A SOCIO-ECONOMIC REGULARITY ESTABLISHED BASED ON AN ANALOGY WITH THERMODYNAMIC PROCESSES WITH FINITE SPEED

- An Equation for Standard of Living -

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Abstract: This paper proposes a quantitative description of the flows of energy, mass and information in a country, based on recently developed concepts in Thermodynamics with Finite Speed. An equation for Standard of Living is derived. As shown in the ‘70 by Georgescu - Roegen in his famous book “The Entropy Law and the Economic Process”, the Second Law of Thermodynamics also applies to Society, not only to heat engines, machine tools, information machines, electromagnetic machines, electrochemical machines (and devices), or biological machines. Since 1930, Onsager and then Prigogine (Nobel Prize winners for the development of Irreversible Thermodynamics) showed that the Second Law also applies to biological systems. Countries are assemblies of Organized Biological Systems (humans, animals, plants) in interaction with "dead systems" (energy resources and raw materials) through various machines invented by humans in the course of history. It follows that the Finite Speed Thermodynamics, which is a recent branch of Irreversible Thermodynamics, can describe qualitatively and quantitatively the irreversible processes taking place in each system independently, but also in the entirety of these systems’ mutual interaction. Based on the equation for Standard of Living (applicable to any country), Economic Policies follow (as suggested by Georgescu - Roegen in his book) that are Optimizing the Functioning of these Systems with "as little as possible irreversibility" (loss of energy, mass, information, people, resources). When applied to Romania, these Economic Policies lead to the conclusion of the need to revitalize the industrial development of Romania. This would be a fundamental and strategic direction, necessary for the optimization of use of energy, materials, informational and human resources that will ensure economic growth and consequently an improvement in the Standard of Living. For a preview of further developing and applying the formula, the paper offers a comparative analysis of the scientific and technological performances in advanced European economies, in the US and in Japan. Based on this analysis we will further develop the formula hereinto include a greater detail, to take into consideration the performance of research and development activities, as well as the degree of dependence of a national economy upon all these latter factors.

Keywords: Equation of living standards, Thermodynamics with Finite Speed in Society, Model of Energy, Mass, Information Interaction in Society, Science, Technology, Research and Development, Economic Development.

1. INTRODUCTION

Based on the ideas of Georgescu-Roegen, in his famous book "The Entropy Law and the Economic Process" Harvard University Press, 1971 [1], we believe that a very deep analogy between Thermodynamic Systems and Economic Systems can be established:

- Both systems consist of a large number of individuals, N, hardly interacting between them;
- Interaction occurs through the exchange of mass, energy and information;
- An economic system of a country interacts (through foreign trade, diplomacy, information) with other economic systems (from other countries).

It might be objected that in thermodynamic systems found in nature there is a tendency from order to disorder, while in society it is mainly from disorder to order, so a constant tendency towards progress. This appearance leads to the idea that Second Law of Thermodynamics does not apply in society.

Actually, in absence of restrictions and rules of social life imposed by political and administrative power factors, the tendency from order to disorder naturally appears (it is permanent) in human society.

If we bring together Irreversible Phenomenological Thermodynamics (by Onsager [2] and Prigogine [3]) and the Information Theory (Shannon's Information Entropy Equation [7] inspired by Statistical Thermodynamics of Boltzmann [6] and Sommerfeld [8]), we can see that Second Law of Thermodynamics also applies to society.

The great advances made in explaining:

a) the “biological paradox" by using Irreversible Phenomenological Thermodynamics,

b) the thermodynamic paradoxes involving information - for example, the Maxwell’s paradox (Maxwell's demon was “solved” by Sillard in 1930' [5] and was followed by the *Informational statement of Second Law*),

led to the evidence that, if Second Law applies to an individual, it will also apply to a *system of individuals*, i.e. a country, and by extension, to the *Earth*.

2. IMPORTANCE OF THIS ANALOGY OR APROACH

● First, it provides a method of treatment that is very well established in science: systems analysis in terms of energy balance, mass, and information. This is equivalent to value balances in terms of “classical economics”. Therefore, the value origin is found in human energy consumption.

Unlike thermodynamic systems, human energy consumption is not always retrieved in energy reserves, but most often is found in obtaining material systems with higher order than the environmental ones. According to Second Law, order generation requires energy consumption. The disorder occurs by itself.

● Secondly, some natural tendencies in the behavior of individuals as society components, and therefore, resulting trends for systems consisting of N individuals can be explained.

