THE MANAGEMENT OF ENTROPY: BEHAVIOR DICHOTOMY OF ECONOMIC ACTOR

Vadim F. Islamutdinov, Kazan Innovative University named after V. G. Timiryasov (IEML) and Yugra State University
Lenar N. Salimov, Kazan Innovative University named after V. G. Timiryasov (IEML)
Vladimir M. Kurikov, Yugra State University
Nailya A. Gareeva, Kazan Innovative University named after V. G. Timiryasov

ABSTRACT

The paper attempts to summarize the achievements in the field of using entropy terminology and methodology in economic research. It exposes the dynamics of thermodynamic and information entropy in economy and management. It reveals the triple dichotomy of entropy of economic actors and introduces the concepts of personal entropy, public entropy, objective entropy, and subjective entropy into scientific discourse. It determines the relationships between the kinds of entropy of economic actors and how they become apparent.

Keywords: Thermodynamic Entropy, Information Entropy, Personal Entropy, Public Entropy, Objective Entropy, Subjective Entropy, Dichotomy.

INTRODUCTION

Modern economy is becoming an increasingly complex and interconnected system which might be hardly described by traditional economic concepts and models. At the same time, the periphery of economic science has seen studies being conducted at the intersection of economics and natural sciences, followed by quite interesting results. One of the ambiguous though interesting *"intersections"* is the use of entropy terminology and methodology in economic research. The relevance of this discipline grows as globalization and environmental problems of humankind do, but studies in this field is fragmented and poorly associate with the concepts and theories accepted by most economists. In this regard, it is necessary to enter entropy into economic terminology, attaching it to the core of economic and management science based on the achievements of modern disciplines: institutional economics, behavioral economics, evolutionary economics.

"The entropy law and the economic process" by Georgescu-Roegen (1971) is considered to have given an impetus to the use of the *"entropy"* concept in economics and management. In this pioneering work he proposed several essential theses:

1. Economic process is an entropic process;
2. Human is striving for low entropy, and the economic deficit is a reflection of the entropy law, which appears to be the most economical in its nature among all the natural laws.
3. Economic activity is in fact a follow-up and complement to the biological human evolution.

Citation Information: Islamutdinov, V.F., Salimov, L.N., Kurikov, V.M., & Gareeva, N.A. (2021). The management of entropy: Behavior dichotomy of economic actor. *Academy of Strategic Management Journal, 20*(4), 1-7.

Based on his work, a whole new discipline in economic science emerged: bio economics or ecological economics, basically aimed at fighting to stop the environment destruction by limiting consumption. Within the ecological economy, a discussion between the proponents of the concept of weak and strong sustainability has developed, e.g. (Gutes, 1996; Krysiak, 2006; Kümmel, 2016). However, the enthusiasm for the concept of thermodynamic equilibrium led Georgescu-Roegen followers into a deadlock. Quite a lot of effort has been made to develop entropy models of static equilibrium in economics; we can refer to the following works as an example (Saslow, 1999; McMahon, 1997; Caticha & Golan, 2014; Kovalev, 2016; Yakovlev & Yakovlev, 2019).

A true breakthrough in using entropy terminology and methodology in economic research occurred with the works by Ilya Prigogine (1977) and their application in economics (Prigogine, 2005). From that moment on, it became clear that economics should be considered as an open dissipative system in a state of dynamic equilibrium, including the parameter of thermodynamic entropy. In this field, we can refer to the following works (Jaynes, 1991; Lozada, 2004; Raine et al., 2006).

The third trend of using entropy in economic research is the application of information theory and information entropy as a measure of the uncertainty of the state of the system. No doubt, the term *"uncertainty"* remains to be prevailing in the economics literature. Although, according to C. Shannon (1949) information entropy is a measure of uncertainty or unpredictability of the system. We can refer to the following works as examples of using information entropy (Chen, 2002; Yang, 2018; Devine, 2018). Though especially interesting results are obtained when entropic terminology and methodology are applied to justify economic behavior, as is done in the works (Etzioni, 1986; Capliny et al., 2017).

Thus, the use of entropy in economics and management has been occurring for a relatively long period of time and widespread, though mainly within the peripheral fields of economic science: ecological economics, econophysics, evolutionary economics, etc. This suggests that despite the attraction of using entropy terminology and methodology in economic research, it faces great methodological challenges.

