Social Entropy Theory, Macro Accounting, and Entropy Related Measures

G. A. Swanson[1] and Kenneth D. Bailey[2]

[1]Tennessee Tech University, Cookeville, TN, USA, GASwanson@tn.tech.edu
[2]University of California, Los Angeles, CA, USA, Kbailey@soc.ucla.edu

Abstract

The concept of entropy has been widely applied in various disciplines, but often with different definitions of the term. The concept of entropy, conceived generically as a measure of system disorder, has a certain quality that begs for generalization across various types of systems. Entropy was originated to describe a very specific aspect of thermodynamic systems, was later extended to a probabilistic formulation, and still later to interpretations in terms of information theory. The most recent applications of entropy are in Social Entropy Theory and Macro Accounting Theory. This paper follows an earlier paper by Swanson, Bailey, and Miller in emphasizing the role of money-information markers in the recurring organization and disorganization of social systems. However, the present paper provides logic statements, mathematical or otherwise, linking the various entropy-related measures. The chief goal of this paper is to identify similarities and dissimilarities among the entropy-related concepts that concern different types of systems. Swanson's Macro Accounting Theory and Bailey's Social Entropy Theory are integrated into Miller's Living Systems Theory to produce a synthesis of entropy-related concepts.

Keywords: entropy, social entropy, money, living systems, accounting principles

Introduction

Entropy, as a measure of system dissipation or disorganization, has intrigued researchers for more than a century. From the moment Clausius (1850) introduced the concept of thermodynamic entropy, the general idea underlying the concept has begged for universal application (Bailey, 2001a; Corning and Kline, 1998). Entropy has been widely applied in a large number of fields, including sociology (Bailey, 1990, 1994), art (Arnheim 1971), economics (Georgescu-Roegen, 1971), and many others (see Bailey, 1990, 1994; Corning and Kline, 1998). The term entropy catches attention. Clausius introduced the term and defined it as a very specific thermodynamic quantity. But the intrigue of the word and the thousands of similar possible quantities in other types of systems propelled efforts to define and measure entropy in even broader parameters.

The general idea underlying the concept of entropy, however, can and should be generalized to other types of systems. But because the term entropy evokes such intrigue, it might be wise to use it with modifiers to identify a series of measures relating to the general idea underlying entropy (system disorganization). Whether or not we linguistically connect them, we should identify such related measures and estimates, and investigate their similarities and differences in anticipation of discovering useful insights that apply generally to all systems composed of matter-energy in space-time.

Swanson, Bailey, and Miller (1997) discuss a progression of entropy-related measures in systems ranging from physical through biological to social, with emphasis on the social systems. This progression is discussed in the context of Living Systems Theory (LST) as developed by Miller (1978), and integrates that theory with Social Entropy Theory (SET) as developed by Bailey (1990, 1994), and Macro Accounting Theory (MAT) as developed by Swanson (1993). This integration is important for at least two reasons. The first reason is that the domains of the theories being integrated are contained progressively each in the other. The very broad domain of LST concerns all living systems existing in space-time and thus contains the domain of the more narrowly focused SET, which in turn contains the domain of MAT (which concerns economic systems of social systems).

Such progressions are necessary if general systems theories are to be applied effectively to finding solutions to major human problems. The second reason is that the progression leads to the identification of useful social system entropy-related measures and to a specific widely used accounting process that measures a certain kind of social organization-disorganization continuum from which entropy-related measures may be derived. This paper extends the discussion of Swanson, Bailey, and Miller (1997) by viewing the same progression of entropy-related measures from an accounting perspective. Viewing the progression from the perspective of the accounting algorithm provides at least a method and perhaps a methodology by which the various measures may be related.

Living Systems Theory

Living Systems Theory (LST) was developed by Miller (1978). It is a comprehensive approach encompassing the analysis of a hierarchy of living systems, with a number of critical subsystems discussed at each hierarchical level. The approach originally studied seven hierarchical levels, but was subsequently expanded to eight levels with the addition of the community level (Miller and Miller, 1992). The eight levels are: the cell, organ, organism (individual), group, organization, community, society, and supranational system. Miller (1978) originally studied 19 critical subsystems, but this number was expanded to 20 subsystems with the addition of the timer subsystem (Miller and Miller, 1992). Two of the critical subsystems process both matter-energy and information. These are the reproducer and the boundary. Eight subsystems process matter-energy only. These are: the ingestor, distributor, converter, producer, matter-energy storage subsystem, extruder, motor, and supporter. The remaining 10 critical subsystems process information only. These are: the input transducer, internal transducer, channel and net, decoder, associator, memory, decider, encoder, output transducer, and timer.