● Mathematical relations that can be obtained support not only a formal discussion, but also a phenomenological, behavioral one.

To try a quasi-quantitative analysis of a national economic system, let’s simplify things at first in order to emphasize methods and usefulness of such treatment. Also, since we intend to establish a method to analyze processes of socio-economic systems based on analogy with thermodynamic systems, we will not consider all indicators characterizing the standard of living of a human collectivity, but only some of them, which will be called *state property of the system*.

A schematically and simplified illustration of a national economic system is represented in Figure 1, by indicating country subsystems with areas, and exchange of mass, energy and information between subsystems and between them and surroundings by arrows.

To simplify things one considers all N members of the society, when acting as consumers, in *Consumption* area. Thus, there are only two arrows from Agriculture area corresponding to food transfer, one outwards for export, $\mathbf{E_a}$, and one towards consumption, **M** (diet of the population).

It is no coincidence that we started with this “interaction”. As food is “energetic fuel” for all beings of the System (Society = Country), it is fundamental for society existence. The major objective of the entire system activity is to ensure the *fundamental requirement of human existence* - **food**. The society has progressed in terms of providing *certain living conditions for human beings which are different from those for animals*: house, clothes, heating, lighting, medical assistance, transport facilities, art, culture, entertainment, etc.

The *standard of living*[*] concept tries to globally comprise all these facilities that a modern society can provide to one of its member. All of them (or almost all) are related to the development of industry and education.

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[*] *Standard of living* represents the satisfying degree of material and spiritual needs for a country people in a given period of time. Living standards - degree of individual welfare.

Lifestyle = assembly of material and spiritual conditions specific for a person life, a social group, a society.

Thus, as degree of importance for the evolution of living standards, these two areas can be discussed in the scheme of Figure 1 immediately after securing vital functions by food.

To resist to outside pressure, a society needs *Defense*.

For an activity “optimal coordination” *Leadership* is needed. Besides all, other related activities to transport, trade, health, culture, art, etc. are needed. They have been embedded in *Other/ Miscellaneous*.

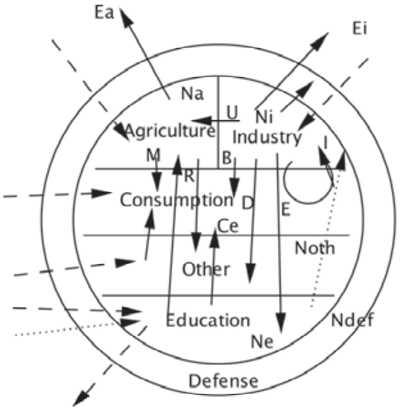

Fig. 1. National Economic System.

Trying to characterize system “operation” or “state” only through several synthetic, statistical parameters comes from the analogy with thermodynamic systems. Actually, this technique is very common in *Economic Statistics*, but the considered parameters do not have a well-defined phenomenological correspondent.

3. SOCIETAL STANDARD OF LIVING EQUATION DERIVED FROM ANALOGY WITH SYSTEMS APPROACH IN THERMODYNAMICS WITH FINITE SPEED

We will consider *Standard of Living* (***T***) all the possibilities that an economic system can ensure to an average individual, excluding the main function of existence, namely *Food*. We operate this exclusion because in a society where an individual can only eat, we cannot speak of a *Standard of Living*, because in this situation the similarity with animals would be too pronounced.

The sum total of all the facilities that an individual benefits from in a society is indicated by the *Income* (***S***). Thus the measures that define the *Standard of Living* (***T***) of the individuals/members (***N***) of a National Socio-Economic System, that we consider in the proposed study, are those that pertain to *Consumption*: *Income* ***S*** and *Expenses with Food/Meals* ***M***.

Standard of Living ***T*** can be evaluated by the difference between the values of these measures:

$$T = S - M \tag{1}$$

This parameter gives us a “synthetic idea” about the *Level of Civilization* or the *Level of Organization* of the respective system.

The source of *Income* is self-evident in only two productive (in a classical meaning) sectors, namely *Agriculture* and *Industry*. We will call the rest of the sectors *Non-productive*. Despite this naming convention, the latter sectors have a vital importance in a modern society. When the level of education of a country becomes sufficiently high compared to (parts of) its outside, the *Sale of Information (Patents, Know How, Advanced Technologies, Software Products etc.)* to the outside of the country becomes possible.

Income cannot be equal with what is being produced because if such were the case the system would become stagnant, or non-evolving. The natural tendency of *the rise of the standard of living* or the tendency to *obtain a profit* leads to *the need for investment*.