The aim of the study is to develop a new methodological approach to strategic management based on the use of terminology and methodology of entropy.

METHODS

The main research methods are the systemic method, the induction method and the abstract-logical method. The systemic method was used to identify the general properties of socio-economic systems, the induction method was used to generalize disparate studies on a given topic, and the abstract-logical method was used to formulate inferences and conclusions.

Literature sources were selected according to the criterion of the productive use of the terminology and methodology of entropy in research in economics and management.

RESULTS

Diversity of Entropy in Economy and Management

The central problem of using entropy in economic research is the variety and ambiguity of approaches to define entropy itself and its understanding in economics. However having

Citation Information: Islamutdinov, V.F., Salimov, L.N., Kurikov, V.M., & Gareeva, N.A. (2021). The management of entropy: Behavior dichotomy of economic actor. *Academy of Strategic Management Journal, 20*(4), 1-7.

referred to the primary sources, two main types of entropy emerge: Thermodynamic (Boltzmann, 1866), and Information (Shannon & Weaver, 1949). The first is used in thermodynamics defines a measure of irreversible energy dissipation, sometimes identified with the measure of chaos in the system. The second is used in the information theory, systems theory, and statistical physics and defines the measure of uncertainty of the system, i.e. it characterizes the probability of any macroscopic state of the system. In doing so, both types of entropy are interconnected, since they have a common mathematical meaning – the logarithm of available microstates of the system and both are time-bound (Figure 1).

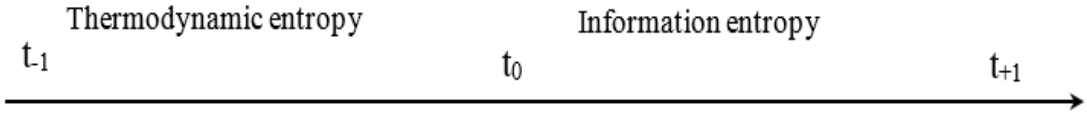

FIGURE 1
TIME ARROW AND TYPES OF ENTROPY

Thermodynamic entropy reflects the irreversibility of time and characterizes the change in the state of the system at the present moment relative to the past. Information entropy reflects the uncertainty of the future and characterizes the probability of changes in the system in the future relative to the present.

With that, one should bear in mind that socio-economic systems belong to the kind of open dissipative systems in a position to decrease their own entropy due to various mechanisms, including by transferring to other systems, e.g., by diverting into the environment (Prigogine, 2005). The value opposite to entropy is called negentropy (Ho, 1994), and in the economy it can accumulate in the form of resources and their universal equivalent – money.

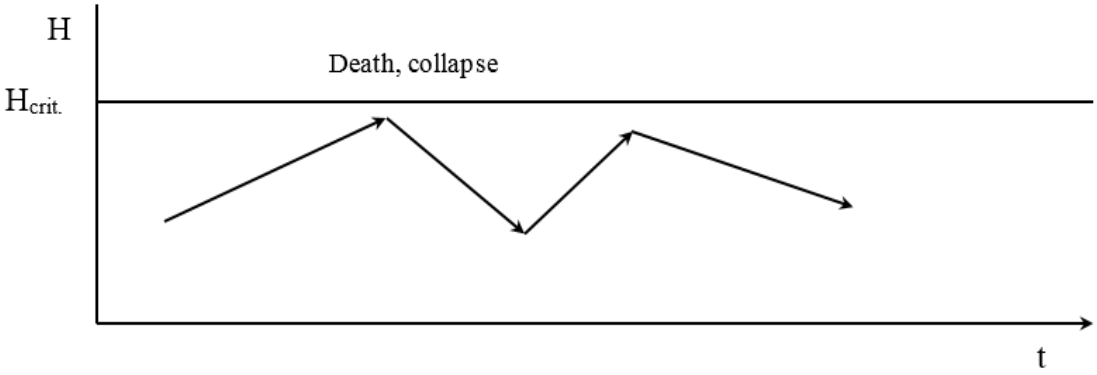

FIGURE 2
DYNAMICS OF THERMODYNAMIC ENTROPY OF ECONOMIC ACTOR

Thermodynamic entropy is suggested to be used as a measure of irreversibility of resources loss to assess the current state of an individual and any socio-economic system, with information entropy as a measure of uncertainty to assess their future state. Then socio-economic relations can be expressed as relations for controlling the level of two types of entropy: thermodynamic (entropy of current state) and information (entropy of the future). Each

