the creation of increasingly complex structures. Whereas the extension of the thermodynamic principle translates into the progressive dissolution of a pre-established order – "the golden age" – in a spreading chaos, the biological concept of evolution is oriented in the opposite direction. This was observed by *H.* Bergson when he stated that "*duration means invention, creation of forms, the continuous elaboration of what is absolutely new*".

This opposition between these two approaches is only apparent in so far as a simple answer can be found to the tantalizing paradox posed by Maxwell's imp.

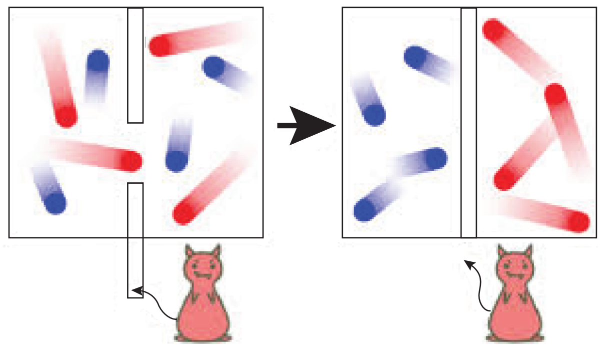

Fig. 1. State (1), state (2).

Remember that, by resorting to a technical strategy, this imp is able to increase the order of a mixture without modifying the total entropic balance. This result is in flagrant contradiction of the second principle of thermodynamics.

The answer is simple: Maxwell's imp can only sort the molecules if he can recognize them. In other words if he has information qualifying the state of the molecules which he wants to separate. To raise the order of the system, Maxwell's imp must have useful information, which has been omitted in the statement of the problem, which made its solution impossible.

Let consider a system *S*, consisting of *N* objects, endowed with reason, in other words capable of integrating, modifying and using flows of information. Consider the system *S* in a disordered state (1) (see Fig. 2).

The *N* objects of the system interact with one another. The friction between these objects corresponds to the production of heat, *dQ*, concomitant with the work supplied by the system. Entropy is formed. Under the effect of these interactions, the system evolves towards its most probable macroscopic state, in other words the one for which its entropy is a maximum, a state in which the disorder is the greatest, in which this "agitation", now at its peak, will be the most inefficient, on the spot and in all directions at the same time. It could be stated [18] that the total loss of efficiency is a measure of the increase in entropy.

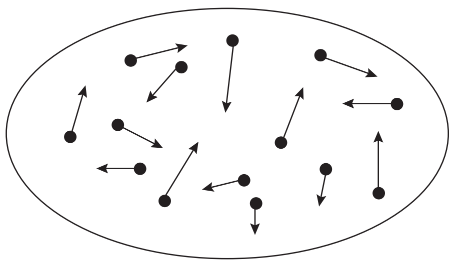

Fig. 2. The system is closed, there is disorder and loss of efficiency. $dE = dW + dQ$. Entropy is formed: $dS = d_iS \geq 0$.

DISORDERED STATE

Consider the system S in an ordered state (2). In this state (2), the N objects are situated on the same level of efficiency. They are all actuated by the same movements. The number of states possible, Ω, is 1. The N objects of the system are in an identical state. In this perfectly ordered state, where there can be neither friction nor collision between the N objects, there is no dissipation of energy as heat: dQ is zero, dS is zero. No entropy is formed.

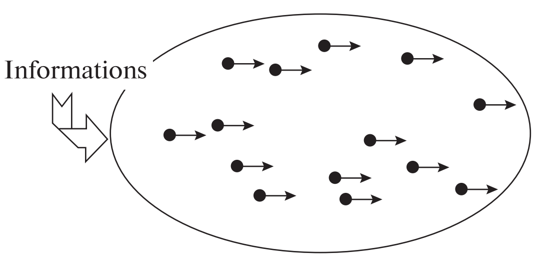

Fig. 3. The system is ordered. There is no production of heat ("degraded" energy): $dQ = 0$. All the energy is converted into work: $dE = dW$, No entropy is formed: $dS = 0$.

ORDERED STATE

This capacity of the system to main itself, or to achieve this ordered state, is only conceivable if the information concerning the state of the objects of the system is transmitted at any time. Without the necessary and sufficient information, the *probability* that the objects of the systems can all remain in the same state is zero. To reduce the number Ω of possible states, in other words to decrease the entropy of the system, ($S = k \log\Omega$), the system must necessarily open towards the exterior and aggregate the adequate information in its functioning.

The passage from a disordered state to a more ordered state, apparently contravening the second principle of thermodynamics, can be explained by the instillation in the system of the information necessary for the adoption, by each of the objects of a behaviour which permits the neutralization of the interactions synonymous with loss of efficiency. The functioning of everything is optimized. The cancellation of the production of entropy by the system is the result of the system's receipt of an *external* flow of information allowing the adoption of consistent, "more ordered" behaviour by the objects of the system. To resume the terms of the enigma posed by Maxwell, one could say that somewhere *outside* the system is an imp which is capable of sending useful information to the objects of the system to adopt the consistent behaviour. This implies an equivalence between information and negentropy (the opposite of entropy) (see Szilard, Gabor, Rothstein and Brillouin (1940–1950)).

