國立交通大學

管理學院科技管理學程

碩士論文

技術創新及分散式資本主義之熱力學解析

A Thermodynamic Perspective on Innovation and Distributed Capitalism - A Conceptual Paper

研究生：沈博仁

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摘要

隨著經濟知識日益分歧、分散以及創新導向。尤其是在這資訊氾濫的知識經濟時代，一種以菁英為基礎及橫向協作為主的分散式市場機制，逐漸取代了中央化、集中化的市場機制。

本研究提供了以熱力學觀點下用以解析市場機制所需之必要背景知識以及工具。由熱力學所衍生出的信息理論被使用來作為分析工具，此工具證明在分析特定序列，尤其是時間序列下之變數及信息時是可行的。這些工具及指標可用以評量一個數列的混亂程度，以及兩個以上數列之間的相關程度。

本研究進一步探討的探討在熱力學觀點下之技術創新及分散式資本主義，特別是在龐大市場下多樣性產品及供應之策略服務創新。其中使用兩種不同的統計熱力學情境，即費米和玻色兩個不同的模型。

結果顯示，玻色模型可模擬並代表一個傳統不可區分的市場，也就是較趨近一個靜態、機會均等的中央化、集中化的市場機制。而費米模型則代表一個逐步發展之可區分的市場，較接近一個機率非均等的分散式市場，充滿著機會且有著最高的效率。

關鍵字： 統計熱力學、信息理論、分散式資本、「熵」

A Thermodynamic Perspective on Entrepreneurship and Distributed Capitalism - A Conceptual Paper

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ABSTRACT

Because economic knowledge is increasingly more dispersed, centrifugal, distributed and innovation-driven, an elite-based and lateral collaboration-centric model of distributed market mechanism forecloses the conventional aggregated and centralized market mechanism, particularly, in an era of knowledge economy with information overflows.

This research provides essential background knowledge and tools to analysis markets behavior in thermodynamic perspective. The derived information theory is used as a tool that is proved useful to analyze variables/information in specified series, namely, time series. These tools/metrics can be used to judge randomness of a series information and dependency of two (or more) series information.

The research also explores a thermodynamic perspective on innovation and distributed capitalism, in particular, strategic service innovation with sizable market diversity and supplies. Two different scenarios are employed, namely, Boson, and Fermion models of statistical thermodynamics.

The results exhibit that Boson models represent conventional indistinguishable markets that are close to centralized/aggregated markets in generic static and equally partitioned with chances. In the meanwhile, the Fermion models represented progressive distinguishable markets that are close to distributed markets in non-equiprobable states for maximum effectiveness with full of chances.

Keywords: Statistical Thermodynamics, Information Theory, Distributed Capitalism, Entropy

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1. Introduction

1.1 Background

Powered by Sir Isaac Newton’s mathematical method and vision of universe developed in 17th century, the new physics described a universe governed by stated rules which can made exquisitely accurate predictions and descriptions. These predictions and descriptions eliminated surprises and unexpects. Furthermore, these provided ways to explain the operation of the world.

In the late 18th century, the dawn of the market era and the onset of the First Industrial Revolution, the founding fathers of economics – Adam Smith, Jean-Baptiste Say and the like – looked into the new field of physic to fashion these new theories of the workings of the marketplace. Exalted Newton's systematizing of the physics of the universe as *"the greatest discovery that ever was made by man,"* Adam Smith enthusiastically borrowed metaphors from ***Principia*** and Newton's other works to fashion classical economic theory. Smith and followers sought to find similarly **predictability** in economics. The incentive-based “Invisible Hand” of classical economics plays the roles of gravity in classical physics, which insisted that the economic systems should adjust the supply and demand to one another spontaneously and precipitously, therefore to reach an **equilibrium** state eventually.

Paradoxically, the economic history is actually full of surprises and unexpects. Especially, as economic knowledge is getting increasingly more dispersed, centrifugal, distributed and innovation-driven, an elite-based and lateral collaboration-centric model of distributed market mechanism forecloses the conventional aggregated and centralized market mechanism, particularly, in an era of knowledge economy with information overflows.

1.2 Research motivation

Ignoring in all luminous achievement of classical economics, there were an unbridgeable gap to explain market behaviors by such Newtonian physics approach as reasons elaborated below:

1. When describing such science of market behavior, it is not avoidable to discuss about human behavior. In such case, the surprises that arise from free will and human creativity are not neglectable.
   The miracles forbidden in Newtonian physics are not only routine in economics; they constitute the most important and bountiful addition of information to the system. In an economy, however, everything useful or interesting depends on agents of change called entrepreneurs. Such deficiency makes it a challenging problem when explaining intermittently continued innovations and revolutions, such as the Second Industrial Revolution based on Fossil Fuels and ICT technologies and forming the Third Industrial Revolution which based on distributed capitalism.
2. The classical Newtonian mechanics, equations encompass and describe change (speed and location) - the initial state and final state. It's not necessary to describe the agent of this change, such as passage of time and the irreversibility of events. In Newton's cosmology, all mechanical processes are in theory reversible and the laws of matter in motion make no allowance for the passage of time.
   But real economic activities are all about the irreversibility of events, for example, how energy and material resources are harnessed, transformed, utilized used up and discarded. And, most of cases, passage of time need to be taken into consideration.

3. Classical Newtonian mechanics is based on equations that related to the behavior of a large system of object to its properties and to the forces exerted on it. Many attempts have been made to apply the accurate models for describing the human behavior, due to complexity of human interactions; can typically be modeled only at the level of a single person.

   The mutual relationship between local individual behavior and global social structure, therefore, makes the human behavior representation as a complex topic. Just like much 19th-century physics has been re-evaluated as the "classical limit" when trying to deal with incompatibilities of particles in quantum level (in the field of quantum chaos), the more general quantum mechanics in statistical mechanics was developed in 20th century which superseded classical mechanics and which contains it as a special case. However, based on the concept of universality in statistical physics, an assumption is that this universality applies in the study of complex human systems.

In the new information era, modern capitalism is an information system governed by the irregular bits and surprises, by the name of entrepreneurship. Disorder, disequilibrium, chaos and noise of market inhibit the creative acts that engender growth - probabilities with skill, and randomness with structure are key. An entrepreneur needs a channel that in most critical respects does not drastically change amid transmission. That is, models developed that based on classical Newtonian mechanics are deficient to explain such market behavior. A different approach is necessary for further research.

1.3 Research objectives

The objective of this study is trying to provide a thermodynamic with statistical mechanics (statistical thermodynamic) perspective on distributed capitalism. It is remarkable that modern statistical physics theories may be used for the study of collective behavior of components, e.g., human molecules or kinetic molecules.

The study widely integrates with cross-disciplinary Work on Knowledge Service, such as Economics, Technology Management, Statistical Thermodynamics, Information Theory and Marketing Strategy, to explain the constituent elements of **technology management**. That is, to explain how the nature of technology may change the ways that the commercialization process is managed, a step further, to portray entrepreneurship, distributed capitalism, and industrial innovation from a thermodynamic perspective.

1.4 Research contribution

The ultimate goal of this research is to develop a **convergent system** of entrepreneurial innovation for continual growth. With the advent of digital technology and information infrastructure, individualized supplies with coded registry and privileged channels of marketing, the existance of the system ensures the adherence to the thermodynamic laws and concepts of entropy to provide and develop corresponding strategies for entrepreneurship facing modern distributed markets.

With the information technology and a thermodynamic perspective, the high-entropy supply-side of entrepreneurship and innovation can be tapped into a converged market channel by a low-entropy carrier of stable PEST environment. With the well management and control by the system, it is expectable that more innovations of technologies or marketing channels can be created from rhetoric into reality.

2. Literature review

As an analogy with similar terms such as “astrophysics” or “biophysics” to describe applications of physics to different fields, **econophysics** is an interdisciplinary research fields that applies physics methods for solving problems in economics and market behavior. In this research, we used **thermodynamics** to study properties of complex market behavior of **distributed capitalism**.

2.1 History of econophysics

In 1870, French-Italian civil engineer Vilfredo Pareto did a dissertation on 'The Fundamental Principles of Equilibrium in Bodies', and two decades later, came be believe that people in socioeconomic systems are types of **'vibrating' molecules** governed by rational mechanics, the study of forces of equilibrium and movement - general equilibrium theory in economics is based on the physical concept of mechanical equilibrium.

In 1929, Italian engineer and theoretical physicist Ettore Majorana completed his MS in physics under Italian theoretical physicist **Enrico Fermi**. He wrote his 'The Value of Statistical Laws in Physics and Social Sciences', wherein he derives a radioactivity and quantum mechanics based theory of sociology. Majorana based on nuclear decay mechanisms, gleaned the tentative view that social theory is not the result of deterministic causal mechanism, but rather of indeterminism, a role of the dice so to speak, in the same way that the energy emission of radioactivity is unpredictable. That is, Majorana clearly elaborated the unpredictability of Social Science and treat statistical mechanism as solution.

The term "econophysics" was coined by the theoretical physicist Eugene Stanley, at the conference Dynamics of Complex Systems held in Calcutta in 1996, to describe the large number of papers written by physicists in the problems of markets. Econophysics was started in the mid-1990s by several physicists working in the subfield of **statistical mechanics.** Unsatisfied with the traditional explanations and approaches of economists - which usually prioritized simplified approaches for the sake of soluble theoretical models over agreement with empirical data - they applied tools and methods from physics, first to try to match financial data sets, and then to explain more general economic phenomena. Libb Thim (2013) gave an introduction and history of evolution about field of econophysics based ‘econoengineering’ with focus on the nature of economic behavior.

In econophysics, the random use of powerful equations by physicists to construct and attempt solutions on economic problems has recently been dubbed 'toolism'. Most of studies use these powerful equations just to solve specific problems rather to find a theory indispensable to the whole structure that it has to be put in its place.

2.2 Market behavior and thermodynamics

The origin of thermodynamics is in the 19th century when practitioners, engineers and scientists like James Watt (1736–1819), Sadi Carnot (1796–1832), James Prescott Joule (1818–1889), Rudolph Clausius (1822– 1888) and William Thomson (the later Lord Kelvin, 1824–1907) wanted to understand and increase the efficiency at which steam engines perform useful mechanical work. From the very beginning, this endeavor has combined the study of natural systems and the study of engineered systems – created and managed by purposeful human action – in a very peculiar way, which is rather unusual for a traditional natural science such as physics.

Not surprisingly then, the laws of thermodynamics were found by economists to be concepts with considerable implications for economics. For instance, economists like Kenneth Boulding (1966), Robert Ayres and Allen Kneese (1969), and Nicolas Georgescu-Roegen (1971) turned to thermodynamics when they wanted to analyze economy-environment inter-actions in an encompassing way, and analytically root the economy in its biogeophysical basis.

