

Islamic Economics and the Environment: A Study on Entropy

Yunus Kutval¹

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Abstract

This study examines the concept of entropy in the context of Islamic economics and the environment. In particular, it analyzes the relationship between entropy and the environment and addresses important environmental issues related to the sustainable use of natural resources. The aim of the study is to emphasize that entropic processes are a highly explanatory variable in the context of Islamic economics, that Islamic economic environmental philosophy should be further synthesized with the concept of entropy, and that entropy can provide an empirical framework for environmental issues. Throughout the study, it is assumed that Islamic economic philosophy has a natural environmental sensitivity and offers a natural measure of degradation. In this context, it is emphasized that the concept of entropy should find a wider place in the Islamic economics literature and Islamic economics theorists should develop approaches in this direction. The fact that the literature on Islamic economics and the environment is quite scarce and the existing studies generally address environmental problems through philosophical propositions brings the empirical concerns of the study to the forefront. In this context, the study focuses on the concept of entropy, which is a very important concept in the physics literature. The fact that there is no literature that deals with environmental problems at the level of Islamic economics and entropy increases the importance and originality of the study.

Keywords: Islamic Economics, Entropy, Environment, Interest.

JEL Classification: G2, G24, B26

¹ Dr. Öğr. Üyesi / Asst. Prof., Kafkas Üniversitesi, İktisadi ve İdari Bilimler Fakültesi, İktisat Bölümü / *Kafkas University, Faculty of Economics and Administrative Sciences, Department of Economics, yunuskutval@hotmail.com, ORCID: <https://orcid.org/0000-0003-0063-9157>.*

1. Introduction

The invention of the steam engine enabled the conversion of heat energy into mechanical energy and the start of the industrial revolution. Scientists conducted various studies between heat and energy conversion in this process and the concept of “thermodynamics” emerged (Kondepudi & Prigogine, 2015). This development in physical science has influenced many disciplines and multidisciplinary fields have emerged. In particular, the effects of entropy, the second law of thermodynamics, have had significant effects on the fundamental inferences about the nature of our physical reality (Floyd, 2007).

Entropy is a law of physics and refers to the inevitable transformation of energy from usable energy (ordered energy) to unusable energy (disordered energy) (Maiseu & Voss, 1995). This transformation is irreversible and works similarly for economic processes (Kümmel & Lindenberg, 2020). In this context, there is an important intersection between entropy and economics. In particular, the concept of entropy is becoming more and more relevant in issues such as economic growth, sustainability, sociology and the environment, and policy recommendations are offered to reduce entropic processes. Islamic principles, on the other hand, succeeded in establishing these recommendations centuries ago through the teachings of the Qur'an and Sunnah, the fundamental sources of Islam.

According to Islam, man is God's caliph and is responsible for everything that happens around him. In this context, it commands Muslim individuals to shape their economic concerns according to social and environmental concerns. It also recommends the production of systems in accordance with the laws of nature, which are accepted as Allah's sunnahullah, not to waste and to use resources in a sustainable manner.

The limited number of Islamic economics and environment studies in the literature and the fact that these studies are generally based on moral and sociological arguments have caused the analytical aspect of the “Islam and Environment” debates to be missed. In order to fill this academic gap, this study has a very important place and offers a new approach to the “Islamic Economics and Environment” literature.

Translated with DeepL.com (free version) In this context, this study will first explain the concept of entropy. Then, it will examine the relationship between entropy and economics through the studies in the literature. Immediately afterwards, discussions on the environmental philosophy of Islamic economics will be carried out. Finally, the analytical link between entropy and the prohibition of interest will be tried to be established. Thus, it will be emphasized that Islamic economics and finance practices actually contain a high level of both economic and environmental sensitivity, and that the concept of entropy should be given more space in order to reveal this connection more clearly.

2. Environment, Economy and Human

The Earth and the myriad of resources that exist within it constitute the basic foundation on which we build our environment and economic activities (Ludwig, & Iannuzzi, 2008). The environment is a concept that has been shaped over billions of years and includes human beings within its structure. Humans are a relatively new but rapidly growing phenomenon compared to the environment (Motesharrei, et. al., 2016). Despite the human population and its increasing needs, the environment and resources are limited. There is a general misconception that our concerns about the environment will disappear with technological developments and measures to be taken. However, new technologies can increase, facilitate or decrease pollution (Grübler, Nakićenović, & Victor, 1999). Therefore, we need to reconsider our perspective on the environment.