So, the question posed by Prigogine, "*Do two irreducible types of physical law exist, one concerning inanimate matter and the second living matter*?" [15], finds a clear answer inasmuch as the flow of information is taken into account: the laws of physics are equally applicable to inanimate matter and to living matter, in so far as the flows of information, of knowledge, governing the functioning and the evolution of the systems, have not been omitted.

The equation developed by Prigogine for the entropic balance of a system is thus satisfied, as well as the second principle of thermodynamics. In order to reverse its entropic balance, the system must adopt an "open" functioning. By incorporating negentropic information, the system will be able to adopt a negentropic functioning (one realizes the importance of the *intrinsic quality* of the information received by the system as well as the *aptitude*, the *expertise* of the agents to receive the information and, if necessary, to adapt it to the local situations they are faced).

With the inclusion of knowledge among the factors of production, the analogy between the Clausius entropy and the Shannon entropy makes legitimate the application of the laws of thermodynamics to the economy.

LANGE MODEL: CYBERNETIC FORMALIZATION [20], PRIGOGINE THEORY

Every system can be represented by a function of state, let say the production function, describing its operation and its evolution. Provided this system is a multi-level hierarchical system, the laws and principles of cybernetics can be applied to it.

The relationships between inputs and outputs can accordingly be represented by using the standard notations of cybernetics:

$$Y = TX. \qquad (3.19)$$

Here X describes the input flow, Y the output flow, and T the transformations, irrespective of type, taking place in the system.

In order to establish the function of state that describes the operation and the evolution of the system, it is assumed, as usual in cybernetics, that all or part of the system can be represented in the form of a set of conjugate elementary sub-systems within which economic transformations take place, described by a sound combination of seven elementary operators. This hypothesis does not imply that the resolution of this formalization is possible.

As part of this analysis, O. Lange proposed a model in which the production function assumes the form of a differential equation with finite differences (See O. Lange, op.cit., pp. 102 and seq).

$$(\Sigma_{r\,=\,0\ to\ n}(\Sigma_{s\,=\,0\ to\ m}a_{rs}D^r E^{\theta_s}))^{-1}X(t) = Y(t), \qquad (3.20)$$

where:

• D_{rs} represents the r^{th} derived operator if $r > 0$, and the r^{th} integral operator if $r < 0$,

• $E^{\theta s}$ is an advance θ_s if $\theta_s > 0$, or a delay θ_s if $\theta_s < 0$.

The "derived" operators describe the continuous processes which take place in the system. The "advance" operators describe discrete phenomena.

O. Lange demonstrated that the following operator of the system, T, could be used to describe any economic system [20]:

$$T = \Sigma_{r=-0\ to\ n}(\Sigma_{s=0\ to\ m}a_{rs}D^r E^{\theta_s}). \qquad (3.21)$$

According to O. Lange, the general solution is written (see O. Lange, op.cit., pp. 102 and seq.)

$$\begin{aligned} Y(t) &= \varpi(t) + \psi(t) = \Sigma_j q_j(t)e^{\lambda jt} + \\ &+ (\Sigma_{r=0\ to\ n}(\Sigma_{s=0\ to\ m}a_{rs}D^r E^{\theta_s}))^{-1}X(t), \end{aligned} \qquad (3.22)$$

where the first term $\varpi(t)$ (t) is the general solution of the homogeneous equation obtained by assuming the second term to be zero, and the second term (t) is a particular solution of the non-homogeneous equation, with $x(t) \neq 0$.

The general solution to the homogeneous equation is written:

$$\varpi(t) = \Sigma_j q_j(t)e^{\lambda jt}, \qquad (3.23)$$

where λ is the root of the characteristic equation, the initial conditions setting the coefficients $q_j(t)$. It is independent of the inputs of the system. It is called the internal structural component, is homogeneous. It is independent of the inputs of the system, since $x(t) = 0$ and depends only on the composition and the internal make-up of the system, on its internal structure.

It may be observed that its form is identical to the characteristic equation of Clausius definition of entropy. This term is a function of the internal resources of the system, that is to say, its material and energy resources, which are known to be rare, limited, apt for alternative uses, and subject to the law of diminishing returned. It describes the operation and hence the evolution of the system, when it functions as a closed system, as a system functioning in autarky; whether this autarky is local, regional or planetary.

The second term, the particular solution to the inhomogeneous equation, is obtained for $x(t) \neq 0$:

$$\psi(t) = (\Sigma_{r\,=\,0\ to\ n}(\Sigma_{s=\,0\ to\ m}a_{rs}D^r E^{\theta_s}))^{-1}X(t). \qquad (3.24)$$

This second term, the input component, depends on the external inputs to the system since $x(t)$ does not equal zero. This second term describes the functioning and evolution of the system as an open system.

