What is Economic Energy?

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ABSTRACT

The law of the conservation of energy has great practical importance in physics. Is a similar law applicable to economics? For an answer, System Dynamic-related methods were applied to the economic Two Sector Diagram. They show the forces of Supply and Demand operating on the economic flows of money, goods and labor. The demand can be expressed quantitatively by a utility function, which shows that economic forces and flows are informational concepts. Consequently, the two main forms of energy in any economic system are code transport and numerical code values. Only the latter are essential.

INTRODUCTION

What is Economic Energy? In search of an answer one may look in vain through economic textbooks and never find such an expression. Why is that so? Have economists overlooked discussing this concept? Or is the lack of this expression so self-evident that one does not need to mention it? After all, economics is a social science, and one does not talk about energy or its time derivative "power" in sciences, which deal with people instead of physical entities.

Still, there is a latent suspicion that physical and social sciences are not all that far apart and that some of the very general laws in physics should also be applicable to social sciences. To our knowledge, however, only a few have investigated the question if such law of conservation exists in economics and if it is energy which is consumed, or something else.

We faced these questions while pursuing the analysis of economic flows in a similar way as it has been done by J. W. Forrester; that is, by using flow diagrams. Yet, we were less concerned with specific dynamic solutions, but with the more basic economic problems, such as the interface between money, labor, goods and information and basic rules, which could be derived from the configuration of these flows.

During these studies we were particularly wondering why economists talked frequently about demand and supply as the basic forces of economy, but never used these forces other than in a literary sense. So one of our main efforts consisted of finding a quantitative expression for such force. But the finding of the force took longer than we thought and as we had discovered it, we did not quite know how to apply it; that is, we had a difficult time figuring out how this force acts upon or interfaces with the various flows, and thus drives them.

Our subsequent investigations were therefore devoted to this problem and we followed step by step the propagation of this force, or rather the energy derived from this force, through the various loops of the economic circuit diagram.

In order to be able to properly explain the relationship of the economic loops among each other and thus to follow the motion of forces (or energy, respectively) through this structure, we begin the following discussion by representing the economy in a sort of bird's eye view. In this view, the economy is compared to a high-rise building.

THE ECONOMY: A HIERARCHY OF LOOPS OF ECONOMIC FLOWS

Such building can be partitioned into a number of floors and so can the interfaces of the various parts of the economy (Fig. 1). Each floor contains a part of the economy. Each of these parts is in the form of a loop shaped by an economic flow. The lowest loop, on the first floor (Fig. 1), is presented by the flows of labor and goods. (The mechanisms of these loops will be explained later (see Fig. 2).)

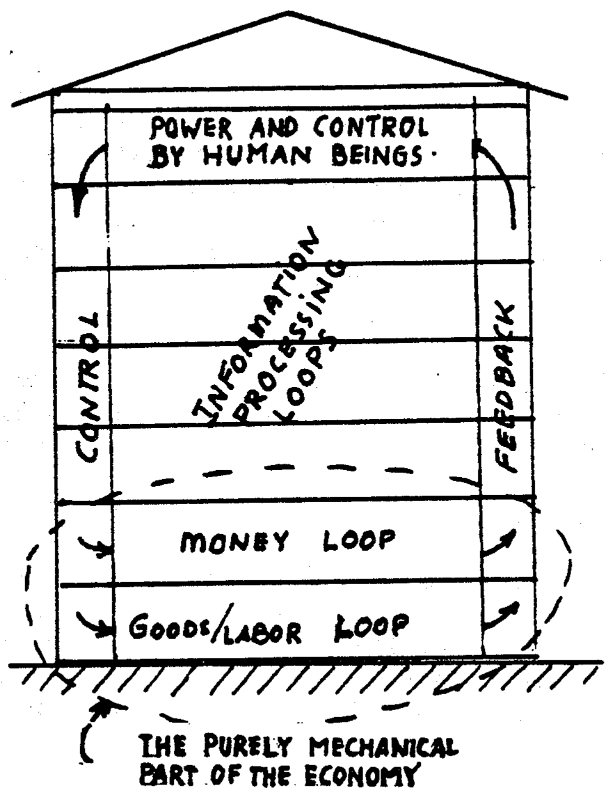

Figure 1. *The "High-Rise Building of Economics*

The building has many floors. Starting with "purely mechanical loops" of goods and labor on the bottom of the building, the more intricate loops of money and information flows are shown towards the top. The floors end with the human information and power system at the top of the building.

This loop is followed by the loop of money on the second floor. All the higher floors exhibit loops of information, which increase in complexity with increasing elevation from the ground. Thus, a kind of hierarchy combines all these floors, and the uppermost hierarchical level, controlling all lower ones, is inhabited by humans who, according to their positions, exert the greatest power for controlling the economy.

All floors in this "high-rise building of the economy" are thus controlled by a flow of control information from the higher information processing levels to the lowest ones and by a feedback of information from the lowest levels to higher ones.

THE ECONOMIC CIRCUIT DIAGRAM

An example of a simple circuit diagram combining floor 1 and floor 2, respectively, is shown in Figure 2. This figure also shows the control and feedback connections to and from the higher level information--floors, just as explained.