To facilitate a better understanding of thing, we will simplify the economic system (Fig. 2).

The Income ***S*** is represented by Consumption:

$$S = M + B + I_{bc}, \tag{2}$$

where: M are expenses with meals; B – costs of consumer goods; I_{bc} – value of investments in consumer goods.

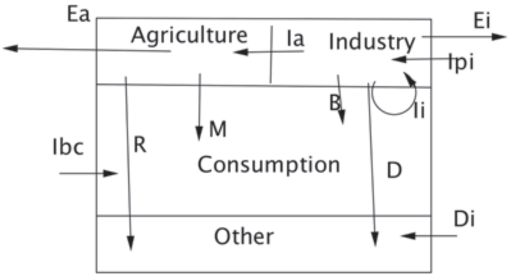

Fig. 2. “Simplified” Economic System.

From equations (1) and (2) the *Standard of Living* can be expressed in monetary units:

$$T = B + I_{bc}, \tag{3}$$

where: ● *Consumer Goods* (***B***) can be evaluated from the totality of *Industrial Production* with the equation:

$$B = P_i - I_i - D - I_a - E_i \tag{4}$$

where: P_i is the industrial production; I_i - investments in industry ($I_i = I_{propri} + I_{import}$); D – other (miscellaneous); I_a – investments in agriculture; E_i – export of industrial products;

● *Investments in consumer goods* (***I****bc*) result from the *totality of Foreign Trade*

$$I_{bc} = E_a + E_i - I_{pi} - D_i \tag{5}$$

where: E_a represents export of agricultural products; E_i – export of industrial products; I_{pi} – investments in industrial products; D_i – miscellaneous.

From equations (3), (4) and (5) we obtain:

$$\boldsymbol{T} = P_i + E_a - I_i - D - I_a - I_{pi} - D_i \tag{6}$$

but

$$E_a = P_a - M - R \tag{7}$$

where R is the *Reserves of Agricultural Products,* and from equations (6) and (7) we obtain:

$$T = P_i + (P_a - M - R) - (I + D)_i - (I + D)_e \tag{8}$$

where: P_i is industrial production, $P_i = P_{in} + P_e$, composed of:
P_{in} – production for internal consumption, $P_{in} = a \cdot P_i$
P_{ex} – production for export, $P_{ex} = (1 - a)\, P_i$, with a = coefficient

$$(I+D)_i = (i+d)_i P_t$$

$$(I+D)_e = (i+d)_e P_t$$

where P_t represents total production.

● ***Domestic value of foreign production*** is derived from equalities:

$$(\textit{Production for export}) \cdot C_{ext} = (\textit{Internal Value of Production for export}) \cdot C_{int}$$

It results the following expression:

$$\textit{Internal Value of Production for export} = (\textit{Production for export}) \cdot C_{ext}/C_{int} = (\textit{Prod}_{\,exp}) \cdot (p_i/p_e)$$

where the prices (C) are inversely proportional to productivities (p).

Whereas relations with the foreign law of supply and demand works, products can be sold only at a competitive price, namely the world price. Therefore, when assessing internal standard of living one must turn the export production value from internal units to external ones. Thus the following equality is considered:

$$(\textit{Production for export}) \cdot C_{ext} = (\textit{Internal Value of Production for export}) \cdot C_{int}$$

Instead of *Production for export* the *value obtained from the sale of this production* should be used:

$$(\textit{Goods exp}\text{orted}) \cdot C_{ext} = (\textit{Goods imported}) \cdot C_{int}$$

It results:

$$a.\ P_i + (1 - a) \cdot P_i\ (P_{int}/P_{ext}) = P_i\ [a + (1 - a) \cdot (P_{int}/P_{ext})] \tag{9}$$

where

$$\mathrm{a = 1 - e} \tag{10}$$

By combining equations (9) and (10) yields:

$$P_i\ [1 - e + (1 - 1 + e)(P_{int}/P_{ext})] = P_i\ (1 - e + e\ (P_{int}/P_{ext}) = P_i[1 - e\ (1 - P_{int}/P_{ext})] \tag{11}$$

In addition, the product shall meet global quality parameters to ensure the sale. If it does not reach the global quality level, the price will be lowered below P_{int} / P_{ext} in order to sale the product.

