THE COMMUNICATION THEORY MODEL AND ECONOMICS

Samuel Bagno

Walter Kidde & Co., Inc. Ultrasonic Division

I INTRODUCTION

In this paper the mathematical theory of communication is used as a model to explain economic activity. In this model the definition of information is given as a function of alternatives chosen from groups of possibilities. Communication theory concerns itself with the flow of those types of information in which averages can be identified. Economic activity is postulated to consist of the communication of choices to the environment in a manner calculated to maximize real income. As such it becomes a subclass of the theory of communication and therefore the theorems developed for communication theory can be expected to apply to economic activity. Entropy, relative entropy, redundancy and equivocation are the terms in which that theory is defined. The most important concepts bearing on our problem and considered in these theorems are that:

(1) In the presence of noise every message becomes disorganized with time;

(2) Redundancy in a message can practically overcome the effects of disorganization;

(3) The minimum quantity of redundancy necessary for such a purpose can be assigned a definite value.

Within the framework of the theory, economic activity is shown to be a process of two-way communication. The money supply has the statistical properties of an entropy-carrying channel, while the unit of money has those of a message. The first concept above therefore indicates that in the presence of noise a fully balanced budget leads to disorganization of the economy. The second concept implies that it is possible to stabilize the economy or to promote its growth by providing an ever-expanding money supply. The third concept implies the law of diminishing returns.

The code carried by money is shown to be the measure of real income and to be subjectively determined as a result of trial and error. Because of the changing environment (noise), this code must continually be relearned. Relearning is shown to be analagous to overcoming equivocation. Inflation, deflation, unemployment and prosperity are analyzed in terms of the properties of the money supply as a communication channel. The width of the channel can be correlated with the political structure of the economic system. The laws of supply and demand and Say's Law are shown to be conditional corollaries of communication theory. They are shown to hold under certain conditions only and often they do not apply.

A theorem is derived which suggests that real income can only be maintained if the money supply increases continually according to an exponential function. Just as Shannon's[6] theorems give a limiting condition, that is, the greatest possible efficiency in the use of additional entropy as redundancy to overcome noise, so this function likewise specifies a perfect limit, an approachable but unattainable ideal. It serves, therefore, a purpose analagous to that of the Carnot cycle which likewise is useful because it defines a limiting efficiency.

Statistical records of economic behavior are presented to demonstrate that within the periods in which these statistical data were taken, the expected function was approached. Other historical examples, including rare exceptions predictable from probability considerations are also cited. Examples are included showing how noise-induced disorganizations of money actually took place. The nature of world trade is also shown to be consistent with the model, with the further implication that an ever-expanding international money supply should be created for this purpose.

It is demonstrated that some forms of taxation can be expected to introduce equivocation into the money channel, so that for each tax dollar more than one dollar must be restored to the economy just to maintain it. Likewise, the post war behavior of European economies is shown to be consistent with the present theory. Thus, communication theory recommends itself as a basis for the formulation of sound fiscal policy.

The relationship of the number of business firms to the number of people they contain is derived and found to be in close agreement with Department of Commerce statistics. This is obtained by postulating that the rate of entropy disorganization, due to random change, is distributed in a frequency spectrum somewhat analagous to white noise, i.e., all frequencies of disorganization being equally likely, and an average time for an organization to react, that is the average of all the possible ways in which the members of an organization may contribute an equal share of entropy in sequence. The same derivation is then used to imply the fallacy of the socialist doctrine. The derivation further implies that the malfunctioning of the Soviet Economy is to be expected both in kind and degree.

The justification of the economic cycle is also shown as following from the above analysis.

II FORMULATION OF THE PROBLEM IN THE LANGUAGE OF INFORMATION THEORY

If we try to analyze the process of hearing a communication such as a telephone message and compare it with the process of consuming goods and services such as, for instance, an apple taken from a fruit bowl on a table, we find that they have much in common. Although it is not obvious that an analogy should exist between the sounds we hear on the telephone and the apple we take from the bowl, it is the purpose of this paper to demonstrate that there is indeed a significant analogy in that both processes can be described in the terms of the mathematical theory of communication.

Two recent papers, one by Kochen[3] and the other by Rothstein[4] would indicate that such an isomorphism might be expected. Here we shall try to demonstrate its existence.

III THE ENTROPY LIMITATION - THE ENTROPY-OUTPUT POSTULATE

In the physical realm, the economic structure can be considered to exist in a number of orthogonal dimensions. These dimensions are the chemical elements and energy, and the information (entropy) necessary to organize matter and energy into useful forms. The elements are orthogonally related because each can be independently identified and because the extent of each in any real structure lends itself to measurement in exactly the same way as the extent of a geometric structure in each of height, or width, or breadth can be measured independently of the other two dimensions. Thus, for example, the quantity of hydrogen in a structure can be measured independently of the other elements it contains, and more hydrogen may be physically attached to the structure without adding more of any other element.

The economic structure resembles a geometric structure in another way. It will be shown that it tends to have a specific identity insofar as its extensions in all independent dimensions are interrelated in some definable way. Thus, for example, in the purely geometric realm, a cube is characterized as extending equally in all three dimensions. Other specific geometric forms have similar characteristic properties. The economic structure can be shown to be specifically definable because it is organized for a specific purpose. It can be postulated that this purpose, so far as each individual is concerned, is the maximization of real income. This purpose defines the optimum structure of the economic system.

Rothstein[4] has pointed out that a measure of the amount of organization is the reduction in entropy from the completely unorganized condition, because of the constraints necessary for organization. Thus, a measure of the organization of a structure is the entropy necessary to describe the constraints introduced in the process of organizing and interrelating its components.

Assume that the economy extends in N dimensions (components), and that these components have the measures M_1, M_2, M_3, M_4, - - - - -. For maximum organization the entropy describing the constraints would likewise be a maximum for some arbitrarily constant weighted sum of these components. We are, therefore, faced with the following condition. If A be the weighting of the ith component we have:

$$(1)\quad A_1M_1 + A_2M_2 + A_3M_3 - - - = S$$

$$(2)\quad H = f(M_1, M_2, M_3 - - -) = \text{Max.}$$

Taking Derivatives

$$(3)\quad \sum_N A_i \frac{\partial H}{\partial M_i}\,\delta M_i = 0 \quad + \sum_N \delta M_i = 0$$

$$(4)\quad \sum_N \left(A_i \frac{\partial H}{\partial M_i} + \lambda\right)\delta M_i = 0$$

$$(5)\quad H = \sum_N \frac{\lambda}{A_i} M_i$$

Since the Lagrange multiplier λ is an arbitrary constant, any other constraints on H will merely limit the range from which λ can be chosen. Let us now impose another constraint on the system. We postulated that the entropy associated with the organization of the system must change as the organization changes. Because of random change inherent in uncontrolled energy, the organization and likewise the entropy associated with it is continually tending to disorganize at a rate T. In order to maintain what organization exists, we are continually reorganizing at a rate of T_1. From (5), and assuming such random change at a uniform average rate H uniformly distributed among the components, it would follow that $RH \doteq K_{11}T$ where K_{11} is a constant.

In order for the organization, therefore, to maintain itself, *in some condition other than pure randomness* we want:

$$(6)\quad \overline{T} \leq \overline{T_1}$$

Under these conditions (subject to the constraint T) we also want the entropy H to be a maximum. This would imply that the range from which λ can be chosen is f (T_1, T, t). Or,

$$(7)\quad H = \sum_N \frac{M_i}{A_i} f(T_1, T, t)$$

(7) is in the nature of an existence theorem since it only tells what we might expect under maximum organization but not how to get it. However, it follows from (7) that the entropy under conditions of maximum organization can be expected to be directly proportional to the measure of each component within the economy. We will postulate that such is the case, and call equations (7) the entropy output postulate. This equation indicates that the extent of the economic organization in

the entropy dimension determines its extent in the others, just as its extent is the other dimensions (under the above condition of maximum organization) would determine its entropy.

We can now postulate that the extent of the economic structure in any dimension cannot exceed that of its container.

Here a brief analysis shows the dimension that limits the economic structure and therefore the amount of our economic well being. We are not limited in our growth by the chemical elements. If we consider only the earth, it is 8,000 miles in diameter and we have barely scraped its surface. Similar considerations apply to each individual chemical element. It is, therefore, inconceivable that the chemical realm bottlenecks us. We are not limited in the energy we have available, since the sun sends down on us several hundred thousand times the energy we use for all our purposes. The bottleneck therefore lies in the remaining dimension, that is, the one measured in terms of entropy, the information necessary to organize the economy for our need.

If, instead of the maximum organization we postulate some more probably attainable organization whose average efficiency is some fraction E of the maximum equation 7 becomes:

$$(8) \quad H = E \sum_{N} \frac{M_i}{A_i} f_i(T_i, T_j, t)$$

and the entropy output postulate would still apply.

Let us, therefore, study that dimension since (postulating free will) it is within our power to extend it and thereby harness more of the almost limitless energy and matter at our disposal for a more satisfying economy.