Citation Information: Islamutdinov, V.F., Salimov, L.N., Kurikov, V.M., & Gareeva, N.A. (2021). The management of entropy: Behavior dichotomy of economic actor. *Academy of Strategic Management Journal, 20*(4), 1-7.

individual being an economic actor, to the extent of their rationality, monitors the maintenance of their own acceptable level of thermodynamic (current) entropy (or else death), and depending on their planning horizon, assesses the information entropy of their future, including the future of their children. In fact, the entire human economic activity (food, medicine, sleep, clothes, transport, etc.) is aimed either at decreasing (preventing a sharp spike), or at transferring to the environment the accumulated current entropy (Figure 2).

As for information entropy, its level is regulated by the economic actor both from above and below. Too high level of information entropy blocks decision-making (entropy of choice), while too low level leads to no choice. Moreover, this range of acceptable information entropy is quite individual and ever changing (Figure 3).

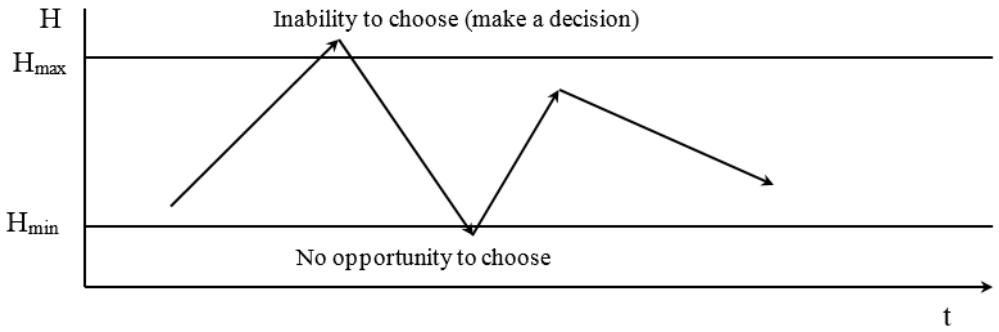

FIGURE 3
DYNAMICS OF INFORMATION ENTROPY OF ECONOMIC ACTOR

The dichotomy is that the individual is permanently due to switch the locus of control between information and thermodynamic entropy. As thermodynamic entropy approaches critical level, the individual above all strives for decreasing, transferring or diverting it. When thermodynamic entropy is far from critical level, the individual tends to slightly increase information entropy, as this allows to satisfy non-material needs, as well as it provides access to new resources, new options for satisfying material needs. That is, an increase in information entropy opens up new ways to decrease, transfer, or divert thermodynamic entropy.

Besides the main types, entropy distinguishes by the level and scale of the socio-economic system, that is, it can be personal and public, wherein one can distinguish a whole range of intermediate values: family, group, region, industry, etc. The dichotomy is manifested in the fact that the individual is often forced to switch the locus of control between personal and public entropy. In this regard, the concepts of individualism and opportunism can be considered in the light of what level of entropy, either personal or public, an individual tends to follow above all. One can also take a fresh look at the problem of deriving the macroeconomic level of economics from the microeconomic one, as the studies into the entropy of complex compound systems show such a relationship (Vozna, 2016; Scharfenaker & Foley, 2017).

Yet another issue with the use of entropy in economics and management is that the economic actor is incapable of perceiving entropy straight forward, since they do not have a specific sense organ for doing so. That is, human can only perceive entropy indirectly through the feelings and sensations they have. Therefore, entropy has to be distinguished by the

Citation Information: Islamutdinov, V.F., Salimov, L.N., Kurikov, V.M., & Gareeva, N.A. (2021). The management of entropy: Behavior dichotomy of economic actor. *Academy of Strategic Management Journal, 20*(4), 1-7.

objectivity degree too: objective, i.e., independent of sensations, but reflecting only the degree of energy (resources) dispersion or real uncertainty of the future, and subjective (Chen, 2002), being perceived with senses. Partially, the signs of this dichotomy were revealed by the behavioral economy followers, with their works (Kahneman & Tversky, 1979) showing that most people are unable to identify risks and uncertainties correctly once they had mathematical statistics skills, and their attitude to risk and benefit depends on the context, i.e. sensations. sensations. In the context of the development of the classification of entropy by the degree of objectivity, the study of the interaction of objective and subjective behavior is of scientific value (Khanmurzina et al., 2020).

