Journal of Thermal Analysis and Calorimetry, Vol. 60 (2000) 1055–1069

SOCIETY AS A MANY-PARTICLE SYSTEM

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Abstract

Statistics: Order–disorder problems in many-particle statistics may be solved by the Lagrange principle:

$$L=T\log P+E\rightarrow\text{maximum!}$$

L is the Lagrange function, $\log P$ the entropy and E a special condition of order for a system of interacting objects. T is an ordering parameter: for low values of T order (E), for high values of T, disorder or chaos ($\log P$) will be at maximum.

Natural sciences: The Lagrange principle corresponds to Gibbs' energy. The cohesive energy E leads to the three structures of matter: the well-ordered solid and the disordered liquid and gas. In binary systems, L leads to phase diagrams and solubility or segregation of materials.

Society: L corresponds to common happiness, which has to be at maximum for a stable society. Emotions E: sympathy, apathy, antipathy lead to three social structures: the well-ordered hierarchy and the disordered democracy and the global state. In binary societies (women–men, black–non-black, Catholics–non-Catholics) intermarriage diagrams correspond to phase diagrams and show the state of integration or segregation, peace or war of the society.

Economics: L corresponds to common benefit, which has to be at maximum for a stable economy, and leads to a (capitalistic) Boltzmann distribution of property E. Economic cycles of production and trade correspond to Carnot cycles of a gas in engineering sciences: a motor works at two different temperatures, economic cycles will tend to produce two different standards of living, rich and poor, or first and the third world.

History: Industrial development corresponds to a heating curve of alloys: the growing productivity has melted away the inflexible structure of monarchies, and has (slowly) transformed Europe into a flexible democratic structure. The French Revolution may be regarded as (first-order) phase transition. Recent takeovers of very big companies show a trend to global activity, free from national ties.

Keywords: distribution of property, integration and segregation, Lagrange statistics, order and chaos, regular solution, society model

Introduction

Society is a many-particle system: the ancient Greek name for city or state is 'polis', the place where many people live. Politics means dealing with a many particle system. Accordingly, in social science we have to focus on the laws of statistics in order to obtain scientific information about society.

1418–2874/2000/ $ 5.00

Akadémiai Kiadó, Budapest
Kluwer Academic Publishers, Dordrecht

This idea goes back to Empedocles of Acragas (495–435 B. C.). In his book 'On Nature' he explains the solubility of wine in water by the attraction and love of relatives, the segregation of water and oil by the hate of enemies. J. W. Goethe (1749–1832) used this idea in his novel 'Die Wahlverwandtschaften' to demonstrate that human relations depend on the chemical laws of society.

In recent years the concept of thermodynamics has been extended to information science [3], economics [4], social-biology [5], population science [6, 7] and other fields. Thermodynamics is a very powerful theory, if it proves valid for part of a system, it should be valid for all parts. As segregation and integration of societies have been shown to follow the statistical laws of thermodynamics [6], it is now the object of this paper to demonstrate, that social science in all parts is governed by these laws.

Statistics

The state of a system of N particles may be calculated [1] by the Lagrange principle:

$$L=T\log P+E-pV\rightarrow\text{maximum!} \tag{1a}$$

A system is only stable, if the Lagrange function is at its maximum!

L is the Lagrange function, P is the number of possibilities of arranging N particles in a self-organized order due to cohesion (E) of the particles. $\log P$ is called entropy and is a measure of disorder. T is the first ordering parameter and may be interpreted as tolerance (of disorder). V is a second condition of the particle system, e. g. volume, and p is the second Lagrange parameter, and may be interpreted as pressure. At low tolerance or high pressure the order E will be at maximum. For high tolerance or low pressure the disorder $\log P$ will be at a maximum, we have chaos.

The Lagrange principle may be applied to self-organization and order–chaos problems in all many-particle systems, it will now be discussed for two systems: matter and societies. These two systems show very similar interactions and, for this reason, we will look for corresponding phenomena in more detail.

Matter

In natural science, self-organization of molecules is determined by the cohesive energy E of the material. The Lagrange function corresponds to the negative Gibbs energy, $G=-L$ [1, 2]. In matter, Eq. (1a) may be interpreted as

A material is only stable, if the Gibbs energy is at its minimum!