IV SYNERGY - THE SUMMING OF ENTROPY

Synergy is a term borrowed from theology. It is equally well suited, however, to describe the process that concerns us in this paper. Synergy is defined as the condition where a number of individual cooperating, create more than the sum of what can be obtained with each acting individually.

We know intuitively that such a condition exists as, for instance in marriage or in the more abstract forms of communication where the cooperation of a team gives more than the sum of each acting alone. We, therefore, would expect to derive such a condition in terms of the entropy describing the constraints of an organization. That such a consideration exists can be shown as follows:

Let us first take an unsophisticated approach to this problem. Assume there is a physical source of wealth such as uranium or some new and desirable method to be discovered that can benefit all. It is obvious that if cooperation and communication did not exist between us, each of us would be required to find a source of wealth by himself if he needed it, whereas if cooperation and communication existed one man could be delegated to find it and he could communicate his findings to all. Generally the communication of his findings would require negligible entropy in comparison to the entropy expended in the search. Therefore, the saving of entropy would be almost directly as the number of individuals cooperating in the enterprise; i.e., the entropy per unit output should therefore vary inversely as the number of cooperating entities. This can also be shown in a slightly different manner. Let the average rate of decisions per individual = $n \frac{bits}{sec}$. Let the number of individuals be W. The rate of bits (not necessarily associated) for all the individuals = Wn. The individual can, therefore, select from 2^n equally likely alternatives per second and the probability of such a selection $= 2^{-n}$. Since the W individuals acting independently can make W such selections per second, the probability of their selection becomes $W 2^{-n}$. The entropy associated with this probability is

$$H = n - \log W$$

The W individuals completely organized would also generate Wn bits of entropy, but since this entropy could be organized for a single selection, it could select from 2^{Wn}. Since the probability of this selection is 2^{-Wn} its entropy would be Wn. Thus, the ratio of entropies put into the selection of an economic organization should vary (under the best conditions) almost directly as the number of individuals involved. Assuming the entropy output postulate, the output should very likewise.

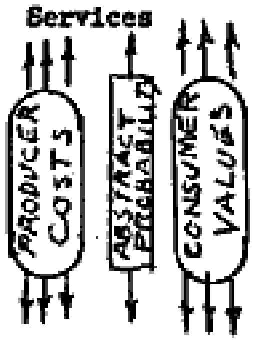
Even under attainable conditions of organization considerably less efficient than the maximums, the quantity of things organized for use should increase for an organized team. An organized economy is, therefore, a desirable goal.

However, organized cooperation between individuals requires communication among the members of an organization. Although this communication may take many forms, it might be expected that the more efficient the communication, the better the team work and the greater the reward. This would also follow from the postulated constraint of the economy, that a tendency for disorganization varies directly with the quantity of things organized, and an equivalent quantity of entropy to that being disorganized must be continually resupplied by communication to maintain whatever organization exists. Let us examine the properties of such communication in more detail.

V THE MEASURE OF ENTROPY

Chart 1.

The following chart should help us further to develop the analogy between the reception of a communication and the reception of goods and services. Here at the three levels of analysis we compare the process presently described by information theory with those which fall into the realm of economic theory.

Level of Analysis	Information Theory	Economic Theory
1. Physical Realm	Physical Message	Physical Goods and Services
2. Abstract Values	Relative values of physical Messages	Relative Values of Goods and Services
Logical bridges connecting analysis levels 2 and 3		
3. Measure of Values	Information Content defined in terms of decision sequences	Decision Sequences isomorphic to information content

The empirical fact that for any individual or group a set of values is established through usage and custom, provides the justification for going from the physical realm to the realm of abstract values. A useful theory requires the further assumption of a scale for measuring these values. In information theory, the value or information content of a message is naturally but arbitrarily defined in terms of decision sequences, a definition justified by the success of the theory. In the following section it will be established that a natural measure of the relative value of goods and services can also be given in terms of decision sequences, and that those decision sequences are isomorphic to their selective information content.

VI ESTABLISHMENT OF VALUE MEASURE

We can consider this problem from two different view points, the producer and consumer.

(1) PRODUCER COSTS

Let us first consider it from the view point of the producer. The producer is naturally interested in the cost of production and it is natural for him to equate value with cost. Suppose we try to build a reasonable postulate for his values in terms of probability. At this point it is necessary to define probability as we use it here. To do so let us start with an elementary economic concept. When we pay a man for his labor (in its broadest sense) we pay him for the organization he puts into the environment by directing his muscle power for our purposes. To do so he transmits a series of messages through his neurons directing his muscle power. We can determine the number of neurons involved, and knowing that each neuron has a yes or no behavior as well as a definite time interval for its action, we can get a direct measure of the number of bits of entropy such labor puts into organizing the environment. For our problem, it is not necessary to know what this number is; it is merely necessary to know that it is a definite number in each individual case. We can then postulate that in a large sequence it will approach a definite average number of bits per unit time, (H).

When we pay money for labor (M_L) the cost of a unit of labor we find that in a large sequence we are paying for the sum of some function of the muscle power, (W), and decisions (H).

(1) $$M_L = \sum_N f(W_L, H_L)$$

where N is the number of units of labor being paid for.

Since we know that on a commercial scale we can pay for the power we use independently of what we do with it, it seems reasonable that we can consider the muscle power independently of decisions. Whatever cost there is above that of power must pay for the entropy, that is for all the decisions labor supplies. Since it has been determined that a laborer generates an average of less than twenty watts with his muscles and power costs less than 5¢ per K.W.H., the power comes to less than a cent a day. His pay is, therefore, essentially for his decisions. This is further borne out because even in the cost of power we find we pay for the decisions that organize the environment by bringing the prime mover and fuel together in the proper order. We can, therefore, write

(2) $$KM_L = H$$

where K is an arbitrary constant that depends on the rules of the game, and is a constant for any one set of rules, i.e., in any ergodic realm.

Since in any large sequence of economic affairs there is an average cost of labor (i.e., money per unit labor per unit of time) equal to M_L, and and since in any large sequence such labor cost is a definite percentage (B) of the total (M_T) money per unit of time per man employed we can write:

(3) $BKM_T = H$ Where $M_L = BM_T$

(4) $BK = \frac{H}{M_T}$ Entropy of money unit.

(4.1) 2^{-BK} Minimum probability of money unit.

We will also postulate that the economy is made up of an ensemble of such sequences with enough ergodicity so that the averages can be depended on for practical purposes. Money can, therefore, be measured in terms of entropy, and its natural unit is the bit.

However, the money supply continually recycles in say α transactions per year on the average, and each unit of money buys KB bits of information (decisions that go to organize the environment) during each transaction. From the above and the Entropy-output postulate it follows that during α transactions per year the unit of money carries, $KB\alpha$ bits per year of real income per unit of money less the entropy losses in the communication channel. Thus we would expect the money supply, in carrying the yearly decisions that organize the environment for use, carries the message of real income.

It likewise follows that in considering economic values we can talk of the entropy per symbol, because the item is truly the symbol of the decisions put into creating it. We can likewise consider the entropy per unit of money in the same sense as the entropy per symbol.

Suppose we now consider value from the consumers viewpoint and see if we arrive at the same entropy measure for value or for money, the practical measure of value.

(2) ABSTRACT PROBABILITIES

An unsophisticated approach might be to consider two equivalent complex items, such as, for instance, two airplane engines. If we consider these engines in terms of the probability that both should happen to be generated by the same irrational labor, we would say that the probability of two engines being built is the square of the probability of one being built and that in each case the probability should be vanishingly small. The cost, however, of the two engines should be double the cost, of one. We would, therefore, expect the cost to increase directly as the logarithm of the probability and to be proportional to the entropy.

(3) CONSUMER COSTS - THE EQUIVALENT MEASURE OF ENTROPY

A more sophisticated approach to the same problem can be given by a derivation analagous to that of Mandelbrot[5] and Blachman[6] These authors considered a universe in which costs were distributed according to some arbitrary probability distribution. The problem they set themselves was to determine the least costly distribution of entropy that would correspond to the arbitrary costs, and conversely if the entropy were arbitrarily distributed, to determine the distribution of cost that would give the most entropy per unit of cost. In terms of our problem the consumer is confronted with an economy that has a multiplicity of items and services which already contain entropy. He is to determine in what manner the costs should be distributed, so that he can obtain the most of the decisions of other people for his money.

This is a problem in variational calculus and can be handled as follows:

(1) $\bar{C} = \sum P_i C_i$

(2) $\bar{H} = \sum P_i \log P_i$

(3) $\sum P_i = 1$

(4) Since we want $\frac{\bar{H}}{\bar{C}}$ = maximum

(5) $\frac{\delta H}{H} - \frac{\delta C}{C} = 0$ also $\delta P = 0$

Using the Lagrange multiplier

(6) $\frac{1 + \log P_i}{\bar{H}} - \frac{C_i}{\bar{C}} + \lambda = 0$

Giving the variational equation

(7) $\log P_i - \frac{\bar{H}}{\bar{C}} C_i + \lambda H + 1 = 0$

For all P_i, multiplying each variational equation by its respective P_i and summing all the resulting equations we get

(8) $\log P_i = \frac{\bar{H}}{\bar{C}} C_i$ Since $\log P_i$ is the entropy (H_i) of the ith symbol (item).