The interdependence between the environment and the economy is a dynamic and multifaceted phenomenon. It has consequences with a wide range of impacts at various sectoral and scale levels. At the macro level, the health of the environment is inextricably linked to the long-term sustainability and resilience of economic systems. The overuse and depletion of natural resources has significant impacts on the environment through the generation of waste and pollution. This can lead to economic destabilization, affect growth and threaten all life, including human beings. Likewise, the pursuit of economic development driven by short-term profit maximization can lead to environmental degradation, loss of biodiversity and disruption of vital ecosystems.

“Since 1900, the use of coal, oil, gas and electricity and the per capita consumption of fossil fuels has steadily increased, and the same is true for material use. The rapidly increasing impact of human activities has resulted in biomass, carbon, nitrogen and phosphorus cycles that have eaten up to 55% of the world's vegetation and negatively affected global photosynthetic productivity. Food demand is expected to double by 2050. There are huge pressures on land, water resources and biodiversity. Greenhouse gases from fossil fuels have become major drivers of climate change, melting glaciers, rising sea levels and increasing ocean acidification. Human activities have contributed greatly to global warming by fundamentally altering the nitrogen cycle, altering water cycles and depleting large freshwater resources. Extreme weather events and other environmental changes have caused severe disruptions to ecosystems. Socioeconomic trends have also accelerated their impact on the world, leading to the spread of metal pollutants and species extinctions. These processes lead to complex interactions between the Earth System and the Human System, creating feedback mechanisms in areas such as human health, economic growth, migration and social conflict” (Motesharrei, et al., 2016).

Adequate measures are not taken for these destructive effects, which are often the result of economic concerns and the search for comfort, and policies that support consumption and waste are produced on the grounds of economic goals such as growth, development, etc. (Sen, 2013). The fact that orthodox economic approaches do not include “ethical” values for the environment causes the problem to deepen. Of course, the environment and resources have an end. But this is determined by nature's own clock, that is, entropy. In this context, it is very important to understand entropy and address it in the context of environmental problems.

3. Entropy

Entropy is a statistical concept, first defined by Clausius in the mid-19th century, that measures the disorder, uncertainty or disorganization of a system (Natal et al., 2021; Bulut, 2017). According to this concept, known as the second law of thermodynamics, the higher the entropy in a system, the higher the disorder or uncertainty in that system (Lieb & Yngvason, 1999; Ursescu & Cioc, 2016). In isolated systems, entropy gradually increases over time compared to open systems, as there is no factor to reduce or prevent entropy, and the system becomes more disordered. This disorder appears as a fundamental element in determining the direction of natural processes and the realization of thermodynamic equilibrium (Lebon & Casas-Vázquez, 2008).

An increase in entropy occurs when a system loses some of its internal energy by transferring it to the outside or expends it by doing work. In addition, factors such as the decrease in molecular order within a system or the number of particles in a system can also cause entropy to increase (Struchtrup, 2014). In a simple example, when a wood stove is used to heat a room, we initially encounter a low entropy state, which refers to the low temperature energy in the room. When we ignite the stove, the fuel, which represents the available regular energy inside the stove, burns and heat production begins. This heat spreads into the room and increases the temperature of the room. However, the heat distribution is not completely efficient. Some of the heat will radiate towards the walls and outside of the room. This means that the irregularity in the heat system inside the room increases. Because some

of the energy has become unusable or unevenly distributed. Therefore, the use of energy causes the entropy of the systems to increase. The room, which is initially a low entropy system, becomes a higher entropy system as a result of energy transfer and utilization. In other words, when wood is converted from fuel energy to heat energy, complete optimization is not achieved and some energy is dissipated. This is one of the most fundamental rules of physics and therefore many topics such as natural resources, energy efficiency, waste management and ecosystems are closely related to entropy (Kåberger & Månsson, 2001; Smulders, 1995).