Table 1
MATRIX OF THE DICHOTOMY OF ENTROPY KINDS OF ECONOMIC ACTOR

By level of economic system	By degree of objectivity	By type	
		Thermodynamic	**Information**
Personal	Objective	Personal objective thermodynamic entropy	Personal objective information entropy
	Subjective	Personal subjective thermodynamic entropy	Personal subjective information entropy
Public	Objective	Public objective thermodynamic entropy	Public objective information entropy
	Subjective	Public subjective thermodynamic entropy	Public subjective information entropy

Note: Compiled by the author based on research findings

Table 2
ENTROPY MANIFESTATIONS IN THE ECONOMY AND MANAGEMENT

Kinds of entropy	How it manifests (how to measure)	What it impacts
Personal objective thermodynamic entropy	Life expectancy Probability of illness and death	Human life and health
Personal subjective thermodynamic entropy	Quality of life	Economic behavior
Personal objective information entropy	Uncertainty of the future Risk probability	Personal choice (to a lesser extent)
Personal subjective information entropy	Feeling uncertain about the future (happiness index)	Personal choice (to a greater extent)
Public objective thermodynamic entropy	Environmental pollution Frequency and destructive power of natural disasters Probability of social unrest	Environmental setting Sustainability of socio-economic systems (states, corporations, etc.)
Public subjective thermodynamic entropy	Environmental and political activism of the population	Sustainability of socio-economic systems (states, corporations, etc.) Environmental and political behavior
Personal objective information entropy	Economic growth rate Transaction costs	Economic growth
Public subjective information entropy	Expectations indices (Inflation, stock exchange, etc.)	Economic and political behavior

Note: Compiled by the author based on research findings

Thus, taking into account at least three dichotomies of entropy, the whole diversity of entropy of economic actor can be presented in the matrix (Table 1). Each of the entropy kinds

Citation Information: Islamutdinov, V.F., Salimov, L.N., Kurikov, V.M., & Gareeva, N.A. (2021). The management of entropy: Behavior dichotomy of economic actor. *Academy of Strategic Management Journal, 20*(4), 1-7.

somehow reveals itself in the economy and management, and accordingly, one can try and measure the level and dynamics of entropy through indirect indicators (Table 2). As the table shows, entropy reveals in a very diverse way, with the manifestations of subjective entropy be very different from those of objective entropy.

Based on the table data, one can see that humankind has accumulated a quite wide set of indicators and indices enough for indirect measurements and management of the entropy level.

CONCLUSION

Thus, the study conducted show that the use of entropy terminology and methodology in economic research is possible and quite productive. However the three dichotomies of entropy have to be taken into account:

1. Thermodynamic and information;
2. Personal and public;
3. Objective and subjective.

Entropy being included in economic research allows for understanding of its regulation and transfer mechanisms in economy and management, as well as for the improvement of the economic behavior model making it more aligned with the modern realities of a globalized world.

Though despite the promising approach proposed, there are unsolved theoretical and methodological problems:

1. Describe mathematically the relationship between thermodynamic and information entropies in economics;
2. Derive the entropy of complex socio-economic systems from the entropy of their constituent elements, such as deriving public entropy from personal entropy;
3. Determine means to assess the level and dynamics of objective entropy in socio-economic systems;
4. Determine the relationship between objective and subjective entropy.

ACKNOWLEDGMENTS

The research was carried out with the financial support of the grant of the Kazan Innovation University named after V. G. Timiryasov (IEML).

REFERENCES

Boltzmann, L. (1866). On the mechanical meaning of the second law of heat theory. *Wienerberichte, 53,* 195-220.

Caplin, A., Dean, M., & Leahy, J. (2017). *Rationally inattentive behavior: Characterizing and generalizing Shannon entropy* (No. w23652). National Bureau of Economic Research.

