An Entropy Theory of Value

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Abstract

More than half century ago, Shannon's identification of information as the reduction of entropy greatly clarified the meaning of information and established information theory as a science. Since all human activities represent extraction and transformation of low entropy from the environment, it is natural to relate economic value to low entropy. However, some conceptual difficulties prevented the development of an entropy theory of value. In this work, we identify economic value as the reduction of entropy mathematically and explore the relation between physical entropy and economic value. In the process, we show how the detailed investigation of information theory, thermodynamic theory and the theory of evolution resolves the conceptual difficulties that confound us for many years. The entropy theory of value, by establishing the theory of value on the firm foundation of thermodynamics, greatly clarified many fundamental issues in economic theory and human activities.

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I. INTRODUCTION

"The problem of value must always hold the pivotal position, as the chief tool of analysis in any pure theory that works with a rational schema." (Schumpeter, 1954, p. 588) However, after several hundred years of devoted works by some of the greatest economists, "today value theory remains in a highly unsettled state." (Mirowski, 1989, p. 147)

All human activities represent extraction and transformation of low entropy from the environment. (Schrodinger, 1944; Prigogine, 1980) It is natural to relate economic value to low entropy. Indeed "there have been sporadic suggestions that all economic values can be reduced to a common denominator of low entropy." (Georgescu-Roegen, 1971, p. 283)

Shannon's identification of information as the reduction of entropy greatly clarified the meaning of information and established information theory as a science. The success of information theory stimulated many research in economics. (Theil, 1967) However, some conceptual difficulties prevented the development of an entropy theory of value, or "information theory of value". (Georgescu-Roegen, 1971; Arrow, 1999) The main work of this paper is to identify economic value as the reduction of entropy mathematically and explore the relation between physical entropy and economic value. In the process, we explain how the detailed investigation of information theory, thermodynamic theory and the theory of evolution resolves the conceptual difficulties that confound us for many years.

Why both information and economic value are the reduction of entropy? From the entropy law, the most universal law of the nature, the increase of entropy of a system is spontaneous. The reduction of entropy in a system, however, takes effort, which is the base for both information and economic value.

In Section II, we develop the mathematical theory of value as entropy. This part follows essentially to Shannon's (1948) classic work. We discuss the implications of the identification of value as entropy. These implications are highly consistent with our intuitive understanding of economic value. In Section III, we utilize the results from information theory, statistical physics and the theory of evolution to discuss the relation between thermodynamic entropy value and the economic value. An important result in information theory is that the amount of information one can receive depends on the statistical relation between the receiver and the sender. Most of the understanding about what determines economic value comes from the detailed investigation about the implications of this result. In Section IV, from the theory of natural selection and sexual selection, we discuss how this entropy theory of value offers a unifying understanding of the objective and subjective theories of value. In Section V, we discuss how information can be understood as a normal economic commodity in the light of this entropy theory of value. By resolving the conceptual difficulties that confound us for many years, we offer a unified understanding of physical entropy, information and economic value. In Section VI, we discuss the relation between economic value and social welfare. Section VII concludes.

II. THE MATHEMATICAL THEORY OF VALUE AS ENTROPY

Value is a function of scarcity. Scarcity can be defined as a probability measure *P* in a certain probability space. It is generally agreed that value of products satisfies the following properties:

(a) The value of two products should be higher than the value of each of them.

(b) If two products are independent, that is, if the two products are not substitutes or partial substitutes of each other, then the total value of the two products will the sum of two products.

(c) The value of any product is non-negative.

The only mathematical functions that satisfy all the above properties are of the form

$$V(P) = -\log_b P \tag{1}$$

where b is a positive constant. (Applebaum, 1996)

Figure 1 is a graph of *V* as a function of P, the scarcity of a commodity. From (1), we can see that value is an increasing function of scarcity. When $P = 1$, $-\log P = 0$. The value of an extreme abundant commodity is zero. When P approaches zero, -log*P* approaches infinity. The value of an extreme rare commodity approaches infinity. So diamond worth more than water.

In general, suppose a service or product, *X*, can perform different tasks, with probability of $p_1,\ p_2,\ \ldots\ p_n,$ Then the value of this product is the average of the value of each task. That is

$$V(X) = \sum_{i=1}^{n} p_i(-\log_b p_i) \tag{2}$$

Therefore, value, just as information, in its general form can be defined as entropy. In information theory, the base of the logarithm function is usually chosen to be two because there are two choices of code in information transmission, namely, 0 and 1. In economics, the base b can be understood as the number of choice of producers.