Theoretical physicists in particular have been conducting in-depth studies on the concept of entropy in relation to the second law of thermodynamics and the fundamental principles of statistical mechanics. These studies provide important findings for understanding the evolution of natural systems and complex structures, thermodynamic equilibrium and natural processes. On the other hand, these findings not only affect the field of physics, but also engineering, biology, chemistry and many other disciplines. For example, the concept of entropy is considered as an important field that deals with efficiency issues such as energy transformations and sustainability. Therefore, research on entropy sheds light on multidisciplinary studies and has a wide impact. In this context, it is very important to examine the relationship between entropy and economics.

4. The Entropy-Economics Relationship

The relationship between economics and entropy was first discussed in 1971 by the American economist Nicholas Georgescu-Roegen in his article “The Entropy Law and Economic Process” (Cojanu, 2009). According to Georgescu-Roegen; economic processes produce final products and services by using low entropy inputs (such as raw materials and energy) in the production phase. In this process, low entropy inputs are transformed into high entropy outputs. In simpler terms, in economic processes, inputs of low order or complexity are transformed into outputs of high order or complexity (Jakimowicz, 2020). This is an explanation of the low entropy responsible for the utility of the good. That is, the value of a good is related to the entropy of the resources spent in its production process, as well as the low-entropy order it embodies. To summarize, Georgescu-Roegen (1971) argues that economic systems also have an entropic structure and that resources and energy tend to be depleted due to this structure. According to him, economic activities are inherently associated with an increase in entropy, which makes sustainability difficult in a world with limited resources.

After the work of Nicholas Georgescu-Roegen, a number of new disciplines have emerged that examine the relationship between economics and physics, including entropy, combining disciplines such as mathematics, physics and economics. Econophysics, quantum economics and complex systems theory are the most prominent among these theories (Jakimowicz, 2020). These new approaches, which offer alternative approaches to traditional economic approaches, aim to understand and analyze economic phenomena in depth.

In general, studies examining the entropy-economics relationship in the literature can be categorized as follows;

Predictability: The market mechanism is built on equilibrium analysis in economic models. Therefore, it is necessary to predict the behavior of the actors in the market and organize economic policies accordingly. Given the difficulty of predicting human behavior, it is necessary to produce useful models to predict which economic agents will react to which policies in accordance with the principle of causality. In this context, multidisciplinary approaches such as “Complexity Economics” have emerged as an alternative to the restrictive agent models of neo-classical arguments (Arthur, 2021). This approach, which basically tries to explain the economy with the laws of physics, makes frequent use of entropy and offers statistical approaches that integrate its chaos into the chaos of economic agents and

thus try to adapt the predictability of entropic processes to economic models (Dyke, 1994; Jakimowicz, 2020).

Environmental Impacts and Optimization: Studies under this heading and its derivatives occupy a considerable amount of space in the literature and aim to evaluate the impacts of economic activities on the environment and provide optimization options to minimize these impacts (Oates, W. E., & Portney, 2003; Schaltegger, & Synnestvedt, 2002). In these studies, entropy is an important tool for predicting the exogenous effects of economic activities. For example, it is used to measure the complexity and disorder of economic systems, to predict environmental degradation processes, or to express the magnitude or direction of disturbances.

While economic activities have a direct impact on the environment, the environment is also very important in determining economic activities (Oates, W. E., & Portney, 2003). Especially from a sustainable development perspective, entropy calculations play an important role in assessing the sustainability of the use of natural resources. Entropy analyses provide a highly functional analysis to determine the efficiency and waste of the use of natural resources. In this context, entropy is the main reference point for quantifying constraints for the efficient use of resources.

Growth: Economic growth is the growth rate of an economy over time or the increase in its production capacity. This growth is usually measured by indicators such as an increase in the production of goods and services, increased employment and higher incomes. Economic growth can increase the welfare of societies, but it can also contribute to resource depletion, environmental degradation and social imbalances (Arrow et al., 1995).

In the discussions of concepts such as economic growth and sustainable growth, entropy has attracted considerable attention in recent years. In fact, Paul A. Samuelson, a Nobel Prize winner in economics and a very important figure in growth theory, stated that entropy economics has changed the perception of economic processes (Daly, 2007).