In a first step, the Materials Balance Principle was formulated based on the thermodynamic Law of Conservation of Mass (Boulding, 1966; Ayres and Kneese, 1969; Kneese et al., 1972). In view of this principle, all resource inputs that enter a production process eventually become waste. By now, this is an accepted and undisputed piece of resource, environmental and ecological economics.

At the same time, Georgescu-Roegen (1971) developed an elaborate and extensive critique of economics based on the laws of thermodynamics, and in particular the Entropy Law, which he considered to be ‘the most economic of all physical laws’ (Georgescu-Roegen, 1971, p. 280). His contribution initiated a heated debate on the question whether the Entropy Law – and thermodynamics in general – is relevant to economics (Burness et al., 1980; Daly, 1992; Kåberger and Månsson, 2001; Khalil, 1990; Lozada, 1991; 1995; Norgaard, 1986; Townsend, 1992; Williamson, 1993; Young, 1991; 1994). While Georgescu-Roegen had, among many other points, formulated an essentially correct insight into the irreversible nature of transformations of energy and matter in economies, his analysis is to some extent flawed by wrongly positing what he calls a ‘Fourth Law of Thermodynamics’ (Ayres, 1999). It may be for this reason that the Second Law and the entropy concept have not yet acquired the same undisputed and foundational status for resource, environmental and ecological economics as have the First Law and the Materials Balance Principle.

But as Georgescu-Roegen’s work and the many studies under his leadship have shown, the Entropy Law, properly applied, yields insights into the irreversible nature of economy-environment interactions that would be not available otherwise (Baumgärtner et al., 1996). Both the First and the Second Laws of Thermodynamics therefore need to be combined in the study of how natural resources are extracted, used in production, and give rise to emissions and waste, thus leading to integrated models of ecological-economic systems (e.g. Baumgärtner, 2000a, 2003, 2004, 2005;

Faber et al., 1995; Perrings, 1987; Ruth, 1993, 1999; Annila and Salthe, 2009).

2.3 Distributed capitalism

Zuboff and Maxmin (2002), in their book "The Support Economy", elaborated that firms no longer "create" value; they can only strive to realize the value that already exists in individual space. In this way, distributed capitalism further expands the concept of ownership. In contrast to managerial capitalism, distributed capitalism means that ownership and control are dispersed, shared by individual end consumers. And, in Zuboff's article (2010) , "Creating value in the age of distributed capitalism" , she further explained the distributed capitalism which encompasses the myriad ways in which production and consumption increasingly depend on distributed assets, distributed information, and distributed social and management systems.

The convergence of **Communications** and **Energy Regimes** created industrial revolutions. In the book "The Empathic Civilization", Jeremy Rifkin (2010) considered the latest phase of communication and energy regimes - that of electronic telecommunications and fossil fuel extraction - as bringing people together on the nation-state level based on **democratic capitalism**, but at the same time creating global problems, like climate change, pandemics, and nuclear proliferationin. Rifkin predicted that the new global economy will be based upon renewable energy, which is called as **distributed capitalism** because these energy sources are **dispersed** rather than **centralized**. They are best controlled by individuals or small communities. This will entail a very different power structure from fossil fuel, financial capitalism and the new structure is **networked** and **decentralized**.

Further described in Rifkin's book (2011) “The Third Industrial Revolution”, a more **distributed** and **collaborative** industrial revolution is forming, and leading to a more distributed sharing of the wealth generated. In industry after industry, network-based innovations are competing with **markets** and challenging proprietary business operations.

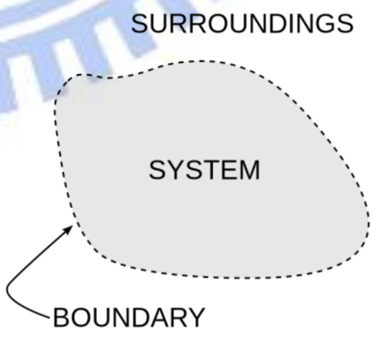
3. Methodology

With thermodynamic theories, we can argue that market behaviors always involve matter, energy, entropy and information. Moreover, the aim of many market activities is to achieve a certain structure. In this manner, we can apply the theories in non-equilibrium thermodynamics, in which structure formations call dissipative structures form, and information theory, in which information entropy is a central construct, to the modeling of economic activities in which the natural flows of energy and material function to create scarce resources. And, a market activity may be described as a dissipative/distributed system, which flourishes by consuming free energy in transformations and exchange of resources, goods and services.

3.1 Entropy and thermodynamics

3.1.1 Thermodynamic systems

The basic concept in thermodynamics is the **thermodynamic system**. Refer to Figure 1, a precisely defined region between the inside and the outside of the system under study. Everything in the universe except the system is known as its **surroundings**. The system is separated from the remainder of the universe by a **boundary**. Transfers and exchanges of **energy**



Source: Thermodynamic. In Wikipedia. Retrieved June 10, 2014, from http://en.wikipedia.org/wiki/Thermodynamics

Figure 1 A generic thermodynamic system

(work, heat) or **matter** between the system and its surroundings take place across this boundary. Thermodynamics distinguishes classes of systems by their boundary sectors described as:

- **Isolated systems:** Systems are completely isolated from their environment. They do not exchange energy or matter with their environment. In practice, a system can never be absolutely isolated from its environment, because there is always at least some slight coupling, such as gravitational attraction.
- **Closed systems:** Systems are able to exchange energy (heat and work) but not matter with their environment. A greenhouse is an example of a closed system exchanging heat but not work with its environment. Whether a system exchanges heat, work or both is usually thought of as a property of its boundary.
- **Open systems:** Systems has a part of its boundary that allows transfer of energy as well as matter between it and its surroundings. A boundary part that allows matter transfer is called permeable. An engine is an example of an open system. In this case, fuel is provided to engine and it produces power that is given out, thus there is exchange of mass as well as energy. The engine also emits heat which is exchanged with the surroundings exchange both energy and matter with their surrounding environment.

Table 1 Interactions of thermodynamic systems

Type of system	Mass flow	Work	Heat
Open systems	✓	✓	✓
Closed systems	✗	✓	✓
Isolated systems	✗	✗	✗

Source: Thermodynamic. In Wikipedia. Retrieved June 10, 2014, from http://en.wikipedia.org/wiki/Thermodynamics

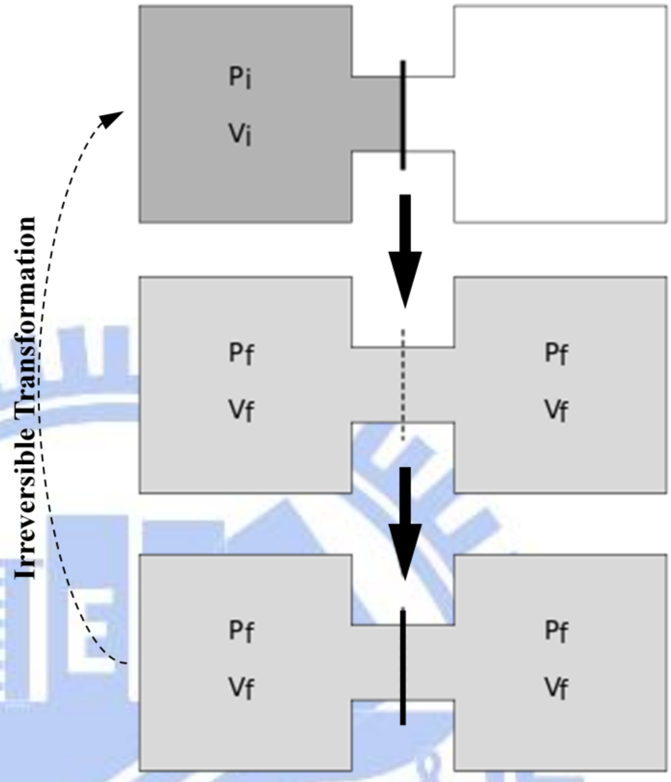
A system is said to be in **thermodynamic equilibrium** when there is **complete absence of driving forces for change in the system**. Technically, the various potentials of the system are at their minimum, such that there are no spatial variations of any of the intensive variables within the system.

- **Intensive variables** are quantities which do not change when two separate but identical systems are coupled.
- **Extensive variables**, in contrast, are quantities whose value for the total system is simply the sum of the values of this quantity in both systems.

For example, **temperature, pressure and chemical concentration are intensive variables while mass and volume are extensive ones**. As long as there are spatial variations in, say, temperature within a system, it is not yet in thermodynamic equilibrium, but there **exists a potential for change**. The equilibrium state is characterized by a uniform temperature throughout the system.

Consider an isolated system that undergoes a transformation over time between some initial equilibrium state and some final equilibrium state, either by interaction with its environment or by interaction between different constituents within the system. If the final state is such that no imposition or relaxation of constraints upon the isolated system can restore the initial state, then this process is called **irreversible**. Otherwise the process is called **reversible**.

Take Figure 2 as an example, at some initial time a gas is enclosed in the left part of an isolated box; the right part is separated from the left part by a wall and is empty. Now, the separating wall is removed. The molecules of the gas will then evenly distribute themselves over the entire volume of the box. The thermodynamic equilibrium of the final state is characterized by a uniform density of molecules throughout the entire volume. Reintroducing the wall into the isolated system separating the left part from the right half would not restore the initial state of the system. Nor would any other imposition or relaxation of constraints on the isolated system be able to restore the initial state. Therefore, the transformation given by the removal of the wall is an irreversible transformation of the isolated system. Generally, a process of transformation can only be reversible if it does not involve any dissipation of energy, such as through e.g., friction, viscosity, inelasticity, electrical resistance or magnetic hysteresis.



Source: Thermodynamic. In Wikipedia. Retrieved June 10, 2014, from http://en.wikipedia.org/wiki/Thermodynamics

Figure 2 An illustration about Irreversible Transformation

3.1.2 Entropy

The analysis which led to the concept of entropy began with the work of French mathematician Lazare Carnot who in his 1803 paper ***Fundamental Principles of Equilibrium and Movement*** proposed that in any machine the accelerations and shocks of the moving parts represent **losses of moment of activity**. In other words, in any natural process there exists an inherent tendency towards the dissipation of useful energy.

In the 1850s and 1860s, German physicist Rudolf Clausius objected to the supposition that no change occurs in the working body, and gave this "change" a mathematical interpretation by questioning the nature of the inherent loss of usable heat when work is done, e.g. heat produced by friction. Clausius described **entropy** as the **transformation-content**, i.e. dissipative energy use, of a thermodynamic system or working body of chemical species during a change of state. **This was in contrast to earlier views, based on the theories of Isaac Newton, that heat was an indestructible particle that had mass**.

