The global economy as a living system

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Foreword

As independent thinkers all nationalities are less important than finding new ways to understand the global economy from an interdisciplinary perspective – one which will contribute to the betterment of our shared planet with its limited resources, especially when we are able to see the world from a tangible physical perspective and intangible economic one.

Some of the following points below from this book can be elaborated on and debated to further such understanding.

1. Paradigm change

The global economy is a living system, not a game of agents (market players). Like any living system, the global economy reproduces its working potential (measured in monetary units as GDP) by consuming primary energy and material resources from the environment and extracting back useless energy (entropy) and other wastes.

2. Physical meaning of value and money

The product value is equal to the system's working potential which is necessary to produce this product. Money is a unit of measurement and a means of the working potential distribution in the socio-economic system.

3. Macroeconomic efficiency

Any living system is an open thermodynamic system that works with efficiency equal to the ratio of the work done and the energy consumed. Accordingly, macroeconomic efficiency R is defined in the book as the ratio of GDP and primary energy.

4. Food factor

Within the framework of the game paradigm, the global economy is not analysed as a living system. Accordingly, the main component of primary energy – the food factor – is mistakenly ignored. The food factor is equal to the sunlight energy consumed in agriculture and seafood production.

5. Numerical estimates of the food factor

The book proposes formulas for the numerical evaluation of the food factor, which allows the correct calculation of primary energy and macroeconomic efficiency.

6. Electricity price as an empirical indicator of macroeconomic efficiency

The average price of electricity is an empirical indicator of the efficiency of a developed economy with an independent electricity system. Thus, the trends of the observed price of electricity and calculated macroeconomic efficiency coincide with good accuracy for the US economy.

7. General principles of living systems in the economy

It is demonstrated that Bertalanffy's principles: openness, isomorphism, feedbacks, steady state – are fully applicable to the economy.

8. The physical concept of information

The book offers the creation of information as the "fifth element" of the general principles of living systems. According to this concept, information is an intangible result of the work done by living observers and the observed system.

9. The two-component nature of economic value

The overall economic value, that is, the working potential of the socio-economic system, contains an objective useful-energy component, as well as a subjective information component evaluated by society.

10. Pricing

Based on the two-component concept of economic value, the pricing mechanism applicable for both energy carriers and intellectual products, is proposed.

11. Global energy prices

The two-component concept of economic value, as well as the corresponding pricing mechanism, are confirmed by qualitatively different trends in the prices of electricity, crude oil and the world grain basket.

12. Climate, energy price and competitiveness of the economy

"Indices of climatic discomfort" were calculated for cities with different ambient temperatures. The results demonstrate that, for equal competitiveness, it is necessary to regulate the prices of energy carriers in the economies that develop in a cold or hot climate.

13. Demand function and its applicability

The existence of a psychologically predetermined demand function confirms the interpretation of the economy as a social living system. However, the applicability of the demand function to the pricing mechanism is rather limited, because the two-component nature of economic value is not considered in this function.

14. Macroeconomic cycle

The macroeconomic cycle was evolutionarily formed in the global economy under the dominant influence of the annual working cycle of grain production. The macroeconomic efficiency growth means the growth of the working efficiency of the macroeconomic cycle.

15. Information, symmetry and harmony in the economy

The physical interpretation of the interrelated notions of information, symmetry and harmony in application to the economy, is introduced.

16. AI systems in the economy

AI systems are not living systems, so they cannot create information. AI systems function in accordance with an instinctive type of behavior based on information created by people in the past. AI systems will free people for more creative work, but they will never completely replace the human mind.

17. The DAVT theory

By analogy with the balanced distribution of working potential (free energy) in biological systems, the concept of DAVT is proposed.

Kenneth Friedman, Regis University, Colorado, USA

About the author

Victor Bartenev graduated from the Moscow Institute of Physics and Technology (MIPT) in 1981, with a PhD degree in biophysics. MIPT provides an excellent natural science education: two of its graduates, Geim and Novoselov received the 2010 Nobel prize in physics.

In 1981-90, the author worked at the Institute of Molecular Genetics, Academy of Sciences of the USSR. Biophysical education and practice stimulated the principal author's approach to the analysis of the global economy, which should be considered as an integral part of the Earth's biosphere.

The collapse of the Soviet Union in 1991 and the shock transition to a market economy caused great damage to fundamental science in Russia: most colleagues of the author emigrated to the USA, UK and other countries to continue their research. However, Dr. Bartenev in the nineties has continued to work in Moscow, mainly in the field of development of computer accounting programs. This work involved in-depth study of the fundamentals of the economy at the micro and macro level. The physical approach to the tax system analysis was expressed in the author's theory of the dynamic added value taxation (DAVT), which is one of the most practically important concepts in this book.

Since the beginning of the two thousandths', the author began an independent interdisciplinary research of the physical and bio-evolutionary foundations of the global economy, united under the name "physical macroeconomics." The research was not funded by any public or private institutions.

The main concepts of physical macroeconomics were initially published in the Journal of Interdisciplinary Economics (2009 Ruth Taplin was then Editor-in-Chief and a founder member with Ken Penney when both were lecturers at Exeter University, UK) and further summarized in the book edited by Prof. Ruth Taplin ("Value-energy interrelationship and dynamic added value taxation", in *Intellectual property: valuation and innovation. Towards global harmonisation. O*xon and New York: Routledge, 2013).

After 2013, the concepts of physical macroeconomics have been significantly updated and expanded, which led the author to the idea of writing this book.

Dr. Bartenev is a member of the Editorial Board of the Interdisciplinary Journal of Economics and Business Law of which Ruth Taplin is Editor-in-chief and Founder.

About the Contributers

Victor Bartenev's work first came to my attention in 2009 when as Editor of the Journal of Interdisciplinary Economics founded by myself and my late colleague, Dr. Ken Penney when we were lecturing at Exeter University in Economics and Management, I was delighted to know of Dr. Bartenev's interdisciplinary approach. This multi-disciplinary analysis has become an increasingly important perspective since the rise of nanotechnology which by its very nature has to be interdisciplinary. Having been a Consultant to the Federation of Electronics Industry in London for nine years, it was very good to know that exploratory work was being done that is truly interdisciplinary, melding the living systems of the physical world with that of the global economy and taxation. The concept that the price of a basic staple bread is not something that the world's inhabitants ever pay a true price for because of the attendant costs of electricity, labour and fertilisers are never truly reflected in the final price of it in both urban rural areas. This is a starting point for the development of the DAVT theory promulgated by the author of this book. As mentioned, Dr. Bartenev has further explored his ideas found in this book in the journal I edit and founded Interdisciplinary Journal of Economics and Business Law (IJEBL) and one of my edited books on added value which he explores in this text as well. His is a multi-faceted analysis that works on a number of levels as shown in the Foreword in the major concepts offered by this interdisciplinary research. The author of this book also collaborates with Professor Alojzy A. Nowak, Dean of the Faculty of Management at the University of Warsaw. It is the oldest management school in Central and Eastern Europe. Nowadays, it is one of the most respected management education and research centers in Poland. The Faculty of Management has partnership agreements with leading universities and business schools worldwide, is a member of international organizations such as: the Association of MBAs (AMBA), the Central and the East European Management Development Association (CEEMAN) and the Baltic Sea Region University Network (BSRUN). Professor Nowak is a well-known economist, lectures abroad at the University of Warsaw in France, Great Britain, USA, Russia, China and South Korea. He is the author of many books and articles on the subject of international finance, banking systems, science policy, economic crises, international economic relations and is published in England, the USA and China. This book is edited and published by the Faculty of Management Press at the University of Warsaw, Poland.

Ruth Taplin

Acknowledgements

I would like to thank Prof. Ruth Taplin for her many efforts in bringing this book to publication. She has coedited the entire book in relation to standard of English and added to the content in some places.

We would also like to thank the University of Warsaw Faculty Management Press for coediting and publication of this book, especially the Dean of the Faculty of Management, Prof. Alojzy Z. Nowak and Editor in Chief of the Faculty Management Press, University of Warsaw, Jerzy Jagodziński.

Victor Bartenev

Preface from the author

Current macroeconomic theory has no predictive power, so, it does not satisfy the basic criterion of scientific truth. Thus, macroeconomics could not foresee the challenges faced by the global economy in various fields.

A common flaw of existing mainstream and heterodox "schools of economic thought" is that they basically rely on the game paradigm that treats the economy as a competition of players in various markets.

The game paradigm does not contain a real (i.e. physical) concept of economic value and, accordingly, it does not explain the physical meaning of money. Also, there is no numerical definition of economic efficiency, because it is impossible to define the efficiency of the game. Meanwhile, a key notion of the efficiency of the economy is widely used by economists and politicians, despite the absence of adequate indicators.

The main problem that the book addresses, is in answer to the question – what is the global economy and what is the real meaning of value and money within it?

The current interpretation of value as a "measure of benefits provided by goods and services to economic agents," as well as the definition of money as a kind of "intermediate means of savings and exchange" have no physical meaning. Meanwhile, value and money supply are real entities that are subject to strict accounting.

A natural science interpretation of the fundamentals of the economy is pursued allowing comprehension of what should be done in the global economy for its sustainable development.

Within the framework of the game paradigm, it is impossible to describe the processes in the global economy, therefore, most people are very skeptical about the predictions or forecasts of economists that resemble the predictions of bookmakers.

Three key concepts are presented as follows:

First, the global economy[1] is a social living system that emerged during biological and socio-economic evolution. This system survives and develops through the actual work done by all its participants, not through their games.

The economy creates value – this means that the working potential of the social system increases due to primary energy consumption. Macroeconomic efficiency (i.e. efficiency of the socio-economic system) can be defined as the ratio of overall value (GDP) and primary energy.

The main component of primary energy is the energy of solar radiation absorbed in food biomass production, primarily in grain production. This *food factor* is currently ignored incorrectly, because the global economy is not analyzed as a living system. Accordingly, world primary energy consumption is currently underestimated by an order of magnitude.

Physical macroeconomics presents formulae and appropriate calculations, which allows for adequate assessments of primary energy and macroeconomic efficiency for the world economy and major local economies.

It is demonstrated that the average price of electricity is an empirical efficiency indicator for developed economies with independent electrical power systems. Thus, our assessments of US economy efficiency may be seen in tandem with the observed electricity prices.

Second, economic value is inherently a two-component value, rather than one component value. Namely, it contains objective (energy) and subjective (information) components due to the fact, that all living systems increase the information component of their working potential instead of the useless heat energy (entropy) released into the environment.

Thus, the four principles of living systems (*openness, isomorphism, feedback, steady state*) formulated by biologist Ludwig von Bertalanffy in his General System Theory[2], are complemented in this book by the "fifth element" – *the creation of information*.

The current stage of socio-economic evolution is characterized by the explosive growth of the informational component of the working potential of the global economy.

Third, the harmonious development of the economy is interpreted in this book as a dynamic balance of all energy and information factors. The main objective of the global economy harmonization is to ensure a balanced distribution of the world GDP. The growing economic inequality, financial and social crises as well as environmental destruction are the consequences of the GDP distribution imbalance. An important contribution to the solution of this problem would be an introduction of the dynamic added value taxation (DAVT), instead of a static VAT which is a destabilizing factor in the economy which could eventually become a universal tax.

1

Introduction and overview

1.1. From game to real paradigm of the economy

Current macroeconomic theory is based on the game paradigm that treats economic relations as competition of players in different markets. The players' goal is to win the maximum number of gaming chips, called "money" which can be accumulated and exchanged for goods and services. The new chips are added to the game by the Central Bank, which is one of the organizers of the game.

The game paradigm emerged when the natural science approach to life processes was only being started to be formed in thermodynamic and evolutionary theories. Currently, science has progressed rapidly, while the game paradigm has remained basically the same. As a result, the real meaning of value and money continues to be unclear in all economic schools.

This book suggests a real (physical) paradigm based on the natural sciences. Most of the interdisciplinary concepts of this paradigm, under the name of "physical macroeconomics" were introduced by the author in his previous works.[3–7]

Physical macroeconomics includes a logically consistent set of concepts supported by macroeconomic empirical evidence.

The central concept is that the economy is a social living system that increases its working potential (overall value) at the expense of primary energy consumption. Money has appeared through a process of evolution as the measure of the working potential of the social system and the means of its working potential distribution

A crucial element of physical macroeconomics is the physical concept of information. Namely, the information is treated as a useful, albeit intangible result of the work done by the living system. Any living system creates information and thus it increases the informational component of its working potential instead of useless heat energy (entropy) extracted from the system into the external environment. As applied to the economy, the creation of information means that the *information* component of overall value is increased.

By considering the existence of *useful energy* and *information* components of economic value, an adequate pricing concept can be formulated; this concept is strongly confirmed by the observed trends in the energy carriers' prices.

1.2. This book and previous physical approaches

Physical and bio-evolutionary approaches to views on the economy are offered by various heterodox schools, such as *evolutionary economics*,[8] *ecological economics*,[9] *econophysics*,[10] *thermoeconomics*[11] (also referred to as *biophysical economics*[12]). A common drawback of these schools is that they attempt to connect natural science concepts with the game paradigm in which there is no real concept of economic value. However, some ideas of the previous heterodox approaches are reflected in physical macroeconomics.

The assertion that the economy should be based on the laws of physics, primarily on the laws of thermodynamics, was first clearly expressed by a British Nobel laureate in chemistry, *Frederick Soddy (1877–1956).* Colleagues sometimes considered his economic views as freakish, however, his proposals for abolition of the gold standard and introduction of the floating exchange rates have been successfully implemented in practice.

Some economists also analyzed the economy in terms of evolutionary biology, that resulted in the creation of evolutionary economics; *Joseph Schumpeter (1883–1950)* is considered its founder. One of his students, *Georgescu-Roegen (1906–1994)* suggested that economic processes correspond to the second law of thermodynamics. An implementation of the entropy concept in evolutionary economics later formed a school of ecological economics.

Also, Georgescu-Roegen is known for his contribution to the development of thermoeconomics (biophysical economics). Thermoeconomists argue that economic systems always include matter, energy, entropy and information; they also suggest that the role of energy in biological evolution can be explained in economic terms such as productivity, efficiency, and so forth.

The author of this book believes that the physical concept of value and other concepts of physical macroeconomics, along with useful concepts from previous heterodox and mainstream approaches, can be combined into a single macroeconomic theory.

Physical concept of value assumes that the economic value is similar (isomorphic to) to the thermodynamic free energy,[13] *however, the economic value is measured in monetary units, not in energy units.*

Accordingly, the physical meaning of money is that money is the unit of measurement and the means of distribution of the working potential (free energy)[14] *of the socio-economic system.*

It follows from the physical concept of value that the money supply in a self-sufficient economy is an endogenous factor determined primarily by the working potential of the social system. That is, the money supply in the world economy is not an exogenous factor regulated exclusively by the Central Banks.

In fact, the world money supply grows in line with the increase in the working potential of the global economy.

Thus, *the physical meaning of the product value is that it is equal to the working potential, needed to produce this product. For consumers, the product value is expressed in monetary units as the product price.*

In accordance with the game paradigm, price equilibrium is achieved independently for specific products according to the relevant demand and supply. However, from the physical concept of value, it follows that equilibrium prices are interrelated, and they primarily characterize the distribution of the working potential of the socio-economic system. The supply and demand for specific products can adjust these prices only in the cases where the demand function is applicable.

According to the game paradigm, the demand function is as a manifestation of the "invisible hand of the market", which is supposedly applicable in all cases. But, in contradistinction, it is not so in most cases (see **Chapter 8**).

1.3. Book overview

The general properties of the global economy, as compared with the physical properties of the thermodynamic system, are considered in **Chapter 2**. We introduce thermodynamic terms that apply to the economy: *open system*, *environment*, *system boundary*, *external (primary) energy*, *useless energy (entropy)*, *working potential (free energy)*, *first and second laws*, *working cycle and its efficiency*, etc.

The macroeconomic cycle in the global economy is like the thermodynamic working cycle: by consuming primary energy and doing the work during the macroeconomic cycle, the global economy increases its working potential (overall value, or GDP) with efficiency that is equal to the ratio of GDP and primary energy.

In **Chapter 3**, four principles of living systems (*openness*, *isomorphism*, *feedback* and *steady state*) formulated by Bertalanffy, are considered in their application to the economy. In addition to these principles, we introduce the fifth one – *the creation of information*.

By creating information instead of useless entropy removed from the system to the environment, the living systems increase the *information* component of their working potential. The growth of information potential allows them to exist, develop and evolve despite the fatal entropy tendency expressed by the second law of thermodynamics.

Socio-economic evolution is a continuation of biological evolution. The appearance of nerves in biological systems and the creation of electrical networks in the economy have been fundamental milestones, after which the information potential growth had accelerated sharply.

Both highly-evolved biological organisms and economies have various levels of self-regulation. At the level of biochemical reactions and market interactions, there is a random self-regulation, while at the macro level, centrally determined regulation plays a key role.

The principle of system similarity (isomorphism) between economic value and thermodynamic free energy is discussed in **Chapter 4**, "Value-energy interrelationships." Based on this principle, macroeconomic efficiency is defined as the ratio of GDP and primary energy. It is demonstrated that *moderate inflation and macroeconomic efficiency growth are closely interrelated notions.*

The principle of isomorphism between economic value and free energy is expressed in the fact that value includes an objective *useful energy* component and subjective *information* component.

The isomorphism principle also means that money is the unit of measurement and the means of distribution of the working potential of the socio-economic system. By consuming primary energy, the economy increases its working potential, measured in monetary units as the overall value, or GDP. The working potential is increased in accordance with the law of conservation of energy, which is expressed in economics (in monetary units) as the balance equation.

The energy sources of the global economy are considered in **Chapter 5**. The main primary energy source is that of sunlight energy. By consuming this energy, the socio-economic system produces food biomass and biofuels, solar and wind electricity that are secondary energy sources suitable for in-system use.

In physical macroeconomics, the *food factor* is the energy of solar radiation consumed in the food biomass photosynthesis. The proposed formula for the food factor calculation allows for the obtention of adequate assessments of the primary energy consumption, which is currently underestimated by an order of great magnitude because the global economy is not examined as a living system.

Based on these correct assessments, the world economy efficiency, as well the efficiencies of the largest economies have been numerically evaluated. In greater detail, primary energy trends and macroeconomic efficiency assessments are presented in **Appendix A**.

Chapter 6 describes qualitatively differential pricing for global secondary energy carriers, such as electricity, oil and grain. It is demonstrated that pricing is primarily determined by the two-component nature of economic value. Currently, the one-component paradigm of economic value is unable to explain these differences.

It is demonstrated, that, in developed economies with independent electric energy systems, the average electricity price is an empirical indicator of macroeconomic efficiency.

Unlike electricity, the price of crude oil contains a non-zero *information* component, so the oil price ranges from the cost of production to a maximum magnitude, being greatly dependent on the information component of the price.

Grain production is an indispensable and the most energy consuming process in the global economy (this is why grain fed livestock such as cattle place such a strain on the economy). The fundamental properties of the world's grain basket – constant production per capita and flat price – means that the grain basket can be considered as an implicit global currency.

In the concluding section of this chapter, we consider the impact of energy prices on the competitiveness of local economies existing in different climates. Indices of climatic impacts are calculated for major world cities.

The physical meaning of the demand function and the range of its applicability to pricing processes, we discuss in **Chapter 7**. The very existence of the psychologically predetermined demand function means that the economy is a social living system. Its applicability to equilibrium pricing is rather limited – in particular, it is not applicable to global energy carriers and intellectual products.

The existence of the macroeconomic cycle in the global economy is discussed in **Chapter 8**. The macroeconomic cycle was evolutionary formed under the dominant influence of the annual cycle of grain production. Thus, in the current global economy, the money supply to GDP ratio is about the same as it was in the ancient economy in which grain served as money.

Therefore, the basis of the stability of the global financial system is the stability of the macroeconomic cycle in which the grain basket is an implicit currency.

Because of the growing efficiency of the world economy, the *useful energy* component in the grain basket price already exceeded the observed price, which is flat. It is suggested in this chapter, that further efficiency growth is possible in the case of "phase transition" of the global economy to a new state with a revaluated grain basket and sharply increased agricultural sector.

The grain in the ancient economy served as money because the total amount of grain was a measure of the working potential of the self-sufficient social system. Gold, bitcoins and other cryptocurrency can't be real money, because their total amount in a self-sufficient economy does not correspond to the working potential of the system.

In **Chapter 9**, we consider the relationship between the distribution of GDP and sustainable economic development. The distribution of free energy in biological systems is balanced due to stabilizing negative feedback – nutritional and metabolic feedback. The distribution of the global economy working potential (world GDP) is unbalanced, and this imbalance is the main cause of crises and social instability. Unbalanced GDP distribution leads to excessive income and tax inequality, which slows economic growth.

The current static tax system is a destabilizing factor because it does not provide a balanced distribution of GDP. The solution to the problem is to replace the static VAT with a dynamic added value tax (DAVT). The DAVT theory is presented in **Appendix B**.

The notions of information, symmetry, and harmony in their application to the economy, are discussed in **Chapter 10**. For living systems, the creation of information means an increase in the information component of their working potential. This increase is the main feature of biological evolution and sustainable socio-economic development. In relation to the global economy, the creation of information is currently expressed in the exponential growth of the *information* component of the world GDP.

Life arose in tandem with the emergence of useful information instead of useless entropy. The creation of information allows living systems to create the conditions of their existence, in which the second law of thermodynamics is not applicable.

The amount of information in living systems cannot be measured in bytes. However, in the case of the economy, the information component of the product value can be evaluated by society in monetary units.

Inanimate AI (Artificial Intelligence) systems use information, which was previously created by people. These systems are not able to create additional information themselves, and therefore they do not pose a threat to humanity.

Symmetry and asymmetry are objective concepts that cannot be directly applied to subjective information. The living observer, whose role is performed by society in the economy, creates information because of the analysis of mutually inconsistent signals from fundamentally different (asymmetric) sources.

Harmony is treated in this book as a dynamic balance of all energy and informational factors. Harmony is an objective property of the sustainable development of all living systems.

Some of the topical problems of the harmonization of the global economy are outlined in **Chapter 11**. Primarily, harmonious economic development means a balanced distribution of world GDP, which includes *useful energy* and *information* components. The *information* component of GDP is increased at the expense of the increased entropy of the environment. Hence, the rapidly growing information potential of the global economy should be primarily directed to the solution of ecological problems (e.g. using increasing information to understand how to deal with such problems).

The highest stage of biological evolution was the creation of the human brain, which made it possible for people to feel a sense of harmony. Perhaps the electromagnetic oscillations in the brain that reflect harmony of the surrounding world in an encoded form can be decoded in future large-scale brain studies; then this will be a fundamental step towards global harmonization.

2

Thermodynamics and physical macroeconomics

A theory is the more impressive the greater the simplicity of its premises, the more different kinds of things it relates, and the more extended its area of applicability. Therefore, the deep impression that classical thermodynamics made upon me. It is the only physical theory of universal content ...

Albert Einstein, "Autobiographical Notes"

Classical thermodynamics is the most important natural science justification for physical macroeconomics, because the interests of thermodynamics and physical macroeconomics associate with an answer to the same basic questions, namely: *What is the working system? How does it interact with its surroundings? Due to what energy sources the work is done by the system and with what efficiency?*

It should be emphasized that the laws and principles of thermodynamics are applicable to economic systems only in an isomorphic sense, not literally. This means that the processes in economic and thermodynamic systems are similar, but these processes are different in nature.

The observed similarities between thermodynamic and economic systems are the consequences of the *isomorphism principle*, which is one of the general principles of living systems (see the next Chapter).

There are three fundamental differences between thermodynamics and physical macroeconomics. First, the working potential (free energy) of the thermodynamic system contains the entropy component, while the working potential of the economy contains the information component instead of the entropy component.

Second, the working potential of the economy is measured in monetary units, not in energy units.

Third, the concept of information does not exist in thermodynamics; the information creation is a fundamental attribute of the living systems only. In turn, the physical concept of entropy applies to living systems at the lowest level of biochemical reactions, not at the macro level.

2.1. The global economy as an open system

The global economy is the result of biological and socio-economic evolution. The evolutionary process began with simple thermodynamic systems in the form of single-celled organisms.

The living cell is an *open thermodynamic system* because, firstly, it contains a lot of molecules that are in thermal equilibrium. Secondly, the living cell is separated from the *environment* (also called *surroundings*) by the *boundary* in the form of the cell membrane. Third, the living cell receives energy and material resources from the environment and it returns energy and material waste (Figure 2.1).