(9) $H_i = \frac{\bar{H}}{\bar{C}} C_i$ let $\frac{\bar{H}}{\bar{C}} = D$ distribution constant

This derivation implies that the costs the consumer would distribute if he tried to maximize the entropy he received for his money would vary directly as the distribution of entropy. In other words, for any item or service his cost should be proportional to the entropy it contains.

These different approaches lead to the same conclusion. Let us therefore, call equation (9) the entropy-money postulate. This postulate has a number of interesting amplications. Thus the average cost per item can be expected to bear the same relation to the total wealth, as the average bits per symbol (item) to the total selective entropy in the system. Furthermore the derivation implies that the consumer tends to order the producer to devote the same fraction of the total entropy to an item as its probability in the market place. Thus, we would expect quantity production to tend to reduce prices. The derivation further implies that if we consider the average item symbolic of the selective entropy it contains, the average item as a symbol will contain $\sum P_i \log P_i$ bits per symbol.

VII THE ERGODIC REALM

D is a ratio that requires some consideration. It is obvious that the ratio depends somewhat on arbitrary conditions. Thus, if the consumer were given twice as much printed money to be paid for the entropy he obtains, and the entropy were fixed, the ratio D could be no greater than half what it previously was. It would be half, provided no other statistical changes resulted from the increasing cost to reduce the entropy within the economy. Such concommitant changes are expected to occur as will be shown later in this paper. However, to the extent that D is arbitrary and has a constant average throughout the economy, it can be said to represent an arbitrary statistically homogeneous realm. Each of these arbitrary realms contain its own set of statistical laws. In this paper we will attempt to derive the limits within which these laws may be expected to act. At any small interval of time, however, we would expect to be concerned with a single statistical realm. In that time interval all parts of the economy can be expected to be reached thru monetary transactions in accordance with the rules of the game, and in a topological sense the economy can be said to be connected. Since it is connected and statistically homogeneous around some unit of value, (money), it can be expected to be ergodic. Within such an ergodic realm we can expect the theorems derived by Shannon for communication to apply. (See Shannon's Mathematical Theory of Communications, Section 5.)

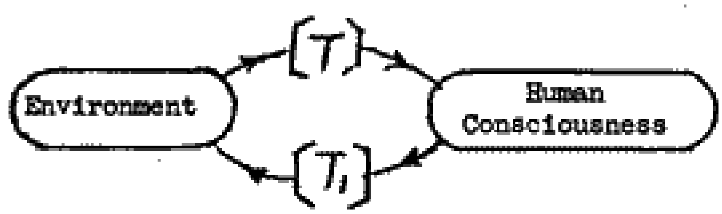
In the economic realm, therefore, we would expect the measure of value to be the decision sequences, just as is the information content in the information theory. Both should be isomorphic and equally well described by the theorems of Shannon. For that reason all of Shannon's theorems have formal equivalents in the economic theory as described simply by substituting terms as in the following chart. It remains to examine the implications.

Information Realm	Economic Realm	Justification
1. Information Source	Human Consciousness	Generator of Entropy
2. Transmitter	Producer	Impressing the Entropy on the Physical Environment
3. Channel	Economy	Flow of Entropy involved in flow of goods and services
4. Receiver	Consumer	Receives the Entropy involved in goods and services
5. Destination	Human Consciousness	Utilizes the received Entropy
6. Entropy	Decision Sequence	
7. Information	Useful Decision Sequences for actual or potential economic organization	
8. Noise	Environmental Disturbances causing disorganization and wasteful decisions	
9. Transmitted Information	Produced goods and services	
10. Received Information	Utilized Production	
11. Equivocation	Waste and spoilage	Equivocation is the difference between transmitted and received information
12. Redundancy	Increased number of decision sequences for a given result	
13. Channel Capacity	Maximum Goods and services (decision sequences) that can be carried by the economy from producer to consumer	
14. Noise added to information	produced goods wear out and spoil	

VIII THE ECONOMIC CHANNEL

In considering entropy limitation, we postulated that an inherent constraint of the economic system is its tendency for disorganization due to uncontrolled random energy. That energy coming from the sun is about 200,000 times as much as we use for all our purposes and is continually tending to tear down whatever organization we put into the economy. To counteract that disorganizing tendency, we are continually reorganizing with the energy at our control. Thus we might expect a circuit of organizational flow shown in its most simplified form in figure 1a.

Fig. 1a



$[T]$ Disorganizing Entropy

$[T_1]$ Organizing Entropy

Because of the tendency of random change to disorganize, the constraints necessary for organization can only be maintained to the extent that entropy is flowing (the disorganization rate postulate). Information theory has given us certain concepts about the flow of entropy. Several important theorems are derivable from these concepts. Among the most important for our analysis are these:

1. Both Wiener[7] and Shannon were able to prove that when random change is added to information some information is always lost. Thus every com-

nel to be free from disturbances such as may be caused by random change.

IX THE QUESTION OF CONSERVATION

Since random change is always occurring, such a lossless condition is not possible. Yet such maintenance of the entropy flow is necessary for the economy to exist. There is, however, another possibility for maintaining the circuit, that is, if the producer and consumer between them resupply more entropy than they receive so that they resupply whatever is lost in the channel due to its random effects. This possibility (in its more general form) is the only way such a circuit can be expected to maintain itself in a real world where an improbable message in a noisy channel must lose its information content.

The improbability of the message carried by the unit of value can be gleaned by considering the quantitative order of things that exist. At an average pay of approximately two cents per minute and an average entropy production per worker of the order of ten bits per second, we would expect to buy in the order of three hundred bits per cent. This would further imply the probability of the selection by these bits as 2^{-300}. Since the total wealth is in the order of 10^{12} dollars one cent acting alone can be distributed among all the things offered for sale, or in the order of 2^{50} ways. The unit of money therefore has a maximum probability of the order of $2^{-300+50} = 2^{-250}$. This is a very small number. The money or what it buys can therefore be said to carry a very improbable message.

This (resupplying of entropy loss due to the improbability of the message) possibility can take either of two forms or a combination of both:

1. The producer can produce more than he gets paid for.

2. The consumer can pay more than he receives by creating more money for the purpose.

The first alternative is much more difficult to accomplish than the second since it involves the voluntary agreement of all producers to sacrifice more work for the common cause. It also involves the knowledge of how much more must be produced of each item (the exact structure of the logan metron matrix acceptable by the consumer.) In case of a random change tending to cause a loss of channel width, any new work not acceptable to the consumer is entropy that does not get through the channel and still more entropy must be added to replace what is lost. That more entropy requires still more work as well as the exact knowledge as to how the work should be distributed to prevent the further possibility of dislocations.

It seems, therefore, that a more desirable way of resupplying this entropy would be by the second alternative, creating more money to make up for what is lost in the entire channel. This gives the consumer the ability to order the production matrix he desires and a forced change in one element of a complex productive matrix need not as readily cause a further loss of entropy.

X THE INCREASING MONEY SUPPLY

Since increasing the money supply seems a more reasonable way of maintaining the channel, it is worthwhile to examine the scope and the limitations of this method. The entropy in the channel has value only if both the consumer and producer are able to utilize it and thereby maintain it in the channel. Thus, the producer must work for the money he receives and the consumer must value the producers' work enough to pay for it. If he does not pay, the entropy never completes its cycle. In economic terms there is no reciprocation of value and, therefore, such transactions cannot maintain themselves. The producer goes out of business.

Each, therefore, must serve as a transducer for the entropy the other supplies. He must be able to extract the entropy he receives from a matrix and pass it on in a different form. This is analagous to the problem of understanding a code.

Understanding a code is merely understanding the significance of the choices involved. In the case of the entropy of a unit of money, the choices involved represent the work that is put into the environment by the rest of the economy. The significance of the choices is that if the choices are correct, real income will be maximized by obtaining the best fit between the environment and ourselves. The environment will be best organized for the well-being of the person who received and spent the money.

That is similar to the property of any code. The entropy that carries the code presents the receiver with definite choices. These choices can be broken down into dichotic choices, yes or no choices between equally likely possibilities. In information theory interpreting the choices correctly reduces uncertainty and therefore carries information. Likewise, by using the money, that is, by utilizing its entropy (the quantity of dichotic choices the money provides) the correct interpretation of these choices carries the work of other people that organizes the environment for the recipient. Thus the correct interpretation of the choices presented is the code the money carries. Therefore, for each person money carries entropy in a definite code, even though the code is subjectively defined in terms of the person's desires.

The correctness of the choices that implies understanding the money code, depends on what the rest of the economy offers. The rest of the economy, however, is continually changing due to random fluctuations and the attempts of others to organize it for themselves. Such changes involve relearning the code carried by money entropy, because if the money is spent in unknown ways it will not result in real income any more than misinterpreting a word will result in information.