In the future, with increasing environmental concerns, it is likely that the entropy-economics relationship will be further considered and researched. In this context, it is expected that the concept of entropy will be integrated more in economic models and studies will increase to better understand the environmental impacts of economic policies. As a result, it is expected that the entropy-economics relationship will be more prominent in the economic literature in the future and will make a significant contribution to economic decision-making processes.

5. Islamic Economics and Environmental Philosophy

Islamic economics' understanding of the environment is shaped by the teachings of the Qur'an and Sunnah (Muhamad et al., 2019). These teachings emphasize the principles of tawheed and the role of humans as stewards or "caliphs" on earth (Dutton, 2003; Islam, 2016). Islam builds the basic principles of environmental ethics on these concepts. This philosophy recognizes that the environment is not only a resource that humans can exploit, but also a trust from Allah that must be cared for and protected. It also emphasizes the balance and harmony between humans and their environment, the need for Muslims to use natural resources wisely, and the importance of avoiding waste and excess. Guided by these principles, Muslims are encouraged to adopt sustainable practices in their economic activities (Hassan, 2005), thus ensuring the long-term well-being of both people and the environment. Some relevant verses and hadiths are as follows;

(Kamer 49) "Verily, all things have We created in proportion and measure."

(Hicr 19-20) "And the earth We have spread out (like a carpet); set thereon mountains firm and immovable; and produced therein all kinds of things in due balance. And We have provided

therein means of subsistence,- for you and for those for whose sustenance ye are not responsible.”

(A'raf 31) “O Children of Adam! wear your beautiful apparel at every time and place of prayer: eat and drink: But waste not by excess, for Allah loveth not the wasters.”

(Rahman 7-8) “And the Firmament has He raised high, and He has set up the Balance (of Justice). In order that ye may not transgress (due) balance.”

(En'am 38) “There is not an animal (that lives) on the earth, nor a being that flies on its wings, but (forms part of) communities like you. Nothing have we omitted from the Book, and they (all) shall be gathered to their Lord in the end.”

(Muslim, Muscat, 10) “If a Muslim plants a tree or sows a crop and man, animal or bird eats from it, it is charity for that person until the Day of Judgment.”

As can be understood from the above verses and hadiths, Islam prohibits all factors that would disrupt the perfect order created by Allah and glorifies believers who uphold these values. In the context of Islamic economics, this philosophy translates into a holistic approach that takes into account environmental sustainability in economic decision-making processes. Islamic principles such as the prohibition of *riba* (interest), fair trade and the emphasis on social justice are compatible with the ethical treatment of the environment (Mirza, & Baydoun, 2000). This means that economic activities should not only be profitable, but also take into account their impact on the natural world and future generations.

The concept of “*amanah*” (entrustment) in Islamic teachings includes the environment and emphasizes the responsibility of present generations to protect the Earth for the benefit of future generations (Muhamad, Syihab, & Ibrahim, 2020). This concept reflects a long-term perspective that goes beyond immediate gains by promoting sustainable development and the use of renewable resources.

Furthermore, the Islamic framework promotes the idea of “*hisba*” (accountability), which encompasses the duty to enjoin good and forbid evil (Attahiru, Al-Aidaros, & Yusof, 2019). In the environmental context, this concept calls for accountability and stewardship, inviting individuals, businesses, and governments to support ethical and sustainable policies.

It would be quite wrong to think that people are at the center of Islam's understanding of the environment. So much so that even the depictions of paradise, which reflects the perfect life and is promised as a reward for believers, express an ecological balance (Kutval & Kanbir, 2021). It also clearly states that animals have as much right on this ecological demand as humans (Masri, 2016).

In conclusion, the environmental understanding of Islamic economics adopts a holistic approach that requires consideration of not only economic activities but also their environmental and social impacts. This approach provides the framework for sustainable development, the construction of a just society and an economic system that respects the environment. In this way, it aims to draw natural limits to economic, social and environmental entropy.

6. Interest and Entropy

Riba (interest), which literally means “excess, increase, proliferation”, is defined as “the real or de facto surplus in loan transactions and exchanges that is not reciprocated” (TDV, March 13, 2024). Interest, which is strictly prohibited in verse 275 of Surah Al-Baqarah in the Quran, is one of the most important issues in Islamic economics and finance and has effects on society, morality and economy (Zakir Hossain, 2009).