After defining information as entropy, Shannon stated: "The real justification of these definitions, however, will reside in their implications." (Shannon and Weaver, 1949, p. 50) In the following we will discuss the implications of this definition.

1. Value and the number of producers

From (2), value is inversely related to the number of producers. Figure 2 displays the relation of value and number of producers. When the number of producers is small, the value of a product is high. That's why monopoly products are valued highly. If the base becomes one, i.e., absolute monopoly without substitution, value becomes infinity. This happens at some religious cults where only the spiritual leaders hold the key to heaven. In these types of organizations, the leaders often enjoy infinite power over their followers. The number of providers of some economic goods depends on the institutional structures, the cost structure of the particular industry and the stage of development. (Acs and Audretsch, 1988; Chen, 2002a) In the following, we only give a brief discussion about institutional structures.

The anti-trust regulations aim at preventing the price fixing from existing providers of a service or product and lower barriers to potential entry. Both measures, by increasing the number of choices, reduce the value of products, and hence the cost to consumers. The value of a product is lower in a more competitive market. However, this does not mean a competitive firm is less valuable. By charging lower prices, it attracts higher volume of businesses. The total value of the product is

$$N\sum_{i=1}^{n} p_i(-\log_b p_i) \tag{3}$$

where N is the volume of the product. The value of the firm may increase as a result.

The patent right and commercial secrets legislation, on the other hand, by granting monopolies and discourage knowledge diffusion, maintains the high value of new products and successful firms. The value supporting legislation encourages innovation and reward good management. The balance between foster competition and protect innovation is always a delicate one. (Arrow, 1999)

An extensive literature surrounds the issue of cost and benefit of import quota and tariffs. (Romer, 1994) The identification of value as entropy sheds new light on this issue. The quota system forces the transfer of production technology to other countries. Ultimately, the diffusion of technology and the increase of the number of producers will increase the base and hence reduce the value of the imported goods. This may result in a net welfare gain to the import countries over the long term, instead of the welfare loss suggested in most literature. However, the quota systems, by restricting the scale of production and reduce the value of the products, do increase the cost and reduce the profit to the original exporters.

2. Scarcity and value

From (1), value is an increasing function of scarcity. In the extreme abundance, i.e., when p=1, the value of the commodity is equal to zero. For example, when water is abundant and readily available. Its value is zero. But when water becomes scarce, p <1, the value for water becomes positive. Since food is essential for survival, most countries subsidize food production in various ways. The abundance of food causes its low economic value.

We next explore the relation between the stages of product development and its value. Suppose an economic system has M persons. The percentage of people who have the product is p. Then the unit value of a product is

$$-\log p \tag{4}$$

The total value of a product is

$$Mp(-\log p) \tag{5}$$

Figure 3 is the graph of unit value and total value of a product with respect to its abundance. When a product is new and scarce, the unit value is high. Its total value is low. As the production increases, the total value will increase as the unit value decreases. When the production quantity is over a certain level, however, the total value of a product will start to decrease as well. Intuitively, this is easy to understand. The market values of manufacturers of mature products are generally low, although the production processes are very efficient and the products are readily available. This observation shows that efficiency is not equivalent to value.

3. Substitutability and value

Many products and services are not identical but can substitute each other to a certain degree. The value of a single product can be defined as its entropy (2). The total value of two products can be defined as their joint entropy

$$V(X,Y) = -\sum_{j=1}^{n}\sum_{k=1}^{m} p_{jk} \log(p_{jk})$$

while the individual value of X and Y can be defined as

$$V(X) = -\sum_{j=1}^{n} p_j \log p_j$$

$$V(Y) = -\sum_{k=1}^{m} q_k \log q_k$$

It can be proved that (Shannon, 1948)

$$V(X,Y) \le V(X) + V(Y) \tag{6}$$

The equality holds only when X and Y are independent, i.e., X and Y are not substitute or partial substitute to each other. This means that substitutability reduces the value of a product. The purpose of brand name management and advertisement of a product is to make a product special and to reduce the substitutability of it, which increases the value of that product.

4. Division of labour and value

In an economic system with M persons, suppose there are n professions. The total economic value of the system can be represented as

$$V = -M\sum_{i=1}^{n} p_i \log(p_i) \tag{7}$$

For simplicity, we assume each profession has the same amount of people, i.e.,

$$p_i = 1/n \qquad \text{for each} \quad i \tag{8}$$

In this case, the total economic value of the economic system is

$$V = M \log n \tag{9}$$

which is an increasing function of n. This means that the finer division of labor will increase economic value of the whole society, which is consistent with the observation.