Miller analyzed all 20 subsystems for all eight levels. While the subsystems have the same name at each level, Miller insisted that his framework was not reductionist, because emergent properties can be identified for each subsystem at each higher level. In general, there is a one-level drop-back in Miller's approach, meaning that the subsystems at a given level are the systems at the next lower level. That is, a given system at the organizational level can be analyzed in terms of its 20 subsystems on the group level, while a given system on the group level can in turn be analyzed in terms of its 20 subsystems on the organism (individual) level. Notice that while, strictly speaking, the 20 critical subsystems only apply to living systems, in reality many of them can also be used to analyze nonliving systems such as an automobile engine.

The comprehensive nature of Miller's approach makes it invaluable in multiple ways as a tool for the analysis of systems. One task of systems researchers is to identify empirical examples of all 160 cells formed by the matrix consisting of the eight levels times the 20 subsystems. Another task specified by Miller is to develop hypotheses, both within a level, and also across levels (so called cross-level hypotheses). Living Systems Theory is also useful as a framework for the comparative analysis of narrower approaches such as Social Entropy Theory and Macro Accounting Theory.

Physical Entropy

The concept of entropy allows us to identify the transfer relationship between two prescribed qualities of energy as unidirectional from "available for work" to "spent."

And, perhaps more importantly, it introduces entropy into closed systems as an abstract quantity—a derived measure—that has a reciprocal and equal relationship to the decreasing available energy. The concept does not simply equate entropy to spent energy, but rather to energy that has been transformed to produce work. The concept implies purposeful action. Energy is transformed from one quality (available for work) to another (transformed) in pursuit of a specific purpose (work).

We will identify the original thermodynamic concept of entropy as Clausius entropy, as shown in equation (1):

$$dS = -dQ/T \tag{1}$$

where S = entropy, Q = heat, and T = temperature of the isolated system. Notice that this is the formal statement of the Second Law of Thermodynamics. Also note that entropy and heat are not represented in this equation, only change in entropy and change in heat. Note still further that this can be viewed as a theoretical or heuristic, as opposed to an empirical, statement. In a true isolated system, dQ would be zero, so (1) would only indicate that entropy change was some positive number, and this is not very helpful empirically. Theoretical physics also considers reversible processes, as in the case where energy flows back and forth across systems boundaries. The equation for reversible processes as shown in equation (2) is:

$$dS = dQ/T \tag{2}$$

While often quoted, equation (2) is not found empirically, as all empirical thermodynamic systems are irreversible (unidirectional), meaning that heat can flow only from hotter to colder bodies, and not vice versa.

Entropy can be related to the important concept of work by equations (3), (4), and (5).

$$F = ma \tag{3}$$

$$W = Fd \tag{4}$$

$$W = Q1 - Q2 \tag{5}$$

Where F = force, m = mass, a = acceleration, W = work, d = distance, and Q = the amount of heat processed by the system in the Carnot cycle, with Q1 being heat absorbed in Step 1, and Q2 being the heat processed in Step 2. In order for work to be done, some form of energy must first be available, and then must be expended during the process of doing work. This can be heat energy (Q) as in equation (5), or some other energy form cable of providing a force which moves a mass a certain distance with a certain acceleration (equations 3 and 4).

Work is an extremely important concept in both classical mechanics in physics, and also in social science disciplines such as sociology, organizational analysis, business, and economics (see Bailey, 1990, 1994). However, meaningful work in social science terms can be quite different than the mere mechanical work in physical terms. For example, if I ask you to move a pile of stones from point A to point B, then physical work is done according equation (4). If I subsequently ask you to return the stones to their original positions with the same acceleration, then the amount of physical work is doubled, according to equation (3). However, sociologically, if the first movement of stones facilitated the construction of a wall (socially meaningful work), the act of returning the stones to their original positions (away from the construction site) undid the useful work. Now the stones are all where they were before, and they cannot be used in construction, and so no sociological work has been done (although energy has been expended, and physical work has been done).

The concepts of work and entropy are clearly related through the concept of energy. Energy is only available for work when entropy is low. As work is done, and energy is progressively expended, entropy rises, reaching its maximum when no energy (either in the form of heat or some other energy form) remains available for doing work at that location.