The studies examining interest with philosophical arguments are abundant in the literature. This literature generally focuses on “moral philosophy”. It is noteworthy that studies on its effects on the economy and the environment are limited. In this context, Diwany (2011) asks “What determines the price (rate) of interest? Are interest rate policies sustainable?” and stated that natural resources are being driven to extinction due to interest. This point of view has emerged with the efforts to put the prohibition of interest in an analytical framework as a problem of balance and measure, considering the verses that Allah has ordained everything created according to a measure (Surah al-Furqan, 25:2) and put an order in everything created (Surah al-Rahman, 55:7-8).

Diwany summarized the issue with the following example. “Assuming that a farmer borrows to purchase agricultural land, two basic scenarios emerge. In the first scenario, the farmer utilizes the agricultural land with high productivity and earns a large income of 150 units. However, these highly productive agricultural practices will cause the agricultural land to become unproductive within 15 years due to factors such as soil fatigue, over-fertilization and irrigation. In this case, maximum entropy will be realized. In the second scenario, the farmer opts for natural farming methods and earns a lower but more sustainable income of 100 units. In this case, the farmland will remain productive in the much longer term. In other words, natural entropy will occur and the sustainability of agricultural land will increase. Financial institutions are aware of both situations and, in order to increase their own profitability, they create interest and repayment plans based on the productivity in the first case. Thus, they put pressure on the farmer to produce at a level that destroys agricultural land” (Diwany 2011; Kutval & Kanbir, 2021). Diwayn's example can be diversified to other sectors and initiatives.

As the above example shows, high productivity does not always mean optimization. Accelerating the entropic processes of agricultural land in order to achieve high productivity in the short run will actually lead to a reduction or even zero total output in the long run. This is clearly a waste of resources (such as the destruction of agricultural land). According to Diwayn, this is because interest is concerned with output rather than sustainability. Therefore, the perpetrator of the waste of natural resources is interest priced at high productivity.

The ancient Greek thinkers Plato (Eflatun) and Aristotle (Demirgil & Türkay, 2017), like Diwayn, considered interest as a phenomenon “contrary to nature”. However, these hypotheses have not yet been tested by empirical studies. Today, the fact that capital is limited and entrepreneurs have to accept the conditions of financial institutions to access this capital increases the destructive effect of interest on the one hand and makes it difficult to account for on the other. In this context, it is necessary to examine the results of empirical studies and to examine whether the destructive effects of interest are at a level worth considering.

7. Conclusion

Islamic economics is a system of economic thought and practice shaped by the teachings and principles of Islam. These teachings aim to regulate economic relations in accordance with natural laws. The importance given to nature and the environment in Islamic economics makes the principles of minimizing entropic processes prominent. These teachings emphasize the prevention of waste, the protection of the environment and the observance of moral values in economic relations. Thus, Islamic economics is based not only on material gains but also on social and moral values.

In this context, conducting academic studies on “Islamic Economics and the Environment” by utilizing the science of physics will provide a scientific basis for philosophical arguments on Islamic economics. It will also play a critical role in addressing sustainability practices, which have become popular in academia in recent years, by establishing a natural connection with the values in Islamic



economics. It is very important for academics working in this field to take care to emphasize this, especially through the concept of entropy, in order to create an analytical infrastructure.

Competing Interest

The author declares that he has no competing interests.

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Ethical Statement

It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited.

Author's Contributions

This article was created as a result of the author's own efforts and reviews. But I declare that I only used artificial intelligence programs as assistants for grammar, spelling errors and English translation.