Does it mean the number of professions will increase to the number of total population to maximise wealth? Wealth, the level of low entropy of human society, is supported by physical low entropy from nature. The level of division of labour is ultimately determined by how much low entropy we can utilise from nature. (Colinvaux, 1980)

Just as information means freedom of choice. Wealth level, as suggested by (7) and (9) also means freedom of choice. Thus people in wealthier societies have more freedom of choice.

The above discussion shows that the implications of identifying value with the reduction of entropy are highly consistent with our intuitive understanding of economic value.

III. RELATION BETWEEN PHYSICAL ENTROPY AND ECONOMIC VALUE

The discussion about the relation between information and physical entropy began with the paradox of Maxwell's demon. (Maxwell, 1871) After Shannon (1948) developed the mathematical theory of information as entropy, the equivalence between information and physical entropy became explicit. (Bennett, 1988) How then the economic value as entropy linked to physical entropy?

"Nothing in biology makes sense except in the light of evolution." (Dobzhansky, 1973, p. 125) Human beings, as most other species, are the result of natural selection and sexual selection for the past billions of years.

Natural selection is the struggle to stay in low entropy state, i.e., to stay alive. Living organisms need to extract low entropy from the environment, to defend their low entropy sources and to reduce the diffusion of the low entropy. In human societies, agriculture is the main low entropy source. Part of health care systems aim at defending our own low entropy sources to be accessed by microbes. Clothing and housing reduces the diffusion of low entropy.

Sexual selection is the struggle between the individuals of one sex, generally the males, to communicate their attractiveness to the other sex in order to form a partnership for reproduction. Human beings, as well as other sexually reproducing species, are the successful descendants of the earliest sexually reproducing species about a billion years ago. (Margulis, 1998) For the system of communication to be successful in different kinds of environments over such a long time, the mode of communication has to be simple, stable and universal. Since the entropy law is the most universal law of the nature, it is natural that the display of low entropy levels evolves as the universal signal of attractiveness in the process of sexual selection. (Chen, 2002b)

Since information is negative entropy and informational entropy is equivalent to physical entropy, (Shannon, 1948; Bennett, 1988) a state of high information content is equivalent to a state of low physical entropy.

Indeed the low entropy state is the main way of advertisement for most sexually reproducing species. Large body size, colorful and highly complex feather patterns with large amount of information content and exotic structures are all different representations of low entropy states. In human societies, the creation of distinct art works, the demonstration of athletic prowess, the accumulation of wealth, and conspicuous consumption - all of which represent different forms of low entropy - are the major methods of advertising one's attractiveness.

Both natural selection and sexual selection suggest that economic value is linked to low entropy resources. In the following we will make more detailed discussion on the relation between physical entropy and economic value.

First, all received signals are subject to the statistical correlation between the receiver and the sender. The entropy level we perceive of a commodity is different from its original entropy level. Following Shannon, the amount of information one can receive, R, would be obtained by subtracting from the entropy level of a commodity the average rate of conditional entropy.

$$R = H(x) - H_y(x) \tag{10}$$

The conditional entropy $H_y(x)$ is called the equivocation. It measures the average ambiguity of the received signal. (Shannon and Weaver, 1949, p. 67) The mathematical details of (10) can be found in Shannon and Weaver (1949) or Applebaum (1996). There are several reasons that contribute to the conditional entropy. First, in the long time of evolution, the brains of human beings evolve to give different type of low entropy different weights according to the value to survival and reproduction. Second, the receiver doesn't have complete statistical knowledge of the signal. Third, noises are added in the process of information transmission.

The understanding of this relation has profound implications to the economic theory.

(a) Fundamentally, how much information one can receive is subject to statistical correlation between the receiver and the sender. In the extreme case when x and y are independent, $H_y(x) = H(x)$ and $R = 0$. So the information y can receive from x is zero when x and y are independent, regardless how much information x is sending out. This means that low entropy sources that are independent of human lives will not have economic value.

(b) To receive or appreciate the value of x, y has to have the proper equipment or knowledge that related to the sender of information. For example, one has to have a TV set to receive TV signals, although TV signals permeate in the air. The TV set can receive the external signal because it resonates with the electromagnetic wave that carries TV signals. In general, the ability to "resonate" with external signal in some degree is the key to receive and appreciate the value of a low entropy source.