This issue is accounted by the *quality and guidance index on the world market – δci*

$$P_i\ [1 - e\ (1 - P_{int}/P_{ext})] = P_i\ [1 - e\ (1 - P_{int}/P_{ext}) \text{ x } \delta_{ci}] \tag{12}$$

The second term of equation (8) can be expressed as:

$$(P_a - M - R) = p_a \cdot N_a - N \cdot m_{st} - m_{st} \cdot r \cdot N = N\ [\ p_a \cdot N_a/N - (1+r)\ m_{st}\ ] \tag{13}$$

where: p_a – *productivity in agriculture*
m_{st} – value of *"standard food"/capita*
r – reserve quota from the *"standard food"* value.

All these wares go to export. The same will happen as for the industrial product export, namely they will be sold at the world price level instead of the domestic production price. Thus, internal value that this export will make will depend on the ratio $P_{a,int}$ / $P_{a\ ext}$. Also, one can consider a quality index of goods and market orientation.

The internal value of food production for export is:

$$\delta_a\ (\ p_{a\ int}/p_{a\ ext}\ )\ N[P_a\ (N_a\ /N) - (1+r)\ m_{st}] \tag{14}$$

For the average living standards (specific living standards), $t_m=T/N$, equations (8), (12), and (14) provide:

$$t_m = (P_i/N)\ [1 - e\ (1 - P_{i\ int}/P_{i\ ext})\ \delta_{ci}] + \delta_a\ (\ P_{a\ int}/P_{a\ ext})\ [P_a\ (N_a/N) - (1 + r)\ m_{\mathrm{st}}] -\!\!- P_t/N\ [(i+d)_i + (i+d)_e] \tag{15}$$

But:

$$P_i = p_i\, N \tag{16}$$

It results from equations (15) and (16):

$$t_m = (P_i/N)\ [1 - e\ (1 - P_{i\ int}/P_{i\ ext})\ \delta_{ci}] + \delta_a\ (\ P_{a\ int}/P_{a\ ext})\ [P_a\ (N_a/N) - (1 + r)\ m_{\mathrm{st}}] -\!\!- p_t\ [(i+d)_i + (i+d)_e] \tag{17}$$

4. PATH TO VALIDATION: COMPARATIVE STUDY OF THE RECENT EVOLUTION OF SCIENCE-TECHNOLOGY RELATIONSHIP IN ADVANCED EUROPEAN ECONOMIES

We have two starting points: (1) the comparative study of the relationship between science and technology in advanced European economies, in the US and in Japan during 1980-2000 [24], as updated, and (2) the comparison of the dependence of value added in the industrial sector in advanced

European economies upon the investment in and the efficiency of R&D in those countries [25]. We present herein an ultra brief synthesis of the findings from those two comparative studies mentioned above.

The essence of Fig. 3 [24, 25], presenting the technological propensities by scientific propensities (standard measures of scientific performance, respectively of technological performance) over time, for the years 1980-1995, in advanced European economies, stems from the following aspects:

1) European Union member states presented in the "map" above of the evolution of technological efficiency as a function of scientific efficiency over time are not at all identical to each other. There exist very large variance between the ability of different advanced European economies to transform performances in science in equally high performances in technology.