REFERENCES

- Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. S., ... & Pimentel, D. (1995). Economic growth, carrying capacity, and the environment. *Ecological economics*, 15(2), 91-95. [https://doi.org/10.1016/0921-8009\(95\)00059-3](https://doi.org/10.1016/0921-8009(95)00059-3)
- Arthur, W. B. (2021). Foundations of complexity economics. *Nature Reviews Physics*, 3(2), 136-145. <https://www.nature.com/articles/s42254-020-00273-3>
- Attahiru, M. S., Al-Aidaros, A. H. M. H., & Yusof, S. M. (2019). The moderating role of Hisbah principles on the relationship between Islamic culture and Islamic business ethics. *International Journal of Innovation, Creativity and Change*, 5(2), 1478-1499. https://www.academia.edu/download/77456070/84_Attahiru_P_1478_2019R.pdf
- Bulut, F. (2017). Different mathematical models for entropy in information theory. *Bilge International Journal of Science and Technology Research*, 1(2), 167-174. <https://dergipark.org.tr/en/pub/bilgesci/issue/32353/335439>
- Cojanu, V. (2009). Georgescu-Roegen's entropic model: a methodological appraisal. *International Journal of Social Economics*, 36(3), 274-286. <https://doi.org/10.1108/03068290910932756>
- Conca, K. (2001). Consumption and environment in a global economy. *Global Environmental Politics*, 1(3), 53-71. <https://doi.org/10.1162/152638001316881403>
- Daly, H. E. (2007). *Ecological economics and sustainable development, Selected Essays of Herman Daly*. Edward Elgar Publishing.
- Demirgil, B., & Türkay, H. (2017). Tarihsel Süreç İçerisinde Faiz Olgusunun Kuramsal Açıdan Gelişimi. *Cumhuriyet Üniversitesi İktisadi ve İdari Bilimler Dergisi*, 18(2), 131-160. <https://dergipark.org.tr/en/download/article-file/370359?sa=X&ved=2ahUKewiUoOr2gYLnAhVDjqQKHWzuDg0QFjAEegQIARAB>
- Dutton, Y. (2003). The environmental crisis of our time: A Muslim response, Foltz R. & F. M. Danny (Ed.), *Islam and Ecology, a bestowed trust* (pp. 322-340), Harvard University Press.
- Dyke, C. (1994). From entropy to economy: a thorny path. Peter Burley & Jhon Foster (Ed.) In *Economics and Thermodynamics: New Perspectives on Economic Analysis* (pp. 207-238). Dordrecht: Springer Netherlands.
- El Diwany, T. (2011). *Faiz Sorunu*. (M. Saraç (Çev) 1. Baskı) İstanbul: İz Yayıncılık.
- Floyd, J. (2007). Thermodynamics, entropy and disorder in futures studies. *Futures*, 39(9), 1029-1044. <https://doi.org/10.1016/j.futures.2007.03.011>
- Georgescu-Roegen, N. (1971). *The entropy law and the economic process*. Harvard university press. <https://doi.org/10.4159/harvard.9780674281653>
- Grübler, A., Nakićenović, N., & Victor, D. G. (1999). Modeling technological change: implications for the global environment. *Annual Review of Energy and the Environment*, 24(1), 545-569. <https://doi.org/10.1146/annurev.energy.24.1.545>
- Hassan, A., (2005). Islamic economics and the environment: Material flow analysis in society-nature interrelationships. *Journal of King Abdulaziz University: Islamic Economics*, 18(1).
- Islam, M. A. (2016). An essay on the ethics of Islam towards environmental resources. *Revelation and Science*, 6(2), 9-23. <https://doi.org/10.31436/revival.v6i2.180>
- Jakimowicz, A. (2020). The role of entropy in the development of economics. *Entropy*, 22(4), 452, 1-25. <https://doi.org/10.3390/e22040452>
- Kåberger, T., & Månsson, B. (2001). Entropy and economic processes—physics perspectives. *Ecological Economics*, 36(1), 165-179. [https://doi.org/10.1016/S0921-8009\(00\)00225-1](https://doi.org/10.1016/S0921-8009(00)00225-1)