3.3.5. Analogy with the Cobb-Douglas function

A parallel can immediately be drawn with the formalism describing the macroeconomic production functions of the Cobb Douglas type, which have been developed to describe the operation and the evolution of economic systems:

$$Y = f(K, L) + residue. \qquad (3.25)$$

These production functions comprise two terms. The first is usually the production function proper. Whatever its formalism is always homogeneous between its variables, in order to satisfy the requirement of replaceability traditionally assumed by conventional economic analyses. Time, an additional variable, which is presumed to represent technical progress, is sometimes incorporated in this first term.

The second term, sometimes called "residue", helps to make the economic reality to "coincide" with the figures obtained by breaking down the first term of the production function. This second term is simply a "grab bag" of everything that cannot be explained, resuming everything that cannot be represented by the harmonious mathematical combination of capital and labor. Some experts agree that the second term is representative of the growth and development of economic systems.

The first term describes operations in a closed system. It corresponds to the internal structural component of the O. Lange solution, noted above. This internal structural component describes the first term of the macro-economic production functions. While this structural component, like the first part of the production function, can shed some light on the operation of the system, it is powerless to explain the growth processes:

$$Y_i(t) = \varpi(t) = \Sigma_j q_j(t) e^{\lambda_j t}. \quad (3.26)$$

The second term, the "*residue*", corresponds to the input component, responsible for the dynamics of the system and for its ability to develop.

$$Y_e(t) = \psi(t) = (\textstyle\sum_{r=0 \ to \ n}(\sum_{s=0 \ to \ m} a_{rs} D^r E^{\theta_s}))^{-1}. \quad (3.27)$$

This input component measures the external input of entropy, resulting from the "opening" of the system by exploitation of knowledge. This second term is responsible for the dynamics of the system and for its capacity to develop.

The functioning and evolution of the societal paradigm is accordingly the resultant of two modes of action:

1. The first mode is deterministic and is described by Hamiltonian function. For any system not supplied from outside, that is to say where the input term in $x(t)$ is identically nil, the functioning, which obviously depends only on its internal properties, is in fact described by a homogeneous, continuous, derivable production function of Hamiltonian form. This is the functioning mode describes by conventional economic logic that is the setting of the ecologistic-malthusian logic. This logic inevitably culminates in the destruction of the societal system.

2. The second mode corresponds to a functioning and an evolution concerned with economic growth that can indefinitely create wealth, while respecting the environment. This implies the "opening" of the system by incorporation of new knowledge.

4. THE RENUNCIATION OF THE KEYNESIAN/MALTHSIAN HYPOTHESIS OF A CLOSED AND CONSERVATIVE SYSTEM

4.1. Two opposite components would explain economic moves

The production function developed from the model of O. Lange leads to the definition of a production function composed of two terms:

$$Y(t) = \varpi(t) + y(t) = Y_i + Y_e. \quad (4.1)$$

It can be understood by considering the developments of two components, the first corresponding to functioning in a closed thermodynamic system, and the second corresponding to the "opening" of the system:

The evolution of any system would therefore proceed from an alternative: the system functions as a closed system. It is accordingly likely that a Lyapunov function exists, positive, increasingly monotonically, concomitant with the production of entropy measuring its economic regression. Or else, the system functions as an "open » thermodynamic system. The scale, quality and incidence of the inputs of new knowledge, concretised by technological innovations, will accordingly play a crucial role in the evolution of the system.

We can sum up:

1. the internal structural component is a function of the entropic production factors, *M* matter, *U* energy, and the tangible capital, K_t. It describes the functioning in a closed thermodynamic system: the production of entropy is positive, but could be sometimes locally nil:

$$\omega(t) = f(K_t, M, U) = Y_i, \quad (4.2)$$

2. the input component which is a function of knowledge as a production factor, *E*, and the intangible part of capital, K_i. This component measures the negentropic input resulting from the use of knowledge

$$\psi(t) = f(K_i, E) = Y_e. \quad (4.3)$$

As all activity within the system generates entropy, by prolonging the analyses of *N.* Georgescu Roegen and by resuming the notations of Prigogine, we can describe the variation in entropy of socio-technico-economic systems with the help of two terms, in order to identify the evolutionary direction of the system towards growth or towards regression

1. *dSi*, generated by the internal component;

2. *dSe*, generated by the input component.

Prigogine explained the first term dS_i corresponds to the entropy produced by the internal variations, modifications, processes and actions of the system, reversible or irreversible. This internal structural component measures the production of entropy generated by the system using only its internal resources.

$$dS_{internal} = dS_i \geq 0. \quad (4.4)$$

For isolated systems, the Malthus's hypothesis of a closed system for Earth, $dS_e = 0$ and,

$$dS = dS_i > 0. \quad (4.5)$$

In that case, the neo-malthusian ecologists would be right: such isolated system is running to the final collapsing.

For Prigogine again the second term, dS_e, describes the variations in entropy associated with the "opening" of the system. It may be positive or negative.

$$dS_e > 0 \quad or \quad < 0. \quad (4.6)$$

The sign of *dS* the total entropic balance, conditions the evolution of the system

$$dS = dS_i + dS_e. \quad (4.7)$$

Contrary to the view of the neo-malthusian ecologists, the fatal final collapse is avoidable, as the value of dS depending of the value of dS_e, is not necessary positive.