In each case, trial and error is necessary. The individual has to learn by trial and error with its concomitant waste of entropy, how to maintain his earning potential and achieve the maximum satisfaction of his desires for the money he spends under the changing conditions. He is thereby continually relearning the code. Because the code must be continually relearned, a certain amount of equivocation must always exist in the money channel.

It can be postulated that learning is analagous to overcoming equivocation, since both are problems of identification in the process of reducing uncertainty. A new unknown can be identified by the method analagous to defining by synonyms, by identifying the unknown with its closest counterpart and then indicating in what way it differs. Such identification requires additional entropy that must be found in the channel.

That additional entropy is equivocation in the sense Shannon defined it, as the difference between the transmitted entropy and the received information. In our case it is the difference between the entropy transmitted by the producer and the entropy utilized by the consumer.

We can arrive at some interesting conclusions about the money channel if we postulate such a coding loss due to the random environmental changes, and apply the theorems developed by Shannon to any ergodic realm within which its transactions take place. (See Ergodic Realm)

XI MAINTAINING CHANNEL CAPACITY - THE MONEY DISORGANIZATION THEOREM

Let H be the maximum entropy rate that can be sent over the channel if no random effects were present. Let R be the actual rate the transmitted entropy is received over the channel with random changes present. Let C be the capacity of the channel. If the coding is proper:

(1) $R \rightarrow C$

Under those conditions

(2) $H - C = I$ where I is the redundant rate that had been added in the process of coding to overcome the effect of random changes.

Under those conditions also (3) $I \rightarrow H_{y(x)}$

Since Shannon showed that the ideal code changes with the ratio of entropy to channel capacity that is necessary to get the transmission through the channel, the entropy to capacity ratio determines the code by which the transmission is carried. The rate of change of this ratio of reception likewise determines the rate at which the codes must be changed for lossless reception. But the rate of change of code causes entropy losses due to relearning. As a first reasonable approximation of such loss, we can postulate that such a code change percentage loss varies as the percentage change in $\frac{H}{C}$ ratio. thus:

(4) $$\frac{d\frac{H}{C}}{\frac{H}{C}dt} = KN$$

(5) $$= \frac{\frac{dH}{dt}}{H} - \frac{\frac{dC}{dt}}{C}$$

Equation (4) can be called the <u>relearning loss postulate</u>.

where N is the percentage of bits per second that is made unavailable by change and therefore transmitted incorrectly over the channel. K is a constant that has the dimension of t where t is the time constant for relearning the code. Furthermore, that is the condition where the entropy carrying ability of the channel is continually replenished by such relearning so that at one instant the capacity of the channel is:

(6) $$C = H - H_{y(x)}$$

Since N causes equivocation at the next infinitesimal increment of time, assuming continuity

(7) $$C + \frac{dC}{dt}dt = H + \frac{dH}{dt}dt - H_{y(x)} - \frac{\partial H_{y(x)}}{\partial N}\frac{dN}{dt}dt$$

or (8) $$C + \frac{dC}{dt}dt = H + \frac{dH}{dt}dt - H_{y(x)} - \frac{dH(N)}{dt}$$

From Shannon, Section 12, we can define

(9) $$H(N) = H\{N \log N + (1-N)\log(1-N)\}$$

subtracting 6 from 7 we get

(10) $$\frac{dC}{dt}dt = \frac{dH}{dt}dt - \frac{dH(N)}{dt}dt$$

Therefore there are three possible results to the information in the channel due to the recoding.

(11a)

if $dH - dH(N) = 0$ The capacity of the channel is unchanged.

(11b)

if $dH - dH(N) > 0$ The capacity of the channel is increased

(11c)

if $dH - dH(N) < 0$ The capacity of the channel is decreased.

Let us assume that the capacity of the channel is unchanged during the continual recoding and relearning, then (11a) applies. Combining it with 9 we get

(12) $$\frac{dH}{dt} = \frac{d[N \log N + (1-N)\log(1-N)]H}{dt}$$

But from (2) and (4) we get

(13) $$KN = \frac{d(H-C)}{H\,dt}$$ since C is constant

(13a) $$N = \frac{1}{KH}\frac{dH}{dt}$$

Substituting (13a) in (12) we get:

$$(14)\quad \frac{dH}{dt} = \frac{d\left(H\left(\frac{dH}{KHdt}\log\frac{dH}{KHdt} + \frac{\left(H+\frac{dH}{Kdt}\right)}{H}\log\left(\frac{H-\frac{dH}{Kdt}}{H}\right)\right)\right)}{dt}$$

To solve (14) let $H = e^{+mt}$ assume m is not a function of time, then $\frac{dH}{dt} = me^{mt}$ Substituting these in (14) we get:

$$(15)\quad m = m\left(\frac{m}{K}\log\frac{m}{K} + \left(1-\frac{m}{K}\right)\log\left(1-\frac{m}{K}\right)\right)$$

Factoring (15) we get m = f(k) = constant and $m = 0$

Since (15) does not contradict the assumption that m is not a function of time, we can write:

$$(16)\quad H = A_1 e^{mt} + A_2$$

This leads to a very interesting conclusion.

If C is the actual capacity of the money channel to carry the economy in an arbitrary ergodic realm and (H) is the entropy that is proportional to the money supply in that realm, the theorem would indicate that with a constant real income in terms of bits received per second, the money supply must increase exponentially as the money supply becomes disorganized.

Entropy may be removed from the channel and saved in order to make up for the random fluctuations in the quantity of entropy flow. Under such savings, the entropy carries more information for the saver simply because the savings can be used to maintain the H/C ratio much more nearly constant and thereby reduce the entropy transmitted wrongly (the re learning loss postulate). Savings can be summed over a short period of time and can be expected to remove equivocation due to fluctuations in H up to amount saved for an indefinitely long period of time. That justifies savings, because if the time during which the H/C variations are reduced for the saver is long enough, much more information will become available to him from the entropy he receives than the amount he removed from the channel by his savings. That is not true for the rest of the economy since only the saver controls the flow of his money. However, he can make it true for others if he gets something in return. Assuming a normal fluctuation in entropy flow after it has traversed the cycles in figure 1b, all variations in flow rate are possible and the more saved the less the equivocation for the saver or those he protects from such variations. This, however, has several other effects. Since all the entropy stored in savings does not traverse the channel (all savings institutions maintaining reserves) the average time of the figure 1b cycle can be expected to increase as the portion of savings increase. The money removed from the channel by savings loses its information carrying ability for the rest of the economy even tho it increases it for the saver. The rest of the economy being larger than the savers economy, more entropy must replace it if the total capacity is to be maintained.

The unit of money carrying a definite amount of entropy in any ergodic realm has the statistical properties of a communication. Both Wiener and Shannon were able to show that the second law of thermodynamics can be expected to apply to it. Since savings is one of the ways by which its information carrying ability (the message of real income) can be expected to decrease, we would expect such savings to increase at a more rapid rate than the increase in the money supply. Thus the recycling time of the 1b cycle can be expected to increase continually with time.

Thus, maintaining the capacity of the channel constant, we might expect on the average that the rate of savings, and replacement to make up for the savings, should be proportional to the average rate of entropy flow in the channel.

On the average we might expect the rate of saving and replacement to be proportional to the average rate of entropy flow in the channel. Thus equation (16) should be modified somewhat but still give an exponential rise of entropy flow. But the ratio of the rate of flow to the total entropy (flowing and saved) might be expected to continually become less at an exponential rate. That would also mean that the ratio of income to money in existence should likewise decrease exponentially.

If the average high rate of employment we maintain throughout practically all of our history with the exception of the 1930s, could be taken to mean a fairly constant capacity (because of the producer cost argument) we would expect our history to show a similar behavior. That such a condition really existed is illustrated in the data plotted by Clark Warburton and shown in figure 2. We might likewise expect the rate of information received to decrease exponentially with entropy. Again (based on the producer cost argument) this should be the average man hours per dollar in existence, and it should also decrease exponentially with time Figure 3, as plotted by the writer from the indicated data verifies the above conclusions. We would further expect the information per unit entropy to obey the same law. Figure 4 in which is plotted labor cost in man hours per dollar against time, both for England and the United States, again verifies the above conclusion.

XII THE BALANCED BUDGET

A variation of the above theorem is the problem of what happens to the capacity of the channel if the money supply is constant. We will also consider this in terms of Shannon's Section 12. Let us assume that in the example shown we start with a channel rate of a thousand bits per second and ten bits per second are transmitted incorrectly. Since in the above example Shannon shows that 81 bits per second would be necessary to remove and become certain about the ten that were transmitted incorrectly, only 919 bits per second would be left after the first second.

After the first recycling of the entropy in the producer-consumer channel we would be confronted with still one thousand bits transmitted but 81 taking care of the former random effects and 919 carrying the message. If now of these 1% is again transmitted incorrectly the capacity would now be 81/1000 X 919 bits. Thus with a constant rate of loss in a recycling channel the useful entropy must be decreased exponentially. If we now apply the same reasoning in relearning loss postulate, the percentage loss of capacity due to relearning must likewise be a constant for constant total entropy. Thus the capacity of a channel with constant entropy must decrease exponentially. (17)

We might also consider this conservation of money under the condition of hoarding as indicated above. We would likewise expect an analagous decay in capacity with an increase in the amount of hoarding.