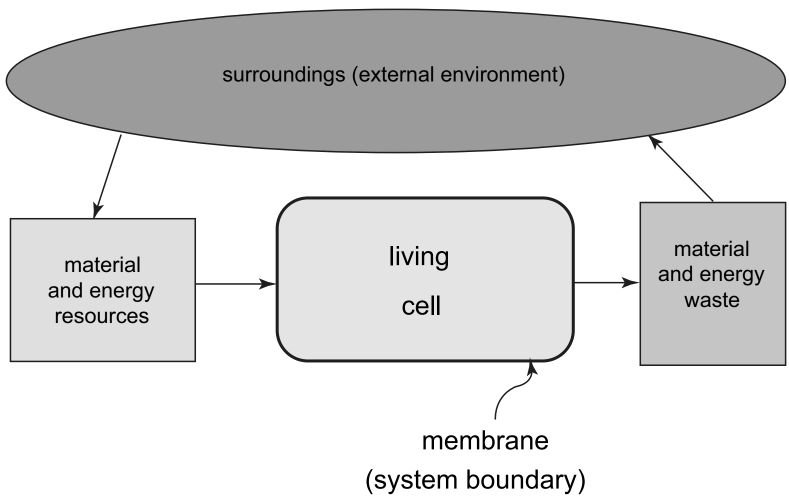


Figure 2.1. The living cell as an open thermodynamic system.

Multicellular organisms are also open thermodynamic systems; in terms of thermodynamics, the human being is an open thermodynamic system which is separated by the skin from the environment.

For primitive society, the walls of the cave were the boundaries of an open thermodynamic system. This society received all the energy and material resources from the environment; for people, the food biomass has been the most important and vital energy source from the ancient times to the present day.

The emergence of grain production was the appearance of the simplest self-sufficient economy which has an *economic boundary* (Figure 2.2).

The notion of economic boundary is much wider than the notion of the boundaries of the cave, because the economic boundary does not restrict volume in the space. Also, the self-sufficient economy produces the food biomass inside the economic boundaries rather than obtaining it from the environment.

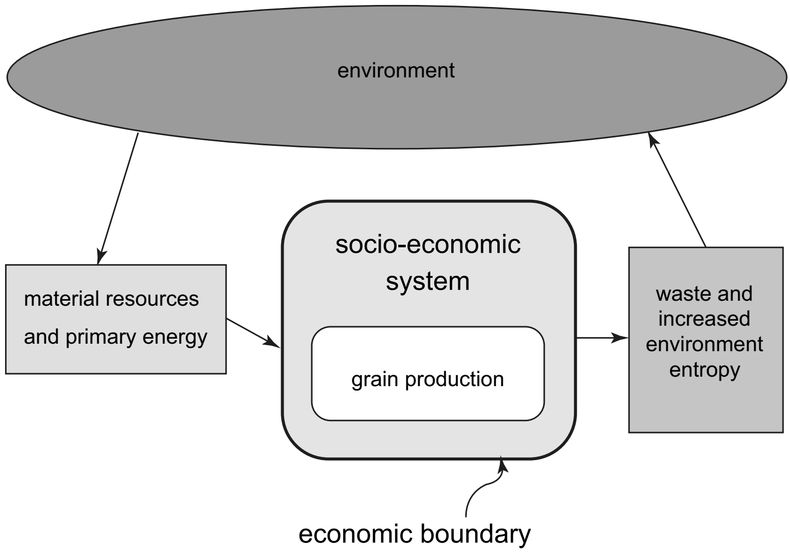


Figure 2.2. The simplest self-sufficient economy.

The open thermodynamic system and the economy do the work by receiving external (primary) energy from the environment. The notion of primary energy exists in current macroeconomic statistics. However, the published amount of primary energy is underestimated by an order of magnitude because the economy is not considered as a living system, so the most important energy factor is not taken into consideration.

2.2. Food factor

The economy receives a lot of sunlight energy which is absorbed into food biomass photosynthesis. This energy ("food factor" in terms of physical macroeconomics) is a major component of primary energy inflow, from ancient times to the present day.

However, the economy is currently not considered as a living system, so the food factor erroneously is also not considered. As a result, the currently published amount of "primary energy" (H_0) is only a small part of the real primary energy. For the world economy, the correct primary energy magnitude is as follows;

$$H \approx H_0 + H_f$$

where the food energy factor H_f is much greater than the H_0 magnitude.

The food factor is considered in greater detail in Chapter 5, "Primary energy and macroeconomic efficiency."

2.3. Energy transfer in the economy

Mutual transformations of different forms of energy take place in the economy in accordance with the fundamental law of conservation of energy. In crossing the system boundary, the inflow of primary energy is transformed into internal energy of the system (Figure 2.3).

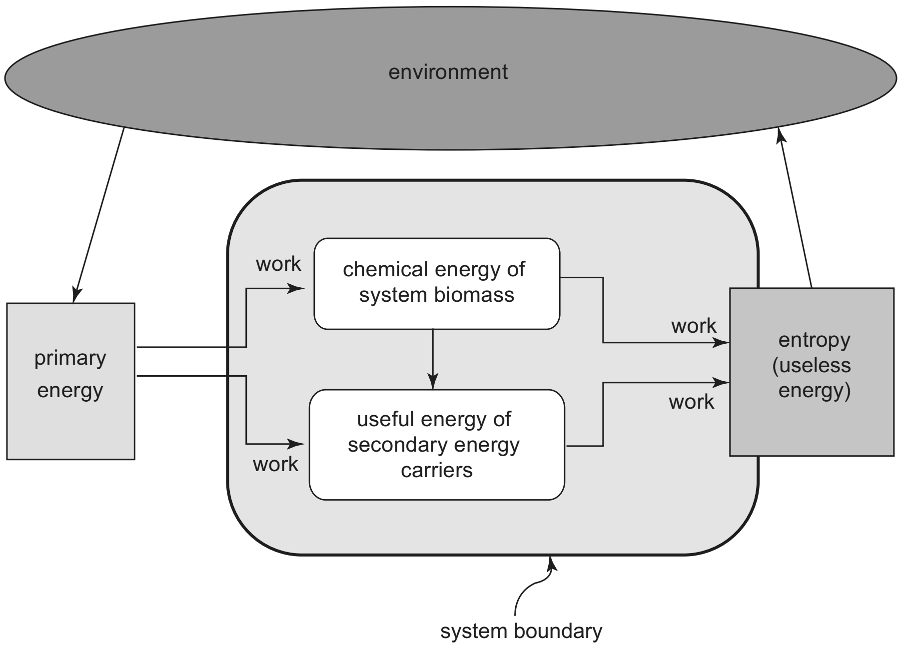


Figure 2.3. Energy transfer and workflows in the socio-economic system.

The primary energy is partly converted into chemical energy of the system biomass. The total biomass increases in a growing economy; the increase primarily in terms of population growth.

Primary energy is also transformed into secondary energy that is suitable for in-system use. The secondary energy carriers – food biomass, fuel, electricity, hot water, etc. – are the products of the working economy, and in turn, the secondary energy carriers are themselves consumed in the working processes.

The principal property of the secondary energy carriers is that they contain *useful energy* that can be used in the economy to do the work. The amount of useful energy is an objective factor that primarily determines the economic value of secondary energy carriers.

Numerous working processes take place at various levels of the economy, and these processes are accompanied by the release of heat due to effects of friction. It is practically impossible to convert this heat into the work, so it is dissipated in the environment as *useless energy*.

2.4. Economy as a working system

In physics, the work amount is equal to the force acting on a material object multiplied by the object's displacement in the direction of the force.

At the level of biochemical reactions inside the living cell, the work is done to assemble DNA and other macromolecules. Much of this work is converted into useless heat in view of the effect of molecular friction.

At the cell level, the work is done by moving the charged particles through the cell membrane that generates electromagnetic pulses in the neural network. In everyday life, people interpret this work as "mental work", though it is physical work at the cell level. Because of mental work, heat is also released.

At the level of tissues and organs, the work is done by muscle contraction. In human society, people do the work at home and workplace. The work is also done by mechanical and electronic devices, and most of the work is converted to heat.

At the macroeconomic level, the total work of the economy is the work done by producers to manufacture goods, plus the work done by society to maintain production infrastructure.

The total work results, on the one hand, in the increase of the working potential of the economy, on the other hand, the environment is polluted with heat and other waste.

Thus, due to the working processes taking place at various levels of living systems (including the economy), primary energy is mainly converted into useless heat. Only a small fraction of primary energy is converted into the increase of the useful energy of the system.

From a physical viewpoint, the main result of the work done by the living system is that the primary energy received from the environment is converted into the useless heat released back into the environment (Figure 2.4).

However, from the standpoint of a *living observer*, the living system does the work to get some useful results, and it does not produce the useless heat only.

The notion of *usefulness* does not exist in inanimate nature, so physics and thermodynamics do not answer the question, for what purpose the work is done. However, the living systems typically do the work with a certain purpose.

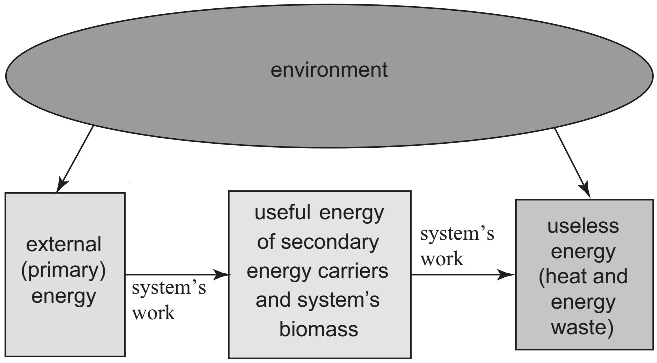


Figure 2.4. Energy transformation in living systems.

The usefulness of the work done can only be assessed by the living observer who analyses and evaluates information, which is created because of the total work done by the system and the observer (the observation process also needs some work!).

Information should be considered as the primary notion, which, in contrast to the primary notion of energy, is applicable to living systems only to describe the results of their work, including the observer's work. Thus, economic information is the result of the work done by the socio-economic system, and society performs the observer function.

2.5. Free energy

Physical macroeconomics treats information as a subjective value which depends on the observer. The information created by the living system does not change the internal energy of the system, but additional information increases the working potential of the system.

In thermodynamics, the working potential (working capacity) is called *the free energy* of the system. The meaning of the term "free energy" is that the free energy is equal to the maximum amount of work that can be done by the system, that is, the free energy is the part of the system's energy that is "free for work".

The amount of work that can be done by the thermodynamic system depends on the working conditions, so there is a so-called Gibbs free energy (for systems at constant pressure and temperature); as well as a Helmholtz free energy (for systems at constant volume and temperature). The Gibbs free energy is more suitable to living systems, because the living systems exist in a narrow range of pressure and temperature; namely the Gibbs free energy characterizes the possibility of biochemical reactions.

The free energy of an artificial thermodynamic system is expressed in energy units – for example, the working potential of a charged battery is expressed in kilowatt-hours. The working potential of a simple living system that performs a single function can also be measured in energy units. Thus, the working potential of muscle fiber, expressed in Joules, is a maximum mechanical work which can be done during muscle contractions.

As for the working potential of a highly developed living organism, it is almost impossible to measure this potential in energy units, since it is unclear what should be measured, considering the aspect of "mental work". However, consumed food energy is an objective physical quantity and it is measured in energy units (in calories).

The working potential of a social system, which produces a sole product, can be estimated as the amount of product manufactured during the life cycle of the system. Thus, the working potential of bee society is the amount of honey produced per year.

The working potential of the socio-economic system, which produces various goods, can be measured neither in energy units nor as the amount of any specific product. Therefore, *people have come up with the money as a unit of measurement of the working potential of the economy.*

The thermodynamic system does the work and increases the working potential of the system due to external energy consumption, the energy balance being kept in accordance with the law of conservation of energy. This indisputable fact is called *the first law of thermodynamics*, which can be expressed as follows: *the free energy change is a consequence of the law of conservation of energy*.

One of the alternative formulations of the first law of thermodynamics is that it is impossible to create a perpetual motion machine of the first kind, which operates without external energy consumption.

The first law of thermodynamics in its application to the economy means that the economy does the work and reproduces its working potential (measured in monetary units as GDP) due to the consumption of primary energy. The first law and, accordingly, the law of energy conservation is expressed in economics (in monetary units) as the balance equation.

A principal feature of the thermodynamic free energy is that it contains two components – the useful energy and the useless energy. During the working process, the useful energy is transformed into the useless energy, and the free energy change is

$$\Delta \text{ (free energy)} = \Delta \text{ (useful energy)} - \Delta \text{ (useless energy)} \tag{2.1}$$

One of the results of the system work is the transformation of external (primary) energy into the useful energy.

All working processes in the living system are accompanied by friction. Because of the friction, the useful energy is irreversibly converted into the useless heat which diminishes the working potential of the system. Therefore, the useless heat and other waste must be extracted from the system to the environment; the extraction process also requires some work.

The fundamental feature of living systems (see next Chapter) is that they create information during their work, not only the useless heat. So, in living systems, the reduction of the working potential caused by the conversion of useful energy into useless heat is offset by the increase in information component of the working potential. That is, instead of equality (2.1) we have for living systems:

$$\Delta \textit{ (free energy)} = \Delta \textit{ (useful energy)} + \Delta \textit{ (information component)} \qquad (2.2)$$

Thus, the creation of information increases the working potential of the living system, and this increase may be considered as an intangible compensation for the conversion of useful energy into useless heat.

Note that the free energy items in equation (2.1) are expressed in energy units. At the same time, the *information* component in equation (2.2) is immeasurable in energy units because information is not an objective physical value. Therefore, the working potential of the living system is immeasurable in terms of energy.

However, in the case of the socio-economic system, people have come up with such a unit in the form of money. The money is used as a measure of the working potential of the economy, so all items in equality (2.2) as applied to the economy, are expressed in monetary units.

2.6. Entropy and the second law of thermodynamics

The transformation of useful energy into useless heat during the working processes reflects intrinsic statistical properties of the thermodynamic system. The thermodynamic system is a statistical ensemble, which contains a lot of thermally moving molecules. Accordingly, at the micro level, the system has many degrees of freedom. Because of molecular friction during the work, the useful energy tends to be randomly distributed (dissipated) among all degrees of freedom – the system tends to the most probable state with a uniform distribution of heat energy.

The tendency of dissipation of useful energy into useless heat is explained by the fact that the return of all the molecules back to their original state is statistically improbable even during the existence of the universe. Therefore, there is a natural tendency towards an increase in the useless energy of an isolated thermodynamic system:

$$\Delta \text{ (useless energy)} \geq 0;$$

this tendency is called the *second law of thermodynamics*.

The second law of thermodynamics is not applicable to living systems, because the living systems are open thermodynamic systems. If you isolate the living system, then it will die, and only after its death, the second law will take effect.

Clausius[15] called the useless energy *entropy*. Accordingly, the second law of thermodynamics is often expressed as "entropy of a closed system increases."

In its current interpretation, the concept of entropy applies only to systems which contain a statistically large amount of thermally moving particles, so the state of the system can be characterized by such a macroscopic parameter as *temperature*. Too simplistic an interpretation of entropy as a "measure of disorder" can lead to inappropriate conclusions. Thus, the second law of thermodynamics is sometimes inadequately illustrated by an example of increasing disorder in a room which is not cleaned.

For living systems, the concept of entropy is applicable only at the level of biochemical reactions. However, the notions of working potential, useful and useless energy are applicable to living systems up to the macro level.

The entropy and the second law of thermodynamics are sometimes referred to as the main factors that determine the functioning of the economy. The famous physicist Schrödinger, in his oft-cited book "What is life?" really emphasizes the importance of "negative entropy" in life processes.[16] However, Schrödinger notes that an exclusively entropy interpretation of life processes is a simplification for readers inexperienced in physics. Instead of entropy, the free energy needs to be considered.

The principal conclusion of physical macroeconomics is that the economic value is identical (isomorphic to) the free energy of the thermodynamic system. The first law of thermodynamics states that the free energy change is a consequence of the law of conservation of energy. Thus, the economy is operating primarily in accordance with the fundamental law of conservation of energy, not in accordance with the second law of thermodynamics. Life exists despite the second law of thermodynamics, not due to this law.

2.7 Entropy and information

The living systems do the work to create such living conditions in which the second law does not apply. Due to their openness, the living systems obtain primary energy from the environment, do the work and extract entropy back to the environment. Instead of useless entropy, the useful information is created. By using the notion of entropy, expression (2.1) it can be rewritten as following:

$$\textit{free energy} = \textit{useful energy} - \textit{entropy component} \tag{2.3}$$

where all equation items are expressed in energy units.

The fundamental property of living systems is that they increase their working potential by creating information, in accordance with expression (2.2). The living system releases the useless energy and thus reduces the entropy component of its free energy, and, simultaneously, the living system creates information. That is, the working potential (free energy) of the living system is:

$$\textit{working potential} = \textit{useful energy} + \textit{information component} \tag{2.4}$$

In its application to the economy, equation (2.4) should be interpreted in an isomorphic sense with respect to equation (2.3). That is, equations (2.3) and (2.4) are similar but different in nature because they refer to non-living and living systems respectively. Therefore, the working potential of the economy is measured in monetary units because it cannot be expressed in energy units.

The principal difference between entropy and information items in expressions (2.3) and (2.4) is that entropy is an objective value that can be measured by physical methods, while information is a subjective value. Information can only be evaluated by the living observer, that is, information depends on the observer.

In the socio-economic system, the observer's role is performed by society. The society evaluates the information component in expression (2.4) by estimating the amount of work that needs to be done to manufacture existing products. In other words, the society estimates economic values of the goods; such estimation is expressed in the form of the goods prices. Accordingly, there are two components in the price of any product – the objective *useful energy* component and subjective *information* component.

The physical notions of energy and information are the primary notions that cannot be defined in more simple terms. We can only definitely say that there is a law of conservation of energy, while the law of conservation of information does not exist because information is a subjective value.

By doing the physical work, the living system creates useful information, not only useless entropy. The creation of information firstly means that the living system, at the expense of the environmental energy, creates locally (within the system boundaries) such conditions in which the second law of thermodynamics is not applicable.

The widespread interpretation of information as "negative entropy" is related to the statistical consideration of entropy as a measure of the uncertainty of the state of the system containing a statistically large amount of thermally moving microscopic particles. Entropy increases with increased uncertainty.

For instance, during the dissolution of lumps of sugar in a glass of tea, the location and velocities of the sugar molecules becomes less definite, hence, the entropy of the closed thermodynamic system "isolated room + glass of tea + sugar" increases.

From a human viewpoint, the amount of information about the system is reduced in the sugar dissolution process. Indeed, before dissolution, the observer could see that a lump of sugar is white and that it has a cubic form, but after dissolution this information has "disappeared". Therefore, in human understanding, information is associated with entropy: the less entropy, the more information – so information is often called "negative entropy".

In this example, it is essential that the observer is a living person, so the observer clearly understands what does it mean – "white and cubic" with regards to the lump of sugar.

Any observer is a living system that lives in the real world. Accordingly, the observer's size is several orders greater than the molecular size. Even the simplest single-celled living system contains a lot of molecules. If we assume the existence of a living observer of molecular size, then such an assumption would lead to thermodynamic paradoxes such as the *Maxwell's demon* paradox.

In the economy, information exists in different forms and at various levels; these differences reflect evolutionary changes during biological and socio-economic evolution. The information component of the working capacity of living systems qualitatively changes in the transition from one evolutionary level to another.

The role of information component in the working potential of a living system may be to some extent illustrated by the example of enzymatic catalysis in biochemical reactions. That is, the information which is encoded by the living cell in the form of the amino acid sequence of the enzyme, determines the 3D structure of the enzyme. The enzyme interacts with the starting reactants of biochemical reaction and spatially orients them so that the energy threshold of the reaction is significantly reduced, thereby, the reaction becomes possible.

The enzyme is not consumed during the reaction and the functioning of the enzyme does not require expenditure of useful energy. Thus, the living system creates and encodes information in the form of DNA nucleotide sequences which in turn encodes the protein amino acids sequences, and thus the system increases its overall working potential.

The physical concept of information in its application to the economy we consider further in Chapter 3, "Economy and general living system principles" and in Chapter 10, "Information, symmetry and harmony in the economy".

2.8. Working cycle and its efficiency

Classical thermodynamics is based on the analysis of heat engines that do the work by heat energy transfer. The fundamental property of heat energy is that it is transferred from a more heated to a less heated body. Accordingly, the work cannot be done unless there is a temperature difference in the thermodynamic system.

In other words, the heater and the cooler must be present in the system. Otherwise, the heat energy of the ocean would be a virtually unlimited source of useful energy, so a so-called *perpetual motion machine of the second kind* could be constructed. One of the alternative formulations of the second law of thermodynamics is that such a machine is impossible.

The thermodynamic system can do the work without limit in time but only cyclically, and at the end of each cycle, the system returns to its original state. The *efficiency* of the working system is defined in thermodynamics as a ratio of the work done during the cycle, to the amount of external energy consumed during the cycle. Maximum efficiency is achieved in the classical Carnot[17] cycle and it equals

$$1-T_{\mathrm{c}}/T_{\mathrm{h}}$$

where the temperatures of cooler and greater heat, T_{c} and T_{h} are expressed in Kelvin degrees.

The working processes in animate and inanimate nature on the Earth, occur due to the cyclical solar radiation inflow. At the global level, the working processes in the climate system takes place in accordance with the annual temperature cycles; the smallest temperature difference is at the equator.

The living systems operate under the heavy influence of the climate temperature and the incoming sunlight energy. Thus, in the global economy, there is an annual cycle of grain production that determines the existence of the macroeconomic cycle (see Chapter 8).

By analogy with the efficiency definition in thermodynamics, *macroeconomic efficiency* is defined in physical macroeconomics (see Chapter 4) as the efficiency of the macroeconomic cycle, that is, as a ratio of the amount of work done by the economy (measured as the GDP magnitude) to the primary energy consumed during the cycle.

The dimension of the macroeconomic efficiency magnitude is [money/energy]. Thus, the concept of macroeconomic efficiency allows the establishment of a numerical correlation between energy and monetary units of economic value.

Note that macroeconomic efficiency should not to be confused with a dimensionless *energy efficiency*, which refers to various energy transformation processes taking place in the economy. For instance, the energy efficiency of the process of photosynthesis in which sunlight energy is converted into the chemical energy of green biomass, is about one percent. The energy efficiency of solar electricity generation is currently about twenty percent (theoretical maximum is 33 percent, see Appendix A).

3

Economy and general living system principles

There exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind. A consequence of the existence of general system properties is the appearance of structural similarities or isomorphisms in different fields. There are, for example, isomorphies between biological systems and human societies.

Ludwig von Bertalanffy, "General System Theory"

The central concept of physical macroeconomics is that the global economy is a social living system which emerged during biological and socio-economic evolution.

Biological evolution began with single-celled organisms which are open thermodynamic systems. More complex living systems, including the economy, inherited the basic properties of opened thermodynamic systems discussed in the previous chapter. Also, the economy functions in accordance with the general principles of living systems noticed by Bertalanffy; these principles include *openness, isomorphism, feedback* and a *steady state*.

We believe that these principles must be supplemented by the fifth element. Namely, the living system possesses a fundamental ability of *information creation*.

3.1. Bertalanffy's principles

The general principles of living systems are interlinked with the basic concepts of thermodynamics because all living systems are open thermodynamic systems. Every living system has a working potential which is similar (isomorphic to) thermodynamic free energy. In application to the economy, the general principles of living systems are as follows:

Openness

The economy is an open thermodynamic system because it exchanges matter and energy with the environment and other systems, thus maintaining the *useful* *energy* component of its working potential. As a living system, the economy creates, transmits and receives information thus increasing the potential of the *information* component.

Unlike the boundaries of biological organisms, the economic boundary does not restrict a certain amount of space. Moreover, the economic boundary may not coincide with administrative borders. A rapid globalization of the world economy is accompanied by integration and erosion of economic boundaries in accordance with the openness principle.

The living systems evolutionary integrate into more complex systems. An objective physical reason of integration and globalization is that the working potential of the united system exceeds the sum of the working potentials of individual systems.

It is principally important that the working potential of the living system includes an information component, and *primarily the increase in the informational component characterizes the development and evolution of the economy*. Hence, information openness is principally important for sustainable economic growth.

Isomorphism

The isomorphism principle means that the most significant structural and/or functional properties of living systems are like those of preceding evolutionary and more simple systems.

Biological evolution began with simple thermodynamic systems in the form of the drops of a "primordial soup", and then in the form of single-celled organisms. The working potential of such systems – in particular, their ability to maintain chemical reactions, is termed free energy.

Physical macroeconomics inherited from thermodynamics the terms "working potential" and "free energy". The principle of isomorphism, in its application to the economy primarily means that economic value is an evolutionary analogue of free energy. The difference is that economic value is measured in monetary units rather than in energy units.