4.2. Entropy, negentropy and growth

The sign of dS the total entropic balance of the system, conditions the evolution of the system. Two alternatives may occur:

Its total balance is positive. The system functions as an entropic closed system. Any system able of entropic production irresistibly evolves to a system where its entropy is maximum and which corresponds to its collapsing. The system will regress and decline, as it was shown by N.Georgescu Roegen, and by the analysts of the Club of Rome in 1972, in their report “Limits of the Growth”.

Or,

Its total balance is negative the system functions as an open thermodynamic system. The system will develop and increase the amount of wealth which will be later dispatched between all economic agents. The outstanding importance, quality and incidence of the knowledge flows play a very important part in the system evolution. Their dynamic make the joined and simultaneous effects of amplification linked to the opening of the system as well as the mechanisms of conservatism for closing the system depreciated it and fight against this amplification.

The evolution of every system is thus the outcome of two opposing mechanisms: one which is descriptive of the evolution of the system functioning as closed, for which the evolution expresses a continuous disorganization measured by the increase in entropy and leading to the disappearance of the original structures; this second mechanism is descriptive of the functioning of an open thermodynamic system: its evolution is the consequence of a growing structural complexification.

1) The internal structural component, a function of entropic production factors, matter M, energy U, and part of capital, tangible capital, K_t, descriptive of functioning in a closed system: the production of entropy is positive, and sometimes locally nil:

$$\varpi(t) = f\left(K_m, M, U\right) = Y_i \rightarrow dS_i > 0. \qquad (4.8)$$

It corresponds to the internal functioning of the system, consuming and degrading limited, rare, alternative-use resources. This production of entropy corresponds to the operation of a closed and dissipative system animated by irreversible processes.

2) An input component, which is a function of knowledge, E. The system functions as an open thermodynamic system, with development and growth. This second mechanism is descriptive of the functioning of an open system. This exogenous component includes knowledge, and the intangible part of capital K_i. This component measures the negative external entropy contribution resulting from the utilization of knowledge. Capital, depending on its form, tangible or intangible, is found in each of these two components, the structural component and the input component. The extent, quality and influence of the flows of knowledge, which are inherently variable, will then play a vital role in the evolution of the system.

Only this second term can be negative, i.e. negentropic. It opposes the regression of the system, indeed even enable to develop by increasing its degree of complexity

$$\psi(t) = f\left(K_i, E\right) = Y_e \rightarrow dS_e > or < 0. \qquad (4.9)$$

Matter aggregates energy and simultaneously with knowledge. This share of incorporated knowledge is part of the added value. The added value is so composed of parts whose entropic characteristics are opposed. Matter is progressively transformed under the cumulative effect of energy and knowledge in consumer goods or productive equipment – tangible capital. The aggregation of knowledge can be interpreted as an increase in their topological complexity, enabling them to optimize the use of matter and energy. The complexity of the system, a factor in development, is increased by adding knowledge. The productive act thus corresponds to a process of enrichment of the flow of matter by the simultaneous incorporation of energy and knowledge.

When the entropy of the internal structural component is equal to or greater than the production of entropy of the input component, the system is said to be self-regulated (the law of requisite variety). It is then capable of nullifying the effects of the input flows that disturb its operation, although this operation leads it to collapse and ruin.

4.3. The “Prigogine way” to abundance

The intrinsic characteristics also roughly describe processes running the paradigm. The extrinsic characteristics, which correspond to the influence of the inputs of knowledge on the system, describe its evolution and its mutations.

The entropic or negentropic nature of the added value incorporated by human activity in the general production and consumption cycle, determines the way in which societal paradigm evolves. By privileging the exploitation of intangible resources, the overall entropic balance can be reversed, and the conditions for resumed growth are satisfied. Wealth can be accumulated without any detriment to the environment by applying Lavoisier’s law: “Nothing is lost, nothing is created, everything is transformed”.

The application of the Lavoisier’s law means that the cycle of production and consumption is no longer completed by consumption, but perpetrated by the permanent recycling of all the products, by-products, scrap and waste generated by the economic processes which animate the societal paradigm and make it live. These outputs of the productive act, the products, the by-products, the scrap and the waste must be considered as raw materials in the same way as conventional raw materials. It must be taken into account as inputs of the productive act. So, increased consumption will correspond to increase production of by-products, scrap and waste, that will correspond to more reprocessing and recycling, that means more jobs and, simultaneously, less pollution and less exploitation of 'virgin' raw materials: let say, which is the definition of sustainable development.

Yet every product is the compromise of an energy/matter resolution. The re-introduction of 'spent' material into the production and consumption cycle can only be achieved at the cost of an increased use of energy. One cannot hope to win on both counts, preserve matter and economize energy at the same time. Carnot and thermodynamics would be completely lost in the shuffle. One cannot act on one of the terms of the equation, matter, without the other term, energy, being altered. One cannot attenuate environmental damage, treat the waste and scrap, recycle it, reprocess it or regenerate it, decrease the sources of pollution, without consuming more energy, knowledge and capital.

