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Laws of Thermodynamic Description In The Economic System

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Abstracts

Thermodynamics is a phenomenological science that derives its concepts directly from observation and experiment. The laws of thermodynamics can be considered as axioms of a mathematical model, and the fact that they are based upon commonplace observations makes them tremendously powerful and generally valid. In particular, the interest of applying thermodynamics in a systematic manner to describe the behavior of economic and financial systems has a long history [29]. In this paper we set out the first and second laws of Thermodynamics, which are fundamentals in the world of physics, and we examine the dynamics of the main processes encountered as applied to economic systems. And also we construct the mathematical model for constant pries process. And finally this paper end with conclusion.

Keywords: Thermodynamics, Economics, 1st law of thermodynamics, 2nd law of thermodynamics, thermal equilibrium, entropy and constant price.

Introduction

The relation between Thermodynamics and Economics is a paramount issue in Ecological Economics. Basically, the Laws of Thermodynamics are relevant to the economy because economic activity is entropic. The integration between economics and thermodynamics at the substantive level is of crucial importance because economic processes obey thermodynamic laws and therefore a sound economic theory must be coherent with thermodynamics. Here, the main objectives for this content of the relations between thermodynamics and economics are critically investigated.

Thermodynamics and economics are expected to follow the same concepts. In first law economics [36], the profit is a non total different form that depends on the path of acquisition. And in the second law of economics, the capital or standard of living is the integrating factor of profit and leads to the entropy of capital distribution.

First Law of Thermodynamics

The first law of thermodynamics states that [35], if the quantity of heat supplied to a system is capable of doing work, then the quantity of heat absorbed by the system is equal to the sum of the increase in the internal energy of the system, and the external work done by it."

Consider some gas enclosed in a barrel having insulating walls and conducting bottom. Let an amount of heat Q be added to the system through the bottom. If 'U_1' is the initial energy of the system, then,

Total energy of the system in the beginning

$$= U_1 + Q \tag{1}$$

After gaining heat the gas tends to expand, pushing the piston from A to B as shown in the figure 1. As a result of this, some work 'W' is done by the gas. The work is external work, since the system undergoes a displacement. If 'U_2' is final internal energy of the system [4], then,

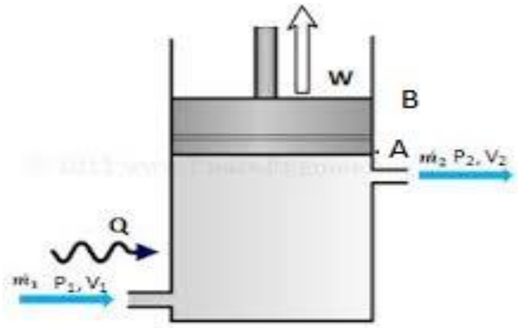

Figure 1: Illustration of First Law

Total energy of the system at end

$$= U_2 + W \tag{2}$$

In accordance to the law of conservation of energy [6], total energy of the system in the beginning will be equal to total energy of the system at end.

So, $U_1 + Q = U_2 + W$ (3)

It may be noted that U_1, U_2, Q, and W all are being taken in same units.

So, $Q = U_2 - U_1 + W$ (4)

When infinitesimal amount of heat dQ is added to the system, corresponding changes in internal energy dU and external work done dW are so small.

Then, $dQ= dU + dW$ or (5)

$$dQ= dU + pdV \tag{6}$$

Therefore, first law of thermodynamics signifies that [10], “energy can neither be created nor destroyed, but it can only be transformed from one form to another”.

The equation (6), states that, If work is done by the surroundings on the system (as during the compression of a gas), W is taken as positive so that

$$dQ= dU +W \tag{7}$$

and if however work is done by the system on the surroundings (as during the expansion of a gas), W is taken as negative so that

$$dQ= dU - dW \tag{8}$$

In thermodynamics it is common to consider two process types [11], reversible and irreversible. In a reversible process, the process is imagined to pass through a continuous series of infinitesimal equilibrium states, such that equation (4) can be written in a differential form:

$$dQ - dW = dU \tag{9}$$

Where incremental work done dW is equal to pressure P multiplied by the incremental change in volume dV.

$$dW = PdV \tag{10}$$

The work done for a reversible process can then be found by summing up all the increments of work. Thus:

$$W = \int_1^2 PdV \tag{11}$$

In a reversible process [12], it is possible for the process to be gradually unwound back through the infinitesimal states to the original position, such that the pressure and volume return to their original values, and the quantities of work done are reversed. Thus for a reversible process the First Law is stated as:

$$dQ - PdV = dU \tag{12}$$

Or in unit mass/molecule terms:

$$dQ - Pdv = du \tag{13}$$

where du is the incremental change in specific internal energy.