(c) "Asymmetric information arises because one party cannot obtain freely (or at all) information available to another." (Arrow, 1999, p. 20) From Formula (10) the reason of information asymmetry is more universal than that. Unless x and y are linearly related, $H_y(x) > 0$ and $R < H(x)$. Since people don't share identical ideas on most things, information loss always occurs when information is transmitted between two persons. Thus asymmetry of information should be the universal starting point in discussion rather than a kind of "market imperfection". (Akerlof, 1970) Education and training reduces equivocation in communication among people with similar background, which generally increases the efficiency in production. But the inevitable division and specialization of labor further increases the equivocation of communication among the small amount of specialists in a particular field and the rest of the society, which increases the transaction costs. Historical evidences show that the transaction costs have been increasing over time. (Wallis and North, 1986)

(d) Formula (10) explains the function and stability of firms. In a firm, because of the common knowledge of many details of the business, $H_y(x)$, the equivocation is small and the information flow is more fluent, which reduces transaction cost. (Coase, 1937) If a person's talent is of amount H(x), the value that is appreciated by others is $H(x)-H_y(x)$. In another firm that people are less familiar with his knowledge, equivocation is high. A person is usually valued higher in his current position than in a potential new position in other firms. That explains the relative stability of employment and long-term stability of firms. (Arrow, 1999)

(e) Formula (10) also explains the difficulties in developing a new product or new theory. If *x* is a new theory that is independent of *y*, a well-established theory. Then the value of *x* is zero to the practitioners of the theory *y*. In general, truly independent ideas have very low economic values at the time of their origin. Indeed, many pioneers, such as Gossen, Bachelier, were largely ignored in their lifetime. On the contrary, ideas generated from an established paradigm have low equivocation and enjoy high valuation. This is why fundamentally new ideas are very difficult to generate in an established field.

(f) The use of a standard commodity, such as gold or paper currency, is to reduce $H_y(x)$, the equivocation, in transactions.

(g) People will generally pursue works with low equivocation. Such as those that can be converted to money easily. For the same reason people follow the styles of movie stars and other famous people. So only low entropy of certain types will be vigorously pursued.

The above discussion shows that the assessment of the low entropy value is subject to equivocation. Other reasons also affect the economic value of a commodity.

Second, organic systems, such as firms, have the capabilities to extract low entropy over a period of time. The value of such system is determined by the discounted total net low entropy it can extract over its lifetime. Chen (2002a) presented a detailed analysis to these processes.

Third, the economic value of a commodity depends on the enforceability of the property right and the level of protection. For example, oxygen, a product from plants, is the vital source of low entropy to human beings. (Lovelock, 1988; Margulis, 1998) Yet there is no economic value to oxygen in most circumstances. Theoretically, it is not impossible for plant owners to claim a share of ownership of oxygen in some way and charge the general public. However it is difficult to enforce the ownership for many reasons. One is that oxygen permeates in the atmosphere. The biological low entropy in more concentrated form, such as wood, coal and petroleum, whose property rights are easier to enforce, do command positive economic value. The incentive to enforce property right over a low entropy resource, which exclude the free access by the general public, is mainly determined by the scarcity of the resource and the cost of enforcement. Different types of low entropy sources have different enforceability under different type of institutional structures. The value of a low entropy source is also determined by the level of protection offered by the institutional structure. For example, an invention that has twenty year's of patent protection is more valuable than one that has ten year's of patent protection. Economic value, as a function of scarcity, is to a great extent regulated by institutional structures.

IV. UNIFICATION OF OBJECTIVE AND SUBJECTIVE THEORY OF VALUE

The objective theory or labor theory of value seeks the invariant measure of value while the subjective school believes value is determined by the subjective utility. The two schools of value theory are in heated debate over a long time. (Dobb, 1973) This entropy theory of value will, however, provide a unified understanding of both theories.

It is easy to understand the objective theory of value from the entropy theory of value. Entropy level may be the closest to an invariant measure of value of labor and other commodities. However, as we analyzed in the last section, the assessment of physical value of entropy is subject to the statistical correlation between the receiver and the sender, which keeps changing. The enforceability of different low entropy commodity will change as well when the institutional structure and technology changes.

How is subjective theory related to entropy theory of value? From the discussion of last section, both natural selection and sexual selection favor low entropy state. "Mind is an organ of computation engineered by natural selection." (Pinker, 1997, p. 429) It calculates the entropy level and sends out signals of pleasure for accumulating and displaying low entropy and signals of pain for dissipation of low entropy. Jevons "attempted to treat economy as a calculus of pleasure and pain." (Jevons, 1957, p. vi) Pleasure is generally associated with the accumulation or display of low entropy level, such as the accumulation of wealth, and conspicuous consumption. Pain is associated with dissipation of low entropy, such as work and the loss of money. So value in subjective theory, as a measure for pleasure and pain, is intrinsically linked to the level of entropy.