At the opposite to a closed system running to the final disaster even if using less and less energy and matter, an open system develop and grow according to sustainable processes by using more and more energy, knowledge and tangible and intangible capital.

Knowledge appears to be the keystone of economic growth, socially efficient and respectful of the environment. This use of knowledge by exploiting flows of information corresponds to the general pattern of technical progress. The opposition to the neomalthusian philosophy is total: in this scheme of things, human activity lies at the source of created wealth.

4.4. The degree of complexity of the paradigm

The evolution of the system is the resultant of a growing structural complexification. The increase of the complexity of the system, a factor in development, occurs by the aggregation of new knowledge and ever denser and richer flows of information. This aggregation takes place in successive waves by the well-known Schumpeterian process of innovation clusters, or by the incrementation process described by Usher. The slow evolutions and sudden mutations of the system would thus be the consequences of the increase, by the integration of knowledge, of the degree of complexity of the "objects" populating the paradigm societal system.

The evolution of the paradigm is both the cause and the result of the increase in its degree of complexity, and hence of the increase in the level of the specialization of each of its parts. The process of evolution, a direct consequence of the negentropic flow of information, thus stands both at the origin and the result of the increased effects of differentiation of the structure of the system, whether this concerns the fractionation and specialization of the parts and the behaviors of economic agents.

Under the effect of these flows of knowledge, always replenished, the level of organization of the system begins to rise. It reaches a peak and then declines if the flow is cut off. Paradoxically, the same factors that give the impetus to societal paradigm and which are the driving forces of its growth can also be responsible for its blockage and its decline. The growth of the complexity of the structure allows its development. Above a certain threshold, where selective specialization generates more blockages than synergies, the negentropic flow issuing from the flows of knowledge can no longer offset the greater total entropy of the paradigm. The total entropic balance changes sign. The paradigm switches to a regressive mode.

This gives rise to situations in which the effects of the disturbances generated by the internal operation of the paradigm is liable to nullify the positive effects of the flows of knowledge. The quality of knowledge is at fault, the levels of fecundity, namely its capacity to create new culturemes.

4.5. Deterministic functioning and chaotic functioning

Any societal paradigm may be presented as an open thermodynamic system incorporating irreversible processes, producing outputs in dual form: an evolved form and a degraded form. Four production factors emerge from the functioning of the system: capital, matter, energy and knowledge. Two are entropic, matter and energy. Knowledge is negentropic. Capital, the aggregation of matter, energy and knowledge incorporated, has a dual nature, entropic and negentropic.

In as much as the system owns at least three degrees of freedom, the preconditions for the appearance of chaotic regimes are satisfied. With four variables of state, K, M, U and E, the societal paradigm possesses all the prerequisites to be described as chaotic regimes.

The chaotic state of the system is measured via the entropy of motion of its trajectory, which approximately corresponds to the speed at which information, in other words, the flows of new knowledge, appear in the system. Above a certain threshold, associated with the sign of the total entropic balance of the system, insofar as the inputs of new knowledge are sufficiently large and significant, the behaviour of the system becomes chaotic. Conversely, for a paradigm functioning as closed and not accepting any flow of new knowledge, the movement towards chaos will be abandoned in favour of a deterministic behaviour, which can be described by Walrasian matrices or by Samuelson equations.

The economic system could be represented in the form of a hyper-surface, $S(Y, t)$, in a four-dimensional space (K, M, U, E). Under the action of the flow of new knowledge, technological innovation, the hypersurface undergoes a local deformation that could be described by continuous, derivable processes. The morphological changes induced by technological progress assume the form of discontinuities. These localised deformations of the system, induced by a technological mutation, can be described by topological features, called "catastrophes", which have been classified and analysed by *R*. Thom.

Conceived as an open U, the societal paradigm, under the action of technological innovation generated by the flow of new knowledge, develops fields of local dynamics in a turbulent environment. This open U exploits the generic resources of capital, energy, matter and knowledge, via temporal processes. This system is not homogeneous. It consists of local economic situations, possibly stable, disjointed by as many transient regimes as there are situations. Each of these situations or economic states is organised into a structure whose complexity is a direct function of the quantity of information it uses, information issuing from the corpus of knowledge it possesses, from the technological foundation on which it stands. There is a field, and there are attractors.

The future morphology of the system is unpredictable. It cannot be described from its former structure. The analysis and projection of older forms into the future do not permit the description of the organisational form that the system will assume. It is also impossible to formally predict the incidence of a local deformation on the final structure of the system. It is also impossible, formally speaking, to determine which innovations will have ultimately minor consequences, and which will correspond to a major technological revolution, a breakthrough.

The integration of knowledge, in the form of innovations, is accordingly reflected by deformations of which the development regime is usually "catastrophic". Hence the growth and development of the system does not obey a linear formalism, but is more like what can be qualified as chaotic. The existence of these chaotic regimes contradict the reductionist concept according to which the behaviour of a system is analysed as a function of the behaviour of its components.