Such process transforming energy or matter, a certain amount of energy is irreversibly transformed into heat. To describe this irreversibly trans-formation of energy: if a certain amount of heat dQ is reversibly transferred to or from a system at temperature T, then ΔS defines the change in entropy S. Then, the change in entropy was defined for a thermodynamically reversible process as

$$\Delta S = \oint \frac{dQ_{rev}}{T} \qquad [1]$$

That is, in thermodynamics, **entropy** (usual symbol S) is a measure of the number of specific ways in which a thermodynamic system may be arranged, often taken to be a measure of progressing towards thermodynamic equilibrium. Entropy can also be interpreted as an indicator for the system's capacity to perform useful work or, energy that is no longer usable. The higher the value of entropy, the higher the amount of energy already irreversibly transformed into heat, the lower the amount of free energy of the system and the lower the system's capacity to perform work. Expressed the other way round, the lower the value of entropy, the higher the amount of free energy in the system and the higher the system’s capacity is for performing work.

Further interpretation about useful work and energy to perform, entropy can be applied in concept to express a measure of the lack of qualities including **order**,

interconnection, arrangement, useful information and nonrandomness. In contrast, the term "negentropy" is used as a measure of order.

The entropy of an isolated system never decreases, because isolated systems spontaneously evolve towards thermodynamic equilibrium, **the maximum entropy**. Systems which are not isolated may decrease in entropy. Since entropy is a state function, the change in the entropy of a system is the same whether a process going from one defined state to another is reversible or irreversible, but irreversible processes increase the entropy of the environment.

3.1.3 The fundamental laws of thermodynamics

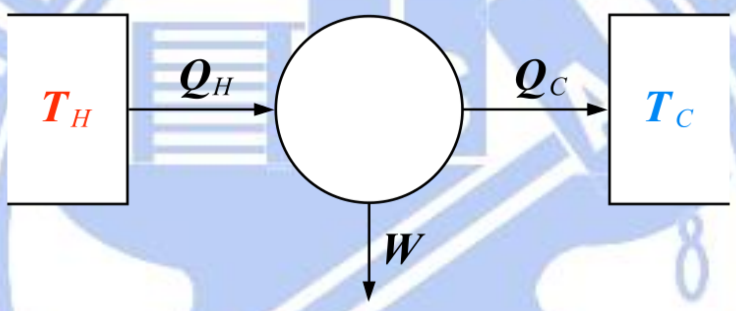
The First law of thermodynamics: The increase in internal energy of a closed system is equal to the difference of the heat supplied to the system and the work done by it: $\Delta U = Q - W$.

In simple words, in an isolated system (which may or may not be in equilibrium) the total internal energy is conserved. That is, in any real process, the energy of the universe is constant.

This means that **energy can be neither created nor destroyed**. However, it can appear in different forms, such as heat, chemical energy, electrical energy, potential energy, kinetic energy, work, etc. For example, when burning a piece of wood or coal the chemical energy stored in the fuel is converted into heat. In an isolated system the total internal energy, i.e. the sum of energies in their particular forms, does not change over time. In any process of trans-formation only the forms in which energy appears change, while its total amount is conserved.

The second law of thermodynamics: heat cannot spontaneously flow from a colder location to a hotter location. The Second Law, so-called Entropy Law, states the

unidirectional character of transformations of energy and matter. With any transformation between an initial equilibrium state and a final equilibrium state of an isolated system, **the entropy of this system increases over time or remains constant**. It strictly increases in irreversible transformations, and it remains constant in reversible transformations, **but it cannot decrease.** Which implies, it is impossible to convert heat into work without wasting some at a lower temperature, as shown in Figure 3 the famous Carnot Engine, it is impossible to transfer heat from a cold body to a hot body without supplying work.



Source: Thermodynamic. In Wikipedia. Retrieved June 10, 2014, from http://en.wikipedia.org/wiki/Thermodynamics

Figure 3 Carnot engine diagram

Differences in temperature, pressure, and chemical potential tend to even out in a physical system that is isolated from the outside world. Entropy of an isolated system that is **not in equilibrium** tends to increase over time, eventually approaching to a maximum at equilibrium, that is, minimum value of useful energy.

Advencely speaking, for an isolated system, any organized structure is not stable. It need to disorganize the surrounding to maintain its organization, in the end, death is a natural process to disorganize itself.

3.2 Statistical thermodynamics

In physics, there are two types of mechanics usually examined: **classical mechanics** and **quantum mechanics**. Whereas ordinary mechanics only considers the behavior of a single state, in quantum statistical mechanics introduces the statistical ensemble, which is **a large collection of virtual, independent copies of the system in various states.**

As a branch of mathematical physics, statistical mechanics is using probability theory, the average behavior of a mechanical system where the **state of the system is uncertain**. A common use of statistical mechanics is in explaining the thermodynamic behavior of large systems.

Classical thermodynamics is difficult to explain concepts in microscopic level, however statistical mechanics shows how these concepts arise from the natural uncertainty that arises about the state of a system when that system is prepared in practice. The benefit of using statistical mechanics is that it provides exact methods to connect thermodynamic quantities to microscopic behavior. Statistical mechanics also makes it possible to extend the laws of thermodynamics to cases which are not considered in classical thermodynamics, for example microscopic systems and other mechanical systems with few degrees of freedom. With statistical mechanics, which treats and extends classical thermodynamics is known as statistical thermodynamics.

Applied these laws to **chemical problems**, it bridged the gap between the microscopic realm of atoms and molecules and the macroscopic realm of classical thermodynamics. Statistical thermodynamics demonstrates how the **thermodynamic parameters** of a system, such as temperature and pressure, are related to microscopic behaviors of such constituent atoms and molecules.

3.2.1 Description in microscopic - molecular model

About microscopic model, there is a basic definition: we cannot distinguish (or observe) behaviors of molecular without perturbing their energies; and once we have done this they are no longer degenerate and the problem is changed. Such property about indistinguishability is a “microscopically separate state” or **microstate.** All of these individual microstates produce the same "macroscopically observable state" or **macrostate.**

One of the first successful attempts to use a **microscopic** model to explain **macroscopic** behavior was the kinetic molecular theory of gases, associated with such names as Maxwell and Boltzmann. This model was based on as simple a molecular picture as could be imagined.

- Molecules are points (or at most, hard spheres)
- The only energy that molecules possess is kinetic energy of motion; moreover, any kinetic energy is possible
- Molecules do not exert any influence upon one another except at the moment of impact; when they do collide, they do so elastically

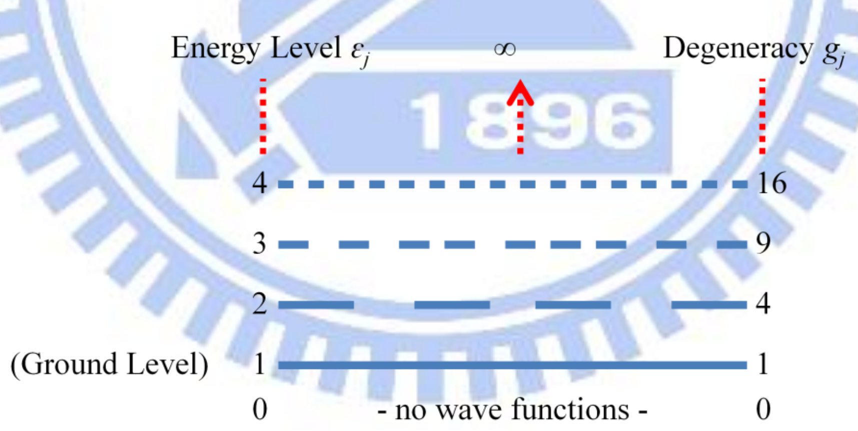
Actually, all three of these assumptions are wrong. Truth is more complicated:

- Molecules are grossly misshapen objects
- The possess many and complex forms of internal energy**;** moreover, **the available energy states are quantized**
- Molecules exert **long-range forces** on one another, for which “collision” is interactions that do not lead to reaction. Elastic collision is even more unrealistic.

3.2.2 Basic definition of statistical mechanics

Assume a collection of molecules – gas, liquid or solid – each having available to it various molecular states describable by wave functions $Ø_k$ of various energies and spatial distributions. Where a **wave function** (also named a state function) in quantum mechanics describes the quantum state of a system of one or more particles, and contains all the information about the system. The measurable property of the bulk system will depend upon how many molecules are occupying which of these states. If we know the distribution of molecules among their possible **states**, we can calculate these properties. And, with this distribution it is possible to calculate properly the quantities we are seeking.

Large numbers of these states will have so nearly the same energy that they can be grouped into one **energy level** and treated together. Assume now that we have n_j molecules of energy ε_j. Let the number of wave functions having an energy ε_j be g_j. This g_j is known as the **degeneracy** or the statistical weight of energy level ε_j , as shown as Figure 4.



Source: Adapted from R. E.. Dickerson, “Molecular Thermodynamics”, W. A. Benjamin (1969)

Figure 4 Degenerate states in a quantum system

The fundamental principle of statistical mechanics is that, energy considerations aside, one microstate is just as probable as any other one. Therefore, the probability of occurrence of any given macrostate $P_{(n_j)}$ is proportional to the number of possible microstates $W_{(n_j)}$, as written below:

$$P_{(n_j)} \propto W_{(n_j)} = \text{number of microstates per macrostate} = \text{total number of ways of arranging indistinguishable particles to produce the distribution } (n_j)$$

3.2.3 Entropy in statistic thermodynamics

We shortly define the entropy S of an arrangement of particles, to be a measure of the uniqueness of the arrangement. Since a given distribution is proportional to the number of ways of obtaining that distribution

$$P_{(n_j)} \propto W_{(n_j)} \qquad [2]$$

To form the probability of a distribution we should divide the number of ways of producing the given distribution by the total number of ways of producing all possible distributions. Take poker as an example, there are 3,744 different ways of obtaining a full house, and, there are 2,598,960 different possible five-card hands. That is, the relative probability of being dealt a full house is 0.00144.

Since we would like to measure simply by the number of different ways by which the distribution can be obtained, $W_{[n_j]}$. We shall define a quantity, known as another definition under statistical mechanics of entropy S, proportional to the logarithm of the number of ways of obtaining a given distribution

$$S_{[n_j]} = k \ln W_{[n_j]} \qquad [3]$$

The constant *k* in Equation [3] can be any quantity, but for convenience, it would be assigned as Boltzmann's constant, 1.3806488 × 10^{-23} m^2 kg s^{-2} K^{-1}. And the standard unit of entropy is

1 cal/deg mole = 1 entropy = 1 e.u.