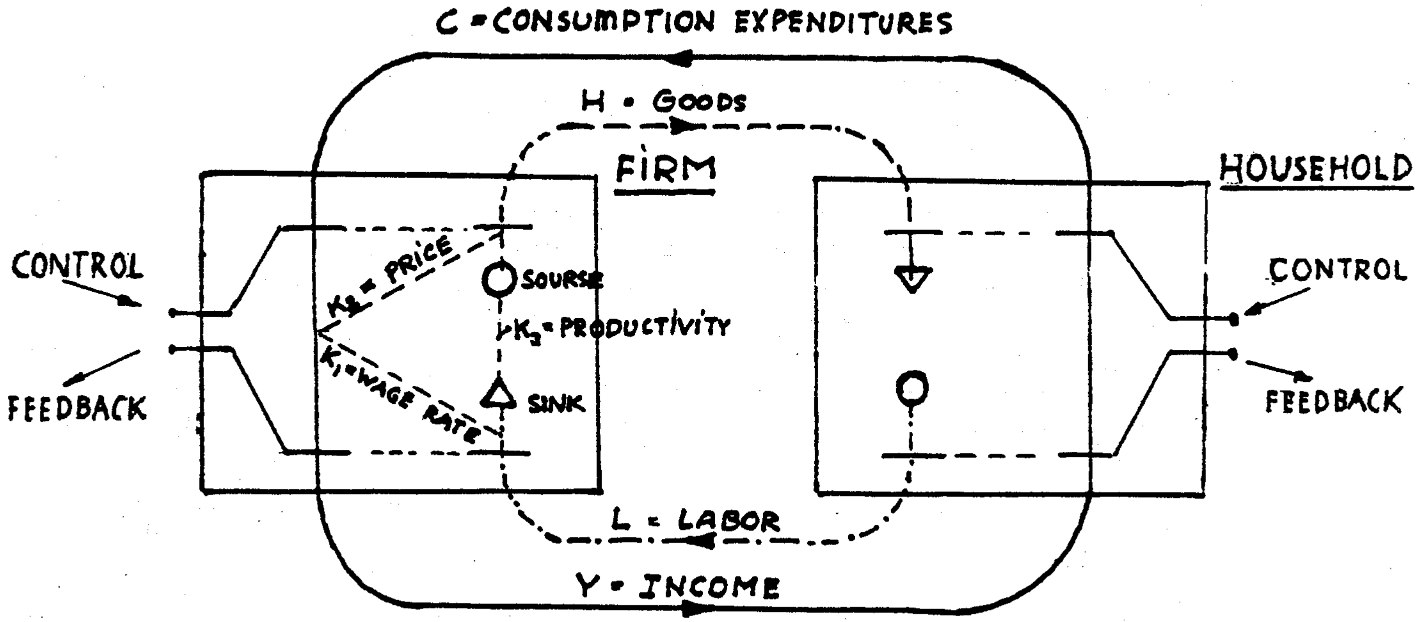

FIGURE 2. The Loops of Goods/Labor (1st floor) and of Money (2nd floor)

Under equilibrium conditions the economic exchange can be represented by two loops: the C/Y money loop and the goods/labor loop between households, the origin of labor, and firms, the origins of goods. The goods/labor loops are only half-loops and bridged artificially by "productivity." The outer monetary loop is closed,as C (consumption expenditures) is set equal to Y (income). The connections between money loop and labor/goods loop are established by wage rate, K_1*, and price,* K_2*.*

Figure 2 can be considered to be an extension of the well-known Two-Sector Diagram of economics. It shows the exchange of aggregated goods and labor between households and firms of a whole country in the lower (inner) loop, and the exchange of money in the form of consumption expenditures and income in the higher (outer) loop. Both loops represent equilibrium conditions; that is, the variables and parameters during the time of observation do not change. The correlation between the money flow (C,Y) and the flows of goods (H) and labor (L) is determined by three coupling coefficients: wage rate, $K_1 = Y/L$ = \$/manhr; price = $K_2 = C/H$ = \$/unit; and productivity = $K_3 = H/L$ = units/manhr, while the fourth coupling coefficient $K_4 = C/Y = 1$. (Note that income comprises all kinds from labor income to dividends, rents, interest, etc.) The combination of these equations leads to the relationship between productivity and real wage rate (wage rate referred to price) during equilibrium conditions. Thus:

$$\text{Productivity } (K_3) = H/L = \frac{K_1}{K_2} = \frac{\text{wage rate}}{\text{price}} = \text{real wage rate}\left(\frac{\text{units}}{\text{manhr}}\right) \qquad (1)$$

But the productivity equation is not the only practical result which can be derived from the diagram.

Derivatives of the above equation lead to further results, showing, for example, the relationships between inflation, recession, unemployment, etc., such as indicated in Table 1.

TABLE 1. Relationships between various stimuli, such as decrease in money supply, and recession, inflation and unemployment, etc., as derived from the productivity equation.

Stimulus	Conditions	Results
Consumption Exp. decreased $\frac{dC}{dt} < 0$ and Income decreased $\frac{dY}{dt} < 0$	Coefficients K_1, K_2, K_3 are kept constant	Recession: $\frac{dH}{dt} < 0$; and Unemployment: $\frac{dL}{dt} > 0$
Simultaneous increase of wage rates, K_1, and prices, K_2: $\frac{dK_1}{dt} > 0$; $\frac{dk_2}{dt} > 0$	Y, C, and K_3 are kept constant	Recession: $\frac{dH}{dt} < 0$; and Unemployment: $\frac{dL}{dt} < 0$

Both the productivity equation and the derivative formulas show that rather interesting results can be derived already from a very simple circuit diagram. But to show more of this kind of analysis is not our present goal and we, therefore, return to our main question: What is economic energy?

THE CONCEPT OF ENERGY IN PHYSICS AND IN ECONOMICS

In physics, the concept of energy is so important because the "Law of the conservation of energy" follows from this idea. It says that the sum of all energies in a closed system remains constant. The use of this law often simplifies analysis and frequently provides a much better grasp of the overall physical situation, permitting easier checks on the correctness of results. For instance, the speed of the driver in a motorcycle accident can often be crudely estimated by the deformation energy which the rebounce of the vehicle has released.

Such universal law of conservation is unknown in economics, and it is not even sure if such physical entities as forces or energy are valid magnitudes in this science. However, on the other hand, very frequently the subject of economic discussions is the dynamics of a particular situation. An example of this kind is the well-known business cycle, where the effects of inventory shifts together with time delays cause periodic oscillations of demand.

It would be, of course, of great advantage if economists could base their analysis on quantitative forces, and on such rules of conservation as they exist in physics. It will be our goal in the next few paragraphs to find out if we can determine such quantifiable forces and rules of conservation in economics as well.