E is the energy of the molecules, (in contrast to thermodynamics, we will denote cohesive energy E by a positive sign and kinetic energy, which breaks up cohesion, by a negative sign). The first Lagrange parameter T is the temperature. V is the volume, the second Lagrange parameter p is the pressure.

Homogeneous matter: In homogeneous materials, we have three states of matter: the well-ordered solid and the disordered liquid and gas. The specific state of the material depends on pressure and temperature, as given by the phase diagram $p(T)$ in Fig. 1.

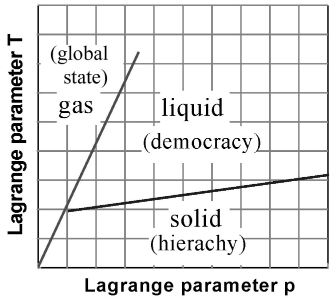

Fig. 1 Phase diagram *T*(*p*) of the two Lagrange parameters, temperature *T* and pressure *p*. The three phases of homogeneous materials: solid, liquid, gas correspond to the three states of a homogeneous society: hierarchy, democracy, global state. In societies, the two Lagrange parameters are social or economic pressure, *p*, and tolerance or standard of living, *T*

Solid: At low temperatures we have the strictly ordered, inflexible solid state. The molecules are tightly bound within the material and have little freedom to move.

Liquid: At higher temperatures we have the less-ordered and more flexible state of a liquid. The molecules are less bound to the material and have more freedom to move, the nearest neighbor order changes with time.

Gas: At very high-temperatures the molecules have enough energy to move freely. They are not bound to the material, there is no structure or order.

Inhomogeneous (binary) matter: different components in inhomogeneous materials will either attract each other, be indifferent, or repel each other: they will form compounds, ideal solutions or segregate with limited solubility.

Examples: Tea with sugar is an example of a binary solution. The solubility of sugar will depend on temperature and, on the concentration of sugar. The temperature *T* needed to dissolve a certain amount of sugar is given by the phase diagram.

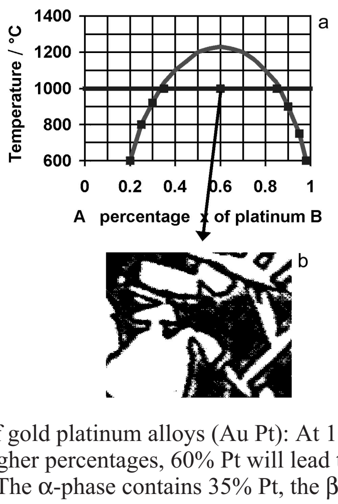

Fig. 2 a) Phase diagram of gold platinum alloys (Au Pt): At 1000°C gold may dissolve up to 35% Pt. At higher percentages, 60% Pt will lead to segregation into the two phases α and β; b) The α-phase contains 35% Pt, the β-phase contains 85% Pt

Figure 2a shows the phase diagram of the binary gold–platinum (Au Pt) alloy. $T(x)$ is the temperature needed to dissolve a percentage x of platinum. At 1000°C up to 35% of platinum may be dissolved in gold. A percentage of 60% platinum may not be dissolved and leads to segregation of the alloy, as shown in Fig. 2b.

The model of bound matter

The phase diagram in Fig. 2a may be calculated from the model of regular solutions. For binary alloys at constant pressure, the Lagrange function is [1, 2]:

$$L(x, \varepsilon, T) = -T\{x \log x + (1-x) \log(1-x)\} + E_{AA} + 2\varepsilon x\,(1-x) \rightarrow \max! \quad (1b)$$

The Lagrange function $L(x, \varepsilon, T)$ depends on three parameters: size $\underline{x}$ of the components, interaction ε between different components and temperature T. The parameter ε considers all interaction energies between components A and B of a binary alloy,

$$\varepsilon = \tfrac{1}{2}[(E_{AB} + E_{BA}) - (E_{AA} + E_{BB})] \quad (2)$$

E_{AB} can be positive (attraction), zero or negative (repulsion). The same is valid for E_{BA}, E_{AA} and E_{BB}. Depending on the sign of the interaction parameter ε, we have AB compounds for $\varepsilon>0$, ideal solutions for $\varepsilon=0$, and segregation for $\varepsilon<0$.

At equilibrium, L is at maximum, and $\partial L/\partial x=0$. This leads to the phase diagram $T(x)$ in Fig. 2a.