There is only one way of constructing a perfectly ordered system, W = 1, that is, entropy = 0. At the other extreme, **the number of ways of obtaining a totally disordered system tends toward infinity for system containing many particles**. As the number of particles increases, the entropy of such a system also tends to infinity. Clearly, **entropy can never be negative, because entropy in negative is meaningless in terms of probabilities.**

The entropy can be calculated in a form of “configurational entropy”, the entropy of mixing. Since the configurational entropy of the pure substances before mixing is zero and the mole fractions of components are always less than one. So, the entropy of mixing is always positive. In any mixing operation, the entropy of the disorder of the system increases, so that mixing always leads to more probable states. This fact leads to the conclusion that **mixing should be irreversible**.

3.2.4 Dilute systems

Systems in which the degeneracy of each level far exceeds the number of objects in that level, or which $g_j >> n_j$, are known as dilute systems.

For dilute systems, $g_j > n_j$ or that the ratio g_j / n_j is large. Define the dilution ratio

$$\frac{q}{n} = \frac{\text{sum over states}}{\text{sum over particles}} \qquad [4]$$

Derived from Maxwell-Boltzmann particle,

$$\frac{g_j}{n_j} = \frac{q}{n} e^{\varepsilon_j / kT} >= \frac{q}{n} \qquad [5]$$

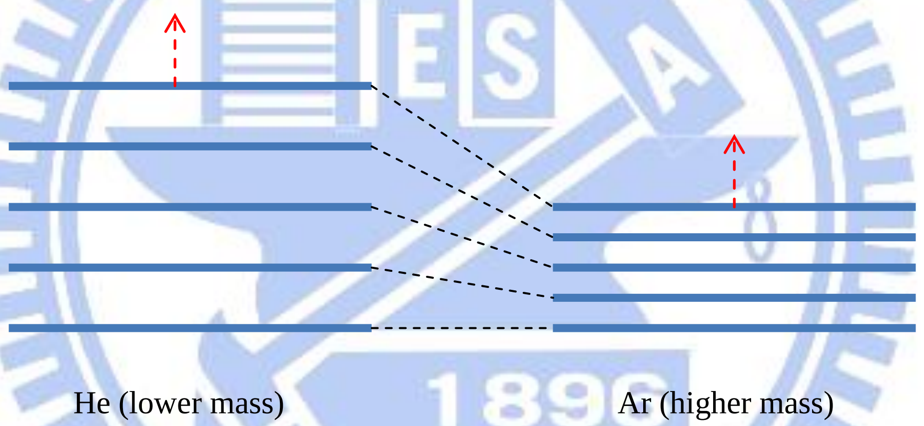
Because the exponential term is always greater than one, then we can say

$$\frac{q}{n} = \frac{g_0}{n_0} < \frac{g_1}{n_1} < \frac{g_2}{n_2} < \frac{g_3}{n_3} < .... \qquad [6]$$

In other words, in the most probable distribution, the higher up the energy ladder one goes, the more states are available per particle or the greater the dilution. If the dilution ratio of the ground state is great enough that one can forget about different types of distribution properties and use **an single simplfied statistics**, the the same will also be true for all the higher energy levels.

3.2.5 Conditions for applicability

As **mass increases** like Argon, it will have more states then Helium in lower mass because its energy levels are more closely spaced than are those of Helium. In general, heavier particles will have more closely spaces energy levels as illustrated in Figure 5.

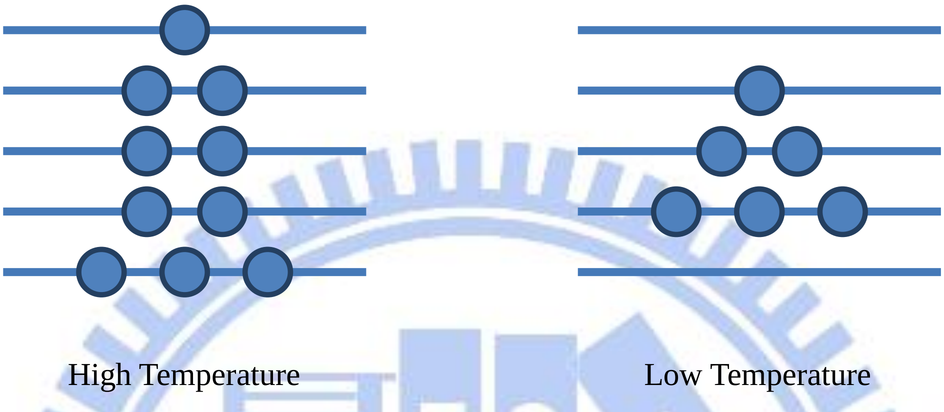


Source: Adapted from R. E.. Dickerson, "Molecular Thermodynamics", W. A. Benjamin (1969)

Figure 5 The effect of increased mass on energy level spacings

Thinking in entropy, entropy increases as molecular weight increase since it leads to the energy level to be more closely spaced (image of the particle in a box), and both dilution ratio and *W* increase.

As the **temperature is lowered,** the total energy of the particles is lowered, thus forcing them to trickle down from upper energy level and fill up the bottom ones, as illustrated in Figure 6.

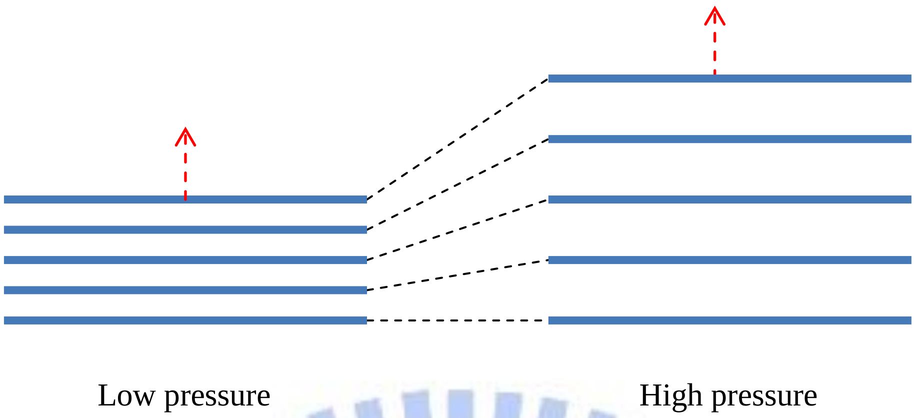


Source: Adapted from R. E.. Dickerson, "Molecular Thermodynamics", W. A. Benjamin (1969)

Figure 6 The effect of lowering the temperature on the distribution of particles among energy levels

Thinking in entropy, a temperature increase results in an increase in molecular motions, a condition that enhances the chances of particle mixing, that is, entropy also rises.

As the **pressure is increased**, the holding of total energy constant results in a decrease in volume. A decrease in volume causes an increase in the spacing between energy levels, so that under conditions of constant total energy, the particles are forced to drop down into lower quantum states, as illustrated in Figure 7.



Source: Adapted from R. E.. Dickerson, "Molecular Thermodynamics", W. A. Benjamin (1969)

Figure 7 The effect of increased pressure on energy level spacing

Thinking in entropy, since volume decreased, there is less room available to molecules, the less different arrangements are possible. Therefore, the energy level moving upwards, the dilution ration decreases and, with less states now available to the particles, *W* decreases as well.

3.3 Information theory - information entropy

Information theory is a branch of applied mathematics, electrical engineering and computer science involving the **quantification of information** as shown in Figure 8. It was developed by Claude E. Shannon to find fundamental limits on **signal processing operations** such as compressing data and on reliably stroring and communicating data.

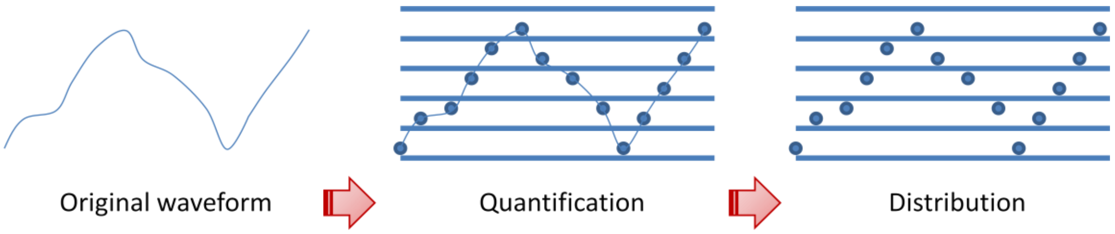


Figure 8 Quantify a waveform into information

A key measure of information is entropy, which is usually expressed by the average number of bits needed to store or communicate one symbol in a message.

Information theory is based on probability theory and statistics. The most important quantities of information are

- **Entropy:** the information in a random variable, it indicates how easily message data can be compressed while the latter can be used to find the communication rate across a channel.
- **Mutual information:** indicates the amount of information in common or dependence between two random variables.

The theory can be explained in continuous or discrete domain.

Entropy *H(X)*

- For quantities of information, giving a discrete random variable X as a measure of the amount of uncertainty associated with the value of X

  X is the set of all messages $\{x_1, \ldots, x_n\}$ that X could be

  $p(x)$ is the probability of x, where $x \in X$

  Entropy H of X is defined as:

$$H(X) = -\sum_{x \in X} p(x) \log p(x) \qquad [7]$$

- For a continuous random variable X with probability density function f_X

  Entropy H of X is defined as:

$$H(X) = -\int f_X(x) \log f_X(x) dx \qquad [8]$$

Joint Entropy *H(X,Y)*

- Consider two discrete random variables X and Y, Joint Entropy $H(X,Y)$ are the entropy of their pairing: (X,Y) defined as:

$$H(X,Y) = -\sum_{x,y} p(x,y)\log p(x,y) \qquad [9]$$

- Consider two continuous random variable *X* and *Y* with probability density f_X and f_Y. The joint probability density of *X* and *Y* will be $f_{X,Y}$.

  The joint entropy of *X* and *Y* is defined as:

$$H(X,Y) = -\iint f_{X,Y}(x,y)\log f_{X,Y}(x,y)\,dx\,d \qquad [10]$$

Conditional Entropy *H(X|Y)*

- Consider two discrete random variables *X* and *Y*, the conditional entropy of *X* given *Y* is defined as the average conditional entropy over *Y*:

$$H(X\,|\,Y) = -\sum_{y\in Y} p(y)\sum_{x\in X} p(x\,|\,y)\log p(x\,|\,y) = -\sum_{x,y} p(x,y)\log\frac{p(x,y)}{p(y)} \qquad [11]$$

- Consider two continuous random variable *X* and *Y* with probability density f_X and f_Y. The conditional probability density of *X* and *Y* will be $f_{X,Y}$.