Looking back at Figure 2, the economic circuit diagram, we recognize a certain similarity to electric circuit diagrams insofar as both cases discuss the flows of carriers, electrons in the electronic case; and goods, labor and money in the other, economic case. In the electronic case, power or energy per unit time is well defined. It is the product of current and voltage: POWER = CURRENT x VOLTAGE = I*V (WATTS). It is this electric energy which obeys the law of conservation which says that energy in a closed system can be neither lost nor gained. It changes only from one form to another, e.g., from inductive energy, stored in a coil, to capacitive energy stored in a capacitor, or to heat (energy). Now remember, the original question was if it is possible to define an economic term which corresponds to the electric energy as explained above.

At first glance the answer appears to be: No! In the economic case, we obviously talk about flows which correspond to currents in the electric case. But nothing like a voltage or force seems to exist in economics and, thus, no force appears to drive these flows. However, if one thinks about it, the analogy between economic loops and electronic circuits based on flows only, appears to be extremely superficial anyway. The elements of an economic loop, such as firms and households, have no functional resemblance to the elements of an electric loop, such as batteries, inductances, and capacitances. The connections in the economic diagram which connect the economic elements and look like wires exhibit none of the properties of electric wires,as they provide no conductive path, which could direct the flows. Also, the current-carriers in electronics are all charged particles (electrons), while the economic flows, such as money, goods and labor, exhibit very heterogeneous properties. But charged particles or not, in order to generate a flow it will be necessary to provide something which pushes the carriers forward; if they are material entities at all, that means a force is required. In the economic case, as the carriers are definitely not charged particles, we may suspect that the forces are of the Newtonian kind and, therefore, the Newtonian terms, $E = \int F*ds$ for potential energy and $E = mv^2/2$, for kinetic energy appear to fit better than the expressions for electric energy. But this still does not tell us which economic term corresponds to energy.

But the economic literature gives us a hint, as economic forces are frequently mentioned. Usually demand and supply are named as the two most prominent candidates. They seem to be the movers of nearly all the activities in the economy. However, if one wants to know more about the real character of these forces, one will find that those expressions are usually used in a literary sense only. No reference is made to Newtonian's law or any other rules or mechanism which could control these forces. In particular, they appear to be lacking in any quantifiable properties. Their usage in the economic literature only implies that when these forces increase they will somehow also cause increases of other variables or parameters, such as: "The rise of computer sales can be attributed to the increased demand caused by youthful players of computer games."

Yet this is not all. Some articles in the economic literature go further in the quantifying direction and relate demand directly to the utility concept, which provides a relative measure of a person's desire to buy a product. Using something like the utility concept, it is possible to reduce the literary term of demand to a quantifiable instrument. The result of such an analysis is shown in Figure 3.

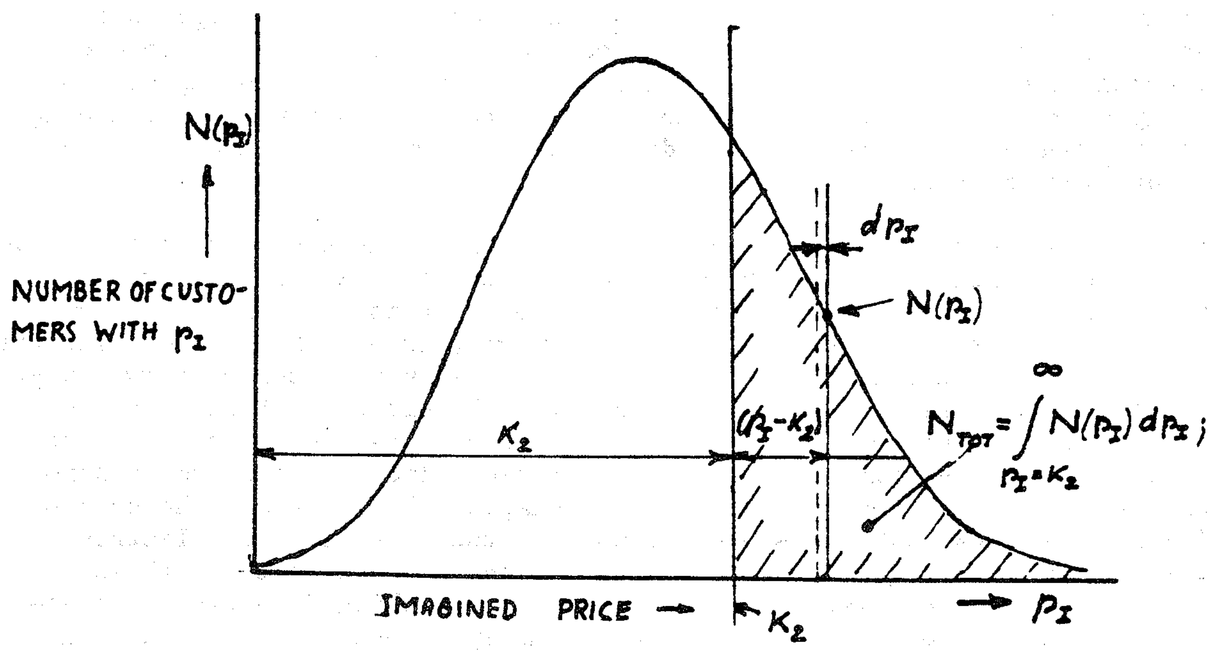

FIGURE 3. Demand, the Economic Force

The diagram shows the random distribution of the number of buyers, $N(p_I)$*, with imagined prices between* p_I *and* $[P_I + d(p_I)]$*. The distribution is intersected by the sales price* K_2*. The area on the right side of* K_2 *(hatched curve) represents all potential purchases. They occur, by definition, only then, when* $(P_I - K_2) \geqslant 0$*, that is, if imagined prices are higher than the sales price.*

The diagram shows a random distribution, $N = f(p_I)$ (e.g., a Gaussian) of buyers of a certain good. p_I is the "imagined price," that is the highest price, when the buyer would still purchase the good. It is based on the desirability of the goods to the buying customer. p_I, thus, means that the customer intends to make the purchase as long as the sales price K_2 is lower than this imagined price p_I, or if: $(p_I - K_2) \geqslant 0$; then: δs; where δs is a (potential) unit of monetary flow; that is, δs is the amount of money which is transacted by one execution of the cash register.