Thus, the physical meaning of money is that the money is a measure of the working potential of the socio-economic system. In other words, the monetary units in economics are isomorphic to the energy units in physics.

The principle of isomorphism is a principle of evolutionary development. For the economy, the isomorphism principle means that evolution is a natural path of economic development. The revolutionary path, that is, a complete rejection of the past results in huge economic losses; in addition, revolutions are usually accompanied by civil wars.

Revolutions are the specifics of human society. In wildlife, there is only evolution, and there are no revolutions. Darwin's theory of evolution is not a theory of revolution. The possibility of biological revolutions would mean that the fish might suddenly come out of the water and mammals might start to fly like a bird. Similarly, revolutionary changes in the economy seem natural only in the dreams and aspirations of adventurous politicians.

Feedback

Feedback is primarily a regulatory tool in amplifier systems of all kinds. The existence of feedback means that output signals are partially returned to the system input. Any living system is basically a feedback amplifier because the living system enlarges its free energy by consuming the external energy, and multiple feedback improves and stabilizes this amplification process.

The economic value is isomorphic to the free energy, so the economic process can be treated as an enlargement of economic value at the expense of primary energy consumption. In a sustainable system, positive feedback must be compensated by negative feedback. The predominance of positive feedback causes system instability – for example, financial bubbles may begin to grow in the economy with insufficient negative feedback.

There is a balanced distribution of free energy in biological systems due to dynamic (nutritional and metabolic) feedback. In the economy, the state of equilibrium is also achieved in definite cases through the objectively existing negative feedback in the form of demand function (see Chapter 7, "Demand function and its applicability").

However, the demand function is not sufficient for a balanced distribution of overall value (GDP), so an additional negative feedback should be created in the economy. This goal can be achieved by means of introduction of the dynamic added value taxation instead of the static VAT (see Chapter 9, "GDP distribution and economic stability" and Appendix B).

Steady state

The steady state of a living system can be described as a "dynamic equilibrium in the state of sustainable development." In physics, the steady state of an open dynamic system is sometimes illustrated by a bath, in which water flows in and out, so that the water level in the bath remains constant. However, this analogy is not suitable for living systems.

Firstly, living systems are developing systems. Secondly, the dynamic processes in living systems are not constant flows of matter and energy. There are cyclical processes at various levels of biological and socio-economic systems, not constant flows.

The life cycle of cereals is determined by the annual cycle of sunlight energy inflows. In the global economy, sunlight energy absorbed in the cyclic process of grain production is the primary energy factor which determines the existence of the annual macroeconomic cycle (see Chapter 8).

The working cycle efficiency is the main characteristic of the thermodynamic system, and it is defined as the work done by the system per unit of the consumed external energy. The development and evolution of living systems also means an increase in their efficiency. Therefore, the steady state of the economy may be treated as the cyclical process of reproduction of the working potential of the socio-economic system (in monetary units, GDP) characterized by the growing efficiency of the macroeconomic cycle.

3.2. Creation of information

Information and energy are the primary concepts that cannot be explained in simpler terms. We can only say that energy is an objective value, while information is a subjective value, which depends on the living observer.

The physical concept of *information* introduced in physical macroeconomics should be considered as an addition to the general principles of living systems claimed by Bertalanffy. Information exists only in living systems, and life arose with the advent of useful information instead of useless entropy.

As for the economy, the mere existence of economic information indicates that the economy should be analyzed as a living system.

The living systems, which have no nervous system (say, single-cell organisms or plants) also perceive, create and transmit information. However, the emergence of a nervous system during biological evolution meant a sharp increase in the information component of the working potential of living systems.

In the contemporary economy, electrical networks are like the neural networks in highly developed biological organisms.

Information is a subjective (intangible) asset in the economy, while useful energy is an objective (tangible) asset. In other words, there are objective and subjective components in the working potential of the socio-economic system. Accordingly, there are two aspects to economic value.

The principal role of society is to interpret and evaluate the information item in product value; such an evaluation results in an appropriate product price. Without society's evaluation, for example, the price of a paperback book would have been equal to the price of energy that may be obtained by burning the paperback.

Thus, society does the observer's work in the economy; the corresponding energy expenses must be offset through appropriate GDP distribution between producers and society, primarily by means of a properly organized added value taxation.

3.3. Socio-economic evolution

Information growth is a fundamental feature of the development and evolution of living systems. The development and evolution primarily means an improved adaptation to changing environmental conditions.

In accordance with the principle of isomorphism, the most useful properties of living systems are inherited in the process of their evolutionary development, perhaps being expressed in other structural and functional forms.

The socio-economic evolution is rapidly accelerating, and it resembles a thousand-fold accelerated biological evolution (Table 3.1).

Table 3.1. The milestones in biological and socio-economic evolution.

Biological evolution	Years ago	Socio-economic evolution	Years ago
emergence of life	~ 3.5 billion	appearance of man	~ 1 million
appearance of multicellular organisms	~ 1 billion	emergence of socio-economic relations	~ 10,000
occurrence of nerves	~ 0.5 billion	creation of electrical networks	~ 100
appearance of man	~ 1 million	emergence of Internet and globalisation	~ 30

Thus, the occurrence of nerves was a fundamental milestone in biological evolution. Similarly, the creation of electric networks was a crucial stage in socio-economic evolution. Due to electrical networks, the economy has gained the ability to create, store and transfer vast amounts of energy and information at the speed of light. Without exaggeration, one can say that electrical networks – the power and information networks, the wired and wireless networks – are the nerves of the modern economy.

The highest stage of biological evolution was the appearance of man. Similarly, the development of the internet and globalisation may lead to the emergence of a qualitatively new living system, as the highest level of the socio-economic evolution. How soon can it happen?

The social system is viable if it is, on the one hand, rather large and self-sufficient. On the other hand, the system should not grow to such an extent that it loses its self-control. For these reasons, we are witnessing the integration processes around multiple control centers in the world, not around a single center.

The integration processes are expressed in the creation of new economic unions and economic associations, but these processes do not mean an imminent merger of these unions soon. Such a global merger would entail the creation of a single control center, which is necessary for adequate functioning of a living system, but it is impossible at this stage of socio-economic evolution.

Social systems develop and evolve in the first instance under the influence of external geographic and climatic factors that determine the areas of their residence and foraging. In the case of the economy, these factors also form the customs and cultural traditions of peoples.

The rate of integration depends on the development of appropriate socio-economic systems with all social systems achieving a comparable development level with that of more advanced systems, and only then can these systems be integrated on an equal basis. Otherwise, the insufficiently developed system would become a raw materials appendage or a source of cheap labor for the advanced system.

The result of global integration – a unified social system – can occur, when the development levels of the local economies will become equal. In this case, a single control center will be possible, but probably it will be a virtual center on the Internet, without an explicit geographical address.

3.4. Self-regulation in living systems

There are various self-regulatory mechanisms in living systems. At the level of biochemical reactions, regulation is carried out primarily through random Brownian movements and interactions of reagents in an aqueous environment. This primary mechanism of self-regulation can exist at a temperature ranging from freezing point to the boiling point of water.

During biological evolution, the growth of information potential of living systems has created more complex regulation mechanisms at different system levels. Regulation at the highest level of a highly developed organism is carried out by centrally determined neural and hormonal signals.

Similarly, the mechanisms of self-regulation in the economy includes both random market mechanisms and regulatory signals received from the central authorities.

The game paradigm of the economy contrasts business to the state, which supposedly prevents agents from acting freely without constraint in the markets. On the contrary, physical macroeconomics asserts the need for coexistence of centrally regulated and market-regulated processes in the socio-economic system, by analogy with highly developed biological organisms.

The existence of different forms of property in the economy is an additional means of self-regulation. The optimum ratio between different forms of property can help generation of more efficient control signals that enable a more rapid increase of the working potential.

In biological societies, such as bee colony society, there is no private property; all members of society are doing their work to increase the working capacity of the entire system. People evaluate the working potential of bee colony society as the amount of honey produced during the year, that is during the complete working cycle in bee colony society.

Bees produce honey and distribute it inside the bee colony society to maintain adequate working potential of all participants in the social system. Thus, honey, as the unit of measurement and the means of distribution of the working potential, can be considered as "bee money." The harvest of honey, that is, the "bee GDP" is distributed in accordance with the instinctive, genetically programmed behavior of bees, which is centrally regulated by physical-chemical signals received from the queen bee.

A balanced distribution of working potential is a major task of self-regulation in any living system. Imbalances can lead to slow development, disease, and ultimately to the death of the system. The balanced distribution of working potential in biological systems is carried out by means of nutritional and metabolic feedback, as well as under the influence of centrally generated control signals.

Similarly, the most crucial factor in economic self-regulation is the ability of the system to generate control signals which, firstly, facilitate more efficient growth of the system working potential (measured in monetary units as GDP). Secondly, the control signals must provide a balanced working potential distribution, through a balanced distribution of GDP among all participants in the socio-economic system.

Tax laws are the most important control signals centrally generated to distribute GDP. However, the existing static tax system cannot ensure a balanced distribution of GDP, needed for a sustainable development of the global economy. The physical concept of dynamic added value taxation (DAVT), presented in Chapter 9 and in more detail in Appendix B, offers a real opportunity to address this urgent problem.

4

Value-energy interrelationships

In mainstream and heterodox economic theories, based on the game paradigm, value is vaguely treated as a benefit (winning) provided by a good or service to economic agents (market players). However, the global economy is a working system, not a game. Accordingly, value is a result of the work done by the social system, and it is not a winning of the game participants.

Inter alia, the difference between the terms “work” and “game” is that the work done is proportional to the amount of external energy consumed during the working cycle of the system, while the game result may not correlate with the players’ energy expenses. Accordingly, primary energy is now erroneously treated as one of the external factors affecting market game outcomes, not as a main factor.

Contrary to game paradigms, physical macroeconomics examines the global economy as a social living system, which does the work and survives due to primary energy consumption.

The relationship between economic value and social labor has long been noted by economists – for example, such views were expressed by Adam Smith and Karl Marx. However, their views could not be based on the concepts of natural science, because even the very concept of physical work appeared only in the first half of the nineteenth century. In addition, at that time it was not imagined that the economy could be viewed as an evolving living system.

4.1. Two components of economic value

As it was discussed in the previous chapters, one of the central concepts of physical macroeconomics is that overall value is a monetary measure of working potential of the socio-economic system. In contrast to the working potential (free energy) in thermodynamics measured in energy units, economic value is expressed in monetary units. In other words, economic value is isomorphic (not equal) to thermodynamic free energy.

By using formal thermodynamic notation, the equality (2.3) can be rewritten as

$$F = U - TS \tag{4.1}$$

where the free energy F includes the useful internal energy (U) and entropy ($-TS$) items expressed in energy units.

Similarly, overall economic value includes two components expressed in monetary units:

$$\textit{overall value} = \textit{useful energy} + \textit{information} \tag{4.2}$$

Note that in (4.2) and further on in the text, the term *information* means "information component of value."

The differences between isomorphic equations (4.1) and (4.2) are the following:

– all items in (4.2) are expressed in monetary units, not in energy units;
– there is an information component in (4.2) instead of an entropy component in (4.1);
– *useful energy* in (4.2) is equal to the value of secondary energy produced by the economy, while the U magnitude in (4.1) equals the internal energy of the entire system.[18]

In the transition from (4.1) to (4.2), the replacement of the entropy component (TS) by *information* is because the economy is a living system for which (4.1) is directly inapplicable.

Both components of thermodynamic free energy in (4.1) are objective physical quantities measured in energy units. As to the economic value (4.2), its *useful energy* component is an objective value, while *information* is a subjective value, which is evaluated by society within the pricing process.

The pricing mechanism is interpreted in physical macroeconomics in the following way.

The working potential of the economy is realized through manufacturing various products. The economic system redistributes its working potential by increasing the production of certain goods and in stopping the production of other goods, as well as by organizing the production of completely new goods and services. That is, *the product value is the appropriate share of the working potential of the economy*.

For society, product value is expressed in terms of the product *price*. Society does the observer's work in the economy and thus it is society that evaluates the *information* item in product value. In fact, society evaluates the amount of work which needs to be done to manufacture the product. This subjective estimation, taken together with the objective *useful energy* component of the product's value, forms the product price.

The physical meaning of pricing is discussed in more detail in the following chapters of this book.

By summing up the prices (p_i) of final products, we may obtain an estimate of the total working potential of the economy (in monetary units) as the GDP magnitude:

$$\textit{working potential} \sim \text{GDP} = \Sigma p_i Q_i \tag{4.3}$$

where Q_i is the quantity of the i-th final product.

In accordance with (4.2) and (4.3), the price of any product includes an objective *useful energy* component and subjective *information* item. The proportion between these components vary widely for various products. Thus, the prices of intellectual products contain only an *information* component, while the energy carriers' prices p_{i}, including food prices, contain both components:

$$p_{\mathrm{i}} = (\textit{useful energy})_{\mathrm{i}} + \textit{information}_{\mathrm{i}} \tag{4.4}$$

4.2. Macroeconomic efficiency: numerical definition

In thermodynamics, efficiency of the working system is defined as the ratio of work done by the system to the amount of consumed energy. Similarly, we can give a numerical definition of macroeconomic efficiency.

The economy produces GDP due to the consumption of primary energy. Consequently, the macroeconomic efficiency (i.e. the efficiency of the socio-economic system) can be defined as the ratio

$$R = \text{GDP} / H \tag{4.5}$$

where H is the primary energy consumed by the economy during the year.

Equality (4.5) means that R magnitude is equal to the economic value which corresponds to the unit of primary energy. In other words, R magnitude is equal to the amount of work done by the economy per unit of consumed energy.

The dimension of R magnitude is [*money/energy*], so the macroeconomic efficiency magnitude can be considered as a correlation coefficient between monetary and energy units of economic value.[19] This coefficient is not a constant – it is growing with ever increasing macroeconomic efficiency, and it is higher in more developed economies.

Among all the products produced by the economy, electricity is a unique product because its price p_{e} in (4.4) contains only the *useful energy* component since society interprets electricity as energy in its purest form, without any information content.

Indeed, when we pay for electricity, we pay just for energy (kilowatt-hours), rather than for, say, the amount of consumed current (ampere-hours). For this reason, among prices of all products and services, only the price of electricity has this dimension [*money/energy*].

Hence, the average price of electricity $<p_e>$ can be considered as an empirical indicator of macroeconomic efficiency also measured in monetary/ energy units. Namely, in a growing economy, the R and $<p_e>$ magnitudes must vary in line with this trend

$$<p_e> \rightarrow R \uparrow \tag{4.6}$$

We will demonstrate in the next chapter that the definition (4.5) and the trend (4.6) are adequate and correct, provided that primary energy is estimated correctly.

By producing h kilowatt-hours of electricity, the economy creates value, i.e. the economy increases its working potential (in monetary units, GDP) by an amount that is equal to the average price of this electricity:

$$\Delta GDP = \Delta \text{ } (useful\ energy) = Rh$$

The price p_i of any other product with the energy content h_i includes the information component in addition to the *useful energy* component:

$$p_i = Rh_i + information \tag{4.7}$$

4.3. Information component of GDP

By summing up the prices (4.7) of the final products produced for one year, we obtain the GDP value:

$$\text{GDP} = R\ \Sigma h_i + I \tag{4.8}$$

where I is the information component of GDP and Σh_i is the total energy content of the final products. Considering that $R = \text{GDP}/H$ we obtain:

$$I = \text{GDP}\ (1 - \Sigma h_i/H) = \text{GDP}\ (1 - r) \tag{4.9}$$

where $r = \Sigma h_i/H$ is the energy efficiency of the economy.

In principle, the maximum information content in the GDP value could be achieved in the case of the pure agro economy. In this case, the energy efficiency is about 1 per cent, in accordance with the energy efficiency of food biomass production in agriculture. Accordingly, the percentage of the information component in GDP value would be very high – about 99 per cent.

At first sight, the conclusion that the agro-oriented economy produces economic value with the highest information component, seems to be doubtful. We used to think that engineers and workers in an industrial economy produces much more technologically advanced products than that of farmers. Yet in reality, grain is a much more information laden product than any other industrial output.

Every seed constitutes a tiny nanotech factory. Placed in appropriate conditions, this factory unpacks and grows, produces several dozen similar factories and does not pollute the environment. Moreover, it improves ecology by consuming carbon dioxide and extracting oxygen. The overall multistage process, programmed by the DNA nucleotide sequence, requires some energy expense at every stage. Finally, only about 1% of consumed sunlight energy is stored in seeds to begin the next production cycle.

People are far from creating similar industrial technologies. They can only improve some details of the natural process through the means of breeding and genetic engineering.

4.4. Inflation and macroeconomic efficiency growth

Economic value production is similar (isomorphic) to the increase in thermodynamic free energy. The isomorphism means that the price p of any product (and GDP) contains *useful energy* and *information* items. The *useful energy* item objectively characterizes the product as an energy carrier, while the *information* item is a subjective evaluation by society of a product's informative features.[20]

Society plays the observer's role in the economy. The observer evaluates the *information* item in the product's price by estimating the amount of work needed to be done by the socio-economic system to manufacture the product. Thus, society is a real, albeit indirect, participant in economic value production.

In accordance with (4.7), the prices of secondary energy carriers with large energy content h must increase with the growth of macroeconomic efficiency R.

Then the prices of other products, with the prevailing *information* item, most likely also will increase due to increased energy expenses in the production cost.

Thus, there are two components of inflation – a leading *useful energy* inflation and an induced *information* component.

The total inflation gives rise to increased GDP, consequently, to increased macroeconomic efficiency, and then the next inflation cycle begins. *Moderate inflation and macroeconomic efficiency growth are closely interrelated notions*.

The increase in working potential of the economy is monetary reflected in GDP growth, in accordance with equality (4.3). Hence, if working potential of the economy increases, then, with the same quantity and range of products and services, prices must also increase. *The increase in the working potential of the economy is an endogenous cause of moderate inflation in developed economies*.

4.5. Physical meaning of money

The real economy is not a game – it is a social living system that survives by spending and reproducing its working potential. The working potential of the economy includes the subjective information component; therefore, it is immeasurable in energy units.

Nevertheless, human society has created a unique unit of its own working potential in the form of money. *The physical meaning of money is that money is a measure of the working potential of the economy.*

Gold and bitcoins cannot be real money, because the total amount of gold and/or bitcoins does not characterize the working potential of the socio-economic system. Though, in some actual cases, gold or bitcoins may be an intermediate means of savings and exchange (see Chapter 8 for details).

As a unit of measurement of working potential, money is constant in a sufficiently developed economy (like units of mass, energy, distance and time in physics), so money does not lose its "purchasing power." *The current prices are real values that adequately describe the increase in the working potential of the growing economy*. *Accordingly, only current prices (and nominal GDP values) are used in this book*.

The socio-economic system maintains its vitality by reproducing the working potential of the system. The total potential should be distributed among all parts of the system, and this important function is carried out through the means of money. Hence, *money is the unit of measurement and the means of distribution of the working potential of the economy*.

The distribution and redistribution of working potential is carried out in operations in which money moves within the system, and these operations are called *payments*.

In wildlife, free energy distribution is balanced. In a sustainable global economy, GDP distribution must also be balanced, but currently this is not the case.

For implementing the two functions of money – measurement function and distribution function – the economy must have sufficient *money supply.* With the growth of the working potential of the global economy, more money is needed for the distribution of GDP. That is, *the increase in the working potential of the self-sufficient economy is an endogenous cause of money supply growth*.

The working potential of the economy contains the information component which depends on society's evaluation. Different societies prefer to produce different goods, so they evaluate differently the working potentials of their economies. These differences are expressed in the existence of national currencies.

Globalisation processes will eventually lead to the creation of a single unit of measurement of the working potential of the global economy, but for now the US dollar is adopted as an international unit in parallel with the existence of national currencies.

The evolution of money as the unit of measurement and the means of distribution of the working potential of the social system, is discussed in more detail in Chapter 8, "Macroeconomic cycle."

4.6. Balance equation and the law of energy conservation

With the help of money, people widely use thermodynamic laws in the economy, although most people have never studied thermodynamics.

The fundamental law of conservation of energy is used in the economy as the balance equation:

$$S \text{ (sales value)} = E \text{ (expenses)} + G \text{ (gain)} + T \text{ (taxes)} \tag{4.10}$$

where all items are expressed in monetary units. Being used at the micro level of the economy, the balance equation expresses (in isomorphic form) the energy balance that exists at the macro level.

Indeed, (4.10) means that energy needed to produce the sold goods (S) is equal to the energy consumed by producers and suppliers (E), plus the energy consumed by society to maintain social infrastructure (T), plus energy gain (G).

The thermodynamic free energy change is a consequence of the law of energy conservation, in accordance with the first law of thermodynamics. Similarly, starting from the balance equation, we can obtain an estimate for the working potential of the economy (in monetary units, GDP).

To do this, one should divide expenses into two parts – the internal expenses, E^{int} (mainly payroll payments) and the external expenses, E^{ext} (payments to suppliers). Then the added value[21] created by individual producers within the annual tax period is

$$\Delta S_+ = S - E^{ext} = E^{int} + G + T \tag{4.11}$$

The overall value (GDP) can be estimated by summing up ΔS_+ values through all producers.

GDP is produced by joint efforts of producers and society, so corresponding energy costs should be offset by a balanced distribution of GDP (see Chapter 9, “GDP distribution and economic stability”).

5

Primary energy and macroeconomic efficiency

The macroeconomic efficiency R is defined in physical macroeconomics as a ratio of GDP and primary energy. The R magnitude adequately characterizes the working efficiency of the economy, provided the primary energy is assessed correctly. However, the currently published amount of primary energy is completely wrong because the crucial food factor is erroneously disregarded.

5.1. Energy sources in the global economy

At present, the energy sources in the world economy are classified according to the scheme, which in general terms is shown in Figure 5.1.

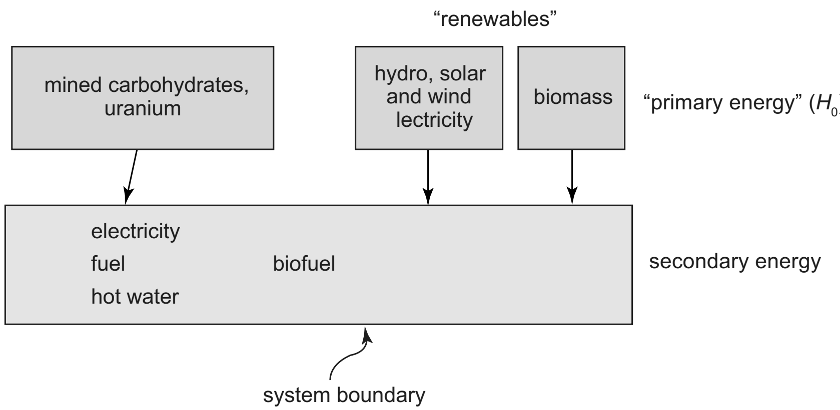


Figure 5.1. The current scheme of the world economy energy sources with incorrectly defined system boundary.

This scheme is incorrect because the "renewables" are classified as the primary sources. However, the "renewables" are produced within the economic boundary, that is, the economy produces "renewables" by consuming primary sunlight energy.

Thereby, biomass, hydro, solar and wind energy must be classified as a secondary energy, and, instead of “renewables”, the state of things must contain “solar radiation” as the primary energy source.

The global economy consumes a huge amount of sunlight energy to produce food biomass. This amount is much higher than the currently published H_0 magnitude – the H_0 is the smallest “industrial” component of the total primary energy H. So, the state of things shown in Figure 5.1, should be completely reviewed.

In fact, for the world economy, primary energy is the energy of the Sun. A small part of this energy was conserved billions of years ago and this energy is currently used by the consumption of hydrocarbons and uranium. But the prevailing part of the external energy inflow is not “from the past” – it is obtained due to current solar radiation inflow. Thus, the correct energy state of things must first contain solar radiation instead of “renewables.”

The world economy obtains the bulk of sunlight energy directly, and the rest of the energy is obtained indirectly, through interaction with the Earth’s climatic system (Figure 5.2).