The model of free matter

The properties of free matter (gases) at constant pressure may again be calculated from the Lagrange function:

$$L = T\log(N!/\Pi N_k!) - \Sigma N_k E_k \rightarrow \text{minimum!} \quad (1c)$$

Because free molecules have only kinetic energy, E is now negative. T is the temperature or mean kinetic energy of the molecules. Equilibrium is defined by L= maximum and $\partial L/\partial N_k=0$. This leads to the Boltzmann distribution of energy in gases:

$$N_k/N = \exp(-E_k/T) \quad (3)$$

Few molecules have much energy, most have very little. On high mountains we cannot breathe well, as only few oxygen molecules have the energy that is needed to climb a high mountain. The Boltzmann distribution is also called the natural distribution of energy.

Society

Societies consist of many different groups, interacting with each other, like women and men, natives and foreigners, or ethnic or religious groups. In societies, groups are bound to each other by emotions like sympathy, apathy or antipathy, as already noted by Empedocles.

Homogeneous societies are governed by the Lagrange function (1a):

A society is only stable, if the common happiness of the society is at its maximum!

Societies have cohesion E, the first Lagrange parameter is tolerance T. Societies also need space or freedom V, and the second Lagrange parameter is pressure p.

In homogeneous societies we have – like in materials – three different states: the ordered hierarchy and the disordered democracy and anarchy. The state of the society depends on social or economic pressure p and tolerance T. (In economics the parameter T will be interpreted as the mean standard of living.) Figure 1 shows the phase diagram of the three different states:

Hierarchy: At low tolerance we have the well-ordered, inflexible state of hierarchy. The people are tightly bound to the system and have little freedom and low mobility.

Democracy: At higher tolerance, we have the less-ordered and more flexible state of democracy, people enjoy more freedom, a high mobility and are less tightly bound to society.

Global state: At very high tolerance, people move freely, have very high mobility, no well-defined order and are not anymore bound to society.

Fractal states of society: These three states have already been noted by Aristotle, and may be found within all groups and societies:

Economies: At low tolerance (standard of living) the form of government is generally hierarchy or dictatorship. This is found in many Third World states and has been found in Europe in medieval times. At higher tolerance (standard of living) the form of government is democratic, as is found in North America, Western Europe, Japan, Australia. At very high mean-income, the ties to states will vanish. This tendency is now observed for big international companies.

Religion: Societies with low tolerance (standard of living) tend to follow a fundamental type of religion with a well-defined hierarchy. This has been observed in history and is still observed in some Jewish, Christian and Moslem societies. At high tolerance (standard of living) religion becomes more liberal. At very high tolerance (standard of living) people tend to leave the ties of a church.

Education: Children are still unable to care for themselves, they are kept and educated in the hierarchic structure of the family. A youth can almost manage by himself and has much more freedom than a child. Only after finishing an education, does a person become an independent adult and leave the family.

Inhomogeneous societies are groups of women and men, countries with people of different ethnic or language background. The groups of people in inhomogeneous societies correspond to components in materials, groups are equivalent and cannot be arranged in any order. In binary societies we may have British–French, citizen–non-citizen, Christian–Moslem groups. This is in contrast to classes, which can be arranged in an order like rich–poor, young–old, slow–fast: a person can be richer, younger or slower than another person, but not more British, more Christian, more citizen than another.

The model of bound societies

Homogeneous and inhomogeneous societies are governed by the Lagrange function (1 b). As for materials, the Lagrange function $L(x, \varepsilon, T)$ depends on the three parameters: size x of the groups, interaction ε between different groups and tolerance T [6].

The parameter ε in Eq. (2) again considers all interactions between the groups A and B of a binary society, E_{AB} is the reaction of group A to group B and can be positive (sympathy), zero (apathy) or negative (antipathy). The same is valid for E_{BA}, E_{AA} and E_{BB}. Depending on the sign of the interaction parameter, ε, we have cooperation for $\varepsilon>0$, ideal integration for $\varepsilon=0$, and segregation with limited integration for $\varepsilon<0$. For inhomogeneous societies, Eq. (2) leads to at least seven different types of social order:

Partnership: Positive values of ε will be obtained if the attraction between different groups is stronger than between equal groups, $(E_{AB}+E_{BA})>(E_{AA}+E_{BB})$ and leads to cooperation between different groups, like marriage between men and women, trade between buyer and seller, or cooperation of employer and employees. Both partners profit equally from cooperation, $E_{AB}=E_{BA}$.