The reversible process therefore is one that cannot be improved upon in thermodynamic terms, as it can be brought back to the starting point without loss and in an irreversible thermodynamic process, however, a complete return to the starting point would not be possible, and there would always be a difference in one of pressure or volume, if the other was returned to its original position, and there would be a net loss of potential work. Figure 2 illustrates a reversible and irreversible process of thermodynamics [25].

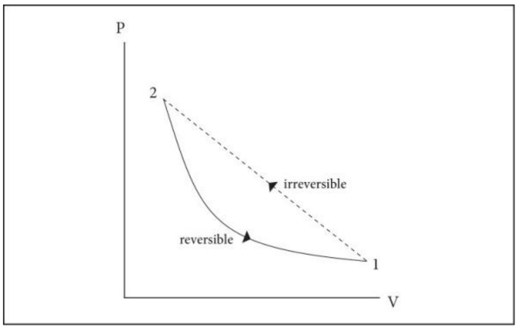

Figure 2: Reversible and Irreversible Thermodynamic Process

For an irreversible thermodynamic process incremental Work done dW is therefore in general less than that for a reversible process. Thus:

$$dW \leq PdV$$

Now, we turning into our economic system [8], a similar formulation to the First Law of Thermodynamics can be postulate, economic systems have elements of both flow and non-flow processes. We imagine a stock of a good which is fed at one end by work input value of the same good (being a function of price P multiplied by volume flow V per unit of time), with a similar work output value of the good coming out the other end of the stock, as in figure 3.

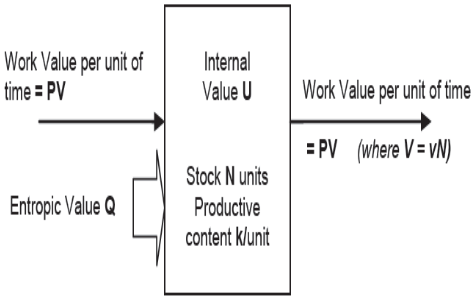

Figure 3: An Economic Stock

For a trader, the price of a unit leaving the stock will generally be larger than that entering it, by virtue of a profit margin, but we will not complicate matters at this point.

The concept of reversible and irreversible [9] thermodynamic processes is not readily understood in economics. An economist might argue that by definition one cannot 'undo' a production process proceeding from a set of inputs to a set of outputs, at least not easily, and likely at a significant cost. One cannot 'undo' a loaf of bread. In the Figure 4 demonstrate the Reversible and Irreversible economics Process.

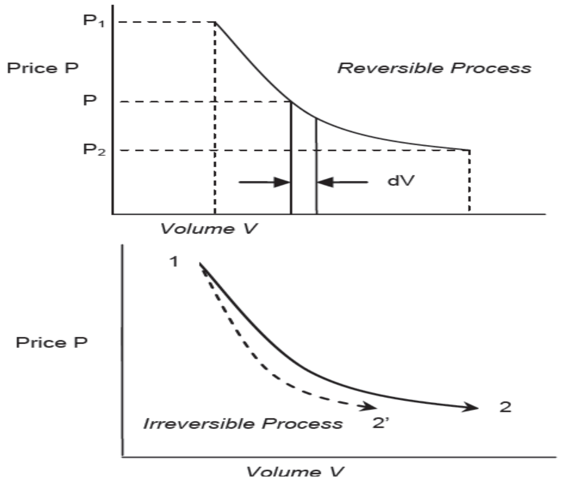

Figure 4: Reversible and Irreversible Economic Process

Second Law of Thermodynamics

The second law of thermodynamics states that the entropy of an isolated system never decreases, because isolated systems always evolve toward thermodynamic equilibrium, a state with maximum entropy [36].