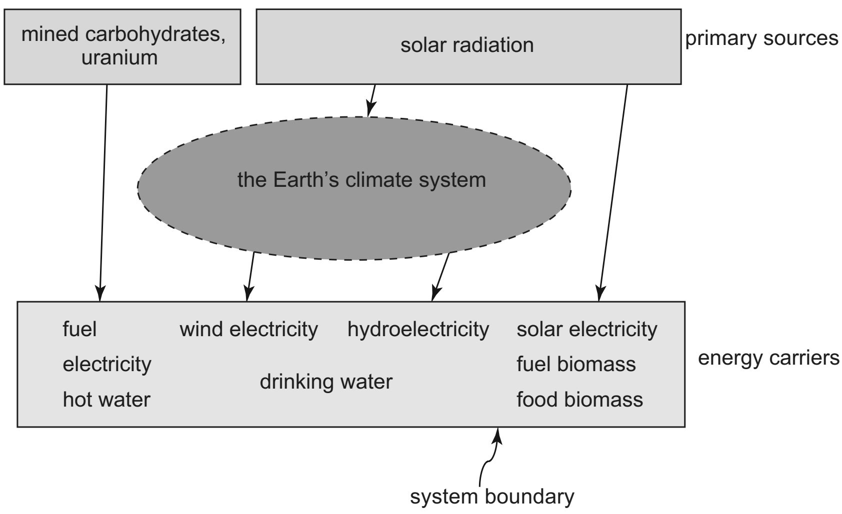


Figure 5.2. The correct scheme of the world economy energy sources.

It makes little sense to term the sunlight as “renewable”, so the term “renewable primary energy” in general should be avoided. Otherwise, we can come to the curious conclusion that sunrises and sunsets are “renewable phenomena”.

By replacing “renewables” with “solar radiation” we do not just refine the classification. Namely this replacement allows us to estimate the actual amount of primary energy.

5.2. Food factor

For the world economy, the currently published H_0 magnitude[22] is about 13,000 Mtoe (2.4 kW per capita). However, this figure is only a small part of the real primary energy H. A correct estimation of primary energy should consider the sunlight energy absorbed in food biomass biosynthesis.

Humans consume about 2,000 kcal of food energy per day. Considering that 1 kcal $\approx 1.2 \times 10^{-3}$ kWh, we can evaluate food energy consumption per capita as:

$$2{,}000 \text{ kcal/capita/day} \approx 2000 \times 1.2 \times 10^{-3} \text{ kWh / capita/24h} = 100 \text{ W/capita.}$$

This energy is very small compared with the H_0 magnitude, so that, at first glance, the "food energy factor" can be ignored. But that would be an incorrect conclusion.

Food biomass is a secondary energy carrier, and its production requires much more sunlight energy than the amount of chemical energy stored in the biomass. The efficiency with which energy or biomass is transferred from one trophic level to the next may be termed ecological efficiency. Consumers at each level convert on average only about 10 percent of the chemical energy in their food to their own organic tissue. At the lowest trophic level (the bottom of the food chain), plants convert about one percent of the sunlight they receive into chemical energy.[23]

Consequently, the world economy consumes for food biomass production 100 times more sunlight energy than 100 W per capita, namely, about 10 kW. The human being is a serious sunlight-consuming machine!

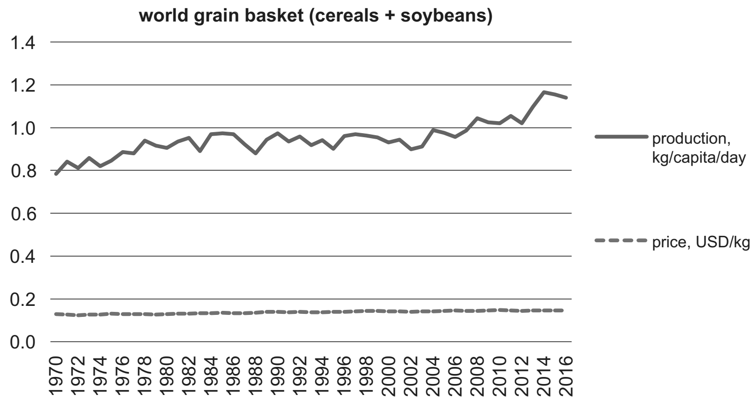
Hence, the real primary energy H must include sunlight energy consumed in agriculture (H_a) plus sunlight energy consumed in seafood production (H_s):

$$H \approx H_0 + H_a + H_s \qquad (5.1)$$

The world economy produces about one kilogram of cereals and soybeans per capita per day (Figure 5.3) to meet the needs of people in food energy that corresponds to the sunlight primary energy of about 10 kW/capita. Accordingly, the agricultural component of the food factor can be estimated as

$$H_a \sim 10 \text{ kW/capita} \times Q_a \qquad (5.2)$$

where Q_a is the number of "grain baskets" per capita per day produced in agriculture (one basket contains 1 kg of grain and soybeans).



Note: The price of grain basket since 1970 was calculated using agro production data presented in the original version of FAOSTAT. In this version, production value is expressed in international prices, which are similar to average spot oil prices in US dollars.

Figure 5.3. The features of world grain basket production. Data source: UN Food and Agriculture Organization, official website (FAOSTAT database).

Fish is on the next level of the food chain after water-inhabiting plants, so the energy efficiency of fish biomass production is about 10 percent of the energy efficiency of green biomass production. Hence, the sunlight energy consumed in seafood production (mainly in fisheries) can be estimated as

$$H_s \sim 100 \text{ kW/capita} \times Q_s \tag{5.3}$$

where Q_s is the number of “fish baskets” per capita per day produced in fisheries (one basket contains 1 kg of fish).

The world production of the grain basket is rather stable and amounts to about 1 kg/capita/day (Figure 5.3). Beginning in 2003, this figure began to grow; the growth clearly linked to biofuel production. Note that the grain basket price (≈ 0.14 USD/kg) was flat for more than thirty years.

The special properties of world grain basket production – flat price and approximately constant output per capita – are of fundamental importance for the whole architecture of the global economy (see Chapter 6, “Global energy prices” and Chapter 8, “Macroeconomic cycle”).

The world economy consumes the greatest amount of primary energy in agriculture, mainly in the cyclical process of grain production. The sunlight energy absorbed in agriculture (H_a), is a major component of the total primary energy H (Figure 5.4).

Thus, grain production is the most energy-consuming process in the global economy. This cyclical process has had a decisive influence on the formation of the annual macroeconomic cycle.

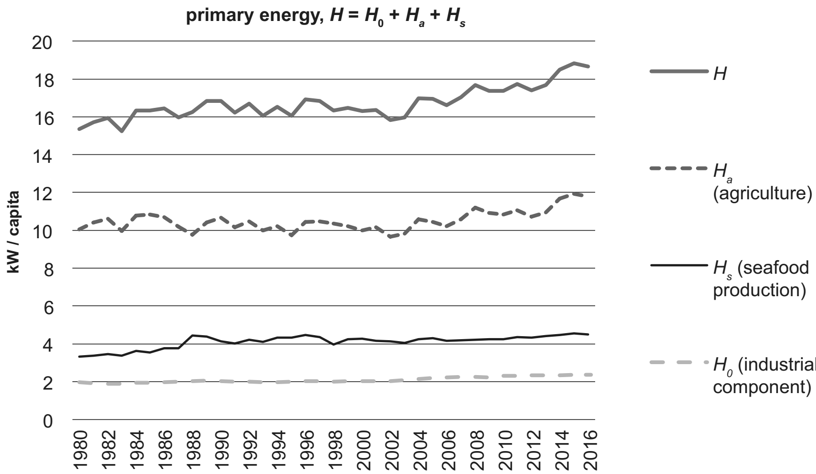


Figure 5.4. Components of world primary energy.

The sunlight energy consumption in the production of seafood (H_s) is also a principal factor in world primary energy. In sum, the food factor ($H_a + H_s$) is the major energy factor in the economy, and it must be considered to adequately estimate macroeconomic efficiency magnitude.

5.3. Efficiency of major economies

The population, GDP and primary energy are extensive macroeconomic parameters, while GDP per capita, primary energy per capita and macroeconomic efficiency are intensive parameters. Our estimates[24] of intensive parameters for the largest economies and available data on the average price of electricity are represented in Table 5.1.

Table 5.1. GDP, primary energy H and its components, macroeconomic efficiency R and average electricity price <pe> in the largest economies, 2016.

Economy	GDP (USD/capita/hour)	H_0 (kW/capita)	H_a (kW/capita)	H_s (kW/capita)	H (kW/capita)	$R = GDP/H$ (USD/kWh)	$<p_e>$ (USD/kWh)
World	1.20	2.4	12	5	19	0.062	N/A
US	6.60	9.3	50	3	63	0.105	0.103
EU	3.70	4.3	17	4	25	0.150	~ 0.200
Japan	4.40	4.7	2	6	14	0.340	~ 0.300
China	0.93	2.9	12	8	23	0.040	N/A

In the case of the US economy, macroeconomic efficiency and average electricity price coincide with high accuracy. Thus, the numerical definition of macroeconomic efficiency (equality 4.7) as well as formulas (5.2) and (5.3) for the food estimation are quite correct.

Statistical data on the average price of electricity are freely available only for the US economy thanks to information posted on the portal of the US Energy Information Administration. As to the EU, the electricity price listed in Table 5.1 (~0.2 USD/kWh) is the average price for households and industry in the euro area.[25] Available indirect data on the average electricity price in Japan (~0.3 USD/kWh) are also consistent with our estimate of the Japanese economy efficiency.

The US economy consumes in agriculture much more solar energy per capita than the other economies do. As a result, the macroeconomic efficiency magnitude and average electricity price are less in the US as compared with the EU and Japan.

The macroeconomic efficiency increases if the GDP is growing, and the primary energy H is declining. For the largest economies, the trends in primary energy, GDP and macroeconomic efficiency are presented respectively in Figures 5.5, 5.6 and 5.7.

The GDP per capita (Figure 5.6) is the main intensive parameter that affects the growth of the world economy efficiency (Figure 5.7).

The primary energy consumption (Figure 5.5) is a more conservative option, because it depends primarily on the food factor, which increases slightly compared to GDP growth. The GDP per capita in the world economy has increased four times in the past thirty-five years (from 0.3 to 1.2 USD/capita/hour), while the primary energy consumption increased by only twenty percent (from 15 to 18 kW/capita).

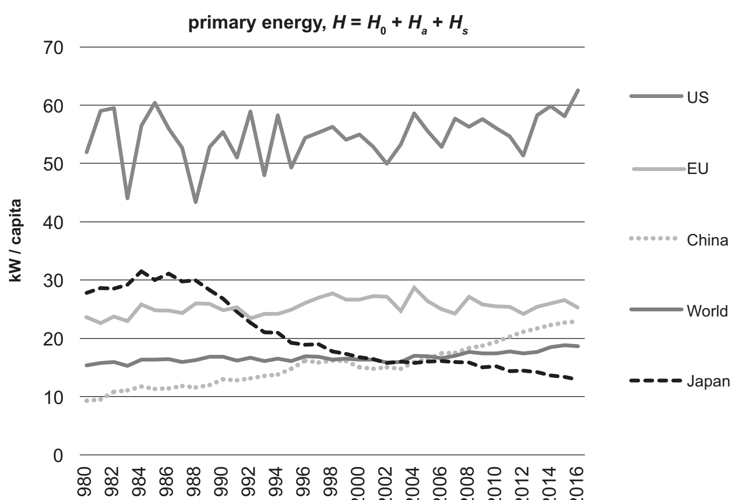


Figure 5.5. The primary energy consumption in the largest economies.

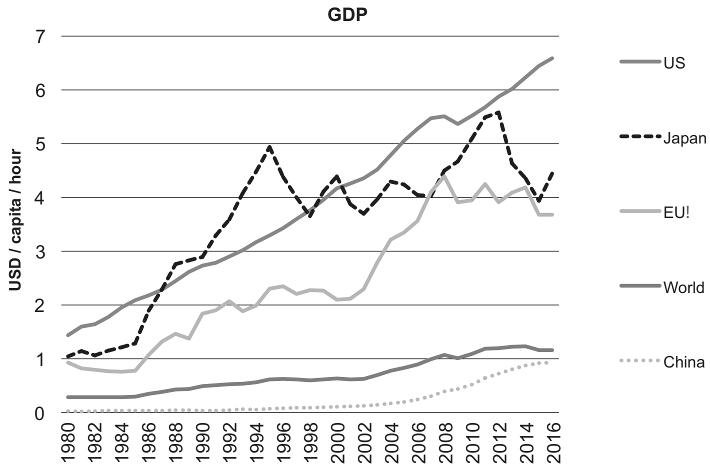


Figure 5.6. GDP per capita in the largest economies.

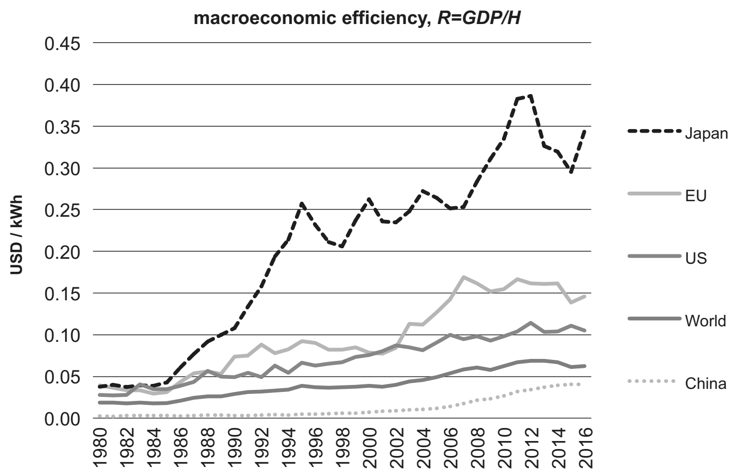


Figure 5.7. Efficiency of the largest economies.

Note that, in the Japanese economy, the large annual fluctuations in GDP, measured in US dollars (Figure 5.6) are associated with the unstable exchange rate of the Japanese yen against the US dollar.

The graphs presented in Figure 5.5 show that the US economy consumes three times more primary energy per capita than the world economy in total. Annual fluctuations in primary energy reflect the difference in the yield of crops; in the case of the world economy, these fluctuations are muted.

The primary energy consumption per capita increased twice in China between 1980–2014, while it decreased twice in Japan. This difference is associated primarily with the opposite trends in fisheries – the fish production increases in China and decreases in Japan, which is reflected in a more rapid growth of the efficiency of the Japanese economy as compared with other economies.

Macroeconomic efficiency growth leads to an increase in the *useful energy* component of energy carriers' prices. Thus, the growing efficiency of the world economy affects the formation of global energy prices (see the next chapter).

The efficiencies of major economies discussed above were calculated with primary energy H magnitude given by equation (5.1),

$$H \approx H_0 + H_\mathrm{a} + H_\mathrm{s}$$

where H_0 is the currently published "industrial" component of primary energy. This component includes energy of solar electricity and biofuels still produced in relatively small quantities. However, in the future, the H_0 magnitude will require clarification in view of the growing production of solar electricity and biofuels; the corresponding correction of equation (5.1) is presented in Appendix A.

6

Global energy prices

The world economy increases its working potential (overall economic value) due to the consumption of primary energy. The primary energy sources (sunlight, hydrocarbons and uranium deposits, the Earth's climate system) are outside the boundaries of the economy, so these energy sources do not contribute to the working potential of the system. Therefore, primary energy has no economic value and, accordingly, primary energy cannot be calculated according to the monetary pricing system.

The economy converts a part of primary energy into the useful energy of secondary energy carriers. The secondary energy carriers (electricity, extracted oil and gas, food and fuel biomass, hot water, enriched uranium etc.) contribute to the working potential of the economy, so the secondary energy carriers have economic values. For society, these values are expressed in the form of the corresponding prices.

In this chapter, the physical concept of pricing is suggested based on the principle of isomorphism between economic value and thermodynamic free energy. Later on in Chapter 7, we clarify the pricing mechanism using the notion of demand function.

6.1. Energy pricing

Like any other economic products, the secondary energy carriers have appropriate shares in the working potential of the socio-economic system. These shares, expressed in monetary units, are economic values of the products. The society (producers and consumers), based on the available information about these products, estimates these values, thus forming the products prices.

In accordance with equation 4.4, the product price p contains two components, that is,

$$p = \textit{useful energy} + \textit{information}$$

The *useful energy* component objectively characterizes the product as a source of physical-chemical energy, while the *information* component is a subjective assessment by society of all other consumer properties of the product.

The product price is a society's estimate of the amount of work that needs to be done to manufacture this product. This work can be done if the economy has an appropriate working potential which contains the *useful energy* and *information* components.

The relationship between the two components of price depends on society's evaluation of available information; the evaluation may change dramatically in extreme situations, for example, if the economy is in a state of war.

Any product containing the useful physical-chemical energy h, is an energy carrier. Its price depends on the macroeconomic efficiency R in accordance with equation (4.7):

$$p = Rh + information$$

In the global economy, the most important secondary energy carriers are electricity, crude oil and grain. The corresponding price trends depend, firstly, on the macroeconomic efficiency magnitude, and, secondly, these trends depend on the society's evaluation of the *information* component in the energy carrier price.

6.2. Electricity price

Electricity is the only product with zero *information* component in its price. Society considers electricity as a source of useful energy, without any information content, so the price of electricity contains only the *useful energy* component (Rh). Accordingly, the average price $<p_e>$ of one kilowatt-hour of electricity in a developed economy with an independent power system is equal to the macroeconomic efficiency:

$$<p_e> \approx R$$

Currently, there are no statistics on the average electricity price in the world economy. However, the available statistics on the average electricity price in the US economy[26] demonstrate that the trend

$$<p_e> \rightarrow R \uparrow$$

really exists (Figure 6.1).

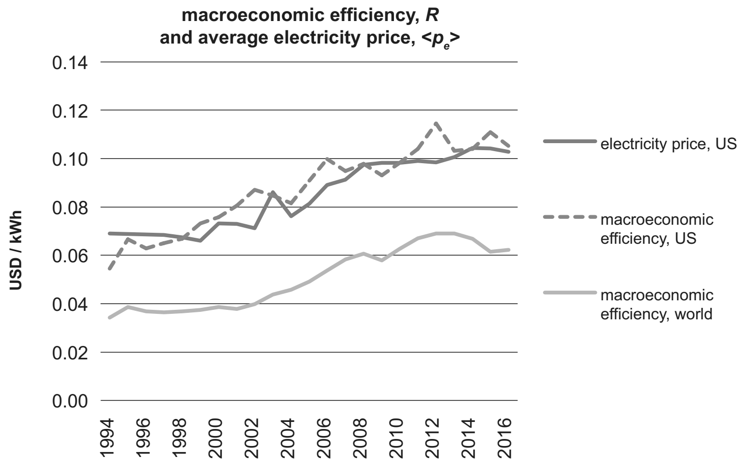


Figure 6.1. Macroeconomic efficiency and average electricity price in the US as compared to the world economy efficiency.

Electricity is a unique product of the global economy. The creation of electrical networks, including energy and information networks, wired and wireless networks, was a crucial step in the socio-economic evolution, comparable with the occurrence of nerves in the evolution of biological systems. The integrated electricity networks to a significant extent determine the real boundaries of local economies.

Electricity is not a commodity that can be stored or sold on the commodity exchange. The generated amount of electricity is dynamically interrelated with the energy needs of all sectors of the economy in real time. Accordingly, the average electricity price is an objective result of the compilation of all energy factors, including the food factor. For this reason, in a sufficiently developed economy, the average price of electricity can be considered as an empirical indicator of macroeconomic efficiency, as demonstrated by the US economy.

The subjective *information* component is absent in electricity prices. Therefore, the demand function to be discussed in Chapter 7, is not applicable to the pricing mechanism in the case of electricity.

6.3. Crude oil price

Extracted oil is an economic product that can be stored in containers, and it can be sold on the stock exchange. Accordingly, the formation of oil prices is very different from the formation of electricity prices because the economic value of oil has an *information* component.[20]

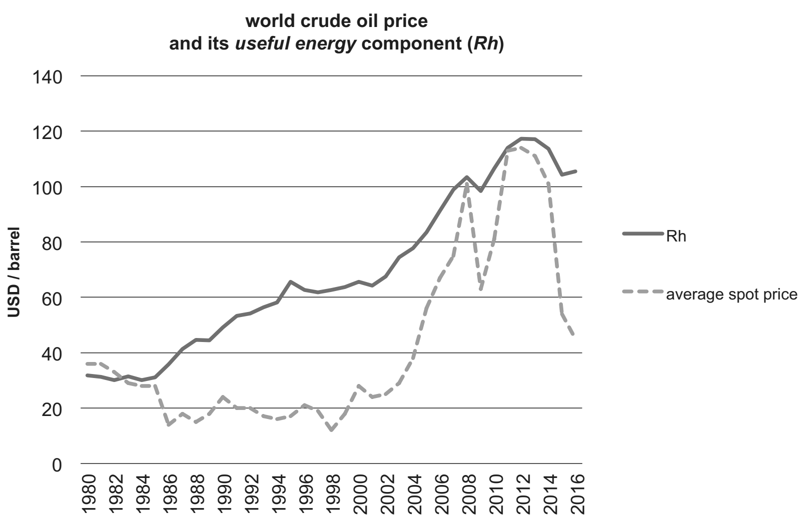
Currently, the main consumer property of oil is that it has a high energy content *h*. Accordingly, the price of oil contains the objective *useful energy* component (*Rh*), which increases with the growing efficiency of the global economy. Also, the oil price contains a subjective *information* component, which can vary widely due to the following factors.

Firstly, crude oil is not only an energy source; it is also a raw material for organic materials production. Therefore, oil extraction means an increase in the *information* component of the working potential of the economy.

Secondly, unlike electricity, crude oil can be produced in excessive amounts. This excessive production means an unnecessary expenditure of the working potential of the economy; appropriate risks are estimated by society as a negative *information* component in the price of oil.

Thirdly, oil is not an indispensable source of energy. The world economy redistributes its working potential in favor of the other energy carriers production, particularly in favor of solar electricity production.

Due to the above information factors, the world's oil price is extremely volatile – it fluctuates within a wide range, from the cost price to the maximum price, which is equal to the *useful energy* component of the price, *Rh* (Figure 6.2).



Note: the crude oil energy content $h = 1.7$ MWh/barrel.

Figure 6.2. World price of oil and its *useful energy* component.

The world oil price dropped to thirty dollars per barrel in 2015. The possibility that the price will again increase up to the magnitude of the *Rh* magnitude depends on various information factors, both positive and negative.

The very high volatility of the price of oil corresponds to the circumstance when the demand function is applicable, but the equilibrium price is absent, because the demand parameter is in an ultra-high range (see next chapter).

6.4 World grain basket price

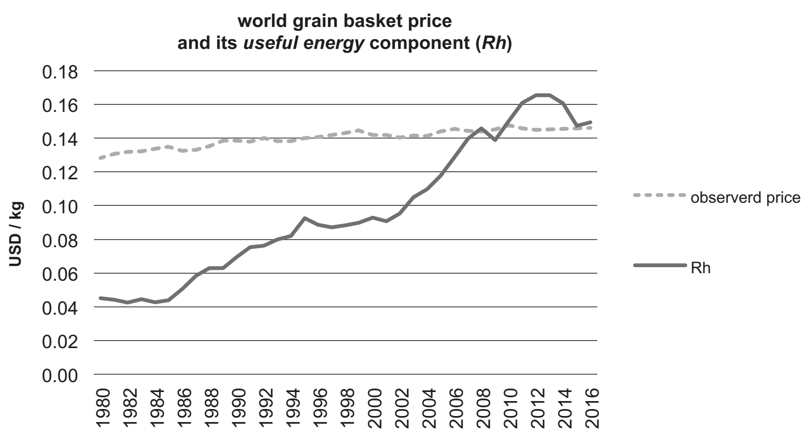
Unlike oil and electricity, grain is a vital product – it is the most important and irreplaceable source of food energy. Therefore, the economic value of the world grain basket should contain a large *information* component that corresponds to the crucial role of grain production in the working potential of the global economy. The principal role of grain production in the global macroeconomic cycle is discussed in Chapter 8.

The world grain basket production has two essential properties (Figure 5.3):

1. production of cereals and soybeans per capita is approximately constant, in accordance with the needs of people in food energy (~ 1 kg/capita/day);
2. the average world price of the grain basket is low and flat (~ 0.14 USD/kg), thus guaranteeing a minimum livelihood for most of the population of the Earth.

The flat price of the grain basket indicates that the grain basket can be considered as an implicit global currency. However, the above fundamental properties of world grain basket production can be challenged for the following reason.

Since world economy efficiency is growing, the *useful energy* component of the grain basket price is also growing and has already exceeded the observed price (Figure 6.3).



Note: The energy content h of the basket is equal to 2,000 kcal/kg, in accordance with the human need for food energy.

Figure 6.3. The dynamics of the world grain basket price.

Accordingly, it became profitable to convert grain into biofuel. As a result, the growing production of biofuels creates a potential threat to food security.

The *useful energy* component of the basket price cannot be higher than the observed price for too long. Therefore, it can be either a decrease in the efficiency of the world economy or a revaluation of the grain basket. The second, more optimistic possibility means that the global economy could undergo a transition to a new steady state with a much higher price of the grain basket and with a substantially increased agricultural sector in the world GDP.