Referring to Figure 3, this means that the area N_{TOT} on the right side of K_2 (indicated as the dashed area) represents the sum of all purchases which could be made under the conditions $(p_I - K_2) \geqslant 0$. N_{TOT} can be expressed as a function of p_I and K_2, as follows:

$$N_{TOT} = \int_{p_I = K_2}^{p_I = \infty} N(p_I)dp_I \ ;$$

where $N(p_I)$ is the number of customers representing an imagined price between $p_{(I)}$ and $p_{(I)} + dp_{(I)}$

DERIVATION OF AN ECONOMIC TRANSACTION EQUATION

Observe that all potential purchases represented by N_{TOT} will be executed by paying only the sales price K_2 and not the prices p_I. Thus, the total potential purchase, able to induce a corresponding flow of money $C(t)$ is: $N_{TOT}(p_I) \cdot K_2$. (Assuming K_2 stays constant during the period of observation.) This purchase must be equal to the flow of money $C(t)$ during the period of purchase $(t_1 - t_o)$, which again must be equal to the product of the flow of goods H and the price K_2 during the same period. Thus, we arrive at the following tentative equation which we call transaction equation because it presents the correlation between the demand and the flow of money and goods.

Transaction equation:

$$\underbrace{N_{TOT}(p_I) \cdot K_2}_{\substack{\text{DEMAND} \\ \text{(purchasing} \\ \text{potential)}}} = \underbrace{\int_{t_o}^{t_1} C(t)dt}_{\substack{\text{FLOW OF MONEY} \\ \text{(kinetic} \\ \text{action)}}} = \underbrace{\int_{t_o}^{t_1} K_2 H(t)dt}_{\substack{\text{FLOW OF GOODS} \\ \text{(kinetic} \\ \text{action)}}} \qquad (2)$$

The meaning of this equation can best be understood by following the transaction process step by step. For this purpose we have again drawn the economic circuit diagram of Figure 2 in Figure 4, but with a number of changes. Again we have shown the firm on the left side and the households on the right, but in addition we have indicated certain essential details to support our explanation, such as the switches, a_1, a_2, b_1, b_2 and the storage devices (A, B,C). Storage devices A,B signify the wallets, where the money is stored, while C marks the only storage device for goods. The switches indicate the actions of the customers and the vendor, the vendor closing his switch every time a price of K_2 is paid and the customer, closing switch a_1 if his condition that $(p_I - K_2) > 0$ is satisfied.

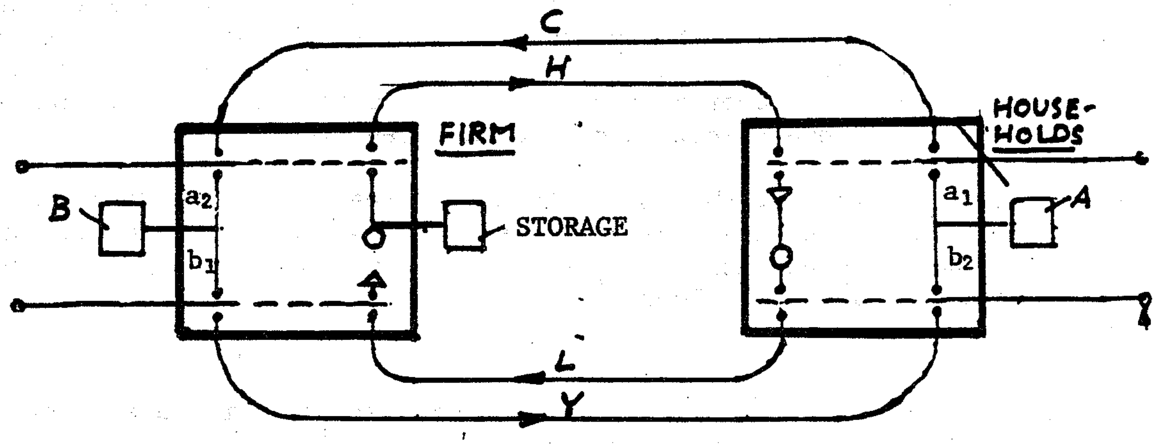

FIGURE 4. The Circular Motion of the Discontinuous Economic Flows

The Transaction Equation (2) which connects demand, the flows of money (C(t),Y(t)) and of goods H(t) and labor can best be explained along the economic circuit diagram of Figure 2, which is shown again on Figure 4, but supplemented by "switches" a_1,a_2,b_1,b_2 *and "storages" A,B in the money loop and storage C in the loop of goods.*

The cycle begins with switch a_1*, when the customer (households) controls the conversion of the demand, accumulated at storage A, together with the closure of switch* a_2*, by the vendor which controls the sales price* K_2*. This action converts the demand to a flow quantity* δC*, which leave A to come to rest at B. This pulsewise, random transfer of* δC *continues until the recycle, that is the payment of workers, takes place.*

The vendor then activates switch "b_1*" and the households close switch "*b_2*" if they consent with the vendor's proposed wage rate* K_1*. The closure of both switches leads the accumulated content of B flow back to storage A and renews the demand of the households.*

Figure 4a presents again the same diagram as Figure 4, but in a way to emphasize the operation as represented by the transaction equation. For this purpose we showed only the storages of the households and of the firm and indicated by arrows how money is transferred between them.

As an initial condition we assumed that all the money supplied to the economy is first accumulated at the storages A of the customers. The distribution of imagined prices, which the customers are ready to pay for the goods H of the vendor is plotted on top of the storage of the households. The customers now enter the vendor's shop and purchase goods randomly, that is, customers with high p_I's may be interwoven with customers of lower P_I's, but they all buy and thus decrease the content of the customers' storages until they are empty, or the period of observation is finished, or a new influx of income is filling up the storages again.