CONCLUSIONS

The Earth is in danger. Two opposite economic logic's are proposed to solve the challenges faced by the Earth. The first logic, the 'ecologically correct' corresponds to Malthusian ecologists. For them only Nature is capable of creating wealth. Man is a predator who can only develop at the cost of Nature. The second logic rejects this approach and finds that wealth is accumulated by human labor and ingenuity. The opposition between these two trains of thought is total. In the view of the Malthusian ecologists, in which the richest of the rich countries will always be richer, and the poor of all countries will be more numerous and ever poorer, human activity does not create any wealth. Unchecked demographic growth and humanity's standard of living are raised at the cost of Nature. Wealth is produced by the consumption and destruction of natural resources. The specter of widespread shortage of natural resources, going hand in hand with the specter of pollution, is now ever more increasingly menacing. This Malthusian ecologist dead end is based on the dogma of a conservative, closed economic system, with limited resources, running by entropic processes. In so far as Economics fits into the framework of a closed system, its total balance is entropic. Such current, and predominant, system of scarcity, called "sustainable development", which sets each-against-the-other in the struggle for survival, will provide, sooner or later, the final catastrophe.

We could evolve in an open thermodynamic system, as described by Prigogine, due to the use of an unlimited negentropic resource: "knowledge". The economic system could be "open" by the incorporation of negentropic inputs, what is to say more and more technological added value.

For example, the answer to the challenge of the "energy transition" weighs in the balance wind power and nuclear energy. In addition to the undeniably more positive effects on CO_2 emissions of nuclear energy, the technological complexity of nuclear energy compared to wind energy, its negentropy superiority, make nuclear energy the primary driving force behind the successful energy transition that will allow humanity to successfully enter the 21st century. The choice of wind energy instead of nuclear energy by Germany, is reminiscent of the choice that this country made at the beginning of the 20th century to develop its aeronautical industry: airships against that of the air planes ... we all know the result!

The negentropic versus entropic alternative would, or not, ensure the respect of environment, the increase of social welfare the growth of the wealth produced by humanity, and the possibility of sharing it with an increasing number of people.

Either will follow the absurd and dark path marked out by neo-malthusian ecologists. Pollution will continue to spread its black wings over the entire planet. The wealth of Nature will diminish and be increasingly expensive. The world's poor will be even poorer and ever more numerous, which will create all conditions for war.

Or we choose to resume economic growth, creating wealth, jobs, preserving our environment, based on the increased use of knowledge.

Additional information on the issues considered in this paper is presented in works [21–45].