The revaluation of the grain basket would exclude the use of grain for biofuel production, also, the revaluation could maintain the principal role of the grain basket as implicit global currency.

With the growing efficiency of the global economy, the *information* component in the grain basket price continuously decreased. Such a decrease provided a flat price of the grain basket, which is essential to the stability of the global economy. As a result, the grain basket is now obviously undervalued.

Thus, a further sustainable growth of the world economy efficiency is possible with a substantial revaluation of the grain basket, that is, with a sharp increase in the *information* component of the basket price.

6.5. Global climate and energy prices

The working potential of the socio-economic system is the sum of the working potential of all society members. In turn, the working potential (i.e. the physical ability to do the work) of each person significantly depends on the ambient temperature.

People work more productively at a comfortable temperature, which can be estimated at about 21°C. If the temperature outside is much lesser or greater than the comfort zone temperature, we must use appliance-based heating or air conditioning. This means an increase in energy consumption and production costs.

Ceteris paribus, the competitiveness of the economy in different climates depend on energy prices and energy consumption for heating and cooling of living and working areas during the year. The heat energy consumption depends on the time (t), and it is proportional to the absolute difference $\theta(t)$ between surrounding temperature $T^{\circ}(t)$ and comfort temperature T°_c:

$$\theta(t) = \left| T^{\circ}(t) - T^{\circ}_c \right|$$

This is the relative magnitude of the total energy consumption we call "climate discomfort index." The climate discomfort index is proportional to the definite integral of θ-function during the year:

$$\textit{climate discomfort index} \sim \int \theta(t)\, dt / 365; \qquad (0 \le t < 365).$$

To perform integration, the temperature fluctuations may be approximated by the sine dependency:

$$T^{\circ}(t) = A + B \sin(2\pi t / 365 + j).$$

Our estimates of the climate discomfort index for some cities are represented in Table 6.1.

Table 6.1. The climate discomfort indexes.

City	A (°C)	B (°C)	*Index*	City	A (°C)	B (°C)	*Index*
Caracas	23.1	1.5	2.1	London	11.3	6.0	9.7
Havana	23.7	3.0	2.8	New York	12.1	12.2	10.0
Miami	24.4	4.3	3.7	Erevan	12.4	13.5	10.4
Los Angeles	17.2	3.6	3.8	Strasbourg	10.5	9.5	10.5
Hong-Kong	23.2	6.0	4.1	Bonn	10.4	9.0	10.6
Buenos Aires	17.7	6.5	4.7	Beijing	12.5	14.5	10.9
Cairo	21.3	7.5	4.8	Boston	10.7	12.5	10.9
Tunis	18.8	8.5	5.6	Geneva	9.9	10.0	11.1
Jerusalem	16.1	7.5	5.9	Glasgow	8.5	6.0	12.5
Singapore	26.9	2.5	5.9	Kiev	8.1	11.5	12.9
Manila	27.6	2.0	6.6	Warsaw	7.8	10.0	13.2
Nice	14.8	7.5	6.6	Oslo	6.3	10.5	14.7
Delhi	23.8	10.0	6.6	Ottawa	6.2	15.0	14.8
San Francisco	14.0	4.4	7.0	Helsinki	6.1	11.5	14.9
Tokyo	16.0	10.5	7.5	Moscow	5.4	12.5	15.6
Istanbul	14.4	9.5	7.6	Saint-Petersburg	4.8	12.0	16.2
Melbourne	13.3	6.0	7.7	Vladivostok	4.5	17.0	16.6
Milan	13.3	10.5	8.6	Novosibirsk	1.6	18.0	19.4
Shanghai	16.3	13.5	9.1	Murmansk	–0.3	12.0	21.3
Tashkent	14.3	13.0	9.4				

Note: The coefficients magnitudes (A and B) were estimated based on the 8-year observations data available at the web-site www.climate-zone.com.

The climate discomfort indexes may differ by more than 10 times in local economies. Hence, for equal competitiveness, the energy prices in corresponding economies must also differ by 10 times, and an appropriate energy price regulation is required.

The differences in climatic conditions had a profound impact on the evolution and development of local economies. The first economies had emerged and developed in hot climates, but then, too hot weather has resulted in an impediment to economic growth.

The development of the economy in hot climates largely depend on the creation of comfortable environmental temperatures for working and living, which requires a large expenditure of energy for air conditioning. Thus, the rapid development of information technologies in India has started with the widespread introduction of air conditioning systems.

Economic progress in tropical countries depends on the increase in solar electricity generation; an appropriate regulation of energy prices is required. In the countries with a hot climate, subsidies for solar electricity production is needed to accelerate the growth of the working potential of the economy.

Another example relates to countries with a cold climate. Thus, due to the cold climate, Russian cities are at the bottom of Table 6.1. For equal competitiveness, energy prices in Russia should be substantially less than in other countries, which calls for appropriate energy prices regulation starting with electricity price regulation.

7

Demand function and its applicability

Qualitatively different trends in the prices of electricity, oil and grain basket demonstrate that equilibrium prices depend primarily on the society's evaluation of the information component in the product value.

The range and quantity of manufactured products are regulated in the economy by its working potential redistribution, so the prices of various products are interrelated. The minimal price spread exists for goods produced in massive quantities by many manufacturers. For such products, the society more accurately estimates their real value.

The above interpretation of pricing is fundamentally different from the current concept of aggregate demand and supply accepted in the game paradigm, which is far from reality in most cases.

Indeed, the concept of demand and supply is based on the paradigm of one-component value. That is, this concept takes into consideration only the product price, without considering its *useful energy* and *information* components. Therefore, this concept can not explain the qualitative differences between the energy carriers price trends discussed above. Also, the concept of supply and demand does not apply to the formation of prices of intellectual products, which are usually piece goods.

However, despite its oversimplification, the supply/demand concept provides a useful notion of the demand function. The existence of the demand function means that the quantity of goods sold decreases with the increase in the goods price.

The demand function is a psychologically predetermined function, and its physical meaning is that the social living system is trying to reduce the expenditure of the working potential of the system, thereby maintaining the system's viability. Therefore, most people prefer to buy products with the lowest price.

In the case of the goods for which the demand function has a real sense, this function can be approximated by the inversely proportional dependency

$$Q = k/p^{\alpha} \tag{7.1}$$

where: Q is the quantity of sold goods;
p is the price of the goods;
α is the "demand parameter" ($\alpha > 0$);
k is some coefficient.

In terms of physical macroeconomics, the demand function existence means that there is a nonlinear negative feedback in the economy, which is an objective stabilizing factor in the formation of equilibrium prices.

If the quantity of sold goods corresponds to the dependency (7.1), then the formation of equilibrium price can be explained based on the balance equation,

$$S\ (sales) = E\ (expenses) + G\ (gain) + T\ (taxes)$$

Indeed, bearing in mind that sales amount is $S = pQ$, and expenses $E = p_0Q$ (p_0 is a cost price), we get:

$$S = k/p^{\alpha-1}; \qquad E = k\,p_0\,/p^{\alpha}$$

If the product price is equal to its cost price, then the sales amount is

$$S_0 = k/p_0{}^{\alpha-1}$$

therefore, $k = S_0\,p_0{}^{\alpha-1}$ and we obtain:

$$S = S_0/x^{\alpha-1}$$

$E = S_0/x^{\alpha}$

where the dimensionless parameter $x = p/p_0$. Hence, the profitability magnitude is

$$\beta = (S - E)/E = x - 1$$

In the economy without taxation ($T = 0$), the profit magnitude (gain) is

$$G(x) = S - E = S_0\,(1/x^{\alpha-1} - 1/x^{\alpha})$$

Note that if the cost price is not varying, then the dependency of $G(x)$ on $x = p/p_0$ means its dependency on the price p. It may be implied in most cases: the cost price is a conservative variable, while the price can always be fixed at any level. With this approximation (so S_0 is constant), the maximum of $G(x)$ is reached at the point

$$x_m = \alpha / (\alpha - 1)$$

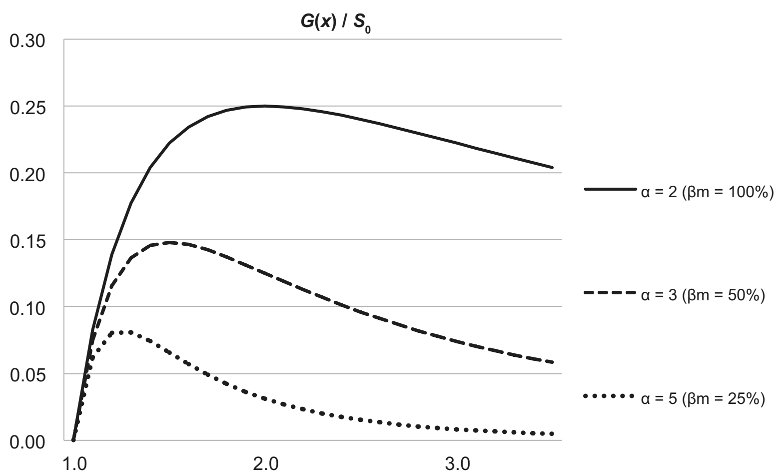
So, the optimal profitability is

$$\beta_m = 1 - x_m = 1 / (\alpha - 1)$$

Consequently, the equilibrium price exists if the demand parameter $\alpha > 1$. In the range of the "ultra-high demand" ($0 < \alpha \leq 1$), the equilibrium price does not exist in the non-taxable economy.

The current static taxation, with constant tax rates, does not contribute to the equilibrium prices formation in the case of the ultra-high demand, so the instability range ($0 < \alpha \leq 1$) remains the same (see Appendix B).

The equilibrium price and optimum profitability are achieved at the point of maximum of the $G(x)$ function (Figure 7.1).



Note: In the range of ultra-high demand ($0 < \alpha \leq 1$), optimum profitability (β_m) and equilibrium prices do not exist, that is, the system is unstable.

Figure 7.1. Gain/sales graphs for the non-taxable economy.

The demand function is not applicable when considering the pricing mechanism for electricity and grain basket. As we have seen above, the average electricity price is equal to the macroeconomic efficiency. The world grain basket price is flat because the grain basket is an implicit global currency; the fundamental reasons of this fact will be discussed in more detail in the next chapter.

As to the equilibrium oil price, we observe that the world oil consumption weakly depends on changes in oil price. Formally, this means that the demand parameter α is in the range of ultra-high demand ($0 < \alpha \leq 1$). Accordingly, the equilibrium price does not exist in the non-taxable economy, and, as it is demonstrated in Appendix B, the equilibrium price also does not exist under the current static tax system.

8

Macroeconomic cycle

The bread around the head
Russian proverb

The cyclic process of grain production is vital and the most energy-consuming process in the global economy. Therefore, the evolutionary process of grain production underlies the annual cycle of world GDP production.

The emergence of money and banking was associated with grain production. In the third millennium BC in Mesopotamia, grain was used as cash deposits and the development of written language was stimulated by the necessity of managing bank accounts.[27]

In the ancient self-sufficient economy which produced mainly grain and in Asia mainly rice, the average grain harvest characterized the working potential of the economy. As the measure of the working potential, the grain was real money. The total amount of grain, that is, the money supply (M) in the ancient economy had to be 10–20% larger than the average grain yield, to ensure the necessary supply of grain in the event of crop failure.

Today, the self-sufficient world economy produces, in addition to grain, a huge amount of other tangible and intangible goods due to the much higher labor productivity in agriculture than in ancient times. Therefore, instead of grain, money has become a measure of the working potential of the economy, and this potential is characterized by the GDP value.

However, the ratio M/GDP in the world economy is now about the same as it should be in the economy in which grain constitutes money.[28]

Moreover, for at least during the last thirty-five years, the price of the world grain basket is flat (see Figure 5.3 in Chapter 5), so the grain basket can be considered as a de-facto global currency.

The concept of the macroeconomic cycle is a logical consequence of the real paradigm of the economy that treats the socio-economic system as a working system, not as a game of the market players. Any working system can do the same work indefinitely in time only by repeating the same working cycle. *The macroeconomic cycle is the working cycle in the global economy, and this working cycle was evolutionary predetermined by the grain production cycle.*

The current economic paradigm considers the economy as a social game. The game can go on continuously or it can be interrupted at any time, so the concept of the macroeconomic cycle does not exist in the game paradigm. Thus, the current one-year period chosen for GDP calculation is quite an arbitrary period, and it can be changed in principle within the framework of the game paradigm.

The annual period of GDP reproduction is an objective period caused by the existence of the macroeconomic cycle. This conclusion is evidenced by the *M*/GDP ratio (≈110%) in the global economy, and this figure can hardly be explained without the concept of the macroeconomic cycle.

The current notion of business cycle in macroeconomics really means that there are spontaneous periods of increase and decrease in extensity of the macroeconomic cycle, like unpredictable periods of drought and favorable weather for a good harvest. The regularity and duration of business cycles are unpredictable, so these cycles, from the physical point of view, are not real cycles.

By using the notion of the macroeconomic cycle, the steady state of the economy can be defined as a cyclical process of the annual reproduction of GDP, characterized by the growing extensive and/or intensive parameters of the cycle.

The existence of the macroeconomic cycle means that global GDP production correlates with the annual cycle of grain production. This correlation exists because the grain production is a vital, irreplaceable and the most energy-consuming process in the global economy.

At the beginning of socio-economic evolution, grain production constituted the main part of GDP. The agricultural sector now makes up about six percent of world GDP. However, grain production is still the basis of the macroeconomic cycle for two reasons.

Firstly, the cycles of the global economy operate primarily due to the sunlight energy absorbed in food biomass production. Solar radiation inflow varies in accordance with the annual cycle of the Earth's rotation around the Sun thus forming the cyclical production processes in agriculture and fisheries.

Secondly, food biomass production, especially grain production is a vital process in the global economy; the specific properties of grain basket production play a crucial role in the structure of the world economy. Due to these properties, grain has fulfilled the function of money in the ancient economy, and the physical basis of the ancient monetary system still continues to date.

8.1. GDP and money supply relationship

The observed relationship between money supply and GDP in the global economy (Table 8.1) can be explained by the existence of the macroeconomic cycle, which is an evolutionary successor of the annual cycle of grain production.

Table 8.1. The broad money (M), GDP and M / GDP ratio in the world economy.[29]

Year	*M, trn USD*	GDP, *trn USD*	*M* / GDP
2012	79.1	71.8	1.10
2014	81.2	74.2	1.09
2016	77.6	75.9	1.02
2017	86.7	79.5	1.09

Indeed, if we imagine a self-sufficient economy that produces only grain and the grain is the money, then GDP is equal to the average yield of grain:

$$\mathrm{GDP} = Yield$$

Also, the money supply equals the amount of grain produced and consumed during the year (*Yield*) plus grain reserves:

$$M = Yield + Reserve$$

The previous grain harvest is gradually consumed during the current year, however, the grain (money in cash) is replaced with written commitments (non-cash money) on the next harvest distribution, so the total money supply does not change. In such an economy,

$$M / \mathrm{GDP} = 1 + Reserve / Yield$$

Table 8.1 demonstrates that currently the "reserve" is about ten percent of the "yield" in the global self-sufficient economy.

8.2. World grain basket as an implicit global currency

In the ancient economy considered above, one seed is the smallest coin. The weight of the seed is constant, so, with the growth of the economy, the GDP increases, but the unit of GDP measurement remains constant. Similarly, contemporary money in the developed economy is constant.

The ancient economy is a self-sufficient economy, so it produces as much grain as needed for its livelihood, that is, about one kilo per person per day. In such an economy, the increase in grain production (i.e. the GDP growth) corresponds to population growth.

The yield of grain is proportional to the physical work done by the ancient economy during its macroeconomic cycle. In such an economy, the yield of grain is proportional to the working potential of the socio-economic system, and the unit of measurement of the working potential (one seed) is constant.

The working potential of the contemporary economy allows for the production, in addition to grain, a lot of other goods. The grain has ceased to be a measure of the working potential of the system, and now money is such a measure.

From 1980 to 2014, the world grain basket price rose just 0.05% per year and the average price was 0.14 USD (Figure 5.3). This means that the grain basket can be considered as an implicit global currency with an exchange rate

$$1 \text{ grain basket} = 0.14 \text{ USD}$$

In the same period, world GDP production has increased from 6.6 to 29.4 USD per capita per day, that is, the working potential per capita has increased by four and a half times.

The working potential of the ancient economy, measured in grain baskets, was one basket per capita per day. The working potential of the world economy measured in grain baskets per capita per day, in 1980 and 2014 equals:

$$6.6 \text{ (USD)} / 0.14 \text{ (USD/basket)} = 47 \text{ baskets in 1980;}$$

$$29.4 \text{ (USD)} / 0.14 \text{ (USD/basket)} = 208 \text{ baskets in 2014.}$$

Therefore, the working potential of the ancient economy, the working potentials of the world economy in 1980 and 2014, correspond to the capability of producing, respectively, one grain basket, 47 grain baskets and 208 grain baskets per person per day (Table 8.2).

Table 8.2. The working potential of the world economy per capita measured in US dollars and grain baskets per capita per day.

GDP per capita per day	Ancient economy	World economy, 1980	World economy, 2014
measured in USD	–	6.6	29.4
measured in grain baskets	1	47	208

For the world economy, there is no need to produce 208 grain baskets per capita per day – the world economy must produce one grain basket to feed people. The huge increase in the working potential of the global economy is related primarily to the increase in the information component of this potential.

The above estimates indicate that the working potential per capita in 2014 has increased by 208 times since the beginning of socio-economic evolution. In 1980, this difference was only 47-fold: the growth of the working potential is accelerating due to exponential growth of its information component.

The flat price of the world grain basket is the fundamental property of the macroeconomic cycle. However, the global economy has come to a point where the situation can dramatically change.

8.3. Global economy: on the edge of "phase transition"

The working potential of the ancient economy can be considered as a standard potential; the current working potential can be estimated in relation to the standard potential.

In the case of a global catastrophe with destruction of industry infrastructure, the working potential of the economy will return to its standard value. For this reason, the working potential of the world economy, allowing for the production of one grain basket per capita per day, is a standard potential, therefore the grain basket is an implicit world currency.

The flat grain basket price is a fundamental stabilizing factor. However, in the coming years, the situation in the world economy may be significantly worsened. Indeed, the *useful energy* component in the basket price is

$$\textit{useful energy} = R\,h$$

where R is the world economy efficiency, and h is the food energy content of the basket (2,000 kcal per capita per day).

With the growing efficiency of the world economy, *useful energy* also grew, and recently it has exceeded the grain basket price (Figure 6.3).

Hence, the world grain basket became an ordinary source of industrial energy, such as a barrel of crude oil, and not a vital source of food energy. Accordingly, the grain basket can turn into an ordinary energy carrier with the same price volatility as that of oil prices.

This system conflict between the flat grain basket price and the growing efficiency of the world economy can be avoided in the case of a sharp increase in the basket price. In this case, a substantial increase in the *information* component of the basket price will take place. Such a sharp increase is analogous to a sudden change in the entropy of the thermodynamic system because of phase transition between different aggregate states of the system (during freezing or melting, evaporation or condensation etc.).

A sharp rise in the world grain basket price would be equivalent to the revaluation of the basket as an implicit global currency, and such a revaluation is needed for further growth of the world economy efficiency, because the *information* component in the world grain basket price is currently significantly undervalued.

Grain is not just a source of energy – the grain is a high-tech and indispensable food product. Accordingly, the *information* component in the grain basket price should be several times greater than the *useful energy* component.

Another alternative to resolve the system conflict between the flat grain basket price and the growing efficiency of the world economy is that the efficiency will stop growing.

8.4 Why gold and bitcoins are not real money?

The physical meaning of money is that money is the unit of measurement and the means of distribution of the working potential of the economy. The grain in the ancient economy and money in today's economy are such units – the work done by the socio-economic system during the macroeconomic cycle is proportional to the yield of grain in the ancient economy, and it is proportional to contemporary GDP.

In nature, the health and vitality of bee society is characterized by the amount of honey harvested during the bee life cycle, which is one year. Honey (bee money) is a measure of the working potential of bee society.

In the economy, gold and bitcoins are not real money, because they are not a measure of the working potential of the system. With significant constraints, gold and bitcoins can be a means of payment and savings, but the total amount of gold or bitcoins is not equivalent to the amount of work that can potentially be done by the self-sufficient social system.

If the economy is not self-sufficient, it can mine gold and it can "mine" bitcoins, thus maintaining the system's vitality through the import of food. But the self-sufficient economy must first produce grain and only then it can produce other goods including gold and bitcoins.

The gold and bitcoins are respectively tangible and intangible commodities, so their use in payments is a commodity exchange. Money is not a commodity – the money is rather the unit of the working potential of the economy and the means of its distribution.

So, the real meaning of monetary payments is that each payment is a single act of redistribution of the working potential of the socio-economic system. Such an act, in the case of a non-cash payment is fixed by two corresponding entries in bank accounts.

Basic properties of gold and bitcoins as compared with real money functions are given in Table 8.3.

Table 8.3. The properties of gold and bitcoins as compared with the functions of money.

Property or function	Gold and bitcoins	Money
free energy (GDP) unit	–	+
means of GDP distribution	–	+
tangible / intangible commodity	+	–
means of payment	–/+ (commodity exchange)	+
means of savings	–/+ (low liquidity)	+

The concept of the macroeconomic cycle and the physical concept of money reflects the importance of grain production in socio-economic evolution.

Grain is a high-tech product and people are far from creating industrial technologies comparable with those realized by nature in each seed. Nevertheless, the *information* component in the grain basket price is now greatly undervalued.

In the event of a global catastrophe with full destruction of the world's industrial infrastructure, most goods will depreciate but not grain. For the survival and recovery of the economy, people will first require a grain reserve.

Nature has placed a vital information potential in grain, and this information is now becoming more and more understandable for people. However, it is people themselves who also create information by developing modern technologies and expanding their knowledge database. The socio-economic evolution will not start from nothing in the case of a global catastrophe. The evolutionarily advanced economy will quickly revive, if people will be able to save grain reserves and the hardcopies of books and other documentation which constitute accumulated knowledge.

9

GDP distribution and economic stability

For sustainable development of a living system, there must be a balanced distribution of its working potential between all participants of the system. In biological systems, the balance is maintained through dynamic (nutritional and metabolic) feedback.

The working potential of the economy is measured in money, and it is distributed through the means of distributing GDP. A balanced GDP distribution is carried out through the pricing mechanism discussed in previous chapters.

In some cases, the formation of equilibrium prices can be interpreted in terms of the psychologically predetermined demand function. However, demand function is not applicable in the case of ultra-high demand. Also, the demand function does not exist in the case of intellectual products and it is not applicable to the formation of global energy prices.

GDP distribution is also carried out by means of taxation. However, the current static taxation, with constant tax rates, does not contribute to economic stability because static taxes do not act a stabilising negative feedback in the manner of demand function.

Due to the above reasons, the distribution of GDP in the global economy is currently unbalanced, and this imbalance is one of the major factors of instability and economic slowdown.

An important practical finding in physical macroeconomics is the concept of dynamic added value taxation (DAVT). A replacement for the static VAT onto the DAVT seems to be necessary for sustainable development of the global economy.

9.1. Income inequality and economic growth

The imbalance in GDP distribution leads to excessive economic inequality. In turn, such excessive inequality slows down economic growth. Natural causes of this slowdown are understood when considering that GDP is a working potential (free energy) of the social living system, which is spent and reproduced during the life cycle of the system, that is, during the macroeconomic cycle. Indeed, the living system has the ability and incentives to grow, if:

1) the external resources of matter and energy are sufficient for growth;
2) the working potential (free energy) of the system is distributed in such a way that all system members receive enough free energy to increase their working potential;
3) all society members spent the received free energy entirely during their life cycle.

The imbalance in GDP distribution and excessive inequality means that the second and third prerequisites of economic growth are absent.

A central reason for the existing imbalance in GDP distribution in the global and local economies is that existing taxes were introduced without any system analysis. Therefore, the current tax systems are too complex and inefficient.

GDP is distributed between producers and society in the first place by means of added value taxation. That is, added value tax is the system-defined tax; all other taxes are optional and may be eliminated if the added value taxation is properly organized. The current VAT scheme is significantly flawed, so it should be fundamentally changed.

9.2. Dynamic added value taxation (DAVT)

For a balanced GDP distribution, stabilizing feedback is to be introduced into the global economy in the form of DAVT. The destabilizing static VAT should be abolished because any changes in the VAT rate and/or the introduction of similar static taxes such as financial transactions tax then become useless measures.[30]

In this section, we introduce the basic system properties of DAVT; a more complete version of the DAVT theory is presented in Appendix B.

Correct scheme of added value taxation

The added value is created in the economy by joint efforts of producers and society. The overall value should be distributed between producers and society to compensate for their energy expenses. The energy expenses in the production of export goods are the same as the energy expenses in the production of non-export goods; therefore, the added value tax must be the same in both cases.