While the households are purchasing the goods, money is flowing out from the storage, commensurate to the number of customers buying per unit time. This overflow of money is identical with the flow of consumption expenditures C(t). At the same time the demand $N_{TOT}(p_I)$ is decreasing as a function of time: N(t), as shown in Figure 4b.

The system of households and firm as shown in Figure 4 forms a closed system and the money flowing to the firm has to return to the households, thus forming a complete closed loop. The velocity of money (and of goods/labor accordingly) in this loop is circular and is divided into two sections: the random velocity of the consumption expenditures, which we have just discussed and the periodic payments of income from the firms to the households. The whole mechanism is comparable to the human blood circulation, where the heart pumps periodically blood into the arteries and the return of the blood occurs on random when the blood flows through the veins. The circular velocity in the economic case is determined by the periodic payments of the firm, which mainly happen once per week, thus:

$$\text{CIRCULAR VELOCITY} = \omega = \frac{2\pi}{T} = \frac{2\pi}{7} \; ; \tag{3}$$

where 2π is the length of the unit circle, and 7 the number of days per week

We have thus described the whole economic cycle and the meaning of the transaction equation, which describes the interdependence of demand, consumption expenditures and the flow of goods becomes more clearly defined. However, our stroll around the economic loop has not yet lead us to a solution of our main question: can we consider demand as the force, which sets the various flows of the economy in motion? Instead, we saw that the flows of money consist of two components, which appear to be rather independent from each other: the circular velocity ω and the quantity Q (which we call fill-factor before; see legend of Fig. 4a).

To overcome our present handicap let us look at our problem from another angle:

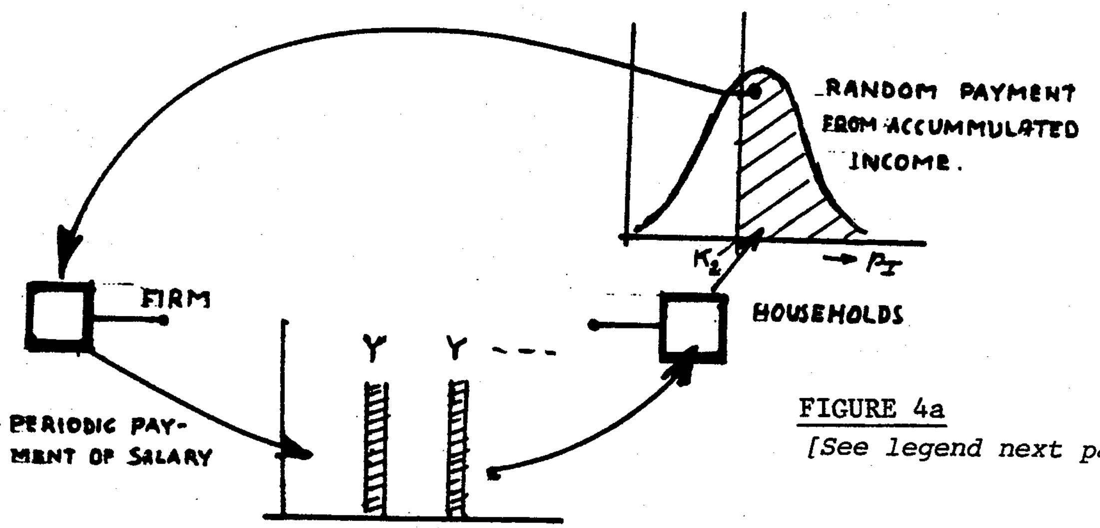

FIGURE 4a
[See legend next page]

FIGURE 4a. *Diagram as in Figure 4, but showing operation of economic flows. Economic cycle begins with storage at the households on the right side. $N(p_I)$ curve shows distribution of imagined prices for the money stored at the households; while K_2 is the sales price asked by the vendor. The lower diagram shows the return cycle, which is periodic. Change of K_2 or $N_{TOT}(p_I)$ does not change circular velocity, but the "fill-factor" of cash return cycle.*

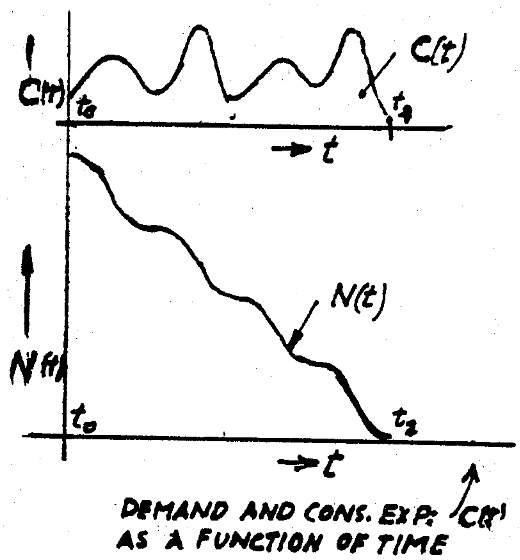

Figure 4b. *The figures show consumption expenditures above and demand during the cycle period $(t_1 - t_o)$. The return cycle occurs at the end of the period at time t_1.*

We may simply return and just as an experiment set the term, which represents the demand to be the economic energy, E_{eco} which we were looking for:

$$E_{eco} = N_{TOT}(p_I) \cdot K_2 \ (\text{\# of customers} \cdot \frac{\$}{\text{\# of customers}}) = (\$) \qquad (4)$$

then the transaction equation tells us that the terms $\int_{t_o}^{t_1} C(t)dt$ and $\int_o^{t_1} K \cdot H(t)dt$ are also in the same category. They are also terms of economic energy E_{eco}.

Accordingly, the flows of consumption expenditures C(t) and income Y, which are time derivatives of E_{eco} can be classified as economic powers, and so can the product of goods H(t) and price K_2: $H(t)K_2$. We can go further and in analogy to electrical circuits, we can consider the expression of economic power as the product of a current: the flow of goods H(t) and of "economic voltage" K_2.