Hierarchy: For positive values of ε and coordination of more than two people we obtain a hierarchy. The profit of the parties is positive, but not equal, one profits more than the other, $E_{AB}\neq E_{BA}>0$. We may think of a mother with children, a teacher with students, any groups with a leader or a monarch and his country. Cohesion in hierarchies is rather strong, $E=E_{AA}+\varepsilon$.

Dictatorship: Positive values of ε may also be found, if one group has cohesive feelings and the other negative feelings, $E_{AB}>0>E_{BA}$. A teacher may be harsh and not well-liked, but the class will have to stay together. A state leader may be a dictator and not well-liked, but the dictator will enforce his rule.

Democracy: The slogan of the French revolution, ‘liberté, égalité, fraternité’ means an equal, positive interaction of people and may be expressed by $(E_{AB}+E_{BA})=(E_{AA}+E_{BB})>0$. This leads to the condition of democracy, $\varepsilon=0$ and $E=E_{AA}$. The Christian commandment ‘love thy neighbor as thyself’ is again equivalent to the same equation and asks for an integrated community of equal believers. The condition $(E_{AB}+E_{BA})=(E_{AA}+E_{BB})>0$ is an equation for ideal integration and cannot be obtained in nature. We hardly find four different interactions to be exactly equal! Chemical solutions can only be nearly ideal. Similarly, Christianity, democracy or integration are ideal states, which can never be reached, completely. However, in democracy, equality can be defined by law: every person is equal before the law! This law and its enforcement is necessary to obtain democracy.

Global state: The condition $\varepsilon=0$ may, however, be obtained by the condition of indifference, $E_{AB}=E_{BA}=E_{AA}=E_{BB}=0$ and $E=0$, there is no cohesion at all. This is a very common condition. People at the beach, at shopping, or at a restaurant, do not interfere with each other. These societies are similar to an ideal gas, they have no interactions and, therefore, no structure or order. But the global state, like the ideal gas, is an ideally integrated society.

Segregation: Attraction between groups is often weaker than within groups, we often find $0<(E_{AB}+E_{BA})<(E_{AA}+E_{BB})$. This leads to negative values of E, and to segregation. Even though the groups A and B like each other, each group may prefer to sit together and speak its own language or worship its own religion. Segregation, or $\varepsilon<0$, corresponds to a limited solubility of alloys or chemical solutions and leads to multicultural societies. Figure 3 shows the probability of intermarriage of Catholics and non-Catholics, as a function of the percentage of Catholics, in 10 different states of Germany and in Switzerland in 1991 [10, 11]. The diagram is equivalent to a phase diagram of binary Au Pt alloys in Fig. 2. Ideal intermarriage along the solid curve is found up to 20% of Catholics and corresponds to ideal integration or ideal solubility. In states with a higher percentage of Catholics, we find segregation with limited integration, as shown for Westphalia in Fig. 3b. Similar diagrams have been obtained for native and foreign Swiss and German people and for African and other Americans in the US [6]. Segregation does not yet mean aggression, but complete segregation is very close to aggression. In peacefully segregated societies, the feelings towards the other group (E_{AB}) are still positive. A typical example are the Amish people, who live completely segregated in Pennsylvania and other states. Amish and non-Amish people do not intermarry, any one who marries someone from the outside, will eventually leave the community. But still there is little aggression between Amish and non-Amish people, because peace is part of the Amish philosophy.

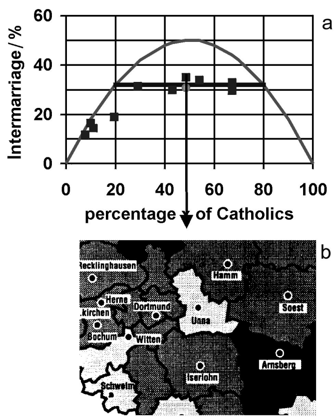

Fig. 3 a) Probability of intermarriage between Catholics and non-Catholics in 10 different states of Germany in 1991 and in Switzerland 1992. Intermarriage is ideal up to the 'solubility limit' of 20% Catholics in a state. For states with higher percentages we find segregation, as for Westphalia with 40% Catholics in b)