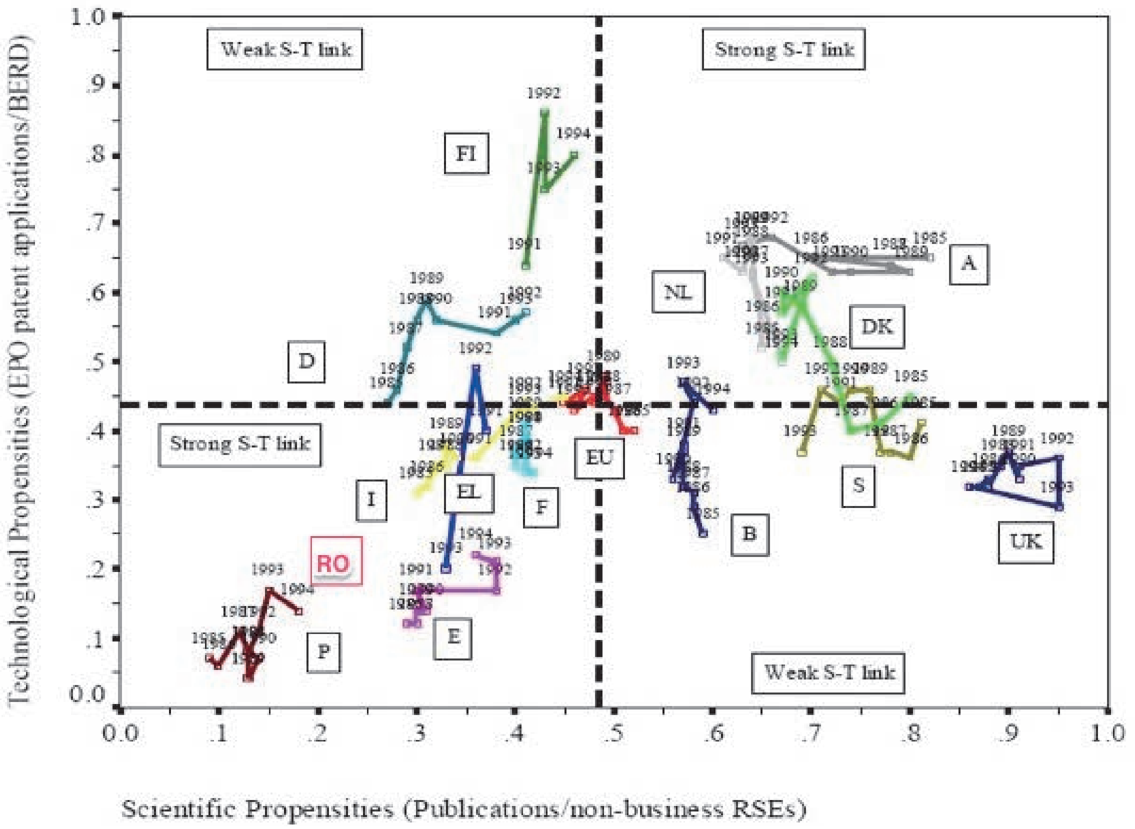

Fig.. 3. Technological performance by scientific performance in advanced European economies [24, 25].
NOTE: Data for Romania (RO) is an average for the period 2000-2006 [26].

2) Some European Union countries seem to manage to use "at its maximum" their scientific performance, transforming it into technological performance. Thus, Austria (A), The Netherlands (NL) and Denmark (DK), in the upper right quadrant, have a strong relationship between their scientific and technological performances.

3) A strong relationship between the scientific and technological performances is also present in the case of countries in the lower left quadrant. In this case, for Portugal (P), Spain (E) and Greece (EL), the more modest scientific performance translates into also more modest technological performance. For comparison purposes, even though data for the exact same time period is not available to these researchers, Romania, a few years later, finds itself in the above "map" also in the lower left quadrant, at about Portugal's (P) placement in 1993-1994, Romania (RO) having both its scientific and technological performances relatively constant at around 0.2 on average for the period 2000-2006 (approximately marked with a pink rectangle) [26]. In contrast, France (F) and Italy (I) made sustained progress during the study period. So did Belgium (B), in fact (right lower quadrant, evolving in time towards the center median of the EU). The evolution of France (F), Italy (I) and

Belgium (B) over time are examples to follow. Belgium's case is the best from the group, as its technological performance grows steady at virtually unchanged scientific performance over the study period.

4) Notable are Germany (D) and Finland (FI), countries where a not so solid scientific performance is being transformed into an exceptional technological performance. This dynamic is principally due to the transformation of technological know-how into new technological know-how and, implicitly, applying this latter very efficiently to the sustained economic growth in these two countries, and further, as we will show in forthcoming follow up work [26], into a proportional sustained growth of the standard of living in the respective countries. Here, in particular, the comparative application of the formula on standard of living proposed above (improved to take into consideration in detail the influence of scientific and technological performances of a country and of the rate of production and/or transfer of advanced knowledge resulting from R&D activities) will show the benefits of strategic sustained growth with finite speed in priority domains with an existing comparative advantage.

5) In the case of the United Kingdom (UK), in the right lower quadrant, apparently an exceptional scientific performance seems to lead to a relatively modest technological performance. This fact, however, is not puzzling after all, and nor is it a negative "stain" on the image of the UK. In fact, it is quite to the contrary. The UK focuses for a long time now its efforts, both scientific and technological, in ultra-modern top fields, and the technological domains in question have much higher scientific intensities than the technological domains found in Germany, Finland or Austria. In the case of the UK we are dealing, of course, with applied genetic engineering and connected fields, all of which have a much higher scientific intensity than automotive industry, for example, as the main contributor to Germany's technological performance, or than systems and terminals for cellular telephony, the core domain of technological performance in Finland.