The connection between entropy and subjective human feeling has long been recognized. The following passage from Eddington was written before the discovery of information theory:

> "Suppose that we were asked to arrange the following in two categories – distance, mass, electric force, entropy, beauty, melody. I think there are the

> strongest grounds for placing entropy alongside beauty and melody, and not with the first three. Entropy is only found when the parts are viewed in association, and it is by viewing or hearing the parts that beauty and melody are discerned. All three are features of arrangement. It is a pregnant thought that one of these three associates should be able to figure as a commonplace quantity of science. The reason why this stranger can pass itself off among the aborigines of the physical world is that it is able to speak their language, viz., the language of arithmetic. It has a measure-number associated with it and so is made quite at home in physics." (Eddington, 1935 (1958), p. 105)

Entropy, which "has a measure-number associated with it", not only "is made quite at home in physics" but also is made essential for measurement by mind and by human societies.

V. THE ENTROPY THEORY OF VALUE AND INFORMATION

Because of the equivalence of entropy and information, an entropy theory of value is inevitably an information theory of value. Information is often regarded as a rather unusual commodity. (Arrow, 1999) We will show that, in the light of the entropy theory of value, information is a usual commodity. Since Arrow (1999) offers a clear description about the special characteristics of information as an economic commodity, our discussion is based on his writings.

> "The algebra of information is different from that of ordinary goods. … Repeating a given piece of information adds nothing. On the other hand, the same piece of information can be used over and over again, by the same or different producer(s)." (Arrow, 1999, p.21)

From (10), the received information is the information of source minus equivocation. Repeating an information helps reduce equivocation. That is why the same commercials will repeat many times on TV. A more detailed analysis of commercials by a company, say Coca Cola, will illustrate the concept more clearly. Most commercials of Coca Cola spread the same information: Drink Coca Cola. The purpose of the commercials is to reduce the equivocation between in information transmission between the sender, Coca Cola company and the receivers, the potential consumers. Usually the same commercial will repeat many times and different commercials are designed to relate the viewers and Coca Cola in different ways. However, the efforts of Coca Cola will not automatically reduce the equivocation between the sender and the receivers. There are other drink companies and other matters in life compete for attention. As a result, the equivocation between Coca Cola and the general public may increase, despite the efforts from Coca Cola. From the thermodynamic theory that all low entropy sources have a tendency to diffuse, repeating the same piece of information is essential to keep it valuable. The essence of life of any individual is to repeat and spread its information.

It is often thought that the use of information is non-rivalry, since "the same piece of information can be used over and over again, by the same or different producer(s)". However, the value or information content will be different for different users or at different time. For example, if an unexpected surge of corporate profit is only used to very few people, i.e., when p is very small and $-\log p$ is very high, the information is highly valuable. Huge profit can be made by trading the underlying stocks. But when it is used to many people, the value of information is very low. In general, when some knowledge is mastered by many people, its market value is very low.

> "The usual logic of the price system depends on the ordinary algebra of commodities. The buyer can buy more or less at the given price (or close to it if there is some element of monopoly). But information is different. In particular, technical information needed for production is used once and for all. It makes no difference whether one unit or one million units are produced; the same amount of information is required. Hence the use of information leads to the most extreme form of economies of scale, the existence of fixed cost." (Arrow, 1999, p. 21)

Actually, a buyer generally buys more or less at the given price for information products as well. For example, one has to pay twice the price if he wants to access Reuters information on two terminals. The variable costs of information service providers are usually not close to zero. From (10), extensive trainings are often required to each user for her to use an information system effectively. Actually, low variable cost relative to the product value is a general property of all high fixed cost production systems. Software development, CPU production, telecommunication industry, the pharmaceutical industry, energy exploration, brand management and certain sectors of financial services, such as investment banking are just some of these industries. Take Nike for example. Its production cost of each pair of shoes may not be higher than generic products. So the variable cost in brand management is very low, while the advertising cost, which is largely a fixed cost in the business of brand management, is very high. While "the use of information leads to the most extreme form of economies of scale, the existence of fixed cost," the existence of fixed cost is a universal requirement in all production processes. From the entropy law, the thermodynamic diffusion of an organic or economic system is spontaneous. The extraction of low entropy from the environment, however, depends on specific biological or institutional structures that incur fixed or maintenance costs. (Chen, 2002a)

> "The peculiar algebra of information has another important implication for the functioning of the economic system. Information, once obtained, can be used by others, even the original owner has not lost it. Once created, information is not scarce in the economic sense. This fact makes it difficult to make information into property. It is usually much cheaper to reproduce information than to produce it in the first place. In the crudest form, we find piracy of technical information, as in the reproduction of books in violation of copyright. Two social innovations, patents and copyrights, are designed to create artificial scarcities where none exists naturally, although the duration of the property is limited. The scarcities are needed to create incentives for undertaking the production of information in the first place." (Arrow, 1999, p. 21)