Aggression: Generally, however, there is always a danger of aggression in segregated societies, if the positive feelings E_{AB} between different groups become negative, $(E_{AB}+E_{BA})<0<(E_{AA}+E_{BB})$. Typical examples are Germans and Jews in Germany before the Second World War, or presently the different ethnic and religious groups in former Yugoslavia, in the former USSR, in Israel or Northern Ireland. In Fig. 4, the rate of intermarriage between Catholics and non-Catholics in Northern Ireland is 3.5% , compared to 32% in Germany and Switzerland [6]. This low rate of intermar-

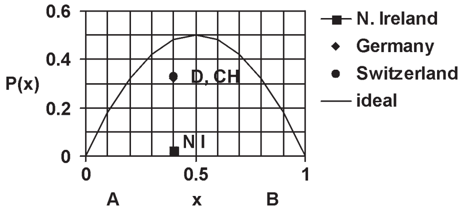

Fig. 4 The rate of intermarriage, *P*, in Northern Ireland between Catholics and non-Catholics is only *P*=3.5%, compared to *P*=32% in Germany and Switzerland. All three countries have the same percentage of *x*=40% Catholics

riage will immediately lead to aggression in Northern Ireland, if a spark of hate is triggered. Unless a strong education for peace has been implanted in the segregated groups, there is only one way to stop war: raising integration by raising tolerance T (or by raising the standard of living T, as will be shown, below).

Phase transitions

Homogeneous societies: In materials, the transition from one phase to the other is called melting or vaporization. In societies, a phase transition is called revolution, reformation or crisis. These first-order transitions are always accompanied by a sudden change of order. A typical example is the French Revolution of 1789 as a transformation from hierarchy (l'état c'est moi) to democracy (égalité, liberté, fraternité). The order was changed abruptly by killing or expelling the nobility. The protestant reformation was also a first-order phase transition.

In inhomogeneous societies we have first- and second-order transitions. Any war may be regarded a first-order transition, because the order will be abruptly changed by the winning party. But phase transitions may also be of gentle second-order. The transitions from integration to segregation in Figs 2 and 3 change the order smoothly and not suddenly.

Economy

The model of free societies: The market laws of a free 'selfish' society corresponds to the model of free matter. The Lagrange function (1c) may be interpreted according to Adam Smith as common benefit of all people:

A free economy always strives for a maximum of common benefit L of all people.

E now may be interpreted as property and T as the mean property per person or household, or as the mean standard of living.

Financial authorities will generally divide people into property tax classes. If there are N_k households or persons in property class E_k, the total amount of taxable money is given by $E=\Sigma N_k E_k$. At the maximum of the Lagrange function (1c) we have equilibrium of the system, the derivative of L with respect to N_k will be zero. This leads to the Boltzmann distribution of property in a free society, Eq. (3): The number of households or people in a property class should decline exponentially with the amount of property.

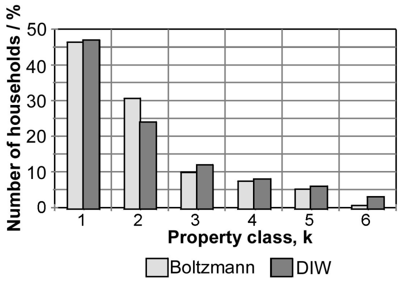

Fig. 5 a) Property distribution in Germany 1993. Data estimated by the German Institute of Economy, DIW, calculation according to Boltzmann (*T*=175 kDM)

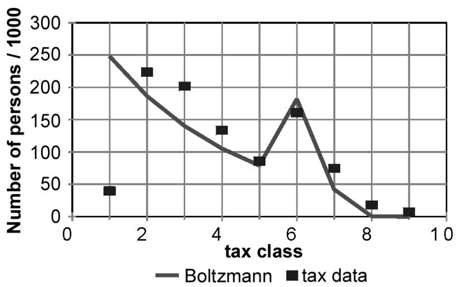

Fig. 5 b) Property distribution according to tax data in Germany 1989, calculation according to Boltzmann (*T*=350)

In Fig. 5a, property data estimated by the German Institute of Economics DIW [8] in 1993 are compared to the calculation according to Boltzmann. The agreement of data and calculations is excellent. In Fig. 5b, the 1989 property distribution has been obtained from German tax data [13]. Due to the missing value of non-taxpayers and uneven tax classes, the calculations in Fig. 5b are not quite as smooth as observed in Fig. 5a. As a result we find: Property follows a distribution according to Boltzmann: many have very little property and only few have very much. For atoms we regard the Boltzmann distribution as natural, for humans we think this distribution to be unfair! Obviously**,** a fair distribution of property is not very probable.