The above is intended to show that if a balanced budget implies the conservation of money, it in turn must disorganize the economy.

Let us consider two examples of how such disorganization might be expected to occur in actual practice.

XIII EXAMPLE OF DISORGANIZATION OF MONEY SUPPLY

1. Suppose we are confronted with a constant money supply and some individual within the economy, being more capable than the rest accumulated a large portion of the money. The money he accumulates he of course uses for earning more of the limited supply. The more his capital earns the less there remains to be distributed as income to the rest of the economy, and the more hazardous therefore becomes the incomes and occupations of others. Since the only way that his money can earn money is if others pay for its use, diminishing its earning potential also reduces earning potential of the money accumulated by the single individual. Thus, his investments tend to become more risky with a smaller possibility of return. Under such conditions, rather than risk his assets he starts hoarding, removing the money from circulation. This further diminishes earnings. The others in the economy find it more convenient to accept the rich individual as a feudal overlord, so that they can barter work for their sustenance directly, rather than rely on the money channel for their living. This further reduces the entropy per unit of money until the entropy it carries tends to approach zero. For that reason it is not surprising that even at the low level of economic activity during the Middle Ages, the total amount of gold and silver mined during that millenium was not sufficient to maintain the economy at the low level at which it then existed, because the money produced by the gold and silver became disorganized (hoarded and demonitized) faster than it was mined.

2. A second example of such disorganization might be a credit economy, where the money supply is the credits that are loaned by the banking system against vendable items as collateral. Suppose in such an economy an individual saved a portion of his earnings in order to go into business. Suppose he saved the money in a bank which loaned out his deposits to industry, so that while he was saving the money was continually being transacted. After saving a certain amount he decides to go into business with his savings. He goes into business expecting a return on his money, a return which must come from the customer. But the customer had developed certain spending habits before this new man went into business. Now, the new investor asks the customer to change his spending habits and leave the money with him rather than where he had left it in the past. In order that the customer relearn his habits a certain amount of entropy must be sacrificed in the process. In other words, the customer must be offered an inducement plus what the customer has been getting before for the same amount of money. Giving the customer more entropy for his money is equivalent to lowering the price level of goods. Lowering the price level of goods first decreases the credit money due to consumer goods directly in proportion. Thus the overall money supply is decreased somewhat. Since business profits depend on the money received by business above fixed charges such as the return on borrowed money and other contractual obligations, any decrease in the money business receives due to the decreasing price level and money supply, must cause a disproportionate drop in business earnings. Since business earnings determine the vendability of business and the vendability determines the credits created for the business, the decrease in money supply due to the decrease in credits from this source becomes out of proportion to the drop in prices. This further reduces the customers ability to buy and the money loses entropy on the average, as credits are withdrawn from circulation, and bankruptcies occur.

Based on the above argument, such a condition must be cumulative unless the money supply is increased from another source. In the following sections of this paper it will be shown that that is exactly what occurred. There appears to have been an exponential increase in money per person from another unrelated source (probably the immigrant) that enabled almost all the employable entropy to be transmitted through the money channel during most of the history of the industrial revolution.

In our model, suppose a dollar is taken out of the economy so that for a time people do not receive that dollar in succeeding transactions. Every one of those people must relearn the code that the remaining money carries for him.

We are thus confronted with the condition where a certain amount of equivocation always exists in the channel, because change is always taking place and people continually have to relearn. Every time a bit of error (a wrong decision) is introduced, more than one bit of redundancy is needed to overcome it and leave the flow of information at the same level where it had been previously. The message the unit of money carries loses its information.

XIV FURTHER IMPLICATIONS OF THE VARYING CHANNEL

A - Real Income

Applying our model in which we regard money in circulation as a channel carrying entropy, we are led to some interesting implications. As the money supply slowly changes we would expect the confusion due to relearning to be a minimum, (as implied by the relearning loss postulate). The increase in money, therefore, would be coded by the people into organization and redundancy in the process of getting the maximum organization out of the channel. The redundancy should largely overcome the equivocation and make more of the useful entropy available to the consumer. A slow increase in the money supply, therefore, should produce the highest real income.

Let us consider how well being can be expected to vary with the width of the channel, (well being in the sense of the satisfaction of desires).

In the case we consider, if random rate of destruction of organization is (KH), a rate proportional to the bits that had been put into organizing the environment (H), the following considerations apply:

$$(1)\quad H_L \doteq \frac{KH}{H}\log\frac{KH}{H} + \frac{H-KH}{H}\log\frac{H-KH}{H}$$

$$(2)\quad T = H_L H$$

$$(3)\quad H = \sum_{t=0}^{t=-\infty}(T_1 - T)\Delta t$$

Where H_L is the bits per bit in the channel required to replace each one lost. T is the rate of communication lost due to random change. T_1 is the total rate of communication to the environment through the channel of the economy. Δt is an increment of time.

As long as T is less than T_1, T is a monotonic increasing function of H. Therefore after a given time $T \rightarrow T_1$. When $T = T_1$, $T_1 - T = 0$ and there is no further communication available for the trial and error process of learning to make our decisions more efficient. That can only be accomplished by the use of the entropy required to describe the trials and errors.

Therefore, the attainable maximum is reached when the economy becomes so improbable that the quantity of bits carried over the channel can just about replace that lost by randomness.

Thus for any rate of communication there is a maximum degree of well-being attainable. Likewise, after that degree of well being has been reached for a given rate of communication, maintaining that degree of well being should require an ever expanding channel width. In an ergodic system (for any fixed rules of the game) this is expected to mean an ever expanding money supply.

B - Democratic and Dictatorial Forms.

Because the received organization is less than the transmitted entropy by the equivocation, a channel which is too narrow to carry all the usable entropy available in itself introduces some equivocation. This equivocation cannot be overcome by redundancy since there is insufficient entropy in the channel. If any of the entropy is used for redundancy, more entropy is used up than the amount of confusion eliminated.

If there is an adequate supply of money (entropy for organization) we can allow redundancy without decreasing the information (useful decision sequences) carried by the money. Thus, we can have greater freedom of action and a greater amount of change and relearning among the individual members of the organization.

If the capacity is small (not enough money), information will be lost if there is the least bit of uncertainty about the message. The channel must therefore be kept free of errors, which would imply it requires a kind of tighter coupling, i.e., feudal systems, 'socialistic' measures and control. Hence there are fewer degrees of freedom for steering oneself, and less adaptability to environmental changes. The result is that freedom and prosperity both follow each other because both are dependent on the capacity, that is, the amount of entropy the communication channel can carry. This in turn depends on the amount of money in circulation. It would be expected, therefore, no mere coincidence that Pitrim Sorokin found, in his survey of the dynamics of history, that economic prosperity and democratic forms increased and decreased coincidentally.

C - Inflation - Gresham's Law

If the money supply increases too fast, it involves so much relearning that confusion uses up most of the entropy in the increased money supply. Under these conditions not enough entropy is left for redundancy to overcome the uncertainties caused by such rapid change.

Redundancy means that more bits of entropy, more message symbols, are used to carry the same potential organization. Financially speaking, that means a price increase, since it means more dollars for the same item. More money is therefore needed to maintain the economy and more money at any instant during such a rapid inflation generally makes things worse. It becomes worse because when money is poured into the economy so rapidly that (based on the relearning loss postulate), the equivocation due to relearning is increased at a rate greater than the money supply, the money is needed in greater quantities than it can be supplied, and this condition results in a runaway inflation. Thus the information given through the channel decreases and with it, real income (actual organization). At such a time people try to change the entropy carrying channel to some other one that will not have so much equivocation. The result has been described as Gresham's law -- bad money drives out good. People find another means of economic communication that is not as subject to change as their old money supply.

D - The Law of Supply and Demand

If we assume that every logan in the productive matrix acts as an independent channel subject only to the restriction that the sum of entropy in all the logans is dependent on the entropy of the money channel, we find a certain degree of freedom in the quantity of entropy supplied to each of these logans by the producer-consumer transducers. The entropy supplied should tend to follow the means that had been established by trial and error and justified by Shannon's theorem 11, the use of redundancy to overcome equivocation, and to thereby keep the capacity of the respective logan at a desired level for the maintenance of the overall organization matrix. That redundancy, when supplied at the consumer level takes the form of a price increase - more money for goods -- at the productive level a price decrease - more goods for money. The expected implication is the observed phenomenon of supply and demand.

This observed phenomena was seized on by economists who observed only the redundancy and not the expected equivocation due to the rate of change. They tried to induce a basic law from their limited observation. The law, as iterated by Say , after whom the law was named is that any money supply regardless of how large or small is always sufficient to take care of the needs of the economy due to the action of supply and demand.

It might be expected from the above that such an observation is faulty and could result in endless misery if economic theorists attempted to wait out the expected equivocation.