Information is a type of low entropy source. The attempt to utilize low entropy source from others is a universal phenomenon of the living systems. "Once again animals discover the trick first. … butterflies, did not evolve their colors to impress the females. Some species evolved to be poisonous or distasteful, and warned their predators with gaudy colors. Other poisonous kinds copied the colors, taking advantage of the fear already sown. But then some nonpoisonous butterflies copied the colors, too, enjoying the protection while avoiding the expense of making themselves distasteful. When the mimics become too plentiful, the colors no longer conveyed information and no longer deterred the predators. The distasteful butterflies evolved new colors, which were then mimicked by the palatable ones, and so on." (Pinker, 1997, p. 501)

So the perceived uniqueness of information industry is quite universal among living systems. Once we look at the living world from the entropy perspective, it can hardly be otherwise. In human societies, the attempt to copy and reproduce valuable assets is also universal. Fashion industry offers another example that illustrates the dynamics clearly.

When a new fashion style is created, it is scarce and hence valuable. This valuable information will then be copied by others. As more people copied the style, p increases, $-\log p$ decrease and the value of the fashion decreases. To satisfy the demands for high value fashions, new fashion styles "are designed to create artificial scarcities where none exists naturally".

The attempt to protect their own low entropy source to be accessed is also a universal phenomenon of the living systems. Animals develop immune systems to protect their low entropy source to be accessed by microbes. Plants make themselves poisonous to prevent their low entropy to be accessed by animals. When space is a limiting factor in survival or reproduction, animals defend their territory vigorously. (Colinvaux, 1978) Whether to enforce the property rights depends on the cost of enforcement and the value of the low entropy source. The patents and copyrights are natural extension from property rights of physical low entropy assets, when information becomes an important class of low entropy assets.

A major motivation in developing information theory is to distinguish the number of symbols and amount of information. (Shannon and Weaver, 1949) A book of five hundred pages doesn't necessarily contain more information than a short paper. Specifically, extension or modification of already very popular products or ideas, which by definition are accepted by many people, is of low information value. At the same time, popular products and ideas are of low equivocation. These products and ideas get copied very often. From information theory, it is the products of low information value that are got copied. This of course doesn't imply that what got copied are not useful. Water, which is of low economic value, is very useful. On the contrary, a fundamentally new idea, is of low probability and high information value. At the same time, its equivocation is high and few people will copy the information. So it is not true that "once created, information as a commodity is no more scarce." The promotion of a fundamentally new idea is in general so difficult that Wallace, the cofounder of the theory of evolution, gave much more credit to the promotion of new ideas over their creation. "No one deserves either praise or blame for the *ideas* that comes to him. … But the *actions* which result from our ideas may properly be so treated, because it is only by patient thought and work that new ideas, if good and true, become adapted and utilized." (George, 1964, p. 280)

VI. ECONOMIC WEALTH AND SOCIAL WELFARE

From the discussion of last several sections, it is clear that economic wealth and social welfare are two distinct concepts. The following example will illustrate this point further.

When the human population density is low, most of the high entropy wastes that humans generate are absorbed by microbes and other natural forces with little human effort. (Margulis, 1998) This vital recycling business is accorded no economic value. As the population density and the level of consumption increases, however, direct human intervention is needed to move the high entropy waste away from where people reside. The economic value of the recycling business is a reflection of the part of human effort in the recycling of human wastes, which is not equivalent to environmental quality of human habitats.

While economic wealth is not equivalent to social welfare, economic value, as the reflection of human efforts, is generally geared toward human welfare. This is why economic prosperity is often consistent with the improvement of social welfare in a particular point of time. However, wealth, as low entropy of human society, is ultimately supported by low entropy from nature. Petroleum and coal, the biological low entropy that is deposited over hundreds of millions of years, is transformed for the use by human societies over several hundreds of years. This is the foundation of the economic prosperity in the last several centuries. Historically, all the early highly developed civilizations with tremendous wealth eventually collapse because the consumption of resources becomes faster than their regeneration by nature. In many sites of early civilizations, the once rich and productive areas have been turned into desolate regions through over exploitation. As social systems collapsed in their original regions, people generally moved away from these desolate regions into more sparsely populated and fertile areas. (Ponting, 1991; Colinvaux, 1980)

In general, wealth represents the total dependence of each other in a society. The increase of one's wealth means the increase of the dependence of others on him and hence the increase of his power. While it is natural for an individual or a company to pursue strategies that maximize wealth, national and international policies often concern more about long term sustainability of ecological and social systems.