To understand why entropy increases and decreases, it is important to recognize that two changes in entropy have to consider at all times. The entropy change of the surroundings and the entropy change of the system itself. Given the entropy change of the universe is equivalent to the sums of the changes in entropy of the system and surroundings:

$$\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr} = \frac{q_{sys}}{T} + \frac{q_{surr}}{T} \tag{14}$$

In an isothermal reversible expansion, the heat q absorbed by the system from the surroundings is

$$q_{rev} = nRTln\frac{V_2}{V_1} \tag{15}$$

Since the heat absorbed by the system is the amount lost by the surroundings, $q_{sys} = -q_{surr}$. Therefore, for a truly reversible process, the entropy change is

$$\Delta S_{univ} = \frac{nRTln\frac{V_2}{V_1}}{T} + \frac{-nRTln\frac{V_2}{V_1}}{T} = 0 \tag{16}$$

If the process is irreversible however, the entropy change is

$$\Delta S_{univ} = \frac{nRTln\frac{V_2}{V_1}}{T} \succ 0 \tag{17}$$

If we put the two equations for ΔS_{univ} together for both types of processes, we are left with the second law of thermodynamics, $\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr} \geq 0$

Where ΔS_{univ} equals zero for a truly reversible process and is greater than zero for an irreversible process. In reality, however, truly reversible processes never happen (or will take an infinitely long time to happen), so it is safe to say all thermodynamic processes we encounter everyday are irreversible in the direction they occur.

In summary, the second law of thermodynamics can stated as "all spontaneous processes produce an increase in the entropy of the universe" [39].

In economic terms the law could be stated as: “It is impossible to construct an economic system which will operate in a cycle, extract productive content from a reservoir and do an equivalent amount of work, in terms of productive content, on the surroundings.”

From the specific stock process set out in this section, it will be noted that although this does not involve a change in productive content k, the example of the fashion trader showed that changes in the three factors of work done W, internal value U and entropic value Q do have an impact on each other. It is also well-known in economic analysis that the interrelationship of price to volume in a process is dependent on the characteristics of supply and demand. It is therefore necessary to pursue thermodynamic analysis further in order to set this in context.

Now in a closed reversible thermodynamic system there exists a property S, such that a change in its value between two states is equal to:

$$S_2 - S_1 = \int_1^2 \left(\frac{dQ}{T} \right)_{rev} \text{ or} \tag{18}$$

In the differential form: $dS = \left(\frac{dQ}{T} \right)_{rev} \quad or \quad dQ = TdS_{rev}$ (19)

For the unit stock format $Pv=kT$, this would be written as Tds s, using lower case.

The property S is called the Entropy of the system, and the value dS is the incremental change in entropy. The suffix ‘rev’ is added as a reminder that the relation holds only for a reversible process. The reader will readily note from the above that entropy change is a function of the entropic value change ΔQ added or taken away, not represented by a change in volume flow of productive content.

In thermodynamics [47], entropy is a property that measures the amount of energy in a physical system that cannot be used to do work. In statistical mechanics it is defined as a measure of the probability that a system would be in such a state, which is usually referred to as the "disorder" or "randomness" present in a system. Given that systems are not in general reversible then, following whatever means are applied to return a system to its starting point, the net change in cycle entropy is commonly stated as:

$$\oint \frac{dQ}{T} \geq 0 \tag{20}$$

Now, by combining equation (3.6) for the First law and (3.15) for the Second law and inserting the term for the incremental work done $dW=PdV$, we could also construct an entropy function for an economic system:

$$Tds=du+Pdv \tag{21}$$

And in unit stock terms $N=1$ we can write:

$$TdS=dU+PdV \tag{22}$$

Equations (21) and (22) set out the general relations between the properties and, when integrated, give the change in entropy occurring between two equilibrium states for a reversible process. It should be noted that entropy change in economic terms is associated with changes in flow of economic value.

A series of economic processes is now examined to develop what the concepts mean in economic terms. The key relationships between price and volume flow are illustrated at figure 5.