Furthermore, we can derive an expression for the economic force F_{eco}, which drives the economic flows.

As $$E_{eco} = \int_o^{2\pi} F_{eco} \cdot d_\Psi \qquad (5)$$

in analogy to the physical expression, $E_{ph} = \int^{s} F \cdot ds$.

The corresponding economic force is:

$$F_{eco} = \frac{dE_{eco}}{d\Psi} = \left(\frac{\$}{\text{degree(angle)}}\right) \tag{6}$$

Further, as the consumption expenditure C(t) can be conceived as the product of the circular velocity ω and the quantity Q:

$$C(t) = Q \cdot \omega = \left(\frac{\$}{\text{degree}} \cdot \frac{\text{degree}}{\text{sec}}\right) = \frac{\$}{\text{sec}} \tag{7}$$

The economic force is:

$$F_{eco} = \frac{dC}{d\omega} = \frac{d(Q \cdot \omega)}{d\omega} = Q; \tag{8}$$

Thus, we have a whole series of equivalent terms between physics and economics. Observe that energy in economics is measured in terms of dollars, but money is not identical with energy. It is the potential to which money is lifted by the demand; that is, by the information which motivated the individual to assign to his dollar bills a specific "imagined price."

EQUATION OF FLOW OF CONSUMPTION EXPENDITURES AND OF GOODS

After this definition of the term "economic energy," let us go back to our prior analysis. The preceding transaction equation can also be expressed in differential form as a flow equation:

$$\text{FLOW EQUATION:}\quad \underbrace{C(t)}_{\substack{\text{The money flow}\\ \text{C(t) is a func-}\\ \text{tion of}}} = \underbrace{\frac{d(N_{TOT}(t)\,K_2(t))}{dt}}_{\substack{\text{The change of}\\ \text{the demand}}} = \underbrace{K_2(t)\,\frac{dN_{TOT}(t)}{dt}}_{\substack{\text{At constant price}\\ K_2(t) \text{ this is iden-}\\ \text{tical with the}\\ \text{change of the num-}\\ \text{ber of customers}\\ \text{with } (p_I - K_2) > 0}} \tag{9}$$

This equation says that the flow of money C(t) is a function of the demand change, which can be separated into a change of the sales price K_2: and a change of the number of buyers with $(p_I - K_2) \geqslant 0$; however, one has to recognize that the sales price in real life does not vary continuously but in discontinuous steps and that with each such step N_{TOT} is different. One has also to recognize that the change of the demand follows a probability function during the flow of C(t).

The Transaction Equation (1) described the relationship between the demand and the flow of money, but it also discussed the flow of goods, and a corresponding equation on the good side can be written:

$$C(t) = \frac{d(N_{TOT}(t)\ K_2(t))}{dt} = K_2(t)H(t); \quad \text{and, as } K_2 = \text{const.}$$

$$H(t) = \frac{dN_{TOT}(t)}{dt} = \frac{C(t)}{K_2} = \frac{Q \cdot \omega}{K_2} = F_{eco}\frac{\omega}{K_2} \tag{10}$$

So far, our equations have only discussed the forward loop. The return loop in the general case is not directly coupled with the forward loop. However, in the case of equilibrium of the flow, that is if $C(t) = Y(t)$ the following equation is valid

$$\int_{t_1}^{t_2} Y(t)dt = \int_{t_o}^{t_1} C(t)dt = N_{TOT}(t)K_2 = \int_{t_1}^{t_2} L(t)K_1(t)dt \tag{11}$$

and $$L(t) = \frac{d(N_{TOT}(t))}{dt} \quad \frac{K_2}{K_1} \tag{12}$$

But this equation also says that during the forward cycle the customers had the opportunity to fully satisfy their demands. If this is not the case, the amount of money stored in the vendor's wallet would only be a percentage of the total and consequently only this percentage could participate in the return cycle, meaning that the income $Y(t)$ has to be reduced accordingly by reducing either wage rates or laying off workers.

Observe also that this kind of analysis is not confined to equilibrium conditions. In case the forward cycle is not equal to the return cycle, the storage device B will accumulate more and more money, while storage A is losing correspondingly, or

$$C(t) - Y(t) = \frac{dA}{dt}$$ where A is the money accumulated in storage A

The advantage of our analysis, which reduces the flows of $C(t)$ to the demand function is that the dynamics of the circuit can now immediately be reduced to the prevailing demand. In practical cases, the demand function, instead of guessing what the "imagined prices" of a group of households may be, should be measured and empirical distribution curves for various situations should be made available.

THE ENERGIES OF INFORMATION AND OF THE TRANSPORT OF THE INFORMATION

What does all this analysis really mean? The analogy, outlined in the previous paragraphs, provides us with a consistent table of relationships between physical and economic terms, such as energy, power and force. But, clearly, in a physical sense, there is no economic force to push money or goods along. Instead, what we observe as economically important is not the physical transaction of money or goods but the transaction of information. Accordingly, the energy term which we were looking for and tried to describe must refer to the minimum energy necessary to transport the information messages which describe the transaction. But is this really the case? Let us investigate this supposition more thoroughly. We may explain the mechanism best by abandoning the concept of moving dollar bills around as the vehicles of either the consumption expenditures (C) or of the income (Y). Instead, we replace this dollar pushing by the concept of a computerized ledger account in action. A transaction in this case means the motion of a data code, representing the dollar value of one participant's potential property, from one location of the computer's memory to another location of the memory, which represents the other participant's property. The electric energy thus stored and moved ranges between 10^{-9} to 10^{-7} Wsec for a 20 bit code and an input capacity of 10^{-12} F/bit.

However, this description of the message transport makes it clear that this kind of energy is not what we are after. Instead it is the "energy" contained in the code itself, and it is the change of this "energy" we are looking for. To make the process of transaction and the difference of the two "energies" clearer, we have presented the transaction process between storage A and B (as shown in Fig. 4) again in a specific example, shown in Figure 5.