However, in accordance with the VAT scheme, imported goods are taxed, while the exported goods are not taxed, and this is incorrect. With an adequate tax scheme, it should be the other way around. That is, *the correct added value tax is the tax on domestic production, not the tax on domestic consumption*. Since the

VAT is a tax on domestic consumption, the VAT tax base is defined incorrectly from the system perspective.

Unlike VAT, the DAVT is a tax on domestic production. The DAVT scheme implies that exported goods are taxed exactly as the goods produced for domestic consumption; such a scheme would allow the problems of tax refund and pseudo-exports to eliminated from the system.

The other flaw in the VAT scheme may be found with the tax base which is inadequate in some cases. That is, if the tax rate is N and the sales amount is S, then the VAT to be paid is

$$SN/(N+1)$$

minus the VAT paid by suppliers. Such a scheme would be correct if the tax rate N is the same for all producers. However, with existing privileged tax rates, the total tax for the chain of producers is determined by the tax rate for the final producer, which is not correct.

A correct added value tax scheme must contain the added value (ΔS) as a tax base, not the sales amount S. Namely, if, in the balance equation

$$S \text{ (sales)} = E \text{ (expenses)} + G \text{ (gross profit, or gain)} + T \text{ (added value tax)}$$

the total expenses E are subdivided into "internal" and "external" expenses,

$$E = E^{int} + E^{ext}$$

then, with the tax rate N, the added value is

$$\Delta S = G + E^{int}$$

The correct added value tax magnitude which is applicable in any cases is

$$T = N\,(G + E^{int}) \tag{9.1}$$

The correct equality (9.1) will be used below both for the VAT and the DAVT to compare basic system features of these taxes.

Eliminating profitability threshold

Let us define the "internal profitability" as

$$\lambda = (S - E)/E^{int}$$

Then the usual profitability is

$$\beta = (S - E) / E = \lambda\ E^{int}$$

By using the balance equation and the correct equality (9.1) we obtain:

$$G / T = (\lambda - N) / (\lambda + 1) / N \tag{9.2}$$

In the case of the VAT (N is constant) it follows from equality (9.2) that the production is unprofitable if $\lambda < N$, that is, there is a profitability threshold. Moreover, the T / G ratio has a discontinuity at the point $\lambda = N$ which means a serious system distortion.

The profitability threshold does not exist in the DAVT scheme with the dynamic tax rate, which is directly proportional to internal profitability:

$$N = n\lambda$$

where n is a constant tax coefficient ($0 < n < 1$). Then for the DAVT we have:

$$G / T = (1 - n) / n / (\lambda + 1) \tag{9.3}$$

Equality (9.3) demonstrates that the profitability threshold does not exist, so all producers, with any internal profitability, can be legal tax payers. Also, the T/G ratio has no singularities. *The system instability in the DAVT-using economy is sharply diminished as compared with the VAT-using economy.*

Balanced added value distribution

As it follows from (9.2), the added value distribution is misbalanced in the VAT-using economy in favor of the high-profit producers: if the internal profitability λ increases from the profitability threshold ($\lambda = N$) to infinity, then the G / T ratio increases from zero to $1 / N$.

In the case of the DAVT, the G / T ratio steadily falls with the growing internal profitability, so the added value distribution is not misbalanced in favor of the high-profit producers. *The DAVT eliminates immanent destabilizing features of the static taxation – the profitability threshold and the tax burden disparity.*

Simplified accounting

Based on the balance equation and (9.3), we get for the DAVT:

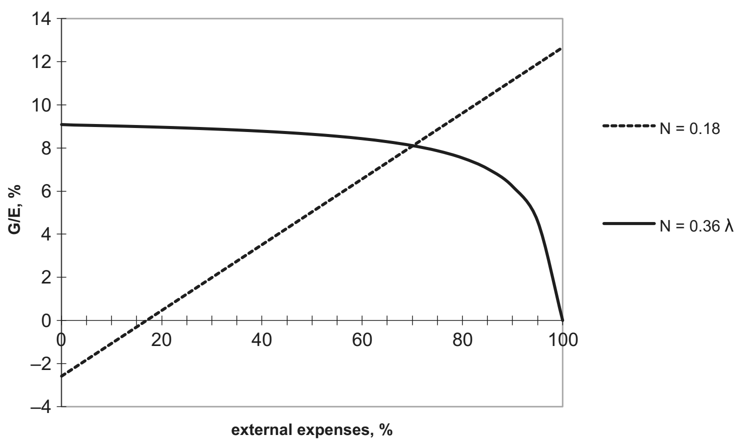
$$G = E^{int}\,(1-n)\,\lambda\ /(1+n\lambda)$$
$$T = E^{int}\,n\ (\lambda+1)\,\lambda/(1+n\lambda) \tag{9.4}$$

DAVT accounting is much simpler when compared with VAT accounting:

– the producers are in equal conditions – the tax coefficient n is the same for all of them;
– the complex schemes of privileged taxation are no longer needed;
– the exporters are the tax payers, therefore, so tax refund problems and pseudo exporting completely disappear;
– the tax burden is shifted from low-profit producers to high-profit producers, so profit tax can be abolished.

Productive economy stimulation

Unlike VAT, DAVT creates incentives for the development of a productive economy. Indeed, in the VAT-using economy, the greater the percentage of external expenses, the more profit. Such an economy encourages mediation and pure speculative operations, and it does not stimulate its own production. On the contrary, the DAVT-using economy stimulates its own production (Figure 9.1).



Note: In the case of VAT ($N = 0.18$) the G/E ratio linearly grows with the increased percentage of external expenses. Under DAVT ($N = 0.36\lambda$) the G/E ratio diminishes with the growing percentage of external expenses and equals zero in the absence of internal expenses.

Figure 9.1. Two different economies: The G/E graphs for a low-profit enterprise (profitability $\beta = 15\%$).

The DAVT-using economy is a production-oriented one; moreover, the profit extraction is impossible if internal expenses are absent. Consequently, a purely speculative financial activity, with zero internal expenses, is meaningless because all income must be paid as tax.

Maximum profitability restriction

Thus, the DAVT does not allow for money making out of thin air. A pure speculative activity, with negligible internal expenses and, consequently, with infinite internal profitability, is unprofitable in the end result.

Also, maximum profitability is restricted by $1/\sqrt{n}$ magnitude. Namely, the gross profit, expenses, DAVT and profitability magnitudes, at the point of maximum profitability are (see Appendix B):

$$G_m = S\,(1 - \sqrt{n})/(1 + \sqrt{n})$$

$$E_m = T_m = S\sqrt{n}/(1 + \sqrt{n})$$

$$b_m = \lambda_m = 1/\sqrt{n}$$

For instance, if the tax coefficient $n = 0.36$ (that corresponds to our reasonable estimates), then the maximum profitability b_m is 167 percent – more than enough for a productive economy.

Theorem on stability

Currently, some "grey" financial schemes involve a fictitious enterprise fragmentation (consecutive or parallel) to diminish the VAT payments and extract super-profits. The possibility of such schemes creates additional instability in the economy. In the DAVT-using economy, the instability decreases dramatically, which is proved by the *theorem on stability* (see Appendix B).

According to this theorem, the DAVT-using economy is stimulated to decrease excessive mediation and fragmentation. Nevertheless, this does not stimulate monopolistic tendencies because only the length and thickness of production chains are forced to be shortened, not the number of chains.

Equilibrium prices

DAVT can stabilize the economy within the ultra-high demand range where both the untaxed economy and the VAT-using economy are unstable (see Appendix B).

Such stability means that the equilibrium price and optimum profitability exists for the products with the demand parameter α which is in the range

$$0 < \alpha \leq 1$$

The global DAVT could stabilize the world oil price, which currently does not have a point of equilibrium.

DAVT as stabilising negative feedback

The features of the DAVT system allows for this tax to be a stabilizing negative feedback introduced into the socio-economic system in addition to the psychologically predetermined demand function.

This DAVT concept was initially suggested[3] through an analogy with the negative feedback amplifier. A crucial negative feedback feature is that the negative feedback sharply improves the electric amplifier stability while the amplification factor is diminished.[31]

In the DAVT tax scheme, the tax rate magnitude is defined as $N = n\lambda$. Since the internal profitability λ can be very large, the N magnitude can also be very large. Hence, the N magnitude should not be considered as a real tax rate. Instead, the N magnitude should be considered as a feedback factor, which can reach infinite magnitudes.

The internal profitability λ is directly proportional to profitability and it is inversely proportional to the percentage of internal expenses:

$$\lambda = \beta E / E^{int}$$

Consequently, the feedback factor N increases with increasing profitability, and it increases with decreasing percentages of internal expenses. As a result, the DAVT does not allow the profitability to be too high, and it does not allow the internal expenses to be too small.

Global DAVT

Unlike VAT, the DAVT is a correct and balanced added value tax; also, DAVT has powerful stabilising features. Therefore, the DAVT can be used as the global system tax.

The global application of the DAVT in the first place means that the tax scheme should be the same for all local economies. Also, local economies must pay part of their DAVT to contribute to solving common problems of the world economy, such as environmental issues, food security, lack of energy resources, production of renewables and so forth.

The global DAVT could stabilize world energy prices, firstly, oil prices. Also, the global DAVT could sharply reduce the number of fraudulent and purely speculative financial transactions.

With the global DAVT, a more balanced distribution of world GDP could help reduce economic disparities and thus encourage a more sustainable development of the global economy.

10

Information, symmetry and harmony in the economy

Physical macroeconomics claims that the creation of information is a fundamental property of living systems. The physical meaning of information is that its creation increases an intangible component of the working potential of the system. In the case of the economy, this increase may be reflected in monetary units as a growth of the *information* component of GDP.

The features of living systems also include the notions of symmetry and harmony. Yet, what is the physical meaning of these notions in application to the economy?

10.1. Entropy and information

In physical macroeconomics, the creation of information is treated as an intangible result of the work done by the combined system

$$\{\text{living observer} + \text{observed system}\}$$

For example, people observe the Sun and other stars, which are open thermodynamic systems. Physical work is performed in the stars under the influence of nuclear, electromagnetic and gravitational forces, resulting in an increase in the entropy of the universe because of solar radiation. At the same time, people perceive solar radiation not only as a source of primary energy, but also as light signals. By analyzing these signals, people do mental work (which is physical work at the level of neurons) and thus they create information. Accordingly, the information component of the working potential of humanity increases, along with an increase in the entropy of the universe.

For a living observer, the creation of information is produced as a useful result instead of useless entropy extracted to the environment. In the combined socio-economic system, society acts as an observer. The creation of information and entropy extraction provide an increase in information potential of the economy, which is reflected in the growth of the information component of GDP.

The global economy increases the informational component of its working potential, while at the same time, the environment is polluted with thermal and other wastes. So, a viable economy should distribute an appropriate part of its information potential (accordingly, an appropriate part of GDP) to minimize dangerous environmental consequences of economic growth.

It is noteworthy that entropy is a thermodynamic concept which can be applied to the economy only for the analysis of physical-chemical processes in various technologies. Entropy is an objective quantity that can be measured by physical methods.

Unlike entropy, subjective information is not an objective physical quantity and it cannot be measured by physical methods; it can only be evaluated by a living observer based on the measurement and analysis of appropriate physical-chemical signals.

10.2. Subjective nature of information

Information is a subjective quantity that depends on the observer. Different observers can evaluate information in diverse ways, in other words, they can differently assess the change in the working potential of the observer and the observed system because of their work.

Thus, from the point of view of human society, the creation of information through the construction of industrial infrastructure means an increase in the working potential of the economy. However, most wild animals negatively assess the information content of this infrastructure, and they flee far away from cities and industrial enterprises. At the same time, the information potential of dirty urban areas can be highly appreciated by the rat community.

The subjective nature of information means that information cannot be characterized only as a "true" or "false" value. Such a binary estimation of information is suitable for abstract and artificial computing systems, not for living systems. For living systems, information can be useful or useless, including all possible intermediate estimates, depending on how the observer evaluates the contribution of information to the working potential of the combined system {observer + observed system}. These evaluations may change with time.

So, Newtonian (classical) mechanics for a long time was considered as a true (i.e. useful) theory, but then it became clear that it is useless for describing a microcosm, where, instead of classical mechanics, quantum mechanics is more applicable.

During a life cycle, some of the useless information is removed from the living system in the form of entropic and material waste. However, the remaining useless and even harmful waste accumulates in the living system, thereby limiting its lifetime. As for useful information, it is genetically inherited by biological systems, also, useful information is transmitted through the learning process.

Within the economy, society performs the role of an observer, who evaluates the *information* component of economic value. This subjective evaluation, together with the objective *useful-energy* component of value, is the main factor in the pricing process, which can be adjusted if the demand function is applicable (see Chapter 7). It is noteworthy that in principle, a demand function can also be interpreted as a manifestation of society's assessment of the information component of value.

Society evaluates the *information* component of the working potential of the economy in monetary units. In local economies, these subjective evaluations may differ, which is reflected in the existence of national currencies. In time, globalisation processes can lead to the disappearance of national currencies and for the emergence of a fully adequate world currency.

10.3. Information: units of measurement

Living systems create intangible information by analyzing received physical-chemical signals. This information can be encoded and transmitted as other material signals.

Physical-chemical signals may be "digitized" in the form of binary signals; the total amount of binary signals is measured in bits (or bytes). However, this amount is not the amount of information in terms of physical macroeconomics.

Thus, the computer text of this book contains about 500 kilobytes of binary signals, and the same quantity of binary signals would contain the text of the same size with a random sequence of characters. Of course, the author's work does not only consist of typed in random characters on the keyboard that would require a very small consumption of useful energy. In the event of such a silly work, the consumed useful energy would be converted into useless heat (i.e. entropy) only, without any additional information creation. Thus, the amount of information cannot be measured in bytes.

The author of this book has created additional information because of the work done which is conceptual in nature, and thereby the author has increased his own working potential. To master this information, the reader must also expend working energy and spend an appropriate amount of useful energy in the process of reading. As a result, the information component in the reader's working potential will also increase.

The price of the book characterizes the increase in the working potential of the socio-economic system because of the energy expended in the writing and reading of it. Thus, the amount of information can be evaluated in monetary units within the economy. The information component in the values of various products is evaluated by society in monetary units in terms of the pricing process.

At present, the subjective nature of information is often ignored, and the amount of information is treated as an objective value that can be calculated in bytes. Thus, the amount of information in the human genome is estimated as the number of possible combinations of nucleotide sequences in human DNA. This assessment is inadequate for the same reasons as in the above example concerning this book.

Biological systems do physical work and create information that is encoded in a DNA nucleotide sequence. During biological evolution, living systems inherit this information "from the past" through their parents as a basis for the creation of additional information. If additional information appears to be useful, that is, if it increases the working potential of the system and its viability, this information can be encoded in the genetic "hardware" and transmitted to the next generation of living systems.

Various biochemical and physiological processes, as well as the instinctive behavior of living systems are mainly based on genetically programmed information created by the evolutionarily preceding systems.

The supreme achievement in biological evolution was the creation of the human brain which is the most powerful material means for the creation of information. However, numerical estimates of the brain information capacity in bytes are too mechanistic and quite inadequate assessments, suitable for computer networks, not for the human brain.

Physical-chemical mechanisms for creating and storing information in the brain are still unknown. In very general terms, the process of transferring information, say in writing and reading a book, is that the brain encodes information in the form of nerve signals and passes them to the hand. According to these signals, the hand writes or prints the text. For this text to become information again, the reader's brain must perceive and analyze the corresponding light signals coming to the brain from the eyes. If the previous information stored in the reader's brain allows the decoding of these signals, the reader will create additional information, that is, he will increase the information component of his working potential.

It is noteworthy that the game paradigm of the economy with its one-component value, is based on the inadequate interpretation of information, which does not consider the fundamental ability of living systems to create additional information. Thus, the mechanistic concept of equality between "aggregate supply" and "aggregate demand" has no real (physical) meaning, and it is completely unsuitable in the case of pricing intellectual products and assessment of value.

10.4. Information and artificial intelligence

AI systems are not living systems, so they do not create additional information. They use the information that was created by people, and this information "from the past" is implemented in computer's hardware and software. Without the participation of people, this information eventually becomes obsolete.

People make computers that play chess and solve mathematical equations better and faster than the people themselves. However, a computer will never be able to write a new physical equation, and it cannot realise a new game.

Nevertheless, children easily invent new games. While playing, children learn to create information in addition to the information that they have genetically inherited or learned from their parents.

Thus, the operation of the AI system is similar to the instinctive behavior of living systems. This behavior is based on the generation of a pre-programmed response to well-known signals, which the system receives from the environment and from other systems. In the event of unknown signals, the AI system becomes helpless.

People need not fear that AI systems will destroy humanity because they do not create information. Computer systems are rapidly improving, but at the same rate they are becoming obsolete and people throw them out in the trash.

The development of AI systems and robotics industry is a great achievement in the increase of the information component of the working potential of the economy. AI systems and robots do the work which does not require the creation of additional information, and they help people to do more creative work.

However, the widespread introduction of robots and AI systems leads to a reduction in jobs, which is one of the future challenges of the global economy.

10.5. From asymmetry to information

Life and information arose simultaneously with the fundamental violation of the symmetry principle, which is observed in inanimate nature. Indeed, before the emergence of life on Earth, the quantities of two mirror isomers of the sugar rings and amino acids were equal in the ocean, so the water solution of these molecules had no optical activity.

However, the first drop of the “primordial soup” contained only one type of isomers, to make it possible to synthesize DNA and protein macromolecules. Life on the Earth has selected the existence in one of the possible mirror worlds.

The entropy of the water solution of organic molecules, which is measured by the calorimetric method, is the same for solution containing selected isomers and for solution with a random mix of isomers. However, from the viewpoint of the living observer, these solutions have different polarization properties, i.e. the observer may provide additional information about the features of these solutions.

Some unknown physical-chemical mechanisms[32] were allowed to break the symmetry of inanimate nature and create living systems that can produce useful information, not only useless entropy.

It is noteworthy that in accordance with the principle of isomorphism, living organisms inherited the symmetry attributes of inanimate nature in necessary cases. Thus, the outer shape of most animals has a plane of symmetry. However, at a molecular level, the asymmetry does persist.

The concept of symmetry and asymmetry is applicable to tangible objects; however, this concept is inapplicable to intangible information in the truest sense. That is, the term “information asymmetry” which appeared quite recently in the economic lexicon, should really be interpreted as “inconsistent signals received by an observer from the same system.” Hence, it’s more correct to state, “inconsistent signals” instead of “asymmetric information.”

People receive inconsistent signals, analyze them and create additional information; otherwise they would act only because of instincts, that are based on information “from the past”.

The AI systems principles (as well as the game paradigm of the economy) are based on the interpretation of information applicable only to the instinctive response of the system. The instinctive action is a system response to certain types of signals, which are well known from the experience of evolutionary preceding systems.

Let the system receive signals S_1 and S_2, the origin of which is well known in advance (Figure 10.1). Then the instinctive reaction is that the control signal (S) is instantaneously generated:

$$S = k_1\, S_1 + k_2\, S_2$$

where the weighting coefficients k_1 and k_2 were programmed in advance; the magnitudes of these coefficients are specified and corrected in the learning process.

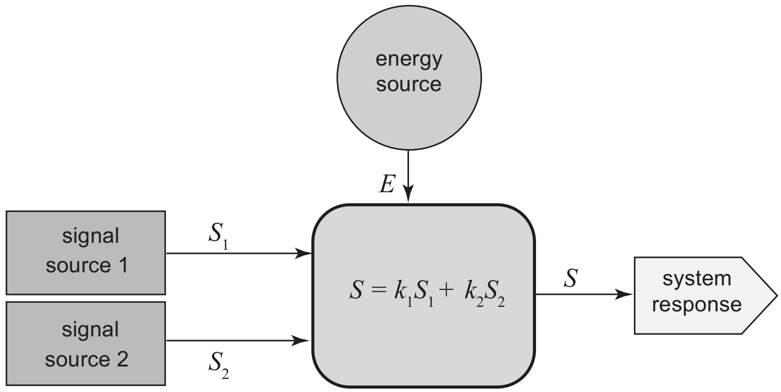


Figure 10.1. Generation of the instinctive response of the system based on the signals received from two well-known signal sources.

The instinctive response requires a relatively small expenditure of energy (E): for the current AI system, about a hundred watts of power is quite sufficient.

However, living systems can create additional information during their life cycle. This information increases the working potential of the system, and this increase requires much more energy expenses than in the case of the instinctive response.

If the living system obtains unpredictable signals, which are inconsistent with the previous experience, then the system does the work to process these signals, and, because of that work, the additional information is created (Figure 10.2).

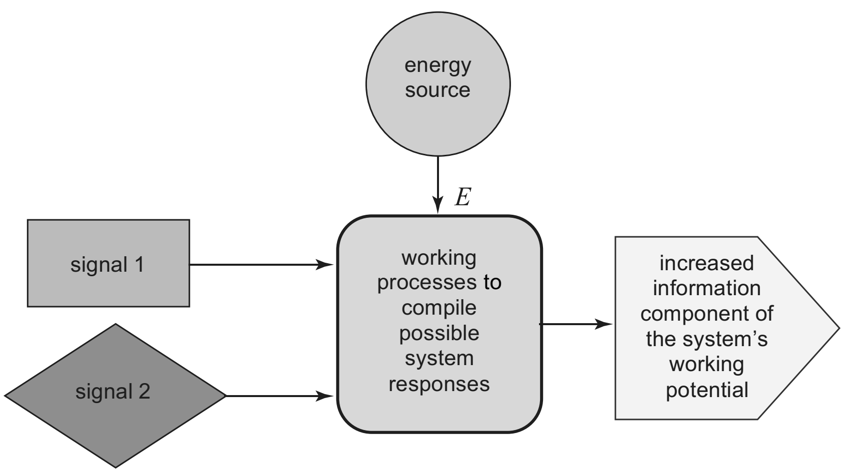


Figure 10.2. Information creation in the living system, based on the processing of two inconsistent (asymmetric) signals.

The creation of additional information requires much higher energy consumption, compared to the energy that is required for instinctive response compiling. Thus, the food energy factor in the global economy (about 17 kW/capita) is two orders of magnitude greater than the energy consumed by most of the current AI systems, for which the PC energy consumption is quite enough.

It is believed that in a few decades, people will be able to create supercomputers with the ability of the human brain, which will consume terawatts of energy. However, such supercomputers will be just very powerful informational systems with an instinctive type of operation. These supercomputers will help people to create information, but they will not be able to completely replace the human brain, because supercomputers cannot create additional information, no matter how much energy they consume.

The instinctive actions in accordance with the scheme shown in Figure 10.1, are the acts in well-known information space. The additional information creation (Figure 10.2) based on the "asymmetric signals" analysis, means access to the "new dimension" of the information space, with corresponding high energy costs.

As we can see, the emergence of life and information, as well information creation, are associated with the notion of asymmetry, although the underlying causes of the relationship between asymmetry and information, we have yet to realize.

10.6. Harmony in the economy

The real paradigm of the economy discussed in this book is based on the physical interpretation of information as an intangible result of the work done by the living system.

In contrast to this paradigm, the game paradigm does not consider the economy as a living system; therefore, economic processes are explained only in accordance with the instinctive type of system behavior. Thus, the pricing explanation is that, because of signals available in the economy concerning supply and demand, the equilibrium price is automatically compiled. However, such an oversimplified mechanism is not adequate in the most important cases, such as global energy and pricing of intellectual products.

In fact, the real economy is a living system, which creates information and takes appropriate decisions based on the analysis of "asymmetric signals" from all possible sources. The creation of information means the growth of the information component of the working potential of the system. This growth is a principal feature of development and evolution of the living systems.

The development and evolution is not characterised by a desire for static symmetry. Instead, there is a tendency for a *dynamic balance*, or harmony between all energy and information factors, between all symmetrical and asymmetrical objects.

Static art pictures and material objects, say, diamonds can be symmetrical and beautiful, but they are not harmonious,[33] while dynamic wildlife possesses harmony. Notes of musical scales look symmetric on paper, but harmony can only be experienced when listening to live music or musical records.

Harmony exists in wildlife mainly due to balanced free energy distribution between numerous degrees of freedom of living systems through dynamic nutritional and metabolic feedback. In the global economy, the distribution of GDP is far from being balanced, so the current state of the global economy is not a harmonious state.

In fact, there are some signs that the "state of mind" of society is changing in the direction of real feelings for harmony, which is opposed to greed. People understand that harmony is a foremost factor for the unity of man and nature, as evidenced by the enormous success of James Cameron's film *Avatar*.