Society and the economy: Society is governed by emotions: common happiness *L*, sympathy or apathy *E*, tolerance *T*. The economy is ruled by money: common benefit *L*, property *E*, mean standard of living *T*. However, the economy is part of society and cannot be separated from society. For this reason, the Lagrange parameters of both systems should be identical. Common happiness, *L*, should be equal to common benefit, emotions, *E*, equal to money, and tolerance, *T*, equal to standard of living.

The equivalence of common happiness and common benefit may be obvious. But it is less obvious to see emotions as being equivalent to money. However, we may calculate our attachment, *E*, to a certain group, by the amount of money we are willing to invest. The investment in our family will be 100% of our income, if necessary. The love for our country will hardly exceed 50% of our income, if we have to pay that much in taxes. And we may not join a country club if the fees are too high. Investment is equivalent to emotional cohesion and corresponds to cohesive or potential energy in natural science. Cash money, on the other hand, corresponds to kinetic energy, both tend to loosen cohesive forces and lead to independence and freedom.

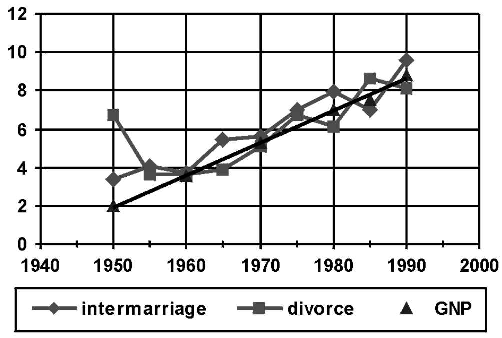

Fig. 6 Gross National Product, rate of intermarriage with foreigners and general rate of divorce in Germany between 1950 and 1990

The equivalence of tolerance *T* and mean income *T* is discussed in Fig. 6. The temperature of a cup of tea may be measured by the amount of sugar dissolved. The temperature of a crystal may be obtained from the concentration of vacancies. Accordingly, Fig. 6 shows the percentage of foreigners integrated and 'dissolved' by intermarriage, as well as the rate of divorce or 'vacancies'. Both rates indicate the tolerance *T* of a society. The gross national product per head measures the standard of living, *T*, of an economy. All three curves are given for Germany, as a function of time between 1950 and 1990, and match very well. This result demonstrates the equivalence of society and economy.

Four models of economic order

Economists usually present distributions by a Lorenz function. Figure 7 shows the four property distributions that may be derived from Lagrange statistics: even, Pois-

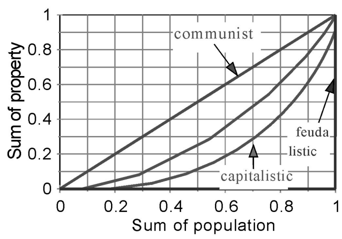

Fig. 7 Lorenz functions of four different statistical distributions: even (communist), Poisson (social), Boltzmann (capitalistic) and uneven (feudal)

son, Boltzmann, uneven. These distributions correspond to four different models of economic order.

Communism (even distribution): The even distribution of property leads to a linear Lorenz function. It is an ideal function. In societies this is called a communist distribution. Due to interactions, atoms will never stay all in the same energy level very long, unless the energy is zero. Accordingly, due to luck, and bad luck an even property distribution will never be stable with time, unless the property is zero.

Socialism (Poisson): Poisson statistics is derived from $L\rightarrow$maximum! with no condition for E. Figure 8 shows the Lorenz curve for US income 1986 [12]. Income and pensions follow a Poisson distribution and not a Boltzmann distribution, because jobs and pensions cannot be accumulated like shares.

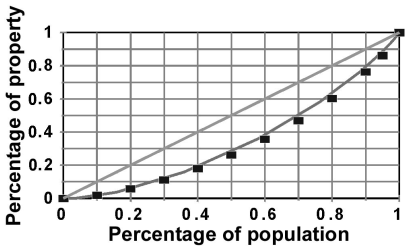

Fig. 8 Lorenz distribution of income in the US 1986. Tax data have been compared to the Poisson distribution

Capitalism (Boltzmann): Property distributions follow Boltzmann statistics, Figs 5a and b. The Boltzmann distribution corresponds to a free democratic and capitalistic society, Fig. 7.