Such a typical example for a transaction function in real life is the operation of a check-out counter in a supermarket. The customer, after he has picked up the goods he wanted, following his notion of the imagined price, p_I, passes the counter, shows the goods he picked, while the clerk operates the cash register. The clerk's operations record price and quantity, and multiply and sum up these numbers for each customer. At the end the clerk releases the transaction pusy-button. The latter action initiates (as Fig. 5 shows) the change of code A_0 to A_1, but also activates the transport of the code from A_0 to B_1 and the change of B_1. The later action requires the "transport energy" mentioned above (10^{-9} to 10^{-7} Wsec). But the real change which we are looking for is shown by the conversion of the code itself from A_0 to A_1 or from B_0 to B_1, respectively (see also legend of Fig. 5), because it is this alteration of the numbers which accounts both for the change in demand and the flow.

Thus, we have proved that the "transport energy" has nothing to do with the economic transaction process itself and that, therefore, we can concentrate our further analysis on the latter term and ask again the question: What, if anything, does the concept of economic energy mean?

Surely, we know now that the transaction process is executed by certain messages in the form of codes and, thus, is an information process. But the real economy, as we experience it, does not appear to be merely an information process; instead, it appears to be real, that is physical. How does this all hang together?

THE CONNECTION BETWEEN MODEL AND REALITY

To show how the physical world and the information world may be correlated, we choose as an example the case of a pendulum.

When a pendulum is moved from its stable position and then released, it swings

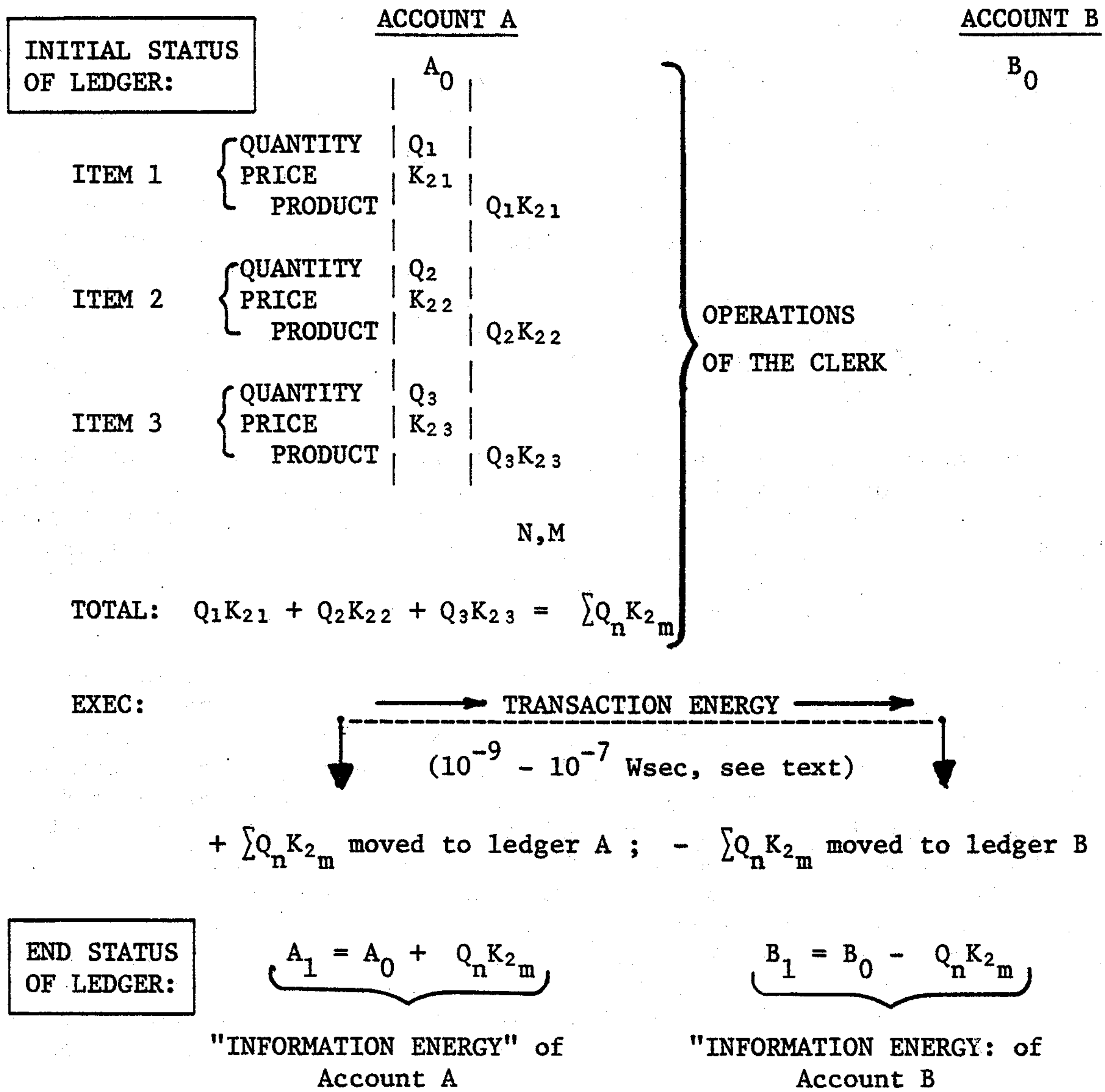

FIGURE 5. The Economic Transaction Process

The figure shows two accounts: Account A of the vendor and Account B for the customer. The initial status of Account A is A_0; then the clerk at the cash register pushes the buttons to input the quantities Q_1, Q_2, Q_3, and sales prices K_{21}, K_{22}, ... etc. for the items bought and to establish the products of those factors. The sum total of these products is then transferred both to Account A (added) and to Account B (subtracted). Observe that this transaction shows the "conservation of economic information energy," as the initial energy is:

$$E_1 = A_0 + B_0$$

while the final "energy" is

$$E_2 = A_1 + B_1 = A_0 + \sum Q_n K2_m + B_0 - \sum Q_n K2_m = A_0 + B_0$$

back and forth, and periodically changes potential energy into kinetic energy and vice versa. This motion is the real world of the pedulum and the periodic swings occur in real time. But it is possible to transfer this process of the real world into another world, the world of models, or information.