Caticha, A., & Golan, A. (2014). An entropic framework for modeling economies. *Physica A: Statistical Mechanics and its Applications, 408,* 149-163.

Chen, J. (2002). *An entropy theory of value*. Available at SSRN 307442.

Devine, S. (2018). An economy viewed as a far-from-equilibrium system from the perspective of algorithmic information theory. *Entropy, 20*(4), 228.

Etzioni, A. (1986). Rationality is anti-entropic. *Journal of Economic Psychology, 7,* 17-36.

Georgescu-Roegen, N. (1971). *The entropy law and the economic process*. Cambridge, MA: Harvard University Press.

Gutes, M.C. (1996). Commentary. The concept of weak sustainability. *Ecological Economics, 17*, 147-156.

Ho, M.W. (1994). What is (schrödinger's) negentropy? *Modern Trends in BioThermoKinetics, 3*, 50-61.

Citation Information: Islamutdinov, V.F., Salimov, L.N., Kurikov, V.M., & Gareeva, N.A. (2021). The management of entropy: Behavior dichotomy of economic actor. *Academy of Strategic Management Journal, 20*(4), 1-7.

Jaynes, E.T. (1991). How should we use entropy in economics? (Some half-baked ideas in need of criticism). Retrieved from https://bayes.wustl.edu/etj/articles/entropy.in.economics.pdf

Kahneman, D., & A. Tversky (1979). Prospect theory: an analysis of decision under risk. *Econometrica, 47*(2), 263-291.

Kahneman, D., & Tversky, A. (1979). On the interpretation of intuitive probability: A reply to Jonathan Cohen.

Khanmurzina, R.R., Cherdymova, E.I., Guryanova, T.Y., Toriia, R.A., Sukhodolova, E.M., & Tararina, L.I. (2020). Computer games influence on everyday social practices of students-gamers. *Contemporary Educational Technology*, *11*(1), 11-19.

Kovalev, A.V. (2016). Misuse of thermodynamic entropy in economics. *Energy*, *100*, 129-136.

Krysiak, F.C. (2006). Entropy, limits to growth, and the prospects for weak sustainability. *Ecological Economics, 58*, 182-191.

Kümmel, R. (2016). The impact of entropy production and emission mitigation on economic growth. *Entropy*, *18*(3), 75.

Lozada, G.A. (2004). Entropy and the economic process. Retrieved from https://content.csbs.utah.edu/~lozada/Research/ENCYC2ME.pdf

McMahon, G.F. (1997). Economics, entropy and sustainability. *Hydrological Sciences-Journal-des Sciences Hydrologiques*, *42*(4), 501-512.

Prigogine, I. (1977). *Self-organization in non-equilibrium systems: From dissipative structures to order through fluctuations.* New York, NY: Wiley.

Prigogine, I. (2005). The rediscovery of value and the opening of economics. In K. Dopfer (Ed.), *The evolutionary foundation of economics*, chapter 2 (pp. 61-69). Cambridge: Cambridge University Press.

Raine, A., Foster, J., & Potts, J. (2006). The new entropy law and the economic process. *Ecological Complexity*, *3*(4), 354-360.

Saslow, W.M. (1999). An economic analogy to thermodynamics. *American Journal of Physics, 67*(12), 1239-1247.

Scharfenaker, E., & Foley, D. K. (2016). *A maximum entropy solution to quantal response equilibria in economic models.* Technical report.

Shannon, C.E., & Weaver, W. (1949). *The mathematical theory of communication*. Urbana, IL: University of Illinois Press.

Vozna, L.Y. (2016). The notion of entropy in economic analysis: the classical examples and new perspectives. *Journal of Heterodox Economics*, *3*(1), 1-16.

Yakovlev, A.A., & Yakovlev, A.V. (2019). Ways of resolving systemic crisis in economic theory. *Actual Problems of Economics and Law*, *13*(1), 923-934.

Yang, J. (2018). Information theoretic approaches in economics. *Journal of Economic Surveys*, *32*(3), 940-960.

Citation Information: Islamutdinov, V.F., Salimov, L.N., Kurikov, V.M., & Gareeva, N.A. (2021). The management of entropy: Behavior dichotomy of economic actor. *Academy of Strategic Management Journal, 20*(4), 1-7.