СПИСОК ЛИТЕРАТУРЫ

1. *Meadows D.H.D., Meadows E., Zahn E., Milling P.* Limits to Growth. New York: Universe Books, 1972.
2. *Maïsseu A.* Elements of Gestalteconomy // 3rd International Conference on Management of Technology, Miami, USA, 17–21 February, 1992. P. 1113–1122.
3. *Maïsseu A., Le Duff R.* L'Anti-Déclin, ou les mutations technologiques maitrisées. Paris: ESF-EME, 1988.
4. *Maïsseu A.* La prise en compte de la technologie par l'Economique, ou de la contestation des credo de l'Economie. FRAMOT I, Compiègne, 4–5 June, 1996.
5. *Maïsseu A.* The teaching of technology management or the challenging of economic dogmas. INFORMS Washington, DC, USA, 5–8 May, 1996.
6. *Maïsseu A.* Human capital, knowledge & know how: basic concepts. PICMET 97, Portland, USA, 27–31 July, 1997.
7. *Maïsseu A.* Sustainable development or sustained decay? The question facing the "with or without nuclear energy" world // Atoms for Peace. V. 1. № 2–3. P. 25–136.
8. *Maïsseu A.* Introduction to Gestaleconomy. MEPHI, Moscow janvier, 2005.
9. *Maisseu A.* Gestalteconomy: The economic bases of Knowledge Management. IJNKM, 2009. V. 2. № 2. P. 174–198.
10. *Maïsseu A.* Gestalteconomy; Paradigm of Knowledge Managemen. IJNKM, 2009. V. 1. № 1. P. 1–32.
11. *Maïsseu A.* De la Féodalité à la Médiacratie, Histoire Economie et Société, 1992. V. 11. № 4. P. 645–673.
12. *Maler K.G.* Environmental Economics. Baltimore: John Hopkins, 1974.
13. *Delattre J.* Système, Structure, Fonction, Evolution, Maloine, Paris, 1971.
14. *Walliser B.* Systèmes et Modèles, Editions du Seuil, Paris, 1977.
15. *Pacault A.* Eléments de thermodynamique statistique. Masson, Paris, 1963.
16. *Rocard Y.* Thermodynamique. Masson, Paris, 1967.
17. *Brillouin L.* La science et la théorie de l'information. Paris: Masson, 1959.
18. *Rosnay J., Le Macroscope*. Coll Points. Paris: Edition du Seuil, 1975.
19. *Glansdorff P. and Progogine I.* Structure, stabilité et fluctuations. Paris: Masson, 1971. P. 270.
20. *Lange O.* Introduction à l'Economie Cybernétique. Sirey, Paris, 1976.
21. *Amigues J.P.* L'effet d'irréversibilité en économie de l'environnement // Cahiers d'Économie et Sociologie Rurales, 1987. № 4. P. 97–112.
22. *Anderson C.L.* The production process: inputs and wastes // J. of Environmental Economics and Management. 1987. V. 14. № 1.
23. *Ayres R.U.* Resources, Environment and Economics. New York: John Wiley, 1978.
24. *Baumol W.J., Oates W.* The Theory of Environmental Policy. New York: Prentice Hall, 1975.
25. *Clark C.W.* Mathematical Bioeconomics: The Optimal Management of Renewable Resources, John Wiley, 1976.
26. *Comolet A.* Le renouveau écologique: de l'éco-utopisme à l'éco-capitalisme. *Futuribles*. September, 1991.
27. *Douglas Hofstadter*. Gödel, Escher, Bach : Les Brins d'une Guirlande Éternelle, Dunod, Paris, 1979.
28. *Elkington J., Burke T.* The Green Capitalists. London: Victor Gollanc, 1987.
29. *Faber M., Proops J.L.R.* Evolution, Time Production and the Environment. Munich, 1990.
30. *Freeman A.M.* The benefits of environmental improvement: theory and practice, Resources for Future. Washington, 1979.
31. *Georgescu-Roegen N.* The Entropy Law and the Economic Process. Cambridge: Cambridge University Press, 1971.
32. *Georgescu-Roegen N.* Demain la décroissance: entropie-écologie-économie, P.-M. Fabre (Ed.), 1979.
33. *Godard D.* Autonomie socio-économique et externalisation de l'environnement // Economie Appliquée, 1984. V. XXXVII. № 2. P. 315–345.
34. *Goodland R.* Environmentally Sustainable Economic Development: Building on Brundtland, UNESCO, Paris, 1992.
35. *Guitton H.* Entropie et gaspillage. Cujas, Paris, 1975.
36. *Kemp R., Soete L.* Inside the green box', in C. Freeman and L. Soete, New Explorations in the Economics of Technological Change, London and New York: Pinter Publishers, 1990.
37. *Krutilla J.V., Fisher C.A.* The economics of natural environments, Resources for the Future, Washington, DC, 1985.
38. *Labeyrie V.* Contraintes écologiques, équilibres et activités humaines // Economie Appliquée. 1984. V. 37. № 2. P. 267.
39. *Passet R.* L'Economique et le vivant. Paris: Payot, 1979.
40. *Pearce D.* Toward the sustainable eeconomy: environment and economics // The Royal Bank of Scotland Review. 1991. № 172.
41. *Pearce D., Mäler K.-G.* Environmental Economics and the Developing World, Ambio, April, 1991.
42. *Pigou A.C.* The Economics of Welfare. Londres: MacMillan, 1946.
43. *Ramade F.* Ecologie Appliquée. Paris: McGraw Hill, 1989.
44. *Remaux B.* La fonction environnement // Enjeux, October, 1992. № 128. P. 26–29.
45. *Robins N.* L'impératif écologique. Paris: Calmann Levy, 1992.

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ЭКОЛОГИЧЕСКАЯ УТОПИЯ ПЕРЕД РЕАЛЬНОСТЬЮ: МАЛЬТУС ПРОТИВ ПРИГОЖИНА

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Мировая экономика переживает турбулентность завершения длинной волны развития, предшествующей ее вступлению в новый цикл, в котором 21 век оставит свой след. Для решения проблем, с которыми сталкивается Земля, предлагаются две противоположные экономические логики: первая – традиционная, основанная на управлении дефицитом, что соответствует мальтузианским экологам; вторая – управление изобилием, является весьма неакадемическим ответом на термодинамический подход Пригожина к экономике и включением знаний в производственную функцию. Доказательство аналогии между определением энтропии Шеннона и определением Клаузиуса открывает путь к новому видению экономики, отказу от так называемого политически корректного подхода к управлению дефицитом в пользу экономики изобилия. Применение концепции открытой термодинамики Пригожина позволяет выйти из тупика идеологии неомальтузианства, которая способна только сделать бедных еще беднее и многочисленнее и пророчествовать конец света.

Keywords: management of scarcity, management of abundance, green neo-Malthusianism ideology, Prigogine's approach, entropy, open system, knowledge