E - The Question of Unemployment.

The properties of the communication channel as presented here has certain implications in regard to unemployment. The unemployed are continually putting their entropy into the economy by trying to stear themselves for the maximum real income. (That on the average should be the maximum real income for themselves and the entire economy as would be implied by the entropy maintenance postulate. However, the money channel may lack the capacity to accept that entropy, in which case it would become, at best, equivocation. Thus there would be a difference between the transmitted and received information. In the ideal case as for instance if all the unemployed were suddenly put into the army and there were no resulting uncertainty the percentage equivocation should approach the percentage unemployment. In that case only the potential income producing ability of the unemployed would be missing from the economy due to their unemployment, and redundancy equal to the equivocation should reemploy all the unemployed.

In general however, unemployment and confusion go together. The unemployed do not know just how to fit back into the economy for satisfying demand, and a certain amount of trial and error is necessary. Every bit of confusion therefore increases the equivocation. Here we can expect the law of diminishing returns as justified by Shannon's theorem X to apply. As a result, the less the percentage of unemployment the more entropy (money) should be required to reinstate a given rate of bit production (the work of the unemployed). For that reason, it is likely that full employment can only be accomplished by excessive redundancy, with its implied runaway inflation and loss of real income. Yet experience during good times seems to indicate that we can approach that ideal closely enough for human decency and happiness.

F - The Question of Taxation and Government Restrictions.

We have indicated previously that whatever makes for a difference between transmitted entropy and received information is equivocation. Thus we would expect it to apply to the difference between money earned and the satisfaction of desires. Therefore, if we take a part of earnings in taxes and make it go through transactions that are not primarily for the satisfaction of desires (taken out of the production consumption matrix) such as payment of interest on a national debt and the salaries of tax collectors to collect that money, we are introducing equivocation into the money channel which can only be overcome by redundancy. Such redundancy is only equal to the bits removed from the channel in the limiting case where there is no resulting uncertainty. That limiting case cannot be expected to exist in practice. That would imply that for every dollar that is taxed for such purposes more than one dollar must be added or spent by the government to bring the economy back to where it was before the tax went into effect. It would further imply that the harder we try to balance the budget by adding taxes under the above conditions the more we must unbalance it (add new money), just to maintain the economy. The unbalance, of course, going into redundancy -- higher prices.

Similarly economic restrictions such as occurred in European countries after the last two wars, and the inflations that followed could, from the above analysis, be interpreted as nothing more than equivocation and redundancy in the economic realm. The equivocation showed up as restrictions that narrowed the money channel so that the economy was presented with less choices. The redundancy showed up as people created more entropy (more money) to overcome the equivocation as they attempted to code the entropy in the channel into the maximum real income.

XV DISCUSSION OF IMPLICATIONS OF MONEY DISORGANIZATION THEOREM

The use of probability to evolve communication theory is based on the assumption that when we deal with identifiable averages nature abhors the improbable. Still the improbable can exist and does. The only thing that we can definitely expect is that in an unlimited time interval the most time will be spent in the most probable condition and the least iime in the least probable. Where the probability becomes extremely small it may never be encountered in human experience. It is for that reason that we are justified in saying in the case of economic organization where the probability is very small, that nature abhors the improbable, and the equivalent of the second law of thermo dynamics applies, with its implication that a fixed money supply or balanced budget bookkeeping (where balanced budget is intended to imply the conservation of money), the economy is practically certain to run down. A survey of our financial history as indicated in fig. 5 shows the money was continually created during our growth. We also know where money was not so created as during the middle ages the economy was one of subsistence and stagnation. It would appear then that when the money supply was fixed by the monetary metals in existence and little was added the economy just ran down. The money channel carried less and less economic organization. Yet it is evident that the wage level cannot sink below the level of subsistence. The result apparently was that the economy became frozen into a feudal state, where it was no longer dependent upon the money supply for the vital necessities.

Every few centuries, however, the improbable occurred, a war or other upheaval happened, and some of the fixed money supply that had become demonitized by hoarding or ostentatious display was redistributed among the people in some small part of the world. There we would find a temporary prosperity existed, and the human mind was able to flourish in the realm which provided a wide communication channel. Such for instance seems to be the explanation of the prosperity that encompassed the ancient world after Alexander the Great liberated the Persian monetary metals, or the Renaissance that followed the Black Plague of 1370 in Europe, where half the existing population was obliterated, and redistribution of hoarded monetary metals was brought about by the general disorganization and looting that followed; so that not only was the money redistributed out of hoarding, but the average per unit population doubled while the population halved.

We can sense that the money's message is improbable because the economy that is built around the money supply consists of so many things that have to fit together despite the fact that random change due to time is always tending to destroy the fit. Such change may show up, for instance, as the wearing out of machines, the death of skilled workers and executives, new methods and business organizations, but the effect is the same, the economic organization tends to have its fit destroyed by the randomness of change.

People through the application of their thought continually try to prevent the tendency of the economy to run down. They continually try to reorganize and improve their organization for making a living. The total organization for making a living is our economy. Thus each attempts to fit into the economy and to figure out how we can get the most out of the organization. Thus we counter act the disorganization caused by change and maintain or even improve the organization that exists, and we use money as indicated in our previous discussion as the medium that carries the organizing decisions. In that way, it carries a message in the same sense as the printed page. We know the printed page invariably loses the sense it contains as change smudges up the print and destroys it. The printed page provides the reader with only the sense it intended to convey while the unit of money may choose the many things of equal value the economy is capable of organizing. Since the unit of money is more probable than the printed page, we would not expect the organization around it to decrease as consistently as the organization around the printed page. It has a higher order of probability because there are so many more things that the money can represent. Nevertheless, although the message conveyed by the money is more probable than the printed page, it is sufficiently improbable that it almost always tends to become disorganized by any change. Thus sometime for short periods as we have shown the real income per unit of money actually increases. So, just as in ancient and medieval history there were apparently short periods when the money became reorganized due to a temporary upheaval, so there were similar reversals of the trend in modern times. These reversals seemed to follow surges of confidence removal of arbitrary restrictions and after monetary inflations. Thus, for shorter periods the less probable followed the more probable.

XVI <u>MONEY AND OTHER COMMUNICATIONS</u>

The coincidental growth of the means of communication, universities, libraries, and other tools that cater to informing the human mind, during the last few centuries outstripped by several orders of magnitude every other result of the industrial revolution. We often speak of our age as a power age, but it is well to remember that the horse was a common beast of burden in the middle ages. Thus even though we now have in the order of ten horse power per productive worker, the increase in power, or in real income, as measured by the things earnings can buy, or in any other result of the industrial revolution, was puny in comparison to the thousands to one that our communications increased.

When we examine how the world's money supply behaved, we find that it too behaved as the other forms of communication, it increased by thousands to one. Thus the Routledge Dictionary of Statistics, London, 1890, cited as 131 million pounds the total money supply of the world in the year 1600. Today the United States alone has a money supply of 200 billion dollars, an increase in the same order as the increase in the other forms of communication.

Such is the implication of their isomorphic behavior. Furthermore, as indicated by Sorokin[12] and others[13] this coincidental behavior seemed to be the rule rather than the exception; the flow of money seems to have been the main communication channel. It determined and then supplied every other logan in the productive matrix with the proper share of entropy and did so as long as the consumer could spend. As long as he could spend because money was being created for the purpose, it apparently provided the communications for an economy built around awareness, the awareness of his desires. Hence the emphasis was on the other forms of communication; and thus the coincidence resulted.

XVII <u>ENTROPY, BANKING AND DEBT</u>

The consumers' spending ability had been created through the mechanism of banking. Basically it was that the money deposited in commercial banks (checking accounts) was largely placed there for the purpose of facilitating its use. It was simpler and less hazardous to write checks against an account in the bank than to carry cash for business purposes. In that way the banking system became the storehouse of a money supply that was continually being used in business transactions despite the fact that it never left the banks. Being entrusted with that money it soon became apparent that the money could create considerable earnings for the banks if they loaned it out to good business risks.

The fact that they loaned it out, however, did not prevent the owners of the money (depositors) from spending the money with other depositors so that while the spending was going on some accounts were debited, others credited without interfering with the total amount the banks had on deposit and which they could loan. The banks loaned money and this money too went into spending.

The people receiving this redeposited it in their accounts in the same banks, thus practically every loan wound up as a new deposit, a deposit people were able to spend (draw checks against) also without those deposits leaving the banking system. In that way the deposits and bank loans increased coincidentally thus increasing spending power. This spending power made possible the flow of entropy that organized the economy. But, based on our former argument, it was necessary for this money supply to increase faster than the income or the wealth (the entropy in the communications channel increasing at a greater rate than the acceleration of its flow rate or the total information in the system). This became possible because as we changed from a subsistence economy to a money economy potential sources of organization became vendable and served as assets, bases for credit.

Even the promises of potential organization became assets and sources of money. The greatest of these was probably the land in the new world that (as long as the immigrant was coming in) served as an almost unending excuse for a spiral of asset inflation and a source for new credits.