VII. CONCLUSION

All living systems survive on extracting low entropy from the environment, against the general tendency of increasing entropy. The knowledge to calculate the entropy level of an object, to extract low entropy from others and to defend their low entropy sources to be extracted are the most important information for all living systems. "Thus when one meets the concept of entropy in communication theory, he has a right to be rather excited --- a right to suspect that one has hold of something that may turn out to be basic and important." (Shannon and Weaver, 1949, p. 13) Weaver made the above perceptive prediction in 1949, shortly after Shannon's work. The following development of information theory has proved his foresight. This paper shows that how the entropy theory of value greatly simplified the understanding of human activities in general and economic activities in particular.

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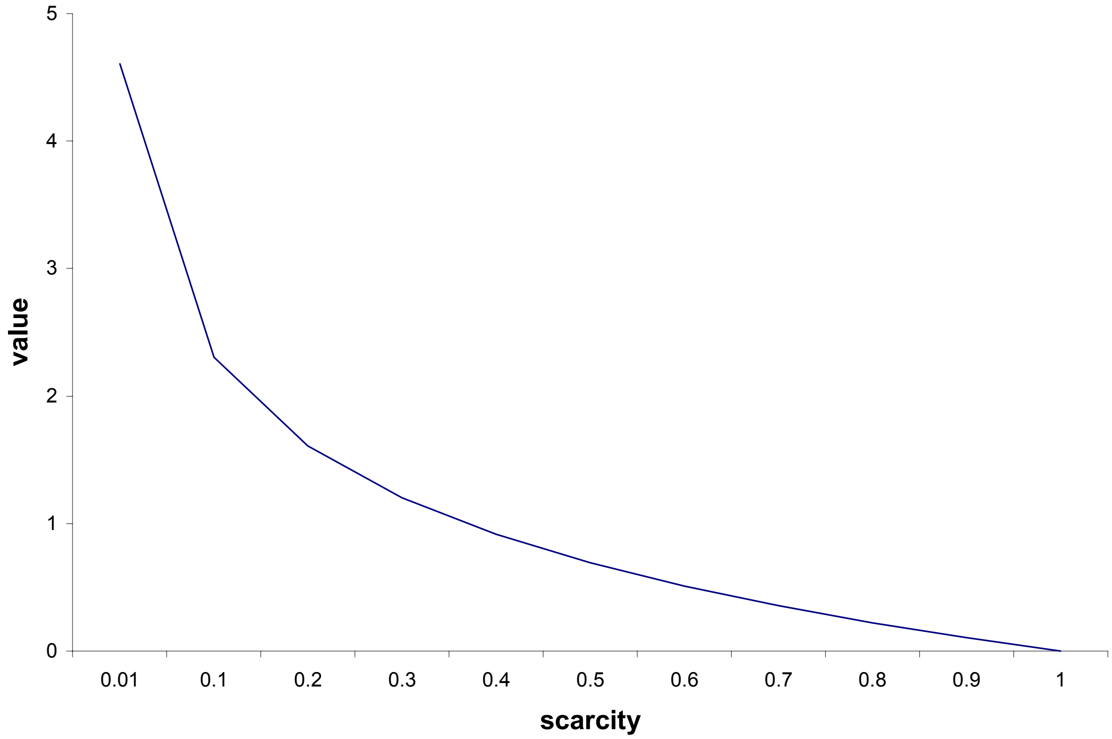
Figure Captions