  The conditional entropy of *X* and *Y* is defined as:

$$H(X\,|\,Y) = -\iint f_{X,Y}(x,y)\log\frac{f_{X,Y}(x,y)}{f_Y(y)}\,dx\,d \qquad [12]$$

Mutual Information *I(X;Y)*

Mutual information measures the amount of information that can be obtained about one random variable by observing another.

- Consider two discrete random variables *X* and *Y*, the mutual information of *X* and *Y* is defined as:

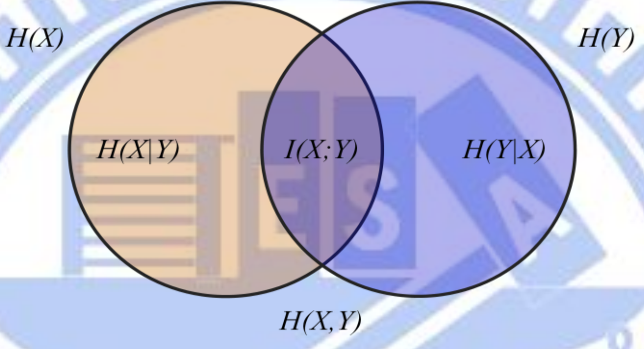
$$I(X;Y) = \sum_{x,y} p(x,y)\log\frac{p(x,y)}{p(x)p(y)} \qquad [13]$$

- Consider two continuous random variables *X* and *Y*, the mutual information of *X* and *Y* is defined as:

$$I(X;Y) = -\iint f_{X,Y}(x,y)\log\frac{f_{X,Y}(x,y)}{f_X(x)f_Y(y)}\,dx\,d \qquad [14]$$

A Venn diagram as Figure 9 shows all possible logical relations.

- $H(X|Y)=H(X,Y)-H(Y)$ [15]
- $H(Y|X)=H(X,Y)-H(X)$ [16]
- $I(X;Y) = H(X)-H(X|Y) = H(Y)-H(Y|X) = H(X,Y)-H(X|Y)-H(Y|X)$ [17]
- If X and Y are independent $H(X,Y)=H(X)+H(Y)$ [18]



Source: Information theory. In Wikipedia. Retrieved June 9, 2014, from http://en.wikipedia.org/wiki/Information_theory

Figure 9 Venn Diagram

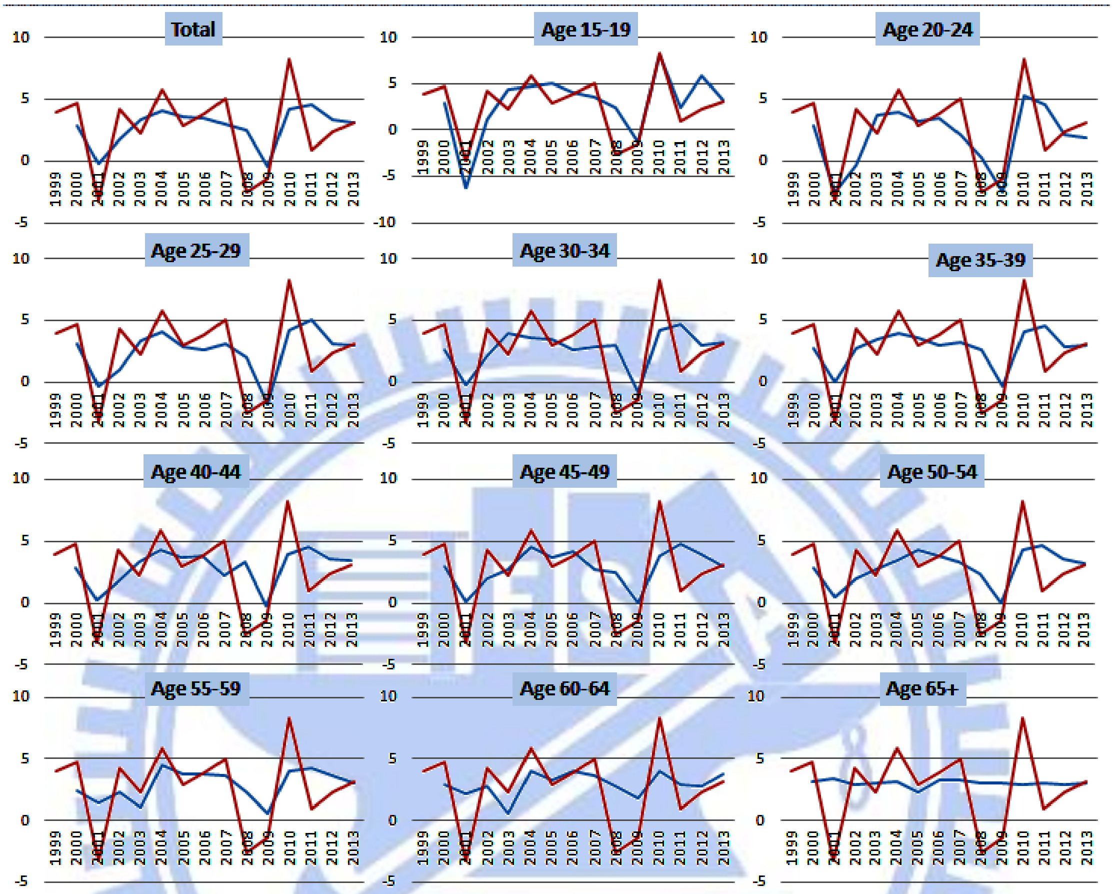
To apply the mutual information, a metric is defined to measure the difference between variables X and Y:

$$d(X,Y) = H(X,Y)-I(X;Y)=H(X)+H(Y)-2I(X;Y)=H(X|Y)+H(Y|X) \quad [19]$$

And, a normalized variant D is defined as:

$$D(X,Y)=d(X,Y)/H(X,Y)=1-I(X;Y)/H(X,Y) \quad [20]$$

A brief demonstration between two discrete information - ***Change in GDP per capita*** and ***0.03-2*Change in unemployment rate by Age*** of Taiwan 2000-2013 - is shown in Figure 10.



Source: Directorate-General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. (Taiwan)

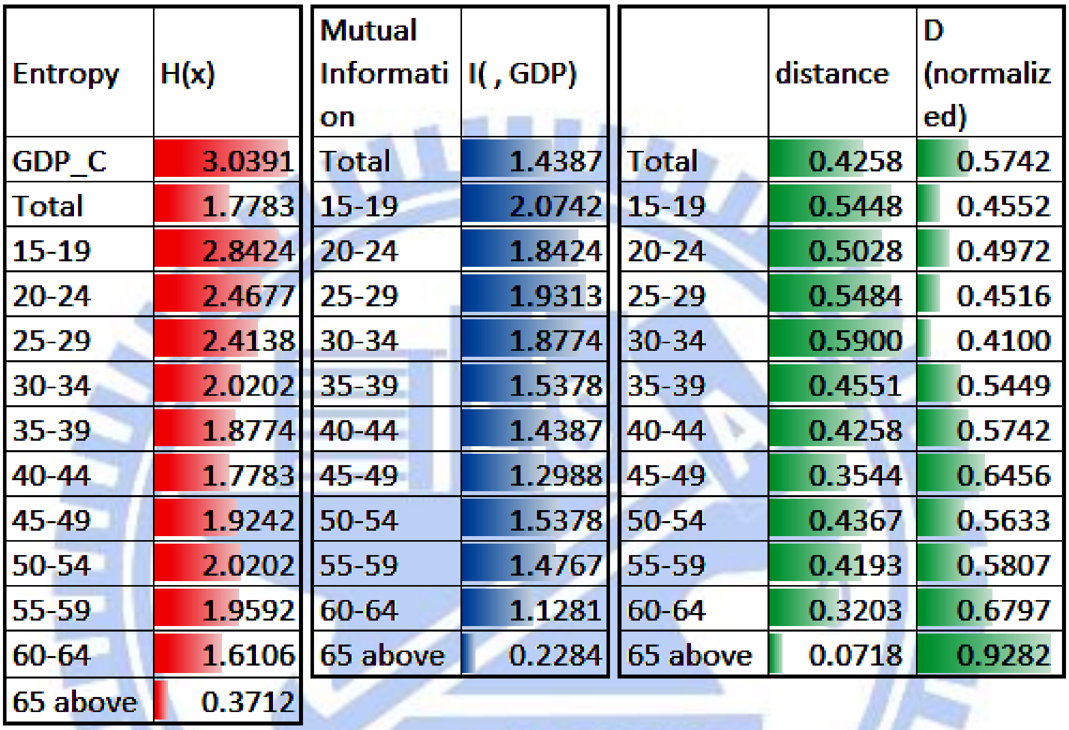
▬ : 0.03-2*Change in unemployment rate - by Age

▬ : Change in GDP per capita

Figure 10 Discrete information - ***Change in GDP per capita*** and ***0.03-2*Change in unemployment rate by Age***, 2000-2013, Taiwan

Based on the information above, corresponding entropy, mutual information and distance of variables were calculated as Table 2Table 2 Calculated Entropy, Mutual Information and distance.

Table 2 Calculated Entropy, Mutual Information and distance



Entropy	H(x)
GDP_C	3.0391
Total	1.7783
15-19	2.8424
20-24	2.4677
25-29	2.4138
30-34	2.0202
35-39	1.8774
40-44	1.7783
45-49	1.9242
50-54	2.0202
55-59	1.9592
60-64	1.6106
65 above	0.3712

Mutual Information	I(, GDP)
Total	1.4387
15-19	2.0742
20-24	1.8424
25-29	1.9313
30-34	1.8774
35-39	1.5378
40-44	1.4387
45-49	1.2988
50-54	1.5378
55-59	1.4767
60-64	1.1281
65 above	0.2284

	distance	D (normalized)
Total	0.4258	0.5742
15-19	0.5448	0.4552
20-24	0.5028	0.4972
25-29	0.5484	0.4516
30-34	0.5900	0.4100
35-39	0.4551	0.5449
40-44	0.4258	0.5742
45-49	0.3544	0.6456
50-54	0.4367	0.5633
55-59	0.4193	0.5807
60-64	0.3203	0.6797
65 above	0.0718	0.9282

The results proved that the approach is usefulness to express properties including disorder, randomness of a variable and dependence between two variables.