Statistical Entropy

After thermodynamics, the next influential theoretical development in physics involving entropy was statistical mechanics, culminating in the famous Boltzmann equation

$$S = k \ln w \tag{6}$$

Where S = entropy, K = Boltzmann's constant, and w = the probability that the system will exist in the state it is in relative to all possible states it could be in (Bailey, 1990, 55). Statistical formulations of entropy began to appear in sociology in the 1960s, most of them based on Shannon's H measure (Shannon and Weaver, 1949). Shannon's H is

$$H = - \Sigma\, pi \ln pi \qquad (7)$$

Shannon's H is widely known as a measure of information. In reality, though, it is not a direct measure of information, and at best measures information indirectly, or inversely. In fact, H is a direct measure of entropy (or it can also be considered a direct measure of disorder or uncertainty). The H measure is inversely related to information or order, just as entropy (S) in physics is only inversely related to energy. As H increases, information decreases. Thus, H can be viewed as a direct measure of entropy, but only measures information indirectly (Bailey, 1990). That is, H is an entropy measure, but also measures the loss of information (as entropy increases, information is lost).

Social Entropy

Social Entropy Theory (SET) applies the related concepts of entropy, energy, work, and information to the study of society. Social organizations range from rudimentary dyads to huge bureaucracies and multinational corporations. All of them are open systems, as they exchange both matter-energy and information across social boundaries with their external environments. But even though social systems are open rather than isolated systems, nevertheless in all social applications, these basic variables have the same general relationship signs (although not necessarily the same units or same constants) as they do in their applications in thermodynamics, mechanics, statistical mechanics, and information theory. That is, in all cases, as work is done, energy is expended, as energy is expended, entropy increases, and as information is expended, entropy increases. In order to have the potential for work, a social organization must be low in entropy. This means that it can be high in energy and information, enabling it to do the work necessary on a daily basis to keep the organization functioning smoothly.

As a simple analogy, the task of constructing a social system from scratch is very similar to the task of constructing a physical structure, such as a stone wall or a house. Assume that the same persons wish to construct both a stone wall and a farmer's economic association. Assume that stones are scattered across the farmer's field, with some lying near the proposed fence site, and some being farther away. If the farmer selects rocks of the same size (m) for the new fence, and moves them with the same degree of acceleration (a), the work done in constructing the stone wall is given by equation (4), with F as a constant.

The same equation can be applied to the organizational meeting of the farmer's economic association. Assuming farmers are the same physical size (m) and travel to the meeting with the same acceleration (a), then the work done in assembling them for the meeting is also given in equation (4) with F as a constant, when d is the distance each farmer travels to the meeting. As the stones are transformed to the fence site, additional work must be done to lift them vertically into place, and arrange them in a non-equilibrium (low entropy, or even “far from equilibrium”) position in the wall. Similarly, after the farmers all arrive at the meeting hall, additional work must be done to write the charter and by-laws for the organization. Still more work must be done to arrange the officers in the meeting hall according to the by-laws (with the president presiding and standing at the front podium, board members seated at the head table, and voting members seated in the middle of the hall).

Again, equation (4) can be used to calculate the amount of work done. However, in the case of the farmer’s association, we need to calculate the variable of vertical social distance (class hierarchy) to describe the social differences among the officers. This can be represented on paper in a diagram (organizational chart), and can be symbolized physically by measuring where the offices are seated in relation to each other and to non-officers. Readers making the transition from the natural sciences to the social sciences can appreciate that much of the work involved in the social task of creating the farmer’s association is actually physical work involved in transporting the participants to the organizational meeting, and physically writing the organizational charter and by-laws. The most unfamiliar aspect of the social task to natural science readers will be the formulation and measurement of the concept of social distance. This is well established in social science through such measurement instruments as the Bogardus (1959) Social Distance Scale, which can be modified to fit this application.

Notice also that in both cases (constructing the stone wall and the economic organization), while the physical work involved is well described by the equations of classical mechanics in physics (equations 3 and 4), this mechanical analysis does not afford a full account of the process. An informational analysis is also required. That is, two different work crews could go into the field to construct the stone wall, and each could do the same amount of physical work. But in one case, if the workers were well coordinated through the application of proper information, a magnificent wall could be built. In the other case, the same amount of work without the proper information could yield the original scattering of stones (all returned to their original positions) by the second crew. The same is true for the social task of organizing the farmer’s association. The same amount of work according to equations (3) and (4) could result in either a sound organization or no progress at all, depending on how information was applied to the process.