For Romania, the preferred future development would be one similar with that of Italy or France, and even better with that of Belgium (albeit this is less probable at this time), and even better yet one smilar with Finland, except of course one applied to the domains where Romania has its own real comparative advantage (yet by far un-realized at the present time) over its global competitors in the respective field. Notable and to follow in strategy is also the case of Denmark. This is a special case because the scientific performance of Denmark in the field of scientific publications in engineering sciences was better even than that of the US during the time period studied [25]. In this context it is worth noting the evolution of Denmark's technological performance over time, whereby Denmark accelerates its ability to transform a good scientific performance into a better and better technological performance.

The formula the authors work on for forthcoming work [26] needs to take into consideration the results presented herein and needs to be validated by these findings and by other findings with more recent data pertaining to the 12 newer members of the European Union, including Romania. We point out especially to the cases of Austria, Belgium, Finland and Sweden (S), since all four countries have a special position in the above "S-T map of Europe," of the technological performance by scientific performance. Indeed, all of the four countries manage to transform well or very well their scientific capital into technological capital and, implicitly, into economic growth based in large and very large part upon their performance in R&D, and most probably, as a result of this latter fact, into a high standard of living for the population.

5. CONCLUSION

►From equation (17) results well argued that *Standard of Living* depends on:

- productivity (p_i, p_a, p_t), that depends on the "production speed" in their sectors,
- the volume of agricultural and industrial exports,
- the quality of export product and on market research,
- the internal productivity degree versus global productivity one,
- the share of population engaged bet on industry
- the volume of investments and other expenses.

►Increasing the Living Standards mainly depends on**:**

- increase of productivity,
- *increase of the number of inhabitants in the industrial sector* (which is limited by the number of jobs, respectively the number of people prepared to occupy such jobs),
- finding new sources of export (brain drain),
- reducing expenses (by Intelligence = Research, Science, Education).

Hence the *need for integrated development of a country industry*, correlated with natural resources and an *efficient and performing system of education, science, and research* ensues. Since the living standards equation (17) was derived based on Thermodynamics Laws (First Law - *Energy Conservation*, and Second Law - *Entropy increase* (disorder)) and these laws certainly apply to the society, we firmly believe that what has been deduced from them becomes *regularity of an optimized economic and social development for a natural tendency to Success*.

Future development of the living standards formula will also include labor productivity of R & D leading to new, improved, optimized, cheaper, and more efficient products [22].

NOMENCLATURE

N – society members
M – meal expenses (food)
E – export
I – industry
a – agriculture

I – investment
R – food stock
Ap – defense
D – miscellaneous/other
e – education

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LEGITATE SOCIAL-ECONOMICĂ STABILITĂ PE BAZA ANALOGIEI CU PROCESE TERMODINAMICE CU VITEZĂ FINITĂ

- O ecuaţie a nivelului de trai -

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Rezumat: Lucrarea propune un ,,Model de descriere cantitativă a fluxurilor de energie, masă şi informaţie**"** într-o ţară, pe baza conceptelor elaborate recent în Termodinamica cu Viteză Finită. Rezultă o ,,Ecuaţie a nivelului de trai". Aşa cum a arătat încă în anii 80' Georgescu Roegen în renumita sa carte ,,Entropie si Economie", principiul al doilea al termodinamicii se aplică şi la ,,Societate", nu numai la ,,Maşini". Încă din 1930, Onsager şi apoi Prigogine (laureaţi Nobel) au arătat ca principiul II se aplică ăi ,,Sistemelor Biologice". Cum ţările sunt ,,Ansamble organizate de sisteme biologice (oameni, animale, plante)" în interacţiune cu ,,Sistemele moarte" (resurse energetice si de materii prime) prin intermediul diverselor maşini inventate de oameni în decursul istoriei, rezultă că Termodinamica cu Viteză Finită, care este o ramură recentă a Termodinamicii Ireversibile, poate descrie procesele ireversibile din fiecare sisteme în parte, dar şi în ansamblul lor interacţional. Pe baza Ecuaţiei Nivelului de Trai rezultă Politici economice de optimizare a funcţionării acestor sisteme cu ,,cât mai puţine ireversibilităţi" (pierderi de energie, masă, informaţie, oameni, resurse, în general) sugerate de Georgescu Roegen. Aplicând aceste Politici economice la România conduce la concluzia necesitaţii reluării dezvoltării industriale a României, ca direcţie fundamentală strategică pentru optimizarea resurselor energetice, materiale, informaţionale şi umane, în vederea asigurării creşterii economice şi, odată cu aceasta, a nivelului de trai.