4. Results

4.1 Network economy and distributed capitalism

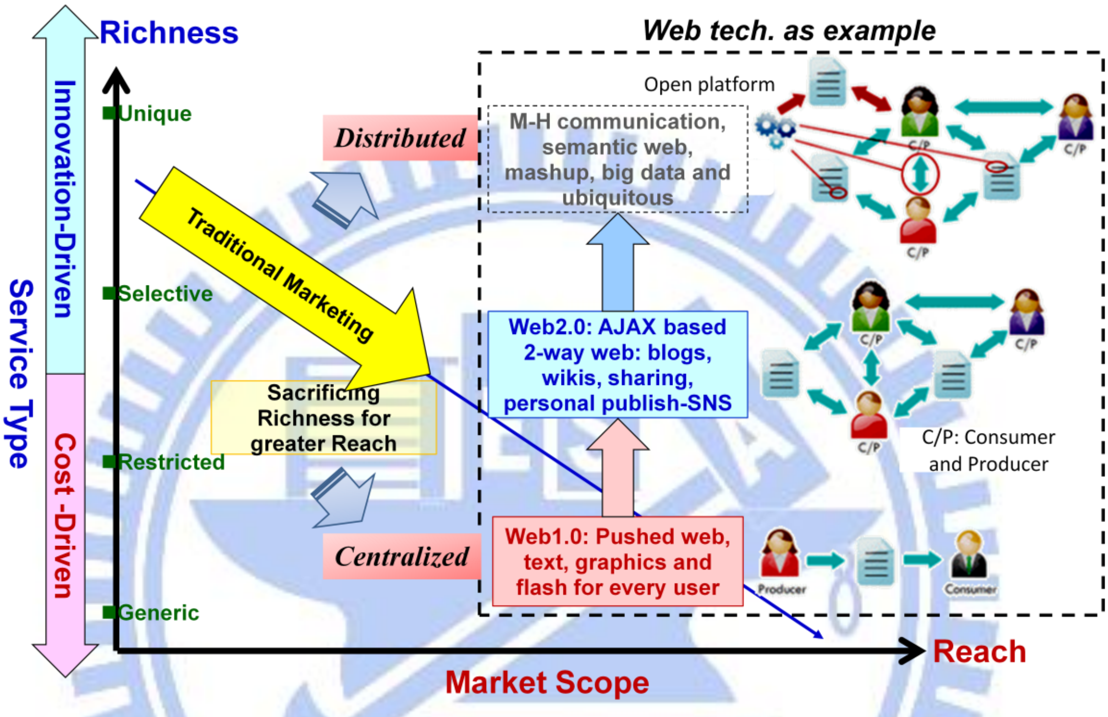
The convergence of **communications** and **energy** regimes created industrial revolutions. Steam Engine, electricity and utility industry (telegraph, railroad…etc) formed the First Industrial Revolution in 18th - 19th century. Carried over to 19th – 20th century, mass production, fossil fuel and ICT technologies formed the Second Industrial Revolution. Along with the First and Second Industrial Revolution, the **centralized, aggregated and rationalized** business model and enterprises established for decades. **Vertical economies** of scale became the defining feature and **gigantic business** operation became the norm.

Table 3 Economics of Integration

		Favor integration and Aggregated Capitalism	***Favor dis-integration and Distributed Capitalism***
Impacts of market competition	***Benefit of generation competition increase under integration***	*Conflicting economic forces could lead to either more or less integration & deregulation*	*The high regional richness and greater interactive mechanism, favoring effectiveness, economies of scope, and customization*
	Benefit of generation competition same or less	*The low-cost and greater efficiency, favoring Large area marketing & commodity distribution systems*	*Conflicting economic forces could lead to either more or less integration & deregulation*

Since 20th century, though many economists and virtually every politician extolled the virtues of the small business, but market behavior of commerce and trade operated in opposite way in real world. The centralized, aggregated and rationalized business model is still in dominant, especially in energy, communication and automobile related fields and companies. Moving into the **new information era**, a new genre of professional administrators took to the helm of these giant new enterprises. A **distributed capitalism** is emerging. As shown in Table 3, a list about impacts of market competition explained **favor** and **benefit** of aggregated/distributed capitalism with increase/less integration.

A more **distributed** and **collaborative** industrial revolution is forming, the partial shift from markets to **networks** brings with it a different business orientation as shown in Figure 11 below. Web technology has its innovation towards distributed market on pursuing market richness in nature, which is is completely different from traditional marketing towards centrialized market on pursuing market reach.



Source: Adapted P. Evans, T.S. Wurster, "Blown to Bits", Harvard Business School Press (2000)

Figure 11 Centralized vs. Distributed Marketing

A comparison between centralized/aggregated and distributed capitalism is listed as Table 4 below.

Table 4 Aggregated vs. Distributed Capitalism

	Aggregated Capitalism	**Distributed Capitalism**
Knowledge Base	Supply & Cost driven; Centralized vertical bureaucrat	Knowledge based; Dispersed lateral & multiple organisms for emerging markets
Strategy & Structure	Linear Hierarchical Centralization for **“Market Reach”;** Concentrated capitalization, standardized and modularized	**Networked Constellation and Curation** for **“Market Richness”;** Dispersed & Specialized Capitalization; non-standardized nor modularized
Marketing Strategy	STP strategy employed & dictated by dominant firms; 4P strategy; Brand name and belief marketing; Centralized Management	CRM-based frequent producer-user interactions to create innovation; brand names and experience marketing; **Democratization of Creative Innovation**
Industrial Structure	Oligopoly	Undefined (amorphous) or emerging structures of industry; **Mesh networks**
Sources of Competitive Advantage	Low-cost Leadership via size advantage; or differentiation via R&D and/or **market leadership Advantages in resources, market share, and technology are key**	Knowledge-intensity, network based economies, closed-linked with key suppliers, and network-size; **Market Innovation via customization and individualization of product**;
Key Institutions	Marketing and MIS Networks; Supply-chain & clustering	CRM and database manipulation for advantage; required global network connectivity

Source: Adapted from G. Gilder, *“Knowledge and Power”, Regnery Publishing, Washington DC*

The **new information era** of **Network-based Innovation** is being emerged with basic principles of:

- Opening (Open proprietary assets)
- Peering (Peer production for a price)
- Sharing (Mass lateral collaboration through Platform)
- Globalizing (Act globally)

There are some features for successful innovations such as

- Serendipitous and combinatorial innovation resulting from mass collaboration is one what global economy truly embraces
- Specializing platforms allow porous interactions among network collaborators, and are to replace monolithic, self-contained, inward focused marketing that conventional marketing insists
- Demand-side management (DSM) is as critical as supply-side entrepreneurship

4.2 Market channel and radio communication technologies

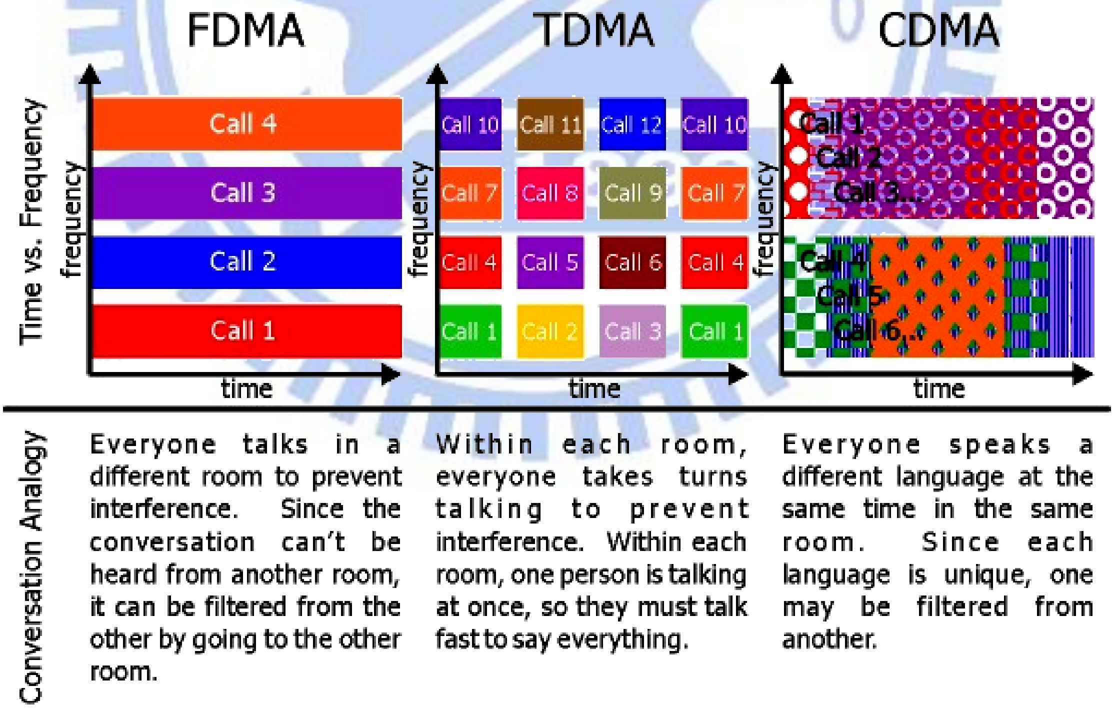
G. Gilder (2013), in his book *"Knowledge and Power: The Information Theory of Capitalism and How it is Revolutionizing our World"*, contends that capitalism is not chiefly an **incentive system** but an **information system**, and follows with an inept and irrelevant explanation of Claude Shannon's **information theory** and radio communication technologies been applied in digital mobile phone systems.

With the advent of digital communication technology that based on the information theory of **Alan Turing** and **Claude Shannon**, mobile phones took a big leap forward. The biggest advantage of the digital technology is that any data whether it is a voice, a text or a picture can be converted into bits and bytes. They are different from earlier various **analog** signals whether radio or TV, the difference between these signals was that of different frequencies and modulations, that is, the characteristic feature of an analog signal is the shape of transmission curve.

Digital mobile phone transmits only two symbols (1 and 0). It is the complex circuits inside that convert the analog information to digital and vice versa.

There are three universal technologies used by Digital mobile phone networks for information transmission.

- FDMA (Frequency Division Multiple Access): puts each call on a separate **frequency**.
- TDMA (Time Division Multiple Access): assigns each call a certain portion of **time on a designated frequency**.
- CDMA (Code Division Multiple Access): gives a unique code to each call and spreads it over the available frequencies.



Everyone talks in a different room to prevent interference. Since the conversation can't be heard from another room, it can be filtered from the other by going to the other room.

Within each room, everyone takes turns talking to prevent interference. Within each room, one person is talking at once, so they must talk fast to say everything.