Order as a Boundary Problem

In social systems, not only the social organization, but also the physical infrastructure supporting it (see Miller, 1978), is generally an open system. True isolated systems, on which Clausius based his analysis of entropy are rarely (if ever), encountered in pure form in the everyday life of modern society. Prigogine’s (1955, 16) famous equation for entropy in open systems is

$$dS = deS + diS \tag{8}$$

Where dS = the total entropy change in the system, deS = external entropy that is exported into the system, and diS = the internal entropy production due to irreversible processes in the system. If sufficient energy is transferred into the house from the external environment, entropy levels can decrease, rather than increasing as predicted by the Second Law. Equation (8) can be widely applied to entropy analysis in social systems of all levels and types, since all are clearly open to some degree.

Close examination of system boundaries reveals that the accurate specification of the degree of order within a system is a boundary problem. That is, a given transfer of energy into a system will result in a lower entropy level (a certain level of system order). If one subsequently enlarges the system without increasing the energy input, the entropy level will be increased, and the degree of order will be decreased. Conversely, decreasing the size of the system, but leaving energy inputs unchanged, will decrease the entropy level and increase the degree of order. Since Clausius limited his analysis to an isolated system, he was able to also confine his entropy analysis to system internals. The notion of an open system necessarily expands the entropy analysis to two or more systems—the sending system (which outputs the energy flow) and the receiving system (which inputs the energy flow).

Secondary Entropy

When energy is transferred across at least one system boundary, then a minimum of two systems (the sending system and the receiving system) are both subject to entropy changes. By definition, the entropy changes in the receiving system are more likely to be planned, while entropy changes in the sending system are more likely to be derivative or residual, depending on how much energy, and of what type, is exported.

In the example above, we can identify the receiving system as the site of the rock wall, and the sending system as the open field where the stones for the wall were obtained. While entropy is decreased by design in constructing the stone wall, entropy is increased in the source (sending or exporting) system. We call entropy in the receiving system primary entropy, while entropy in the sending system is secondary entropy (Bailey, 1999). As the sending system loses energy, it experiences an increase in secondary entropy, and becomes increasingly disordered. That is, since energy is neither created nor destroyed, according to the First Law of Thermodynamics, we expect the primary entropy decrease in the receiving system to be accompanied by a concomitant increase in secondary entropy in the sending system.

A common example of secondary entropy occurs when a new dwelling is constructed. Here, the materials are nailed together (in the receiving system) to construct a two-story house. Since this is a distinctly non-random arrangement, entropy is lowered. But in the adjacent yard (sending system), scraps are thrown in an unorganized heap, representing secondary entropy. While the degree of order in the scrap heap may be nonrandom, and thus below maximum entropy, it is nevertheless likely to be quite high in entropy. Primary entropy in the receiving system is low, indicating a high level of potential energy in the distinctly nonrandom arrangement of the building, while the discarded scrap pile in the sending system shows that secondary entropy is high, as potential energy is low.

Measuring Social Entropy

For the purposes of Social Entropy Theory, a society is operationalized as an entity occupying a bounded spatial area (S). It comprises a population (P) which uses information, including cultural elements (I), and technology (T) to organize itself (O) in a manner that is conducive to optimizing its level of living (L) by attaining some entropy level well below the maximum. This is known as the PILOTS or PISTOL framework (Bailey, 1990, 1994). A society that is operationalized in this manner incorporates a host of physical systems, such as industrial plants, construction companies, and a variety of work groups. As such, the society utilizes virtually all of the equations presented above (1-8), with the Prigogine entropy equation ((8) generally being considered most representative of an open system such as the society. For example, work groups of various sorts within the society do work which can be measured by equations (3), (4), and (5).

The entropy equation most widely used in social measurement is Shannon's H (equation 7). The application of this measure to sociology is easily illustrated in the distribution of wealth. It is customary to divide the United States population into five equal categories, each category representing 20 percent of the population (Bailey, 2001b). If wealth were equally distributed across all categories of the population, then H would be maximized, indicating maximum entropy. But social action on a daily basis typically results in a hierarchy of wealth, so that the top 20 percent of the population has more than 20 percent of the total wealth in the society, while the bottom 20 percent has less than 20 percent of the total wealth. This results in entropy (H) levels below the maximum. Notice that while equations 1 and 2 represent change in entropy, equation (7) represents a static (rather than dynamic) measure of entropy. It thus shows the categorical (statistical) measure of entropy resulting from the work process.