Feudalism (One-sided distribution): If one person owns everything and the rest of the society owns nothing, we have an extremely uneven and unfair distribution, which may be referred to as feudalism. Figure 9 shows the Lorenz curve of the 1985 gross national product GNP of the world population (without Soviet-Union) after Barro and i Sala Martin [9]. Obviously, the GNP of the world population is even below the capitalistic Boltzmann distribution and rather in-between a capitalistic and a feudalistic distribution. Most of the GNP is owned by the First World, and little is left for the Third World.

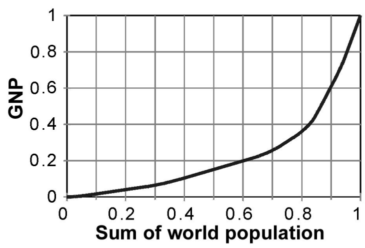

Fig. 9 The 1985 gross national product GNP of the world population (without the Soviet Union) after Barro and Sala i Martin [9]

Market laws and business cycles

In order to understand the feudal-like distribution, we have to look into the mechanism of market laws and business cycles, and we will now apply the laws of Lagrange statistics or thermodynamics to business. We may compare the economic market to a heat bath of a liquid, the heat to productivity and temperature to the mean income or standard of living.

1. The first law of thermodynamics now corresponds to the total value of a market or society: $dE=\delta Q+\delta A$. The total value E of a market is given by the capital Q and work A produced within a year, and is given as Gross National Product, GNP.

2. A high GNP will lead to a high standard of living T, or $E=CT$. If two markets with different standards of living T are combined, the new standard of living will be in between the former values. It is like mixing hot and cold water. The unification of Germany is a good example for mixing two markets. It also shows that a uniform standard of living T can only be obtained by stirring and mixing partners from both sides.

3. Manufacturing a certain product from many single parts, in Europe or in the Third World, requires the same labor (or change in entropy dS of the parts) in both countries. But the capital Q for the production of this product will depend on the living standard T of each country: $\delta Q=TdS$. (Q is the capital, T the standard of living and S the entropy function $S=\log P$ of the system. In calculus, the differential δQ is called a non-total differential form, the value of Q always depends on the path of the integral).

These three laws (of thermodynamics) are the basis of the Carnot cycle (Fig. 10) in civil engineering. Motors, heat pumps or refrigerators operate at two different temperatures T_1 and T_2 to transform work into heat and heat into work.

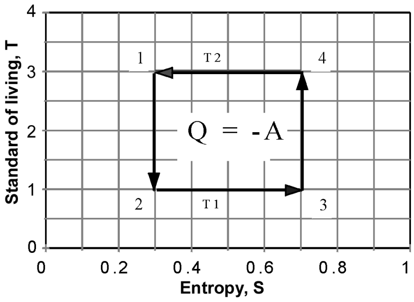

Fig. 10 Capital T–S diagram of a business cycle: products are manufactured in a cheap market T_1 and sold in a more affluent market T_2. S is the entropy, it will decrease by manufacturing. Capital and products turn in opposite directions

In the same way the three laws are also the basis of business cycles in companies, or economic cycles in state economies, Fig. 10. Business depends on producing cheap price (T_1) and selling at a more expensive price (T_2). Economic cycles transform capital into work and work into capital. As in Carnot cycles, work A is given by

$$\delta A=CdT-TdS$$

The efficiency of the cycle is $e=(T_2-T_1)/T_1$ and grows with the difference in T.

Colonialism: If the capital Q earned during each cycle in Fig. 10 is spent in the more affluent market, this country will become even richer. The difference in standard of living will grow with time. This has been practiced by the colonial powers in the last centuries.

Booming economy: If the money earned during each cycle is spent in the less affluent country, the standard of living will grow until it reaches the standard of the richer country. The efficiency of this business cycle will then go to zero.