Figure 1: Value and scarcity
Figure 2: Value and the number of producers
Figure 3: The unit value and total value of a product with respect to scarcity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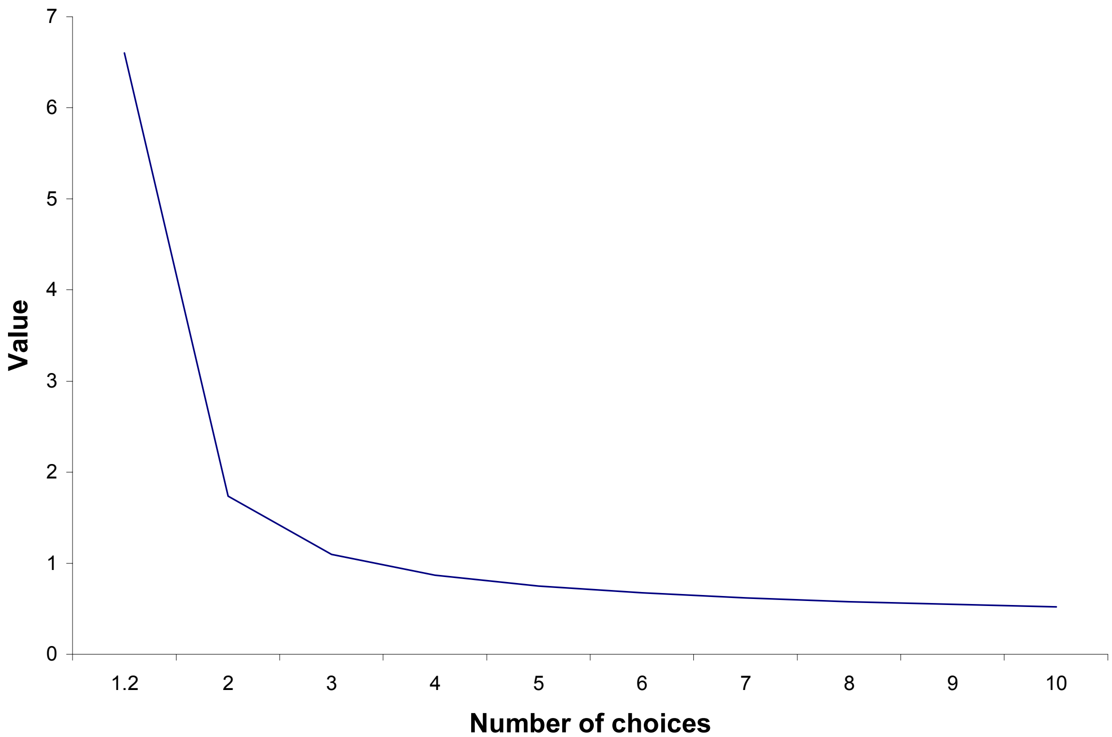
scarcity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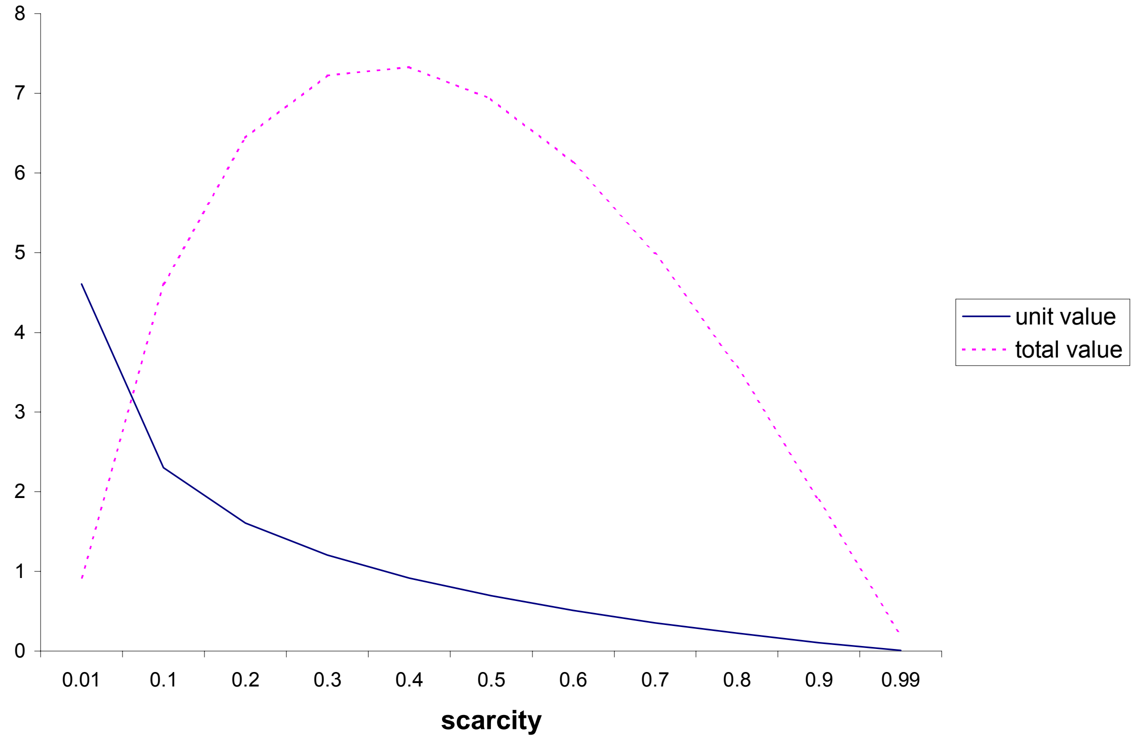
Number of choices



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scarcity
unit value
total value