One problem in applying statistical entropy to society has been the difficulty of solving microstate/macrostate problems (Bailey, 2001b). For example, when Krishnan (1981) computed entropy measures of wealth for Canada, Allison (1981) claimed that the analysis was flawed, and offered different computations that he said were the correct ones. Bailey (2001b) showed that the confusion resulted from the tabular fashion in which the probabilities were presented, resulting in microstate/macrostate confusion. Bailey than offered a solution to the microstate/macrostate problem by presenting a rigorous technique for data presentation which effectively eliminates the problem.

While it may seem that Clausius entropy cannot be directly applied to society, the reality is that while isolated systems may be rarely encountered in daily living, heat transfers are common, and are necessary for many routine social actions, such as for heating in winter (for example). Thus, it is abundantly clear that entropy, rather than being confined to thermodynamic systems, in reality is characteristic of all systems, including social systems. While the specifics of entropy measurement may differ for each type of system, the same general relations hold for all systems. Thus, it is an error to think that because Boltzmann's equation (6) yields a calculation for S rather than dS as in Clausius entropy (1), that these are somehow two different kinds of entropy. While the units, constants, variables, and empirical values may differ for different types of systems, the basic entropy concept, and its relations to work, energy, and order remains the same across all types of systems.

It was originally believed that entropy was a unique characteristic of isolated thermodynamic systems. This led to the erroneous conclusion that entropy could not decrease in a system. Since it obviously decreases in social and biological systems, this was a clear anomaly. The existence of empirical evidence showing decreasing entropy did not mean that the Second Law was incorrect, but only that most systems are not isolated (closed), and that energy transfers enable entropy decrease in open systems, as Prigogine demonstrated (8).

It is an error to conclude that entropy only applies to thermodynamics and not to sociology. However, it is helpful to use adjectives (modifiers) to indicate the various types or applications of entropy that pertain to different types of systems. This facilitates computation, and shows that while units and variables may change across systems, the basic notion of entropy does not (just as the basic notion of work does not, whether we are analyzing it in physics or in sociology). The most common types of entropy used in contemporary systems theory are Clausius entropy (1), Boltzmann entropy (6), and Shannon entropy (7). While H is used most commonly in social applications, all three types, along with the equations for work (3-5), are basic equations of Social Entropy Theory (SET), as well as being basic equations for thermodynamics, statistical mechanics, and information theory, as all of these areas are incorporated within modern society. Thus, rather than being a different application of entropy, Social Entropy Theory is seen to be essentially an incorporation of the other entropy types into social analysis. This correctly recognizes that society is built upon the physical infrastructures described in mechanics and statistical mechanics within society, and also in information theory.

Macro Accounting Theory

Swanson's (1993) Macro Accounting Theory (MAT) uses accounting principles to analyze energy transfers, and the resulting entropy changes, in open systems such as social systems. According to MAT, the condition of the unidirectional (irreversible) flow of available energy to entropy occurs only within a closed system, and cannot be extended to systems opened to flows of available energy from another system or from the environment. As soon as available energy flows from one system to another, exchanges of available energy and entropy occur. Reciprocating flows of available energy and entropy are inextricably connected at a moment of time. Available energy simply cannot be extracted from one system for inclusion in another without increasing the entropy of the energy-exporting system. The transferred energy is no longer available for work in the exporting system.

Entropy is not somehow independently created in the energy-exporting system. It is actually a reciprocal transmission from the system receiving the energy. The receiving system decreases its entropy. How does this work? The answer is quite straightforward when we remember the reciprocal relationship between available energy and entropy. Available energy decreases towards zero and may be increased away from zero by importation from outside the system but not by internally reversible flows. Entropy, alternatively, increases toward a maximum and may be decreased away from that maximum by exportation, but again, not by internally reversible flows.

The decrease in entropy brought about by the exchange allows the imported available energy to be unidirectionally transferred to entropy within the receiving systems without exceeding the maximum entropy limit. If more available energy is imported than an amount equal to the system's initial available energy minus its entropy, the system grows with respect to the energy available for work. In other words, it gains more organized potential for work than its initial potential. In this situation, the entropy of the system is lowered by the amount of the potential for work in excess of the system's initial potential. As the system has increased its energy available to do work, it has equally increased the amount of the maximum potential entropy set by the initial condition of the beginning closed system.