These credits poured into the economy to maintain and increase the flow of information. From the previous argument we can gather the implication that we thrived on acceleration, and that our entire fiscal policy had been built around the assumption that such an acceleration of organization was a necessary part of the state of things. Otherwise there could be nothing in the channel to supply the necessary redundancy to overcome equivocation. The argument would further imply that such redundancy must be created intentionally if we are ever to hope for a highly organized steady state level. An indication of the rapid acceleration of credit during our era can be gathered from the following estimate compiled by a Robert Doane .

Year	Debt - Millions of Dollars Robert Doane
1500	400
1600	1,000
1700	1,500
1800	8,500
1890	--
1900	400,000
1929	700,000

XVIII <u>THE CYCLIC BEHAVIOR OF THE CHANNEL</u>

There are a number of other conclusions we can arrive at about the expected properties of the channel based on our previous discussion. Let us first explore the implications of the disorganization rate postulate in a little more detail. The postulate states that there is a tendency toward disorganization:

(1) $RH = K_{11}T$

(2) $\overline{T} \leq \overline{T}_1$ For the maintenance of economic organization.

There is a time delay $\mathcal{T}$ between the rate of disorganization T and our attempt to reorganize T_1 due to the fact that we cannot act instantly, especially in large groups, (due to the hierarchical structure of those large groups). Hence the attempt to reorganize is, by the time it is applied, relevant to a disorganizing condition that occurred in the past, thus we find:

(3A) $T = f(t)$ and (3B) $T_1 = f(t+\mathcal{T})$ where t is time.

Since T_1 is intended to make up for T as we sense it.

(4) $f(t) = f(t+\mathcal{T})$

The solution of (4) indicates that f(t) is either a constant, or oscillatory around some constant average value T. However, since f(t) is random, it cannot be constant and must therefore be oscillatory. Since $\mathcal{T}$ is not necessarily constant but can be expected to vary with the size and the structure of the economic entity, we might

(3) An organization having its communicating time t_5 can only take care of one half of the disorganization occurring in that time interval. Therefore, two such organizations should be necessary to take care of the disorganization occurring in the time interval it is capable of handling.

(4) (t_4) represents the minimum reorganizing time a single individual is capable of handling.

XX CAPITALISM VERSUS SOCIALISM AS IMPLIED BY THIS ANALYSIS

Since single individuals cannot generate the intricate matrixes of entropy that larger organizations are able, it is obvious that as a single individual, even though he might react at the fastest rate to overcome the disorganization of the economy, he is helpless when confronted with the more intricate portions of such matrixes. Thus, with individuals acting alone, the maximum T is not attainable. It is equally evident, from the above, that a large organization likewise cannot attain the maximum by itself.

The money channel in the Capitalistic economy enables the consumer to communicate the disorganizing tendency to the producer in all the various combinations of consumer and producer found most desirable by the varying matrix of disorganization in the manner described above. The nature of the disorganization must vary because it is random, and because all too often as in the case of death, we cannot reconstruct, we can only substitute in order to maintain the average entropy of the system. Thus, various changing combinations with their universal communicating channels are necessary to keep $\overline{T} \doteq \overline{T}_1 = MAX$..

We might expect the above to explain the fallacy of socialism, where the constraints are such that only the large (state-owned and operated) organizations are allowed, and where the communication must taken place through a planning hierarchy; there we are confronted with the condition very much analagous to that illustrated by t_1 in figure where the only real income is H_R whereas H_W is the entropy wasted to generate intricate but uselesss structures, for some such nebulous purpose as the worship of a Sun God (ancient Egypt), or a dictator (parallel obvious) as indicated above. Meanwhile the real income might be expected to be very low, since the proportionate rate at which such an organization can take care of disorganizations faster than its time would be inversely proportional to the time ratio, or we might roughly expect the real income to be represented by the shaded area. Anything above that shaded area would be attainable real income that is lost by such malorganization.

It is the authors contention that if such structures were not modified by the black markets, stealing, and other means of relaxing the constraints, the people they contain could hardly be expected to survive.

A number of other corollary implications might be drawn from the above analysis. For instance, we might expect that the condition of greatest organization is when $\overline{T}$ equals $\overline{T}_1$ equals max. unattainable limit, equals W_n bits per second, where W is the population, and n the average entropy rate generated by a producing individual. $\overline{T}_1$ should be greatest when all the combinations of W are allowable.

Because of the large time of communication of the large organization and its large number of individuals, a great quantity of entropy is always in the process of flowing through the organization. That great quantity of entropy implies a considerable equivocation for each bit lost, requiring an excessive amount of redundancy (paper work, remade production, etc.)

Since we might expect H_T to increase directly as the number of individuals for the time t, because T_1 would increase, an increase in the number of individuals from W to W_1 would make the new H_T' equal $\frac{W_1}{W} H_T$. Because of the symmetry of the disorganization hyperbola, the old value of H_R would occur when the new t_1' equals $\frac{W_1}{W} t_1$. . Thus an increase in the number of individuals in such a hierarchy should actually be expected to decrease the reorganizing entropy per individual.

XXI CONCLUSION AND SUGGESTED EXPERIMENTS

A theory is only useful to the extent that it mirrors reality. In this paper several attempts were made to meet the test. This was done by trying to show statistically that the unit of money behaves as Shannon's Theory of Communication would lead us to expect a communication should. Furthermore we might expect certain statistical distributions of entropy that the analysis indicated might be expected of the economy in general. The writer cannot help feeling that those tests, although suggestive, are by no means conclusive. Therefor the analysis contained herein would suggest a number of other statistical experiments to test its implications. For instance;

(1) The question of unemployment would suggest that the rate of monetary inflation with any percentage unemployment should approach the equivocation implied by Shannon in Section 12 of his Mathematical Theory of Communications, but as modified by the learning loss postulate, and the constraint that wages cannot sink below subsistence. The validity of such a hypothesis could be tested statistically.

(2) The money disorganization theorem would lead us to expect all money supplies to behave analagously to our own in their particular ergodic realms. This also could be verified statistically.

(3) The quantitative behavior of the growth of feudalism and of democratic forms and how they were related to the width of the money channel can be statistically determined and correlated to the above analysis.

(4) The dynamic behavior of the Leontief matrix should be tested statistically for its agreement with the above model.

(5) The average reaction time of business firms to an arbitrary change in rules of the game may be tested statistically for agreement with the apriori averages used in this paper.

(6) It would be worth while to examine the co-incidental growth of money and other means of communication.

These experiments are somewhat beyond the scope of the writer, an engineer whose time is fully committed to another line of endeavor, but they may be used to determine how closely the above model fits reality.

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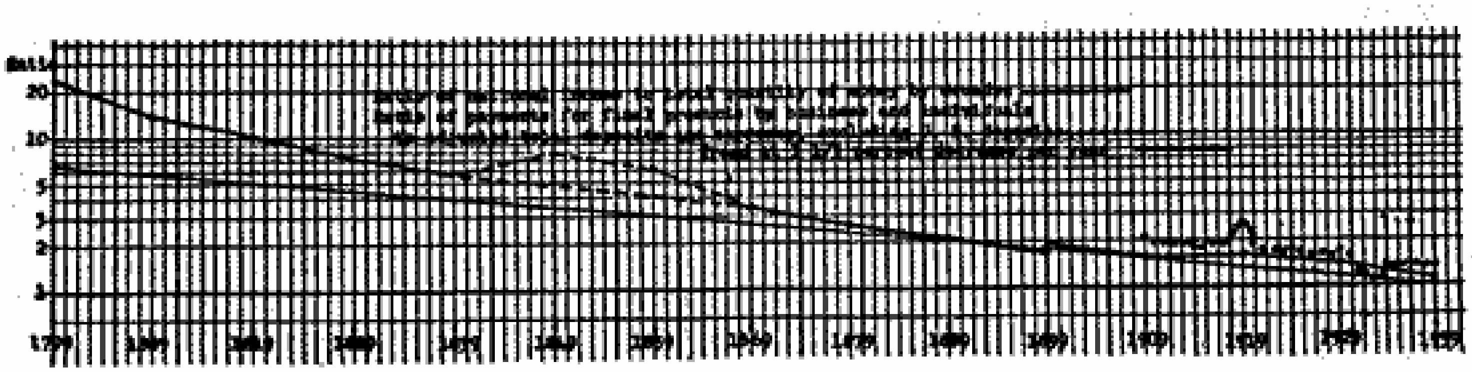

Fig. 2

Ratio of national income to the total quantity of money by decades: 1799-1939. Source: Clark Warburton.[10]

Ratio of payments for final products by business and individuals to adjusted total deposits and currency excluding U. S. deposits.

Trend at 1 1/3 percent decrease per year.