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REFERENCES

1. Meadows D.H.D., Meadows E., Zahn E. and Milling P., *Limits to Growth,* New York, Universe Books, 1972.
2. Maïsseu A., Elements of Gestalteconomy. *3rd International Conference on Management of Technology,* Miami, USA, 17–21 February, 1992, pp. 1113–1122.
3. Maïsseu A., Le Duff R., *L'Anti-Déclin, ou les mutations technologiques maitrisées,* Paris, ESF-EME, 1988.
4. Maïsseu A., *La prise en compte de la technologie par l'Economique, ou de la contestation des credo de l'Economie,* FRAMOT I, Compiègne, 4–5 June, 1996.
5. Maïsseu A., The teaching of technology management or the challenging of economic dogmas, *INFORMS* Washington, DC, USA, 5–8 May, 1996.
6. Maïsseu A., Human capital, knowledge & know how: basic concepts, *PICMET* 97, Portland, USA, 27–31 July, 1997.
7. Maïsseu A., Sustainable development or sustained decay? The question facing the "with or without nuclear energy" world, *Atoms for Peace,* vol. 1, № 2–3, pp. 25–136.
8. Maïsseu A., *Introduction to Gestaleconomy,* MIPHI, Moscow janvier, 2005.
9. Maisseu A., Gestalteconomy: The economic bases of Knowledge Management, *IJNKM,* 2009, vol. 2, no. 2, pp. 174–198.
10. Maïsseu A., Gestalteconomy; Paradigm of Knowledge Managemen. *IJNKM*, 2009, vol. 1, no. 1, pp. 1–32.
11. Maïsseu A., De la Féodalité à la Médiacratie, *Histoire Economie et Société*, 1992, vol. 11, no 4, pp. 645–673.
12. Maler K.G., *Environmental Economics,* Baltimore, John Hopkins, 1974.
13. Delattre J., *Système, Structure, Fonction, Evolution*. Maloine, Paris, 1971.
14. Walliser B., *Systèmes et Modèles, Editions du Seuil*, Paris, 1977.
15. Pacault A., *Eléments de thermodynamique statistique,* Masson, Paris, 1963.
16. Rocard Y., *Thermodynamique.* Masson, Paris, 1967.
17. Brillouin L*., La science et la théorie de l'information,* Paris, Masson, 1959.
18. Rosnay J., Le Macroscope, *Coll Points,* Paris. Edition du Seuil, 1975.
19. Glansdorff P., Progogine I., *Structure, stabilité et fluctuations,* Paris, Masson, 1971, p. 270.
20. Lange O., *Introduction à l'Economie Cybernétique,* Sirey, Paris, 1976.

21. Amigues J.P., L'effet d'irréversibilité en économie de l'environnement, *Cahiers d'Économie et Sociologie Rurales,* 1987, no. 4, pp. 97–112.
22. Anderson C.L., The production process: inputs and wastes, *J. of Environmental Economics and Management*, 1987, vol. 14, no. 1.
23. Ayres R.U., *Resources, Environment and Economics,* New York, John Wiley, 1978.
24. Baumol W.J. and Oates W., *The Theory of Environmental Policy,* New York, Prentice Hall, 1975.
25. Clark C.W., *Mathematical Bioeconomics: The Optimal Management of Renewable Resources,* John Wiley, 1976.
26. Comolet A., Le renouveau écologique: de l'éco-utopisme à l'éco-capitalisme, *Futuribles*, September, 1991.
27. Douglas Hofstadter, *Gödel, Escher, Bach: Les Brins d'une Guirlande Éternelle,* Dunod, Paris, 1979.
28. Elkington J., Burke T.*, The Green Capitalists.* London, Victor Gollanc, 1987.
29. Faber M., Proops J.L.R., *Evolution, Time Production and the Environment,* Munich, 1990.
30. Freeman A.M., *The benefits of environmental improvement: theory and practice, Resources for Future,* Washington, 1979.
31. Georgescu-Roegen N., *The Entropy Law and the Economic Process.* Cambridge, Cambridge University Press, 1971.
32. Georgescu-Roegen N., *Demain la décroissance: entropie-écologie-économie,* P.-M. Fabre (Ed.), 1979.
33. Godard D., Autonomie socio-économique et externalisation de l'environnement, *Economie Appliquée*, 1984, vol. XXXVII, no. 2, pp. 315–345.
34. Goodland R., *Environmentally Sustainable Economic Development: Building on Brundtland,* UNESCO, Paris, 1992.
35. Guitton H., *Entropie et gaspillage,* Cujas, Paris, 1975.
36. Kemp R., Soete L.*, Inside the green box', in C. Freeman and L. Soete, New Explorations in the Economics of Technological Change,* London and New York, Pinter Publishers, 1990.
37. Krutilla J.V., Fisher C.A., *The economics of natural environments.* Resources for the Future, Washington, DC, 1985.
38. Labeyrie V., Contraintes écologiques, équilibres et activités humaines, *Economie Appliquée*, 1984, vol. 37, no. 2, pp. 267.
39. Passet R., *L'Economique et le vivant,* Paris: Payot, 1979.
40. Pearce D., Toward the sustainable eeconomy: environment and economics. *The Royal Bank of Scotland Review*, 1991, no. 172.
41. Pearce D., Mäler K-G., *Environmental Economics and the Developing World*, Ambio, April, 1991.
42. Pigou A.C., *The Economics of Welfare,* Londres, MacMillan, 1946.
43. Ramade F., *Ecologie Appliquée,* Paris. McGraw Hill, 1989.
44. Remaux B., La fonction environnement. *Enjeux,* October, 1992, no. 128, pp. 26–29.
45. Robins N., *L'impératif écologique.* Paris, Calmann Levy, 1992.