That is to say, we can describe this process of periodic changes of the pendulum's energy analytically, using pencil and paper. As soon as we do this, we make the transition from the real world into the "unreal" model world. Of course, instead of pencil and paper, one can feed a computer with an appropriate algorithm and suitable data and then recognize the motion of the pendulum on the screen, just as in the real world.

Yet, while this description of the operation of a physical object and its "information" model seem to explain the relationship of both realistically in the case of a physical situation, there still appears a further difference between the economic "real world" and its information world. This difference is easy to recognize: In the pendulum case, there is no real connection between model and pendulum. One can change the oscillations of the model pendulum quite independently from the real one. But, this is not the case in economics. Here, the information path is closely connected with the physical output. If one changes the demand or the money flow, one also changes the flow of goods and labor. Thus, a change in the input information causes a direct reaction of the physical world.

We can most conspicuously descrive this immediate interface between such information model and the real world by comparing it to biology. It is well-known since Watson's and Crick's studies, that the genetic program or "blueprint" for a cell is documented by its DNA-sequence. This DNA blueprint is then transposed into amino acids, which form peptide chains which form the real cell. The model blueprint, the DNA, is thus closely connected with the end-product, the cell. The comparable economic process is far simpler, but it also contains the essential sequences: the blueprint, in the form of demand; the messengers, in the form of money for the transfer of information; and the real physical end-product.

But what is this real end-product? Is it the flow of products, and of labor?

THE NATURE OF THE PHYSICAL LOOP OF ECONOMICS: A LEGAL INFORMATION CYCLE

We have seen that the flow of information as it concerns "economic energy" is controlled by humans. Vendor and customers control it together from the "input side"' which means, at the point of economic exchange (e.g., the cash register). The control is performed by the vendor who determines the sales price (K_2) and the customers, who perceives the imagined prices (p_I) and the quantity (Q). This input, as we have seen, sets a cycle of information in motion, which accounts for the economic monetary flow C(t), measured in dol lars. This information cycle in turn controls the output, which is represented by the physical, the real world of goods and labor. But one has to realize that the "reality" of this cycle is not the physics of goods or labor or the handling or transportation of the goods or the handling of labor. It is rather a question of who owns these entities. In other words, it is the question of their proprietorship as it is changed, according to the monetary information cycles. In other words, it is a legal information cycle.

Thus, the output of the monetary information cycle controls a legal information cycle. For instance, if the sale which we are talking about concerns a piece of real estate, sold between two participants predominantly in the form of money, then the information about the deal, exchanged between the two, is not enough. It also has to set in motion a legal cycle, where this change of property is documented and approved by legal authorities representing the public or at least a neutral third party. Of course, this formal legal approval also has to be backed by authorities of the executive branch, e.g., the police, which steps in, if the legalized transaction is not completed. If these legal authorities are absent, e.g., in case of anarchy or civil war, those transactions are in jeopardy.

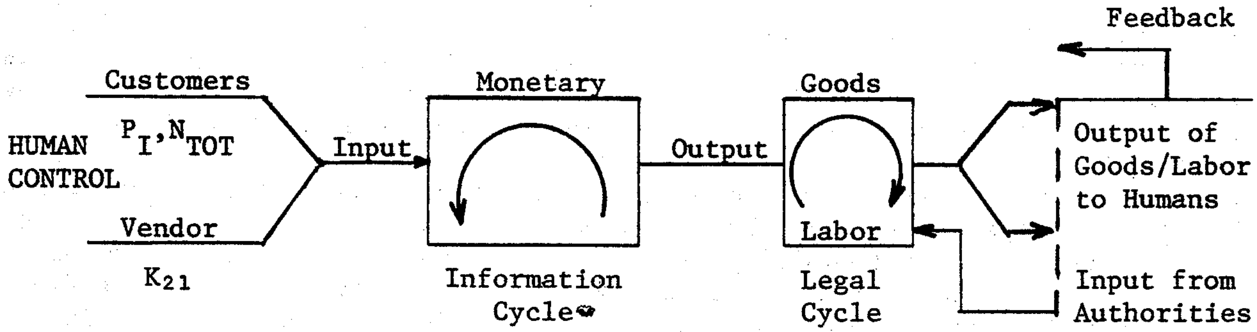

FIGURE 6. Economic Loops Process Information

This figure shows the processing of information as it takes place in the four states of the economic cycles: the control input, the monetary information cycle, the legal cycle of goods, and the output with the feedback. The control input codes the information of the monetary cycle, which in turn transmits the code to the legal cycle and releases the final property information to the output leading to both the vendor and customer.

CONCLUSION

The simplest form of the economic Two Sector Diagram under equilibrium conditions was used to pursue the transaction process of the flows of money, goods and labor and information. It was our purpose to find out if rules, such as the "Conservation of Energy" in physics, are also valid in economics. A special economic "demand" function was assumed to be equivalent to the term "energy" in physics, and from this expression other equivalents, such as "power" and "force," etc. could be derived in economics. If one follows this reasoning, economic energy would be measured in dollars and economic force in dollars per degree. However, economic energy is not a physical entity but an "informational" expression and the amount of dollars represents just a numerical value describing the informational process.

The Two Sector Diagram under equilibrium conditions is too simple a structure to fully recognize the power of the concept of demand being the equivalent of energy in economics. To prove its value, we intend, therefore, to further pursue the concept in four directions: (1) to probe its practical usefulness for solving real dynamic problems of the economy; (2) the explain the relationship between this concept and the system dynamics paradigm; (3) to develop a unified economic theory, which uses productivity as the interface between macro- and micro-economics; and (4) to develop an economic value system which is based on these new concepts and certain human factors.

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