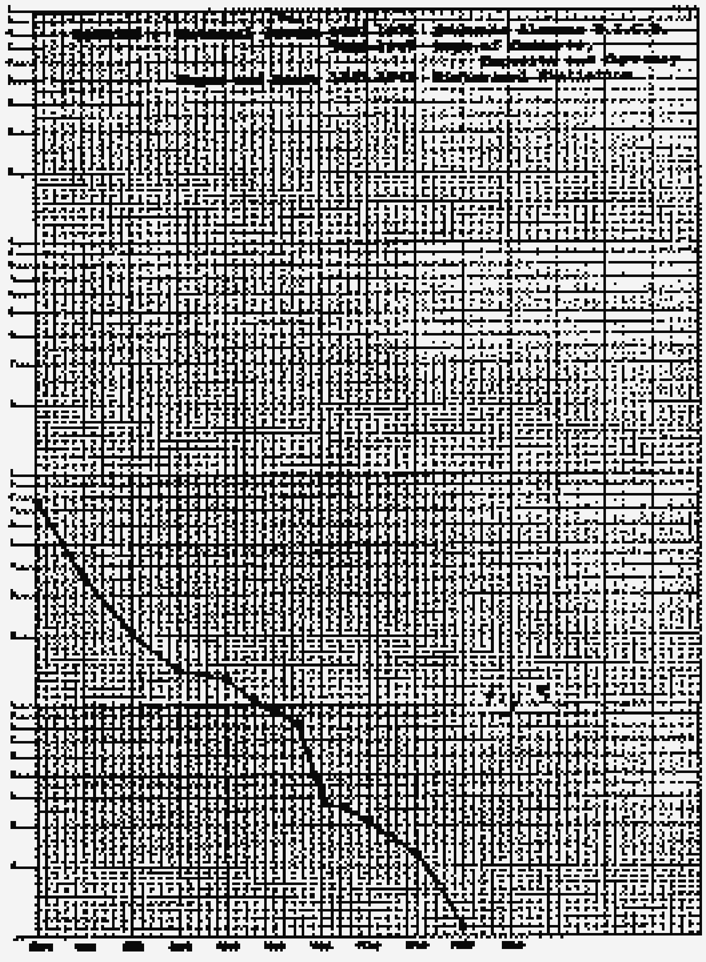

Fig. 3

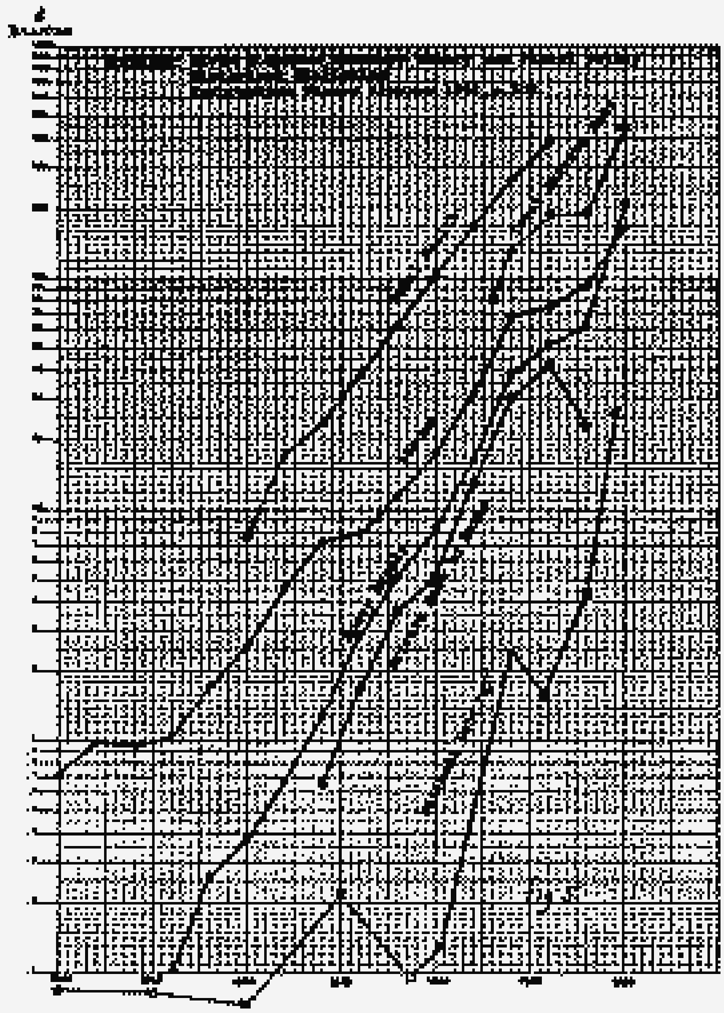

Fig. 5
Comparison of rate of acceleration of income and wealth to money supply and debt.

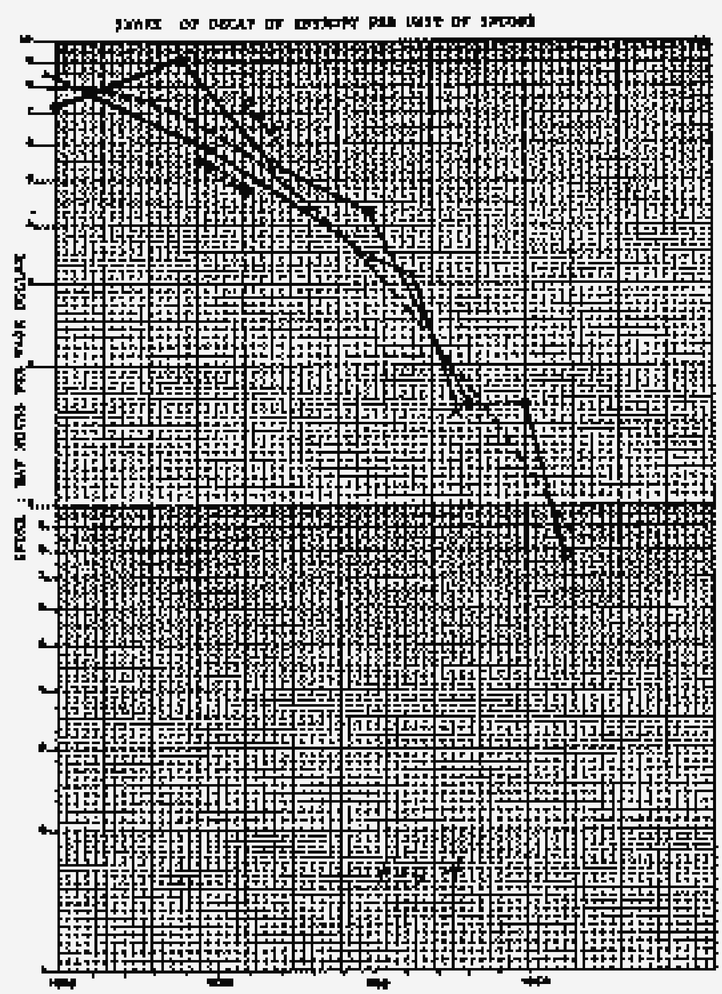

Fig. 4
Index of decay of entropy per unit of income.

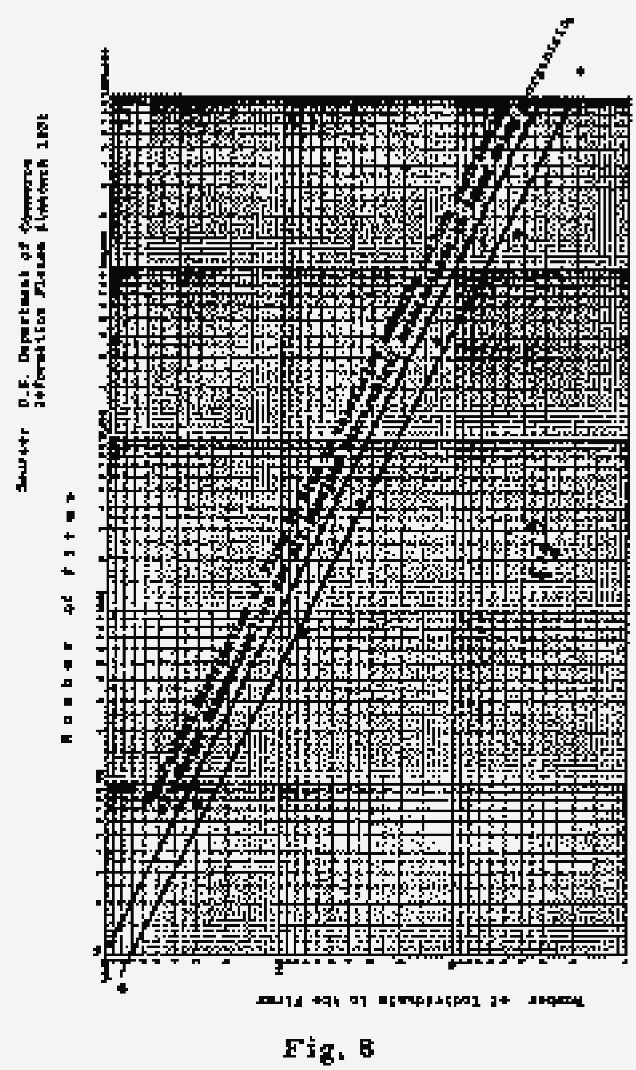

Fig. 6