- Kondepudi, D., & Prigogine, I. (2015). *Modern thermodynamics: from heat engines to dissipative structures*. (2nd ed.). John Wiley & Sons. <https://doi.org/10.1002/9781118698723.ch1>
- Kutval, Y. & Kanbir, Ö. (2021). Çevre ve ekoloji, İslam iktisadı yaklaşımı, İstanbul: İktisat yayınları.
- Kümmel, R., & Lindenberger, D. (2020). Energy, entropy, constraints, and creativity in economic growth and crises. *Entropy*, 22(10), 1156. <https://doi.org/10.3390/e22101156>
- Lebon, G., Jou, D., & Casas-Vázquez, J. (2008). *Understanding non-equilibrium thermodynamics, foundations, applications, frontiers*. Berlin: Springer. <https://doi.org/10.1007/978-3-540-74252-4>
- Lieb, E. H., & Yngvason, J. (1999). The physics and mathematics of the second law of thermodynamics. *Physics Reports*, 310(1), 1-96. [https://doi.org/10.1016/S0370-1573\(98\)00082-9](https://doi.org/10.1016/S0370-1573(98)00082-9)
- Ludwig, D., & Iannuzzi, T. (2008, June 2). Hidden Dimensions of Stewardship. *Human and Ecological Risk Assessment: An International Journal*, 14 (3), 437-438. <https://doi.org/10.1080/10807030802077207>
- Maisseu, A., & Voss, A. (1995). Energy, entropy and sustainable development. *International journal of global energy issues*, 8(1-3), 201-220. <https://doi.org/10.1504/IJGEI.1995.063497>
- Masri, A. H. B. A. (2016). *Animal welfare in Islam*. Kube Publishing Ltd.
- Mirza, M., & Baydoun, N. (2000). Accounting policy choice in a riba-free environment. *Accounting, Commerce & Finance: The Islamic Perspective Journal*, 4(1), 30-47. https://www.academia.edu/download/39927490/Accounting_Policy_Choice_in_A_Riba_free.pdf
- Motesharrei, S., Rivas, J., Kalnay, E., Asrar, G. R., Busalacchi, A. J., Cahalan, R. F., ... & Zeng, N. (2016). Modeling sustainability: population, inequality, consumption, and bidirectional coupling of the Earth and Human Systems. *National Science Review*, 3(4), 470-494. <https://doi.org/10.1093/nsr/nww081>
- Muhamad, A., Syihab, A. H., & Achour, M. (2019, June 26). Quranic Messages on Environmental Sustainability: an Expository Study of Its Relevance. <https://doi.org/10.1163/22321969-12340069>
- Muhamad, A., Syihab, A. H., & Ibrahim, A. H. (2020). Preserving human–nature’s interaction for sustainability: Quran and Sunnah perspective. *Science and engineering ethics*, 26(2), 1053-1066. <https://link.springer.com/article/10.1007/s11948-020-00192-7>
- Natal, J., Ávila, I., Tsukahara, V. B., Pinheiro, M., & Maciel, C. D. (2021). Entropy: From thermodynamics to information processing. *Entropy*, 23(10), 1340, 1-14. <https://doi.org/10.3390/e23101340>
- Oates, W. E., & Portney, P. R. (2003). The political economy of environmental policy. In *Handbook of environmental economics*, 1, 325-354. [https://doi.org/10.1016/S1574-0099\(03\)01013-1](https://doi.org/10.1016/S1574-0099(03)01013-1)
- Schaltegger, S., & Synnestvedt, T. (2002). The link between ‘green’ and economic success: environmental management as the crucial trigger between environmental and economic performance. *Journal of environmental management*, 65(4), 339-346. <https://doi.org/10.1006/jema.2002.0555>
- Sen, A. (2013). *A survey of sustainable development: social and economic dimensions* (Vol. 6). Island Press.
- Smulders, S. (1995). Entropy, environment, and endogenous economic growth. *International Tax and public finance*, 2, 319-340. <https://link.springer.com/article/10.1007/BF00877504>
- Struchtrup, H. (2014). *Thermodynamics and energy conversion*. Springer. <https://doi.org/10.1007/978-3-662-43715-5>
- Türkiye Diyanet Vakfı (TDV) (13 Mart 2024). İslam Ansiklopedisi. <https://islamansiklopedisi.org.tr/riba>
- Ursacescu, M., & Cioc, M. (2016). Evaluation of information entropy in organizational system. *Management and Economics Review*, 1(2), 82-91. <https://www.ceeol.com/search/article-detail?id=681022>



Zakir Hossain, M. (2009). Why is interest prohibited in Islam? A statistical justification. *Humanomics*, 25(4), 241-253. <https://doi.org/10.1108/08288660910997610>