The natural human tendency to harmony is particularly evident in people's love of music. Perhaps the electromagnetic oscillations in the human brain correspond to the major-minor rules of musical harmony.[34] If so, then we can assume that music reflects the universal harmony of the world.

Harmonic oscillations underlie universal harmony: they define the stable states of atoms and molecules manifested as the emission spectra; they form the orbits of the planets; they are components of electromagnetic waves in the heart and brain. The global economy is functioning in accordance with the macroeconomic cycle which corresponds to the annual period of the Earth rotation around the Sun.

Harmony cannot be numerically evaluated. Nevertheless, harmony is an objective notion that characterizes the dynamic equilibrium (steady state) of symmetrical and asymmetrical objects in nature and human society. Harmony of the world lies in the fact that, from the micro level to the scale of the universe, the behavior of systems meet the objective rules of behavior of the harmonic oscillator. In the human brain and in human society, these objective rules are possibly reflected in the form of music.

Music always accompanied the work of people and let them more quickly relax after work. Hard physical and mental work requires musical stimulation: haulers chorus sang their songs, and Einstein played the violin. Nowadays, people can listen to music from their smartphones all day long.

Any AI system is not able to write a new physical equation or a new musical melody, because the computer does not have a sense of harmony. For most people, a sense of harmony is reflected in their love of music, which will increasingly prevail over love of money.

11

Harmonisation of the global economy

Physical macroeconomics interprets harmony as a dynamic balance of all interrelated factors (energy, material and information factors) in a steady state system. Harmony is a fundamental property of the existence and sustainable development of living systems; therefore, a vital global economy should be a harmonious component of the Earth's biosphere.

11.1. Energy and environmental factors

Like any living system, the global economy creates information and thus it increases its working potential through the consumption of primary energy and the extraction of useless heat. Accordingly, the macroeconomic cycle is accompanied by an increase in environmental entropy.

When the global biosphere of the Earth was forming, hydrocarbon surpluses were buried deep underground. Otherwise, the energy balance of the biosphere could be broken, and the further harmonious development and evolution of living systems could stop.

Currently, the world economy burns too much fossil hydrocarbons and releases a lot of carbon dioxide into the atmosphere, thereby creating a real threat of the energy balance disruption. *The increase in information potential of the social system through the development of clean energy technologies is a priority for global economy harmonisation.*

The main energy factor in the global economy is the food factor H_f which is equal to the total sunlight energy consumed in agriculture and seafood production:

$$H_f = H_a + H_s$$

In ancient agricultural economies, the food factor magnitude was about 10 kW per capita; this figure corresponds to the production of one grain basket (1 kg of cereals and soybeans) per capita per day.

The standard working potential of the economy, which allows the production of one grain basket per person per day, can be considered as the unit of measurement of the world GDP. For this reason, the grain basket is an implicit currency in the global economy. In view of the accelerated increase in the information component of the working potential, the world GDP per capita is currently two hundred times higher than the standard potential.

Prior to the era of industrialization, the increase in the working potential per capita depended mainly on the growth of labor productivity in agriculture, and this increase was not accompanied by a significant increase in primary energy consumption. The total primary energy H was approximately equal to the primary energy consumed in agriculture:

$$H \approx H_a \, (\sim 10 \text{ kW/capita})$$

Of course, people also used secondary energy carriers for heating and cooking, such as using hydro and wind power for threshing grain, but additional primary energy consumption was much less than the H_a magnitude.

The food factor H_f was the main energy factor defining the increase of information potential of the global economy up to the end of the last millennium, thanks to the enormous working capacity of the human brain.

In the XIX century, the increase in information potential was reflected in the creation of thermodynamics as a theoretical basis for the construction of heat engines, which significantly accelerated industrialization. Also, electromagnetic theory had allowed for the development of electric networks. As a result, total primary energy consumption per capita (H) began to grow, and primary energy consumption in industry (H_0) became a significant addition to the food factor:

$$H \approx H_f + H_0$$

However, erroneously, only the industrial component (H_0) of primary energy is currently considered in macroeconomics, since the economy is not analyzed as a living system. The H_0 magnitude is 2.4 kW per capita in the world economy (Figure 11.1).

Among the largest economies, the H_0 magnitude is the highest in the US economy ($\sim$ 10 kW/capita); since 2000 this figure has been gradually declining due to development of energy saving technologies.

In the EU and Japanese economies, the H_0 magnitude is also declining, but it is twice as high as the world average. The highest growth of "non-food" primary energy consumption is now observed in China, where the H_0 magnitude has already surpassed the world average.

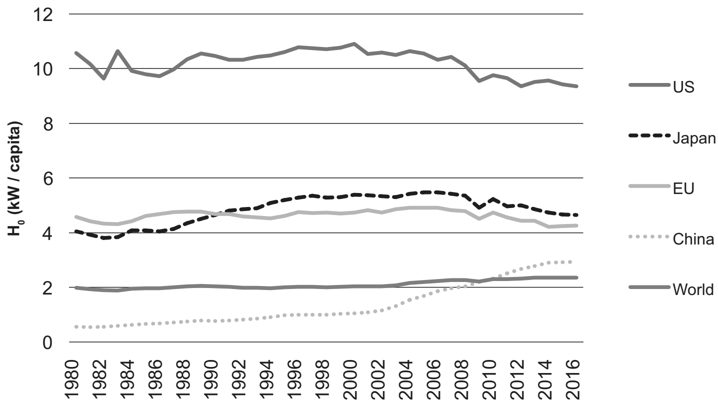


Figure 11.1. The industrial component (H_0) of the total primary energy in major economies.[22]

To create comfortable enough living and working conditions for the majority of the world population, the H_0 magnitude in the global economy should be increased twice, to a value of about 5kW per capita. However, such an increase cannot be achieved by increased mining of hydrocarbons and uranium because these energy resources will eventually run out, and the environment is polluted with heat, CO_2 and radioactive waste.

The increase in solar power generation is the only viable way to double the H_0 magnitude without disrupting the energy balance of the biosphere. It is encouraging that solar electricity generation demonstrates an exponential growth (see Appendix A), and this trend is correlated with the explosive increase in the information component of the world GDP.

11.2. Monetary factors

Among all the factors influencing the global economy harmonisation, the role of monetary policy should not be exaggerated. The point is that according to the game paradigm, the amount of "gaming chips" (the money supply) in the global economy mainly depends on the decisions of Central Banks. However, by emphasizing a decisive role of monetary policy in the creation of economic growth incentives, the cart is put before the horse.

An adequate economic policy should be based on an understanding of the real role of money as the unit of measurement and the means of distribution of the working potential of the economy. Money supply in the self-sufficient global economy is an endogenous factor, that is, the world economy generates as much money as it needs to distribute the working potential of the global socio-economic system (in monetary units, the world GDP).

The working potential of the local economy is more adequately evaluated by society in its own national currency, rather than in foreign currency. The existence of national currencies is due to various levels of development of socio-economic systems that have a different social mentality.

Thus, GDP per capita in the Japanese economy, expressed in US dollars, shows large fluctuations (Figure 5.6 in Chapter 5). However, Japan's GDP, expressed in yen, grew steadily during the same period without sharp fluctuations.

Therefore, the creation of several centers of generating the world's reserve currencies seems to be desirable for a more balanced GDP distribution and more harmonious development of the global economy.

11.3. Global DAVT

Harmonisation of the global economy is not possible without a balanced distribution of its working potential, i.e. the world GDP. At present, this distribution is unbalanced, causing economic crises, income inequality and social instability.

Unbalanced distribution of GDP and, accordingly, excessive income inequality slow economic growth.[35, 36] The natural causes of this slowdown and the corresponding tax counteraction measures were discussed in Chapter 9.

Among large countries, Russia became one of the leaders in terms of inequality indicators: in 2016, one percent of the population possessed 89% of all household property.[37] In the US and China, the appropriate figures are much smaller – 78% and 73% respectively.

Excessive income inequality is obviously one of the causes of the current stagnation in the Russian economy, but the author of this book is a witness to the fact that this reason for economic slowdown is not officially advertised or widely discussed in Russia.

Added value taxation is the main systemic means for distributing GDP, but, in the form of a static VAT, this facility is a destabilizing factor in the economy. Therefore, VAT must be replaced by DAVT (see Chapter 9 and in more details Appendix B).

Unification and partial globalization of national tax systems based on the DAVT would contribute to a more sustainable and harmonious development of the world economy.

11.4. Macroeconomic cycle maintenance

The emergence of the ancient economy began with the fact that people have borrowed from the wilderness and began to apply on a commercial scale, a high-tech process of the self-reproduction of cereals.

The cyclic process of grain production is a vital working cycle in a self-sufficient economy. Accordingly, the minimal working potential of the economy, which allows producing one grain basket per person per day, can be taken as a reference point, or a standard potential.

Grain production is the most energy-consuming process in the global economy. Nevertheless, this process is environmentally friendly and does not disturb the energy balance of the biosphere. Grain production is a harmonic basis of the macroeconomic cycle, and this cycle should not to be distorted by using grain to produce biofuels.

Grain is a highly information-containing product. Nanotechnology and biotechnology, implemented by nature in a single seed, allow people to use most of the information potential, which was created by living systems during the biological evolution. The global economy is far from the creation of such super-technological and environmentally friendly industrial technologies.

At the beginning of socio-economic evolution, grain was the unit of the working potential of the economy which produced mainly grain, that is, in ancient times, grain constituted real money. Currently, money is a unit of measure and a means of distribution of the working potential of the social system, which produces an enormous number of other commodities besides grain.

The growth of macroeconomic efficiency R is expressed in a significant increase in the price of most products, however, the world grain basket price remains flat. This means that the grain basket is an implicit global currency, which to date became clearly undervalued.

The development of the global economy approaches the point where a further sustainable growth of the world economy efficiency is hardly possible without revaluation of the grain basket. The grain basket revaluation would mean transition of the world economy to a new steady state, with a revaluated *information* component in the grain basket price. An appropriate increase in the world agricultural sector would contribute to the stabilization of the macroeconomic cycle – in particular, the grain basket revaluation would exclude the use of grain for biofuels production.

The growth in the agricultural sector, with corresponding development of organic foods production, would encourage many people to work, rather than relying on benefits. The current global economy is too speculative and militarized, and it grows to a considerable extent due to the spontaneous and inharmonious growth of financial bubbles.

Over the millennia, sunlight energy consumed in grain production was the main energy factor that shaped an economic architecture based on the production of one grain basket per person per day. Accordingly, the macroeconomic cycle has been formed under the dominant influence of the annual cycle of sunlight energy consumed in agriculture.

Currently, a large amount of sunlight energy is also consumed in seafood production, especially in fisheries: the H_s magnitude is about 5kW per capita in the world economy (Figure 5.4). Seafood production has no decisive influence on the macroeconomic cycle, however, global seafood production has a significant impact on the aquatic biosphere. Seafood production is an important "overtone", which complements the harmonic cycle of grain production. Therefore, sustainable reproduction of aquatic food resources, as well the protection of the water environment ecology, are important components of the global economy harmonisation.

11.5. Globalisation of information

The highest stage of biological evolution was the appearance of human beings. The working potential of the human brain is immeasurably greater than that required for grain production. Therefore, for a relatively brief period of the socio-economic evolution as compared to the biological evolution, the global economy has created a great deal of information, implemented in agriculture and industry, as well as in medicine, science and art.

More recently, the appearance of electrical networks and Internet has allowed the global economy to make a transition to a qualitatively different state characterized by sharply increased capacity for the creation of information. The emergence of information networks is a fundamental milestone in the socio-economic evolution, which is comparable to the emergence of nerves in biological evolution.

Thanks to the neural network, a highly developed living system can quickly create and transmit information through centrally determined signals that provide adequate system behavior. The globalizing economy is covered by wired and wireless information networks, and it is developing towards the formation of a unified social system with a common information potential, which is created by world society and which is freely accessible to all members of society.

The creation of a common information space will be the highest stage of socio-economic evolution. During the biological evolution, the creation and accumulation of information in the form of a single gene pool of all living organisms was accompanied by the development and complication of universal harmony in nature. As a result, biological evolution did not stop at a more primitive stage – it resulted in the appearance of man, with his love of harmony, which is clearly expressed in people's love of music.

Therefore, there is reason to believe that the highest stage of socio-economic evolution will be more harmonious than the previous stages. The globalisation of information will allow the ending of the pernicious information monopoly of the local establishment and its media, which mainly encouraged greed for power and money, not harmony.

The information potential of the world economy is being globalized in the form of social networks, e-journals and e-books, cloud storage of information and other information technologies. Despite all the shortcomings of the current information globalisation, which in an accelerated form repeat the flaws of the previous evolution of living systems, the universal human sense of harmony stabilizes this process.

11.6. Global harmonisation and the human brain

Perhaps the electromagnetic oscillations in the human brain reflect the harmony of the surrounding world, and this reflection determines the prevailing desire of people to harmonise their social life, despite the rivers of bloodshed in world history because of greed. It seems now that harmony wins in a global counter-state with greed, albeit with a slight advantage.

People's love for music was expressed in the creation of a theory of musical harmony, which is essentially based on the rules of a harmonic oscillator. As for social harmony, fundamental studies of the human brain are necessary to comprehend its natural science foundations.

Fundamental studies of the human genome have made a huge contribution to global harmonisation. These studies have supplemented the information potential of humanity with information "from the past" that was created by living systems during biological evolution. The results prove that all living organisms, from the *E. coli* to the *homo sapiens*, have common or related genes, that is, human society is an integral part of the united biosphere of the Earth.

The study of the natural science foundations of brain functioning is a much more complicated task, and it is not known beforehand whether it can be completely solved at all. It is unclear whether it is possible in principle to understand the mechanism of understanding, that is, whether there is an unsolvable logical loop here, analogous to the one who first appeared, the chicken or the egg.

It seems that one of the possible natural scientific approaches to fundamental brain research is the Fourier analysis of the brain's electromagnetic waves in comparison with the musical sound waves. Indeed, musical harmony evolved from simple rhythms to classical and electronic music, along with the development of human society; this development firstly means the growth of the brain information potential.

However, if we assume that the collective intelligence of mankind is like a symphony orchestra, then the question arises: Who is the Conductor?

Appendix A.

Primary energy: future trends

The sunlight energy consumed in the solar electricity production is five times higher than generated electric energy, in accordance with the energy efficiency of solar panels (about twenty percent). The sunlight energy consumed in the fuel biomass production, is one hundred times more than energy content of biofuel due to energy efficiency of photosynthesis (above one percent).

To calculate the appropriate amount of primary energy, the energy efficiency of the solar electricity production and biofuel production should be considered. Hence, the scheme of the primary energy sources in the global economy (Figure 5.2 in Chapter 5) should be detailed as it is shown in Figure A1.

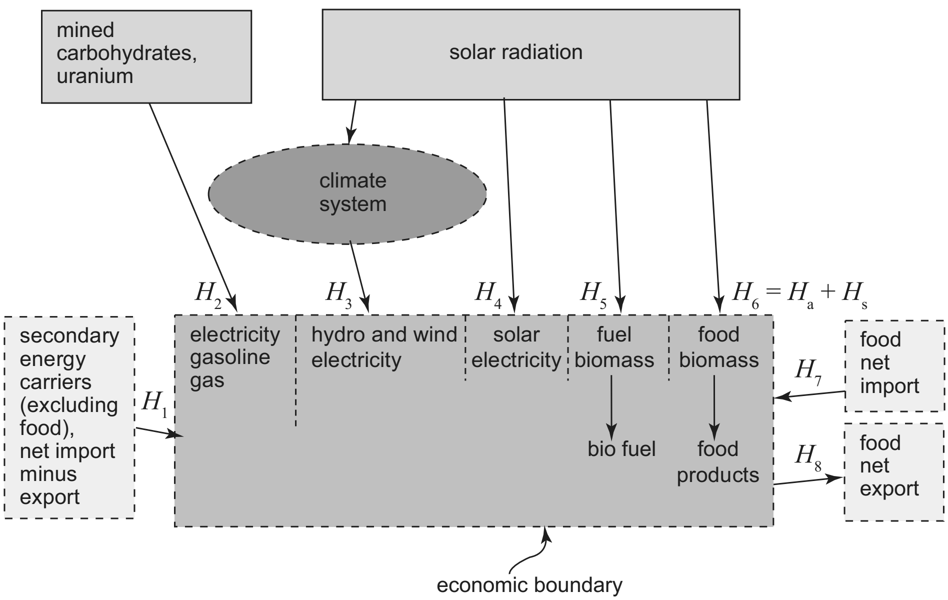


Figure A1. The primary energy and its components in the local economy.

The world economy receives primary energy only from the environment, while the local economy can exchange primary energy with other economies through export and import of energy carriers.

The primary energy $H = \Sigma H_i$ is converted into the useful energy $h = \Sigma h_i$ of secondary energy carriers with energy efficiencies r_i ($0 < r_i < 1$), so that $h_i = r_i H_i$. Therefore, the primary energy equals

$$H = \Sigma h_i \, / r_i$$

Primary energy components H_1, H_2, H_3. In view of the improvement of energy-saving and recycling technologies, the corresponding energy efficiency is close to 100 per cent, that is $r_1 = r_2 = r_3 \approx 1$.

Sunlight energy consumed in the solar electricity generation (H_4). The energy efficiency of solar electricity generation can not exceed 33.7 per cent, in line with the theoretical maximum efficiency of solar cells.[38] Modern technologies allow reaching about 20 percent efficiency, i.e. $r_4 \approx 0.2$. So, the H_4 component is approximately five times higher than the amount of generated electric energy.

Sunlight energy consumed in the fuel biomass production (H_5). The biomass is produced in the process of photosynthesis. Maximum energy efficiency of photosynthesis does not exceed 1–2 per cent[39] (Hall & Rao, 1999), so that $r_5 \approx 0.01$.

Sunlight energy consumed in the seafood production and agriculture ($H_6 = H_a + H_s$). The H_a and H_s magnitudes can be estimated in accordance with equations (5.2) and (5.3).

Food net import (H_7). This component of primary energy is relatively small and can be neglected. Indeed, the energy content of imported food products does not exceed the human needs in food energy (100W per capita), while the total primary energy consumption is greater than 10kW per capita for almost all the local economies.

Food net export (H_8). Some local economies produce more food than it is required for its own needs, and the surplus food products are exported. However, the food export does not significantly reduce the primary energy consumption, because the amount of sunlight energy that was consumed in the food biomass production is much higher than the energy content of exported food. Therefore, this component may also be omitted.

As a result, a corrected formula for the primary energy estimation is:

$$H = \Sigma h_i \, / r_i \approx h_1 + h_2 + h_3 + 5h_4 + 100h_5 + H_a + H_s \qquad \text{(a.1)}$$

For better accuracy, the corrected formula (a.1) should be used instead of (5.1).

The corrected estimates of the primary energy and macroeconomic efficiency magnitudes for major economies are represented in Table A1.

Table A1. GDP, primary energy *H* (with detailed components) and macroeconomic efficiency *R* in major economies, 2016.

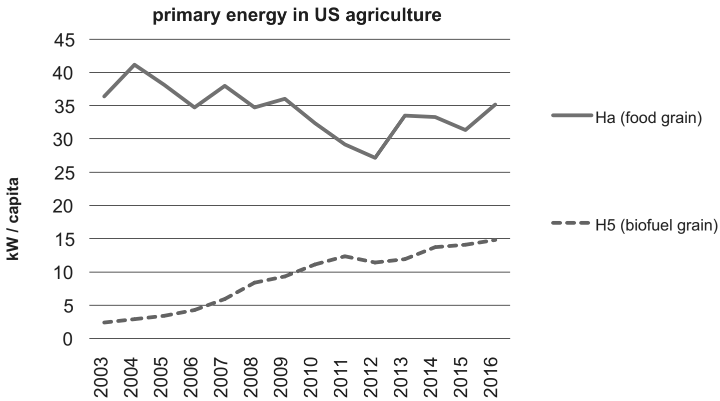
Economy	**GDP (USD/capita/hour)**	$H_1 + H_2 + H_3$ **kW/capita**	H_4 *(solar)* **kW/capita**	H_5 *(biofuel)* **kW/capita**	H_a *(agro)* **kW/capita**	H_s *(seafood)* **kW/capita**	H **kW/capita**	$R = GDP / H$ **(USD/kWh)**
World	1.20	2.3	0.067	1.5	10	5	19	0.062
US	6.60	9.1	0.260	15.0	35	4	63	0.105
EU	3.70	4.2	0.330	3.5	13	4	25	0.145
Japan	4.40	4.5	0.590	0.0	2	6	14	0.340
China	0.93	2.9	0.070	0.2	12	8	23	0.040

In the US economy, the sunlight energy consumed in the production of biofuel (H_5) is 15 kW per capita. At the same time, the reported amount[22] of the US "renewable primary energy of biofuels" in 2016 is 30.1 Mtoe (0.13 kW per capita). That is, the reported value is a hundred times undervalued compared to the real value of primary energy, because the energy efficiency of the fuel biomass production ($r_5 \approx 0.01$) is not considered.

Thus, the US economy in 2016 consumed about 15 kW/capita of sunlight energy to produce biofuel. This value is only two times less than the sunlight energy consumed to produce grain for food purposes ($H_a = 35$ kW/capita). In the world economy, such a ratio would represent a real threat to the global food security.

The production of biofuels in the world economy has increased six-fold from 2002 to 2016. If the growth of biofuels production continues, this production would be a dangerous competitor to food biomass production. Also, the growth of biofuels production leads to the global environmental damage due to deforestation.

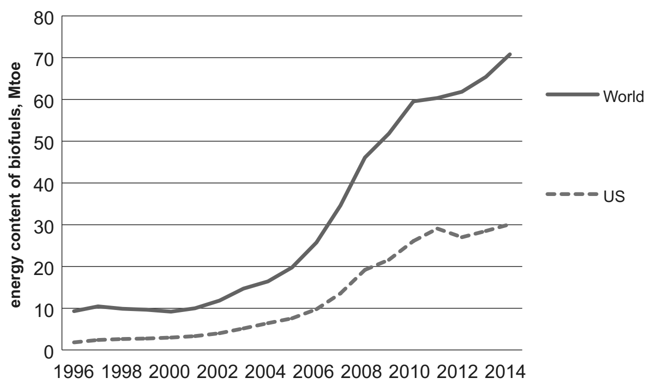
Because of the high oil prices, the production of biofuel began to rise since 2002 in some countries, and, in the US. This trend has led to the fact that a growing proportion of grain is converted into biofuel (Figure A2).



Note: The graphs correspond to the H_a and H_5 components of primary energy (Table A1).

Figure A2. The sunlight energy consumption in US agriculture.

The grain conversion into biofuel means that the vital food product is burned in a furnace. Since 2011, the growth in biofuel production has slowed down in the US, but the world production continued to rise (Figure A3).



Note: The graphs correspond to the h_5 magnitude in equation (a.1).

Figure A3. Biofuels production in the world and US economies.

It is hoped that the fall in oil prices will lead to the cessation of biofuels production that is necessary for the global food security. In addition, it is time to stop global deforestation.

Table A2 represents the estimates of primary energy and efficiency of some local economies in accordance with corrected equation (a.1).

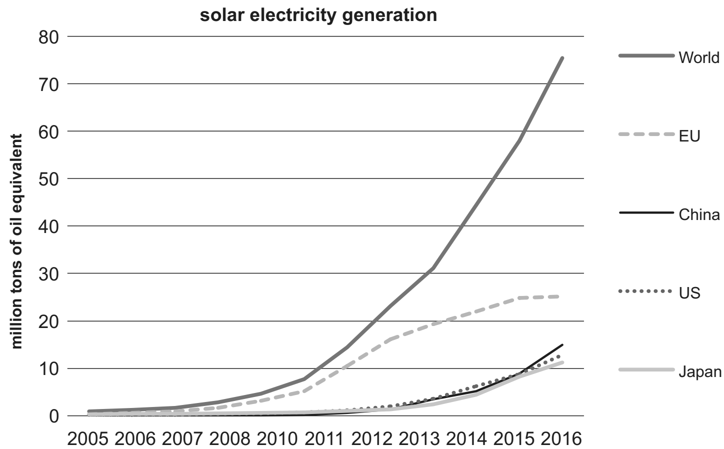
Table A2. GDP, primary energy H (with detailed components) and macroeconomic efficiency R in local economies, 2016.