Both available energy and entropy are measured on a ratio scale. Zero has meaning for both. Measurement on this scale results from Clausius' fortuitous equating of the amounts of initial available energy and maximum potential entropy. Although he was concerned only with closed systems, his definition respects both the constraint of unidirectionality of internal flows from available energy to entropy and the constraint that external flows must consist of exchanges of available energy for entropy and vice-versa. The positioning of the measure of entropy on the ratio scale is consistent with linguistic logic as well. That is, it makes sense. Within the idea of entropy, energy not available to do work cannot be made into energy available to do work. However, unspent energy can be spent. Energy not yet transformed by doing work can be transformed into entropy as work is done.

The interchangeable use of related terms when referring to elements of exchanges processes is not uncommon in accounting parlance. We generally perceive revenues as inflows and expenses as outflows, when they are actually outflows of implied ownership rights, and inflows of the same respectively. We do this for the same reason that low entropy is perceived as increased potential work. The reason is that the other side of the exchange is where our interest really lies—with the inflow of assets that provides the outflow of implied ownership rights in the revenue case, and with the imported available energy that provides the outflow of entropy in the low-entropy case.

Accounting for changes in available energy requires a double-entry method. An increase or decrease in available energy requires an equal but opposite action in entropy. In the case of internal flows, the action can only decrease available energy and increase entropy. In the case of exchanges between systems, however, available energy can both decrease and increase with the opposite actions occurring simultaneously in entropy. At its inception, a closed system contains a certain amount of available energy, and its maximum potential entropy (MxEn) is equal to its initial available energy (IAE) as shown in equation (9)

$$\mathrm{IAE} = \mathrm{MxEn} \tag{9}$$

As its available energy (AE) decreases, its entropy (En) increases to a maximum just equal to its initial available energy (equation 10)

$$\mathrm{IAE} + (\mathrm{AE}) = -(\mathrm{En}) + \mathrm{MxEn} \tag{10}$$

Where the signs indicate direction of flows, + is inflow and – is outflow.

Double entry of equal but opposite flows keeps the equation in balance. The balancing amount is always the remaining available energy and remaining potential entropy. For example, let IAE be 500 ergs and AE be decrease by 50 ergs. If the amount of unavailable energy is represented by UAE, then

UAE + (AE) = -(En) + MxEn

Initial condition	500	+ (0)	= -(0)	+ 500	= 500
Change	___	+ (-50)	= -(+50)	+___	= 450
Balances	500	+ (-50)	= -(+50)	+___	= 450

The terms IAE and AE may be combined and IAE may be indicated as a beginning balance in the AE account because these terms account for the same substance. The terms En and MxEn, alternatively, cannot be combined because they do not account for the same substances. En accounts for entropy and MxEn accounts for a maximum above which the entropy account cannot rise. MxEn never changes and in these balancing equations, may be considered a constant for a particular system. Thus, the equations may be reduced to equation (11).

$$+(\mathrm{AE}) = -(\mathrm{En}) + \mathrm{MxEn} \tag{11}$$

Now the example may be stated as follows:

Initial Condition	+ (+500)	= - (0)	+ 500	= 500
Change	+ (-50)	= - (+50)	+ ___	= 450
Balances	(+450)	= - (+50)	+ 500	= 450

When the closed system is opened to inflows and outflows of available energy and entropy, the double-entry accounting system is unchanged. For example, assume the same 500 ergs initial condition, but that 75 ergs of available energy is imported. Not the situation is as follows:

	+ (AE)	= - (En) = MxEn
Initial Condition	+ (+500)	= - (0) + 500 = 500
Change	+ (+75)	= - (75) + ___ = 75
Balances	+ (+75)	= - (-75) + 500 = 575

When the entropy account balance is negative, available energy is that amount greater than the initial available energy in the system. The system has grown in this substance by that amount rather than shrinking as always occurs with actions within the system. Additional potential entropy from imported available energy is indicated by the outflow (-) balance in the entropy account, allowing the spread between the maximum and the current balance to expand.

Time is always present in an accounting for matter-energy systems in time-space. Balances in accounts are always amounts per time. In some accounts, unidirectional flows are accumulated, and in others net amounts of inflows minus outflows (or vice-versa) are tallied. The accounts accumulating the unidirectional flows have an implicit denominator of one accounting period. The implicit denominator of accounts that net bi-directional flows is the number of accounting periods in the past existence of the system. By introducing terms for time, we may calculate how long a system has existed or how long it will continue to exist.