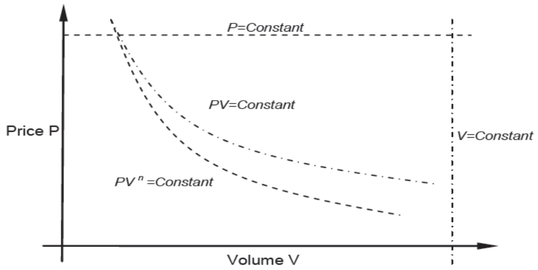

Figure 5: Price – Volume Relationship

Constant Price Process

A constant price process is one than involves a change in volume flow per unit of time, but no change in price. Work done is *not* therefore zero, and any entropic value dQ entering or leaving the system must equate to the work done dW in changing the volume flow, plus the change in the internal value dU of the system. Hence equation (21) for a reversible process as with the constant volume process, by differentiating the ideal economics equation $PV=NkT$ and we have:

$$PdV+VdP = NkdT \tag{23}$$

But, since in this process price remains constant, VdP is therefore zero and we can then write:

$$PdV = NkdT \tag{24}$$

Here, we set the relation between the change in the internal value dU and the change in the index of trading value dT. Now we could write a single stock unit and for a multiple unit stock,

$$du = C_v dT \quad and \quad dU = NC_v dT \tag{25}$$

Where C_V is specific value at constant volume.

Hence by combining equation (21), (24) and (25) we have

$$\begin{aligned} TdS &= NC_v dT + PdV \\ &= NC_v dT + NkdT \\ &= NC_p dT \end{aligned} \tag{26}$$

Where $C_p = \mathrm{C_v} + k$ is specific value at constant price, being analogous to the specific heat at constant pressure in a thermodynamics system. Here, we choose to define the specific value at constant volume C_v to be proportional to the embodied value/productive content k, and another factor ω, which will encompass both the lifetime and other aspects. Hence in our constant volume economic system we could write

$$C_v = \omega k \tag{27}$$

Where ω is value capacity coefficient.

From the equation (27), we can write for the constant price process

$$C_p = \omega k + k = \ \omega + 1 \ k \tag{28}$$

The higher value of the specific value C_p at constant price, compared to that of the specific value C_v at constant volume, recognises that in adding value to the internal value U, volume movement of units takes place. Additional value is flowing through, i.e. not only the entropic value ωk, but also volume of real productive content k into and out of the stock.

Now by substituting value the in the ideal equation $PV = NkT$ in equation (23) at constant price process and we get

$$\frac{dV}{V} = \frac{dT}{T} \tag{29}$$

And $$\frac{V_2}{V_1} = \frac{T_2}{T_1} \tag{30}$$

Thus the percent change in the volume flow rate V matches the percent change in the index of trading value T; which is what one might expect for a constant price process. A change in the index of trading value finds its way wholly into a change in volume flow, and not price.

Now, combining equation (19), (26) and (28), the entropy gain for the process is

$$dS=\left(\frac{dQ}{T}\right)_{rev} = NC_p\left(\frac{dT}{T}\right)_{rev} \qquad (31)$$
$$= Nk \;\; \omega+1 \;\left(\frac{dT}{T}\right)_{rev}$$

By using of integrating, we get the constant price for reversible process,

$$S_2 - S_1 = Nk \;\; \omega+1 \;\; ln\left(\frac{T_2}{T_1}\right) \qquad (32)$$

And substituting equation (30) in the above equation and we get

$$S_2 - S_1 = Nk \;\; \omega+1 \;\; ln\left(\frac{V_2}{V_1}\right) \qquad (33)$$

Thus stating that the change in entropy for the constant price process in terms of the changes in the index of trading value and the associated volume flow rate.

This figure 6 is will explain the constant price process, in terms of P – V and T – S Diagram.

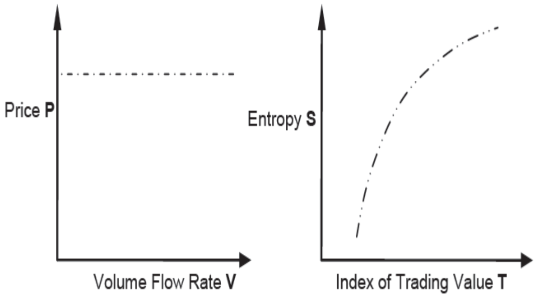

Figure 6: Constant Price Process

From the above discussion, the process is close to a constant price process is highly elastic, as a small change in price can result in a large change in volume flow.

Conclusion

From the above discussed the scope of the phenomenological analysis the first and second lows of thermodynamic in the economical system. Here I described the relationship between the thermodynamics and economics by using of energy conservation in the system both reversible and irreversible process. And entropy changes in the system and surroundings by using of isothermal expansion. Finally, I constructed the mathematical model for change the entropy by using of constant price process in the economical system.

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