Economy	GDP (USD/capita/hour)	$H_1 + H_2 + H_3$ kW/capita	H_4 (solar) kW/capita	H_5 (biofuel) kW/capita	H_a (agro) kW/capita	H_s (seafood) kW/capita	H kW/capita	$R = GDP / H$ (USD/kWh)
Norway	8.10	12	-	-	5	110	127	0.063
Australia	5.70	8	0.40	0.6	38	1	48	0.120
Germany	4.90	5	0.70	5.2	9	1	21	0.230
UK	4.60	4	0.20	0.7	8	2	15	0.300
France	4.40	5	0.20	4.5	18	2	29	0.150
Italy	3.60	3	0.60	1.3	8	1	13	0.270
Poland	1.40	3	–	3.1	13	2	21	0.068
Turkey	1.10	2	0.02	–	12	2	16	0.068
Russia	1.00	6	–	–	23	8	36	0.028
Brazil	1.00	2	–	12.0	12	1	27	0.037
S.A.	0.61	3	0.08	–	5	3	11	0.058
Iran	0.60	5	–	–	6	3	13	0.046
Indonesia	0.41	3	0.08	–	5	3	11	0.058
Egypt	0.39	1	–	–	7	4	12	0.032
Ukraine	0.24	3	0.02	–	42	1	46	0.005
India	0.20	1	0.01	0.1	6	2	9	0.023

At present, the sunlight energy consumed in local economies for solar electricity generation, is an inconsiderable component of the total primary energy. However, the solar electricity is the most promising secondary source of energy, especially for tropical countries.

The solar electricity production is growing exponentially in recent years (Figure A4).

An exponential growth of the solar power generation and increased production of electric vehicles means that demand for oil will decrease in the future. Therefore, the world crude oil price is unlikely to be very high again.



Note: the graphs correspond to the h_4 magnitude in equation (a.1).

Figure A4. The solar electricity generation in largest economies.

Crude oil, electricity and grain are the most important secondary energy carriers in the global economy. However, their consumer properties are qualitatively different, that is, the society estimates the *information* component in the values of corresponding products in completely diverse ways. As a result, both the formation of equilibrium prices and the price trends for electricity, oil and grain are fundamentally different.

Appendix B.

Appendix B. DAVT theory

The dynamic added value taxation (DAVT) theory is one of the most important practical conclusions of physical macroeconomics. The current static tax system, with consistent tax rates, does not allow for a balanced distribution of the overall added value (GDP). Therefore, the static tax system – primarily the VAT – is a destabilizing factor in the economy.

In general terms, the need the for the introduction of DAVT instead of VAT is proposed in Chapter 9 "GDP distribution and economic stability." The system properties of DAVT in comparison with those of VAT are discussed further below in more detail.

Balance equation

The law of energy conservation is expressed in economics as the balance equation:

$$S\ (\text{sales}) = E\ (\text{expenses}) + G\ (\text{gain}) + T\ (\text{taxes}) \qquad \text{(b1)}$$

Starting from the balance equation, a mathematical expression follows for added value. To do this, one can divide the expenses E into two parts – the internal expenses E^{int} (create added value) and external expenses E^{ext} (external payments to suppliers). Then the added value created by the manufacturing process for the annual tax period is

$$\Delta S_+ = S - E^{ext} = E^{int} + G + T \qquad \text{(b2)}$$

The total added value produced by the economy (on an annualised basis, GDP) is obtained by summing ΔS_+ through all producers.

The socio-economic system produces the overall value by the joint efforts of producers and society, and corresponding energy costs can be offset by a balanced distribution of GDP. This can be achieved by a properly organized added value taxation.

Any multi-tax system, perhaps with overlapping tax bases, can be reduced to added value taxation. Accordingly, we shall imply below that the T item in equation (b2) is a *system-defined* added value tax. Other ancillary taxes[40] can be included in the E and G magnitudes.

Harmonious and sustainable balance in nature is maintained by a balanced distribution of free energy through dynamic nutritional and metabolic feedback. In the economy, the distribution of added value between producers and society is currently out of balance; the reason for the imbalance is that the existing static tax system (with consistent tax rates) cannot perform the stabilizing function of negative feedback.

A possible solution is that the destabilizing static taxation should be replaced by DAVT. From a system-wide perspective, the DAVT is a stabilizing negative feedback introduced into the economy in addition to the psychologically predetermined demand function.

Basic relations

The added value tax magnitude in equation (b2) is

$$T = N\,(G + E^{int}) \tag{b3}$$

where N is a tax rate. The above formula indicates that T is a tax on internal (domestic) production.

It is noteworthy that the VAT is a tax on domestic consumption since its value is defined as $N/(N+1)$ part of the sales value S, debited by the VAT paid by suppliers.

The VAT definition is correct if only the tax rate N is the same for all producers (i.e. if there are no preferential tax rates). The VAT cannot exist without preferential tax rates due to extremely harmful VAT influences on the low-profit producers. So, we shall assume below that both the DAVT and the VAT values are defined in accordance with the correct definition (b3).

A dimensionless parameter can be introduced – "internal profitability"

$$\lambda = (S - E)/E^{int} \tag{b4}$$

Internal profitability and usual profitability $\beta = (S - E)/E$ are related by equation

$$\lambda = \beta E / E^{int}$$

Then from relations (b2), (b3) and (b4) we obtain:

$$\begin{aligned} G &= E^{int}(\lambda - N)/(N+1) \\ T &= E^{int}(\lambda + 1)\,N/(N+1) \end{aligned} \tag{b5}$$

Hence,

$$G/T = (\lambda - N)/(\lambda + 1)/N$$

and the case of static VAT (N = constant):

- the production is unprofitable if $\lambda < N$, i.e. profitability threshold exists;
- the T/G ratio is equal to infinity if $\lambda = N$ that means a serious system distortion;
- the added value distribution is misbalanced in favor of high-profit producers: with internal profitability increasing from the profitability threshold to infinity, the G/T ratio increases from zero to $1/N$.

Profitability threshold elimination and balanced added value distribution can be achieved if the tax rate N is directly proportional to internal profitability, and it is not constant. That is, for the DAVT tax rate we get

$$N = n\lambda$$

where n is constant tax coefficient ($0 < n < 1$).

Then in the case of the DAVT we have

$$G/T = (1-n)/n/(\lambda + 1)$$

As contrasted with the VAT, under the DAVT:

- the profitability threshold does not exist; consequently, all producers are the legal DAVT payers (so the shadow sector of the economy is shrinking);
- the T/G ratio has no singularities so there are fewer system distortions;
- the added value distribution is no longer misbalanced in favor of high-profit producers.

The DAVT eliminates inherent destabilizing features of static taxation – the profitability threshold and the disparity of added value distribution.

DAVT accounting

As it follows from equations (b5), under DAVT:

$$G = E^{int}(1-n)\,\lambda/(1 + n\lambda)$$
$$T = E^{int}\,n\,(\lambda + 1)\,\lambda/(1 + n\lambda) \qquad \text{(b6)}$$

The above formulas are useful primarily for theoretical considerations. As for practical purposes, primarily for accounting, it is more convenient to rewrite these formulas in a form that does not contain uncertainties at zero internal expenses.

To do this, a dimensionless parameter *"y"* can be introduced that describes the expenses structure:

$$y = E^{ext} / E$$

and accordingly

$$E^{int} = (1 - y)\, E$$

The internal profitability λ is linked to the usual profitability β as follows:

$$\beta = (S - E) / E = \lambda\, E^{int} / E = \lambda\, (1 - y)$$

If external expenses are absent ($y = 0$) then $\lambda = \beta$. Therefore, instead of formulas (b6) we obtain:

$$G = (1 - n)(1 - y)\, E(S - E) / [(1 - y)E + n(S - E)]$$
$$T = n(S - E)(S - yE) / [(1 - y)E + n(S - E)] \qquad \text{(b7)}$$

Equations (b7) mean that for the current tax period there is no need to calculate the internal profitability magnitude.

At the same time, the chief accountant should not fear making a loss (as in the case of VAT) because production is unprofitable only if total expenses exceed sales. In such a case, the DAVT payment should to be deferred until the next tax period.

DAVT accounting is much simpler than VAT accounting:

- all producers operate under equal conditions, because the tax coefficient n is the same for all of them;
- sophisticated schemes of preferential taxation are no longer needed;
- since DAVT is a tax on domestic production, all exporters are tax payers. Therefore, the problem of VAT refunds and pseudo exporting completely disappear.
- the tax burden is shifted from low-profit producers to high-profit producers, so the auxiliary income/profit taxes could be abolished.

Productive economy stimulation

In contrast to VAT, the DAVT stimulates the productive economy, not the speculative one. In the VAT-using economy, the greater percentage of external expenses, the more profit. Such an economy encourages mediation rather than own production (see Figure 9.1 in Chapter 9).

Under DAVT, the profit is diminishing in line with the increasing proportion of external expenses. Hence the economy that utilses DAVT is a production-oriented one. Moreover, under DAVT, profit extraction is impossible if internal expenses are absent. Consequently, a purely speculative financial activity, with zero internal expenses, is meaningless: the entire amount of income ($S-E$ value) should be paid as DAVT. DAVT is really an effective way to combat financial speculation, as opposed to financial transactions tax.

Maximum profitability restriction

DAVT does not allow for money made "out of thin air." A pure speculative activity, with negligible internal expenses and, consequently, with infinite internal profitability, is unprofitable.

Moreover, the maximum profitability magnitude is limited to the value of $1/\sqrt{n}$. This conclusion can be illustrated by using equations (b7).

It is apparent, the G magnitude equals zero if expenses are absent ($E = 0$) or equal to sales ($E = S$). The profit maximum is reached with some optimal expenses value $E = \varepsilon S$, where $0 < \varepsilon < 1$. Then, from the condition $\partial G / \partial \varepsilon = 0$, the resultant equation for optimal ε_m magnitude:

$$(n' - 1)\, \varepsilon_m^2 - 2n'\, \varepsilon_m + n' = 0$$

where $n' = n/(1 - y)$.

Hence, $\varepsilon_m = \sqrt{n'}/(1 + \sqrt{n'})$ and corresponding profit value is

$$G_m = S(1 - n)/(1 + \sqrt{n'})^2$$

This value is biggest if $y = 0$, that is, with zero external expenses. Finally, we arrive at the resultant expressions for the gross profit, expenses, DAVT and profitability magnitudes at the point of maximum profitability:

$$G_m = S(1 - \sqrt{n})/(1 + \sqrt{n})$$

$$E_m = T_m = S\sqrt{n}/(1 + \sqrt{n})$$

$$\beta_m = \lambda_m = 1/\sqrt{n}$$

For instance, if the tax coefficient $n = 0.36$ (that corresponds to our reasonable estimates), then the maximum profitability is 167 percent – more than enough for a productive economy.

Theorem on stability

Some “grey” financial schemes involve a fictitious enterprise fragmentation (consecutive or parallel) in order to both diminish the VAT payments and to extract super-profits. Such schemes create further instability in the economy. In the DAVT-using economy the instability decreases dramatically, which is proved by the following theorem:

Theorem on stability. Let there be an enterprise with internal profitability λ, gain G and DAVT (or VAT) value T. Suppose that this enterprise is fragmented to a group of enterprises with parameters λ_k, G_k, and T_k, the sum of internal expenses being kept. Also, both the sales and the external expenses are equal for the initial enterprise and for the group of enterprises. Then under the DAVT ($N = \lambda$) the inequalities $\Sigma G_k \leq G$ and $\Sigma T_k \geq T$ are true, the equalities being fulfilled if only $\lambda_k = \lambda$. As to the VAT-using economy, the system is indifferent to any subdivision, i.e. $\Sigma G_k = G$ and $\Sigma T_k = T$.

Proof. For an initial enterprise we have: $E = E^{ext} + E^{int}$, and internal profitability is equal to

$$\lambda = (S - E) / E^{int} = (G + T) / E^{int}$$

The total sales value for the group of enterprises is equal to the sales value S for the initial enterprise and satisfies the balance equation:

$$S = \Sigma (G_k + T_k) + \Sigma E_k^{int} + E^{ext}$$

Considering that internal expenses are kept, i.e. $E^{int} = \Sigma E_k^{int}$, we arrive at equations

$$(S - E) = \Sigma (G_k + T_k) = \Sigma \lambda_k E_k^{int}$$

Hence,

$$\lambda E^{int} = \Sigma \lambda_k E_k^{int}$$

Thereby, by introducing the “sales vector”

$$\boldsymbol{S} = \{\lambda E^{int}, E^{int}\} = \{G + T, E^{int}\}$$

the theorem conditions can be rewritten as $\mathbf{S} = \Sigma \boldsymbol{S}_k$.

The DAVT (or VAT) magnitudes are:

$$T = N(G + E^{int}) \quad \text{and} \quad T_k = N(G_k + E_k^{int}).$$

Under the VAT ($N = \text{const}$), for the first component of the sales vector we have:

$$G + T = G + N(G + E^{int}) = (N + 1)\ \Sigma G_k + N\Sigma E_k^{int}$$

Consequently, for VAT-using economy, $\Sigma G_k = G$ and $\Sigma T_k = T$.

Under DAVT ($N = n\lambda$), in accordance with formulas (b6),

$$G = (1 - n)\, E^{int}\, \lambda\, /\, (1 + n\lambda)$$

Proof of the inequality $\Sigma G_k z \leq G$ is equivalent to its proof for the case of two enterprises, with sales vector $\boldsymbol{S} = \boldsymbol{S}_1 + \boldsymbol{S}_2$. Then the inequality to be proved, $G_1 + G_2 \leq G$, can be transformed into the following inequality:

$$za\, /\, (1 + na) + (1 - z)(b - za)\, /\, [(1 - z) + n(b - za)] \leq b\, /\, (1 + nb)$$

where: $a = \lambda_1$; $b = \lambda$; $z = E_1^{int}/E^{int}$. By reducing to a common denominator, we get

$$nz\ (a - b)^2 \geq 0$$

The equality is fulfilled if only $\lambda_1 = \lambda_2 = \lambda$, QED.

The above theorem demonstrates that the economy which utilses DAVT is stimulated to decrease excessive mediation and fragmentation. Nevertheless, this stimulation is not a promotion of monopoly because only the length and thickness of production chains are forced to be shortened, not the number of chains.

Market equilibrium

To assess the DAVT properties with respect to market equilibrium, one should consider that in this case the S and E variables in equations (b7) are not arbitrary variables, because their magnitudes are defined in line with the demand function.

For qualitative estimates it can be assumed that all producers are self-sufficient ones, so the external expenses are absent ($y = 0$). Consequently, the internal profitability (λ) and the usual profitability (β) magnitudes coincide ($\lambda = \beta$).

At first let us consider a non-taxable economy ($N = 0$ or $n = 0$). Market equilibrium is maintained due to the demand function which should be considered as an objectively existing nonlinear negative feedback in the economy.

The demand function can be approximated by the dependency

$$Q = k\, /\, p^a$$

where: Q is the sales amount;
p is commodity price (so $S = pQ$);
α is demand parameter ($\alpha > 0$);
k *is* some coefficient.

Under this approximation, the price elasticity of demand is constant and equals to $p/Q\ (\partial Q/\partial p) = -\alpha$.

Bearing in mind that $S = pQ$ and $E = p_0Q$, where p_0 is a cost price, the results for sales and expenses at the point of market equilibrium:

$$S = k/p^{a-1}; \quad E = kp_0/p^a$$

If the commodity price is equal to its cost price, then the sales amount equals

$S_0 = k/p_0^{a-1}$, therefore, $k = S_0 p_0^{a-1}$ and we obtain:

$$S = S_0/x^{a-1}$$
$$E = S_0/x^a \quad \text{(b8)}$$

where the dimensionless parameter $x = p/p_0$.

Since profitability $\beta = (S - E)/E = x - 1$, then the profit magnitude under zero taxation is

$$G0(x) = S - E = S_0\,(1/x^{a-1} - 1/x^a)$$

It is noteworthy that if the cost price is not varying, then the dependency of $G0$ on $x = p/p_0$ means its dependency on the price p. With rather good approximation it may be implied in most cases: the cost price is a conservative variable, while price can always be fixed at any level. Under this approximation (so S_0 = constant), the maximum of $G0$ is reached at the point $x_m = \alpha/(\alpha - 1)$, so the optimal profitability magnitude is

$$\beta_m = 1 - x_m = 1/(\alpha - 1)$$

Consequently, the non-taxable system is stable if demand parameter $\alpha > 1$. In the range of ultra-high demand ($0 < \alpha \leq 1$) the maximum profit magnitude does not exist that means the system instability.

If the VAT (N = constant) or the DAVT ($N = n\lambda$) are introduced into the system then the corresponding maximum profit magnitudes G_N or G_n are defined by formulas (a5) or (a7) combined with expressions (a8).

After taking derivatives, from the condition $\partial G/\partial\beta = 0$, we get equations for optimal profitability magnitudes:

$$\beta_N = (1 + \alpha N)/(\alpha - 1)$$

in the case of VAT, and

$$\alpha n \beta_n^2 + (\alpha - 1)\beta_n - 1 = 0$$

in the case of the DAVT.

It follows on from the above equation that the DAVT stabilizes the economy in the ultra-high demand range (that is, in the range of $0 < \alpha \leq 1$).

For instance, if $\alpha = 1$ then we get the finite optimal profitability magnitude for DAVT: $\beta_n = 1/\sqrt{n}$, while in the case of VAT the corresponding β_N magnitude is equal to infinity.

Thus, both the non-taxable economy and the economy that uses VAT are unstable in the ultra-high demand range.

DAVT as a stabilizing feedback

The features of DAVT examined allows for this tax to be an artificial negative feedback introduced into the economic system in addition to the objectively existing (psychologically predetermined) demand function.

The DAVT "tax rate" is defined as

$$N = n\lambda$$

Since the internal profitability λ can be very large, the N magnitude can also be more than unity. Hence, the N magnitude should not be considered as a real tax rate. That is, the N magnitude should be considered as a feedback factor, which in principle can reach infinite values.

The internal profitability is directly proportional to profitability and inversely proportional to the internal expenses percentage:

$$\lambda = \beta/(1-y)$$

Consequently, the feedback factor N increases with increasing profitability, and it increases with the decreasing internal expenses percentage. As a result, first, the DAVT does not allow profitability to be too high. Second, it does not allow internal expenses to be too small.

The first property leads to the restriction of the maximum profitability by $1/\sqrt{n}$ magnitude. Due to the second feature, the internal expenses percentage is stimulated to increase. Consequently, the DAVT stimulates a productive economy, not a speculative one.

Dynamic versus static taxation

The powerful stabilizing properties of the DAVT are the result of a negative feedback function performed by this tax. The static taxes, including VAT, cannot perform a negative feedback function in principle. If the new static taxes are introduced or the rates of existing static taxes are increased, then economy distortions and instabilities will grow even more.

The differences between DAVT and VAT properties qualitatively reflect the difference between static and dynamic tax systems in general. The main differences between the DAVT and the characteristics of VAT are summarized in Table B1.

Table B1. The VAT and DAVT comparative features.

Tax characteristics	VAT	DAVT
tax rate	$N = \text{constant}$	$N = n\lambda$
tax accounting	$N/(N+1)$ part of the sales value S debited by VAT paid by suppliers	in accordance with expressions (a7)
tax type	tax on domestic consumption	tax on domestic production
tax exempts	exporters and privileged producers	no exemptions
T/G ratio	$(\lambda + 1)\ N/(\lambda - N)$	$n\ (l+1)/(1-n)$
profitability threshold	$\lambda = N$	no threshold
maximum profitability	unlimited	$1/\sqrt{n}$
instability range	ultra-high demand, $0 < \alpha \leq 1$	no instability
tax-stimulated activity	intermediation and speculation	own production
resistance to tax fraud	low resistance; export tax return fraud is encouraged	high resistance; export tax return does not exist

Notes and literature

1. In this book, the term "economy" is synonymous with the term "socio-economic system."
2. Bertalanffy, L. (1968). General System Theory: Foundations, Developments, Applications. New York: Braziller.
3. Bartenev, V.N. (2009). "Value-Energy Interrelationship and Dynamic Added Value Taxation", *Journal of Interdisciplinary Economics,* 21(2), pp. 273–294.
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6. Bartenev, V. (2015). "Discussion paper: Information, symmetry and harmony in the economy", *Interdisciplinary Journal of Economics and Business Law*, 4(2), pp. 89–109.
7. Bartenev, V.N. (2016). "Discussion paper. The evolution of the EU and the former Soviet Union: the system-wide basis", *Interdisciplinary Journal of Economics and Business Law*, 5(1), pp. 81–107.
8. Nelson R. and Winter S. (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press.
9. Common, M. and Stagl, S. (2005). *Ecological Economics: An Introduction*. New York: Cambridge University Press.
10. Mantegna, R.N. and Stanley, H.E. (1999). *An Introduction to Econophysics: Correlations and Complexity in Finance*. Cambridge University Press.
11. Sieniutycz, S. and Salamon, P. (1990). *Finite-Time Thermodynamics and Thermoeconomics.* Taylor & Francis.
12. Chen, J. (2015). The Unity of Science and Economics. A New Foundation of Economic Theory. Springer.
13. In physics, the working potential of the thermodynamic system is called *the free energy* of the system. The meaning of this term is that the free energy is equal to the maximum amount of work that can be done by the system, that is, the free energy is the part of the system's energy that is "free for work".
14. The term "working potential" is used interchangeably with the term "free energy" in this book.
15. Rudolf Clausius (1822–1888) is one of the central founders of thermodynamics.
16. Schrödinger, E. (1946). *What is Life?* New York: Macmillan.
17. Nicolas Léonard Sadi Carnot (1796–1832), often described as the "father of thermodynamics".
18. Thus, the *useful energy* component in (4.2) does not include the biomass of the population. Note that in the slave economy, this component of the overall value included the biomass of slaves.

19. The equality (4.5) resembles the relationship between the units of mass and energy in physics, according to Einstein's equation ($E=mc^2$). However, the principal difference is that the mass-energy ratio is a fundamental constant in physics, while the macroeconomic efficiency magnitude is not a constant in physical macroeconomics.
20. The subjective *information* component of economic value can be called a "speculative" component; however, the term "speculation" has no physical interpretation.
21. There are three terms used in the economic literature with the same qualitative meaning: "added value", "value added" and "surplus value". In this book, we use only the "added value" term.
22. BP Statistical Review of World Energy (2015), www.bp.com.
23. American Heritage Science Dictionary (2005), Houghton Mifflin Company.
24. Data sources for our estimates: *Food and Agriculture Organization of the United Nations* (www.fao.org) and *BP Statistical Review of World Energy* (www.bp.com).
25. Data source: http://epp.eurostat.ec.europa.eu
26. Data source: US Energy Information Administration (www.eia.gov/electricity).
27. Davies, G. (2002). *A History of money from ancient times to the present day*. 3rd Edition, Cardiff: University of Wales Press.
28. Money and quasi money (M2) constituted 112.9% of the world GDP in 2014 (World Bank).
29. Data source: https://www.cia.gov/library/publications/the-world-factbook
30. Intrinsically, the financial transaction tax is a usual sales tax, that is, a simplified version of the VAT.
31. Palumbo, G. & Pennisi, S. (2002). *Feedback amplifiers: theory and design*. Dordrecht: Kluwer Academic.
32. We prefer not to include the heavenly and otherworldly forces in our considerations.
33. It is said that the face of the Mona Lisa looks so lively and mysterious because it is slightly asymmetrical.
34. When we forget what we were going to do, we feel a sense of discomfort. A similar feeling arises when we do not hear the completion of a musical phrase.
35. Dabla-Norris, E., Kochhar, K., Suphaphiphat, N., Riska, F. and Tsounta, E. (2015). "Causes and Consequences of Income Inequality: A Global Perspective", *International Monetary Fund: Strategy, Policy and Review Department* (www.imf.org sdn1513.pdf).
36. Boushey, H. and Price, C. (2014). "How Are Economic Inequality and Growth Connected?", *Washington Center for Equitable Growth* (http://equitablegrowth.org/wp-content/uploads/2014/10/100914-ineq-growth.pdf)
37. Shorrocks, A., Davies, J., Lluberas, R. and Koutsoukis, A. (2016). *Global Wealth Report 2016*. Credit Suisse AG Research Institute.
38. Shockley, W. & Queisse, H.J. (1961). Detailed Balance Limit of Efficiency of p-n Junction in Solar Cells. *Journal of Applied Physics*, 32, p. 510.
39. Hall, D.O. & Rao, K.K. (1999). *Photosynthesis* (6th Edition). Cambridge University Press.
40. We do not consider at all a simplified version of VAT – the sales tax, because it contains a serious system defect, namely, multiple taxation of the same base (added value) in the production chain.

List of illustrations

Figures

Tables

List of abbreviations

AI	artificial intelligence
BP	British Petroleum
DAVT	dynamic added value taxation
DNA	deoxyribonucleic acid
EU	European Union
FAO	food and agriculture organization
GDP	gross domestic product
GST	general system theory
EIA	energy information administration
PC	personal computer
S.A.	South Africa
UK	United Kingdom
UN	United Nations
US	United States
USD	United States dollar
VAT	value added tax