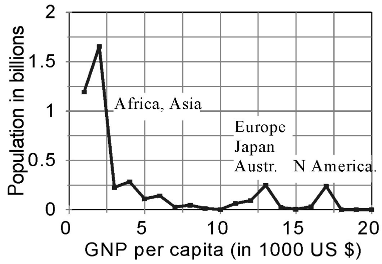

Fig. 11 World population and standard of living (in US $1000 per capita and year) in 1985 after Barro and Sala i Martin [9]

Two-class world: Fig. 11 shows the population in billions as a function of standard of living T, which may be measured as GNP per capita [9]. Obviously, the industrial countries in North America, Europe, Japan and Australia are the democratic, capitalistic countries with a high standard of living, and the countries in Africa, Asia and S. America are mostly hierarchic state economies with low standards of living. This two-level distribution of the world economy is the reason for a nearly feudal Lorenz function of world GNP in Fig. 9.

History

We may now look back in time. The historical development of the GNP with time corresponds to a heating curve $T(t)$ in traditional metallurgy. Figure 12 shows the gross national product or standard of living $T(t)$ as a function of time. Until the Middle Age manual labour allowed only low productivity and a low standard of living. Accordingly, all societies had an inflexible hierarchic structure with kings, emperors, dictators and a slow growing state economy. Hierarchy was found in all social structures, in state, church, economy and family. The growing productivity due to mechanization and the invention of the motor have melted away the inflexible structure of monarchies and have slowly transformed Europe into a flexible, democratic and capitalistic structure. In Fig. 12, the change from linear to exponential growth can be related very well to the beginning of democracy in Germany and Japan. In China this change may be extrapolated from the data.

This change is still going on, Eastern countries have only very recently transformed into democratic states and even in Western Europe, equal rights for women

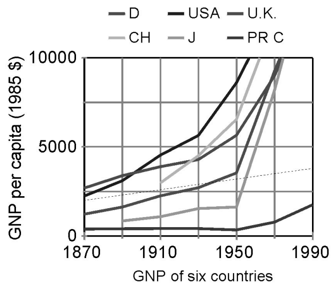

Fig. 12 Economic growth in six countries after Barro and Sala i Martin [9]. Transition from linear to exponential growth is marked by transition from hierarchy to democracy in Germany and Japan

are not yet fully established. Due to the effective Carnot process of the economy the present world is divided into:

First World: (democratic, capitalistic, mobile, high living standard, low fertility, peaceful neighbor relations, aggressive trade relations,)

Second World: in transition from Third to First World, and

Third World: (hierarchy, state monopoly, immobile, low living standard, high fertility, aggressive neighbor relations, weak trade position).

Future: We may also try to extrapolate beyond the year 2000, even though the Lagrange function L does not depend on time, explicitly. L depends on time only indirectly, by productivity $Q(t)$:

The present division of our world between First and Third Worlds will be preserved if the economic motor stays as productive as at present. If trade barriers can be reduced, both worlds will have a higher standard of living.

Third World: an exponential growth of population will lead to overpopulation, starvation and wars for survival in Africa and in parts of South America and South-East Asia. Only a sufficiently growing economy will reduce overpopulation and eventually lead to a democratic peaceful government. But the transition from hierarchy to democracy will again only occur after a first-order phase transition in each country, a revolution or a war.

Second World: some countries are in a state of transition from hierarchy to democracy. According to Fig. 12, these are generally countries near or above $2500 per capita and year. However, like the melting point for different materials, this value will vary for each country, due to history, religion and present government. The transformations in India, South Africa or Central America seem to be stable now. The transitions in China, Indonesia, and parts of North Africa and South America in the near future may not all be peaceful, as we now observe in Yugoslavia.

First World: the high standard of living will lead to diffusion (migration) and integration of people from poor countries into rich countries. The First World, (Europe, Australia) will become, more and more, a peaceful, global community, as already observed in the US today. A continuing growth of economy will lead to depletion of present resources, and the human mind will have to find or invent new resources, in order to avoid wars and segregation in the future.

Conclusions

Society has been treated mathematically like a many-particle systems by Lagrange statistics and the models of regular solutions. Humans are, of course, much more complex than atoms and, according to the model, this should lead to a large number of Lagrange parameters, one for each additional human feature. But because we have obtained reasonable results so far, it seems that we have found the parameters, which are most important to social interactions: sympathy or antipathy, nationality, religion and ethnicity, productivity, standard of living and social pressure. Any further more-detailed models of social science and the economy should also fit into this very general theory of Lagrange statistics and the modern developments of thermodynamics.

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