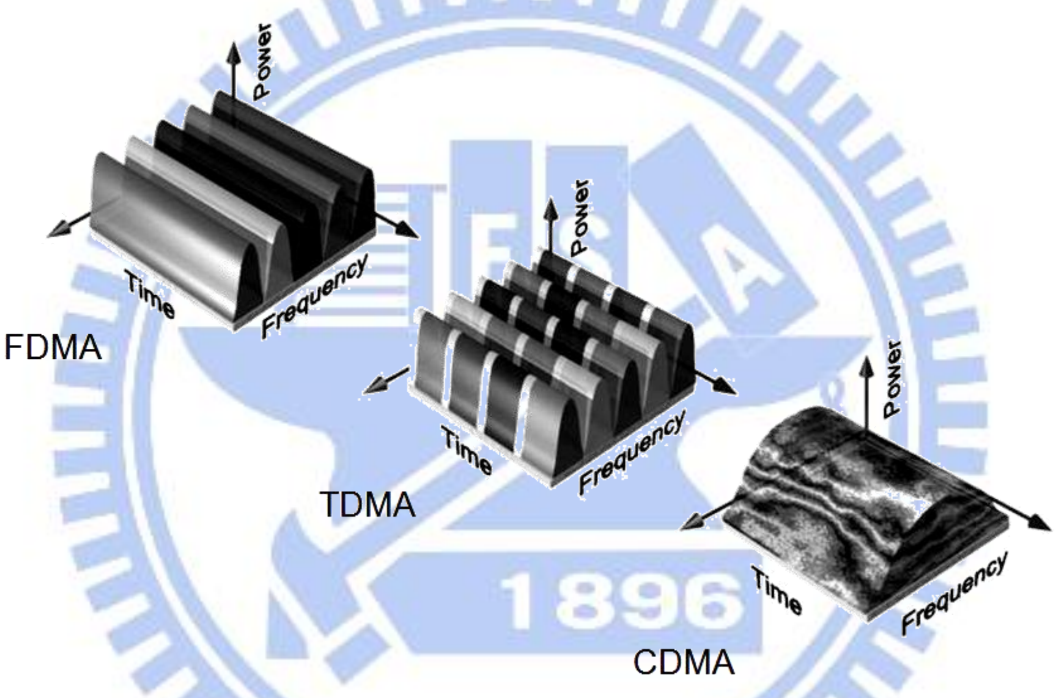
Everyone speaks a different language at the same time in the same room. Since each language is unique, one may be filtered from another.

Source: Wonder Whizkids. Mobile Phone Features. Retrieved June 14, 2014, from http://www.wwk.in/mobile-phones?start=2

Figure 12　FDMA, TDMA and CDMA Technology

Refer to Figure 12, a discription over FDMA, TDMA and CDMA technologies in conversation analogy. It is easier to understand the difference among these technologies.

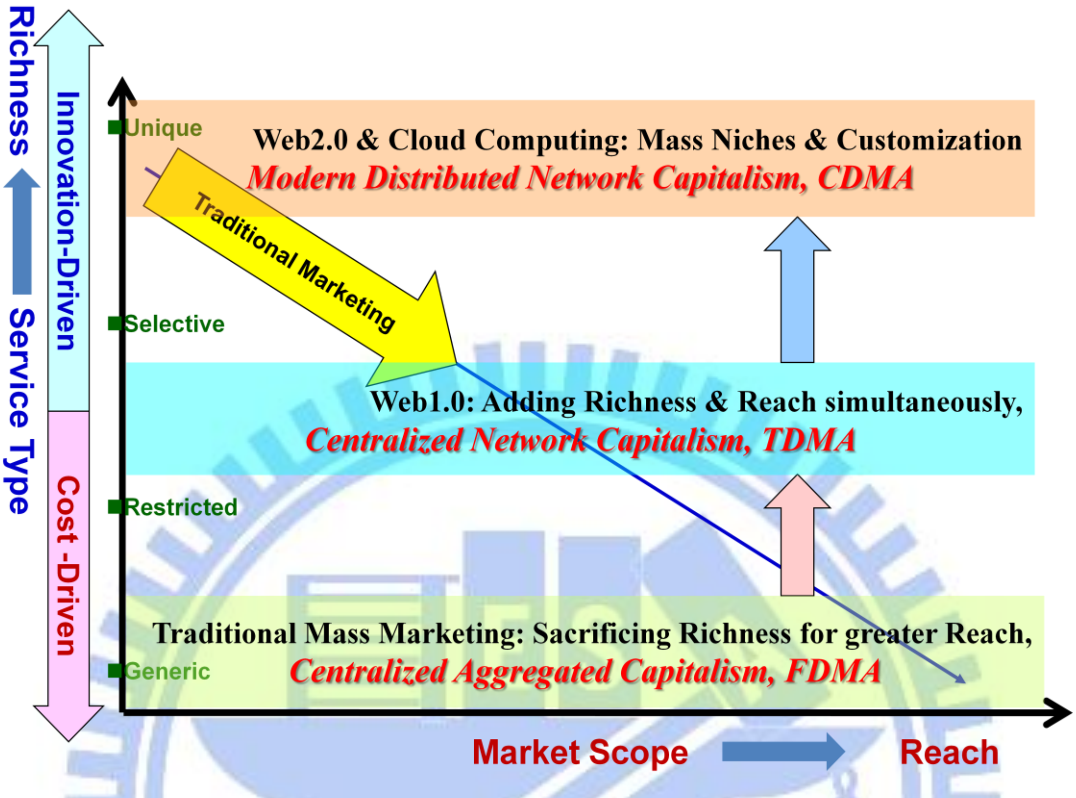
Refer to Figure 13, an illustration about the access methods in FDMA, TDMA and CDMA. It is easy to find that CDMA is easier to gain more efficiency in point of view from spectral usage.



Source: Adapted from Sky DSP. Chapter 1. Retrieved June 14, 2014 from http://www.skydsp.com/publications/4thyrthesis/chapter1.htm

Figure 13 Access methods in FDMA, TDMA and CDMA

Analogize to marketing service type. CDMA gives a unique code to each call which makes it possible to be in uniqueness and customization, that is, distributed network capitalism. In the meanwhile, FDMA puts each call on a separate frequency which make the property close to traditional centralized/aggregated capitalism as arranged in Figure 14.



Source: Adapted P. Evans, T.S. Wurster, "Blown to Bits", Harvard Business School Press (2000)

Figure 14 Centralized vs. Distributed Marketing in point of view from communication technologies

4.3 A thermodynamic perspective on distributed capitalism

The objective of the thermodynamic approach is, to explore the likehood explosion in a network-based market structure, including:

- A novel business model to portray the market structure as a function of different types of innovation
- A design algorithm of marketing channels in accordance with typology of products or/and services
- An optimized product-market condition upon which mass innovation can be achieved

- The best market structures that would accommodate varying degrees of innovations
- A measure of entropic loss is used as a parameter to gauge the likelihood of market saturation and collapse

4.3.1 Distributed model and thermodynamic principles of information platform

In distributed marketing model, information drives business processes, creating viable business model for profitability. As the free market mechanism tends to favor divergence of customer preferences, the Say's low of classical economics claims the opposite, the law actually applies to aggregate, economy-wide supply and demand. A more accurate phrase is "aggregate supply creates its own aggregate demand." This interpretation means that the act of production adds to the overall pool of aggregate income, which is then used to buy a corresponding value of production - although most likely not the original production.

As elaborated in Table 4, there are clear differences between aggregated and distributed models.

In thermodynamic perspective over traditional marketing,

- **On the supply-side:**
  Entropy is a measure of disorder, or freedom of choice, amid the entrepreneurial exercises, i.e. the greater the entropy on the supply-side, the greater the room for maneuvering the strategic entrepreneurship.
- **On the demand-side:**
  Entropic loss always is accompanied with a change in the form of energy. The greater conversion efficiency, the greater the entropic loss - lost to the environment (closed systems), or embedded in product or service (open

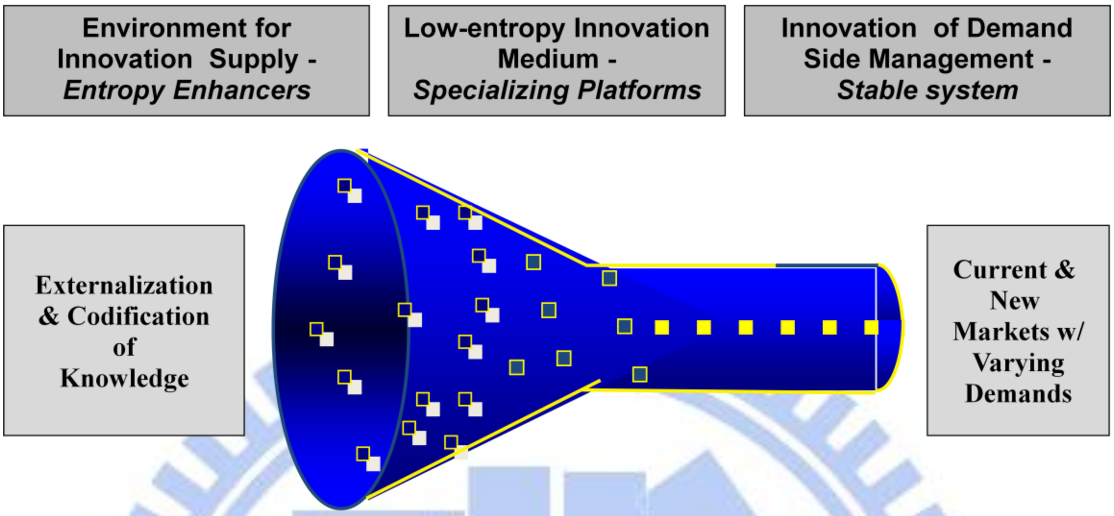
systems) to be consumed.

Irreversibility of the entropic loss is likely to create a detrimental effect on environment, because it leaves less room for additional entropic losses, e.g. carbon emissions and global warming.

Economic systems are open systems. Whereas economies of scale stress the criticality of high-order vertical chain integration, scope economies externalize resources to increase system disorder, as elaborated in section 3.2.3 about definition of entropy, that is, **to increase entropy**. And, explained in section 3.1.3 about the second law of thermodynamics, treat a specified economic system as isolated thermodynamic system, **the entropy of this system** strictly increases in irreversible transformations, and it remains constant in reversible transformations, **but it cannot decrease**. In the case that the phenomenon fail to be controlled by market mechanism, as the total entropy is completely exhausted, that is, the system will fall into a stable & equilibrium state cannot carry any useful information and there is no room for creativity. Therefore, there is an urgent need for **demand side management** to conform to the high entropy supply-side of entrepreneurship and innovation.