This basic accounting system provides an isomorphism for generalizing the basic idea underlying the concept of entropy to elements of physical systems other than available energy. It may also be used to generalize beyond physical systems to chemical, biological and social systems. Substance accounting provides terms and relationships for applying Clausius' idea to many different types of systems. Social Entropy Theory provides an expanded framework for applying these ideas to social systems, and macro accounting provides a means of measuring, with money information markers, a certain kind of recurring organization-disorganization.

Money-Information Markers

Swanson, Bailey, and Miller (1997) discuss the concept of a money-information marker (MIM). According to Miller (1978), a marker is a physical object (such as paper) that carries information. While the previous section discussed energy exchanges, modern exchange-based societies also exchange a great deal of information in addition to their large exchanges of energy. While space precludes full analysis of information exchanges it will suffice to note that, pursuant to earlier discussion in this paper, information is used to direct work in modern society. Thus, a society wishing to organize itself into a highly functioning entity may discover that access to energy is insufficient to this task, if the information necessary for mobilizing the energy into socially-productive work is lacking. Thus, if time permitted, we could write an accounting analysis of information transfers similar to the analysis of energy transfers presented in the previous section.

One example of a money-information marker is a United States one-dollar federal reserve note. Another example is a United States one hundred-dollar federal reserve note. What is interesting about these two notes is that each of them represents approximately the same amount of information, and each of them presumably has the same amount of available energy, and thus each will produce the same amount of heat and light when burned. However, notice that if I wish to buy energy in another form such as gasoline, or information in the form of intellectual property such as computer software, the one-hundred dollar-note will buy 100 times as much energy or information as the one dollar note. This anomaly becomes even more glaring when we realize that both the 100 dollar note and the one dollar note cost about the same to produce because each takes presumably the same time to engrave and print.

The basic anomaly is that while one has 100 times as much "value" as the other, they both cost approximately the same to produce. Obviously, one would be unwise to produce any one dollar bills, and should print only 100 dollar bills, as they are far more valuable, thus the cost/benefit ratio for producing them is much more favorable. This apparent anomaly is one reason why critics of removing United States currency from the gold standard see it as "fiat" money with no intrinsic value. In Marxian terms, value comes from labor. The act of backing a currency by a precious metal such as gold thus goes a long way towards removing the apparent anomaly, since 100 times as much gold is used to back a 100 dollar bill as to back a one dollar bill, and a great deal more labor must be expended to mine 100 times more gold, thus giving the 100 dollar bill a greater intrinsic or labor value than the one dollar bill. Sociologically, the situation is more complex. While it may not cost the United States government any more to engrave and print a 100 dollar bill than a one dollar bill, the social value and power of the government would be eroded if it did not socially construct and reproduce the 100 dollar bill as being in fact 100 times more valuable than the one dollar bill.

Although it may not be totally clear at this point, one reason the money-information marker has anomalous interpretations is because it is a neutral entity that serves as a useful commodity basis for both matter-energy and information exchange. A person needing stores of available energy or information for performing socially necessary work that will enable the society to function on a daily basis need not keep piles of gold or wheat or gasoline, or libraries or computers full of information. Instead, he or she only needs a store of money information markers in the form of currency, and increasingly may need only a piece of accounting information such as a bank account number, which can in turn reveal a number indicating the amount of money-information markers (for example dollars) that the individual possesses. This money can be exchanged for needed matter-energy or information, which can in turn be used to conduct useful work that can further the needs of the society.

Concluding Remarks

This paper has used Living Systems Theory (LST), Social Entropy Theory (SET), and Macro Accounting Theory (MAT) to illustrate in general how the concept of entropy can be applied to social systems, and in particular, how work, energy, entropy, and information are all related. The role of these concepts in modern exchange society was illustrated, and accounting theory was used to formalize the exchange process.

While the present paper has focused on external relations (such as energy transfers) between sending and receiving systems, in reality, exchange relations in modern society are much more complex. Bailey (2005) has distinguished between four basic types of social exchanges: internal-vertical, internal-horizontal, external-horizontal, and external-vertical. The exchanges discussed in the present paper have been primarily the third type (external-horizontal), but it is important to note that, with some modification, the basic accounting model presented here can be applied to the other three types of exchanges as well.

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