Predictability and order are not spontaneous and cannot be left to “invisible hand”. It takes **a low-entropy carrier** to bear high-entropy information in modern distributed capitalism. The low-entropy carriers are the effects of leadership in the **public** (policy for stable political and economic environment) and **private** (market and business practices) sectors alike to exercise wisdom and courage, embodying a hierarchic principle to enable the high-entropy creations of successful capitalism.

According to description above, the ultimate goal of the distributed model is to develop a convergent system of entrepreneurial innovation for continual growth. Prior to its full deployment, animated partially polarized and specialized **platforms** are needed to expedite the convergence, as show in Figure 15.



Source: adapted from H. Chesbrough, Presentation of the Minnesota LES, May 18, 2006

Figure 15 Innovation and specialized platform

The stochastic view on information: The stream of high-entropy bits in a message flows through a low-entropy determined channel by multiple **specialized platforms**. Information economy is defined as surprise **(entrepreneurship)**, is the overthrow, not the attainment, of equilibrium. The environment to well incubate innovation is what matters most.

Information technology allows individualization, personalization, codification of product-markets to create high-entropy randomness in the supply-side, and with a low-entropy channels and specialized platforms, **entrepreneurial creativity and distributed operations** become a reality.

4.3.2 Distribution of molecules in statistical thermodynamics

Based on properties of molecules, in statistical mechanism, not all distributions are possible and not all possible distributions are equally probable. There are physical limitations upon the ways in which molecules can be distributed among energy states (or ways in which energy can be partitioned among molecules). Moreover, not all possible distributions are equally probable.

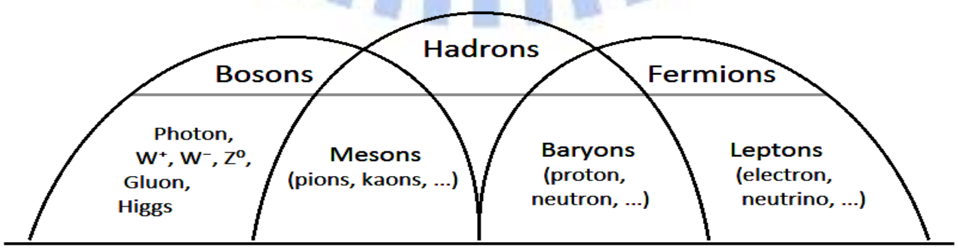
Consider a system of three particles, each with individual wave functions $\emptyset_k$. Then to a first approximation the wave function of the three-particle system can be built up as a sum of triple products of individual wave functions

$$\psi_{123} = \sum_j \sum_k \sum_l a_{jkl} \phi_{j(1)} \phi_{k(2)} \phi_{l(3)} \tag*{[21]}$$

Since the individual particles do not have labels, any acceptable system wave function must be in form that $|\Psi|^2$ is unchanged by a formal exchange of numbering of any two particles. This means that the wave function itself must be either symmetrical or antisymmetrical with respect to such an exchange

$$\Psi_{132} = +/- \ \Psi_{123} \tag*{[22]}$$

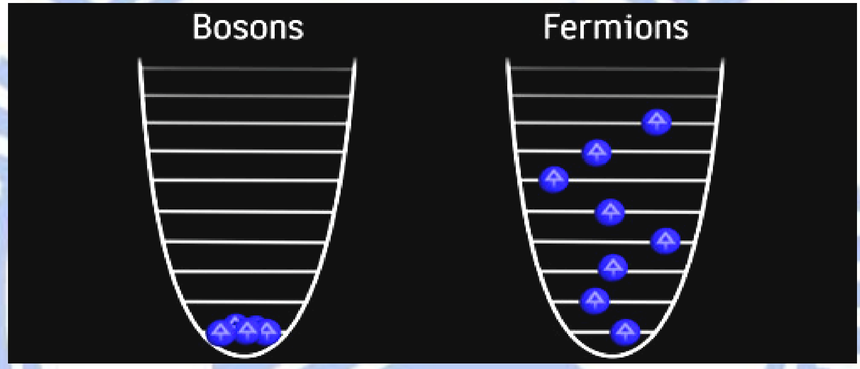
The fundamental particles – electrons, neutrons and protons – are all **antisymmetric**. While composite particles - nuclei, atoms, molecules - are **antisymmetric** if they are built up from an odd number of fundamental particles and **symmetric** if from an even number. In summary, antisymmetric particles are known as **Fermi-Dirac particles or “fermions”**. And, symmetric particles are known as **Bose-Einstein particles or “bosons”** as shown in Figure 16.



Source: R. E.. Dickerson, “Molecular Thermodynamics”, W. A. Benjamin

Figure 16 Particles in different type

Two fermions cannot occupy the same wave function. If they did, then an interchange of the labels designating these two particles would leave the system wave function completely unchanged, and its behavior would be symmetrical. Therefore we can say that each wave function of an energy level is **either empty or filled with no more than one particle (0 or 1).** Total number of particles in this energy level n_i must be equal to or less than the degeneracy of the level g_i. That is, for fermions, it is meaningless if n > g. For bosons no such restriction exists, and a**ny number of bosons may be piled into one single wave function** as illustrated in Figure 17.



Source: R. E.. Dickerson, "Molecular Thermodynamics", W. A. Benjamin

Figure 17 Property for bosons and fermions over wave functions

In simplified, imaging that there are several energy levels in a system, each level has distribute n_j identical objects and g_j boxes. Then, the core research of distribution is: **how many ways can one distribute n_j identical objects among g_j boxes.**

Therefore, research topics can be narrowed down to:

- Which of the many conceivable distributions (n_j) are physically possible?
- What are the relative probabilities of occurrence of those distributions that can exist?

4.3.3 Statistics - Fermi-Dirac statistics

According to the properties of fermions elaborated above, the final expression of the number of possible permutations is

$$P_d = \frac{g_d!}{n_d!(g_d - n_d)!} \qquad [23]$$

That is, n_d objects (particles) among g_d boxes (energy levels). Where,

- P_d : Permutations of n_d particles in g_d boxes
- n_d : Objects (Particles): number of customers in each segment, and are ranked in the order of non-increasing probability of occurrence
- g_d : Boxes (Energy Level)): number of segments

We can get distribution as shown in Figure 18. And, take entropy $S = k \, Ln \, P$, we can get entropy S of fermions distribution as Figure 19.

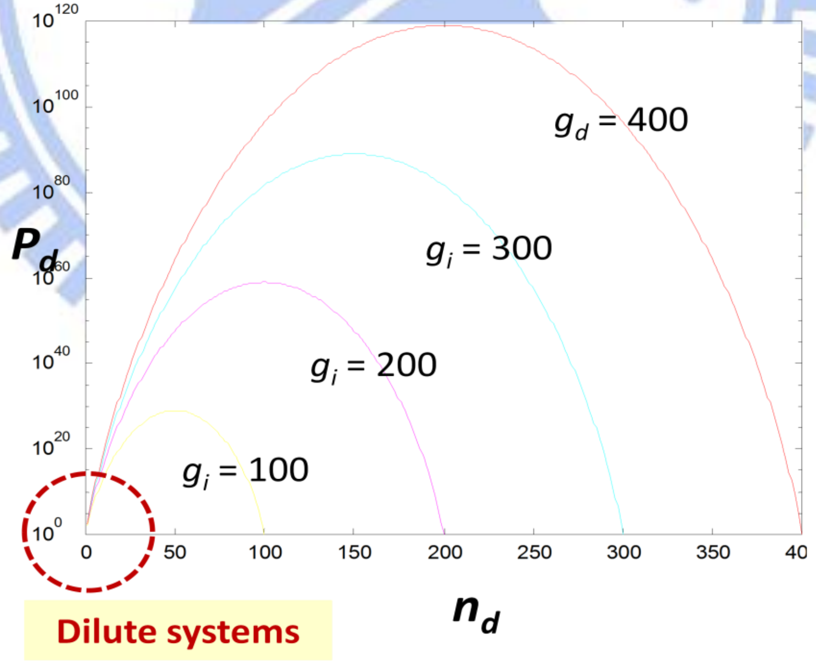
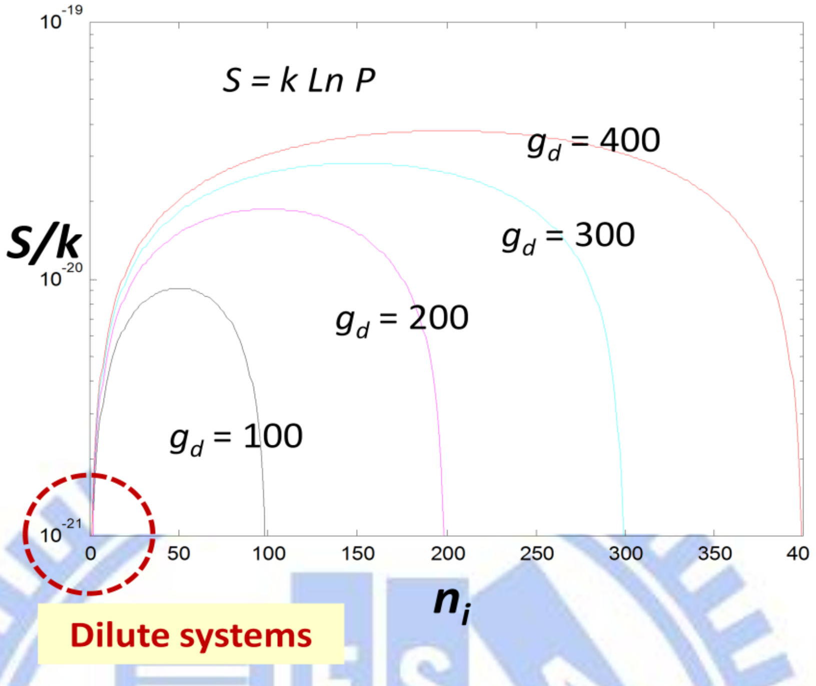


Figure 18 Fermions distribution



Dilute systems

Figure 19 Entropy S - Fermions distribution

4.3.4 Statistics - Bose-Einstein statistics

According to the properties of bosons elaborated above, the expression of the number of possible permutations is

$$P_i = \frac{(g_i + n_i - 1)!}{n_i!(g_i - 1)!} \qquad [24]$$

That is, n_i objects (particles) among g_i boxes (energy levels). Where,

- P_i : Combinations of n_i particles in g_i boxes
- n_i : Objects (Particles): number of customers in each segment
- g_i : Boxes (Energy Level)): number of segments

We can get distribution as shown in Figure 20. And, take entropy $S = k\,Ln\,P$, we can get entropy S of fermions distribution as Figure 21.

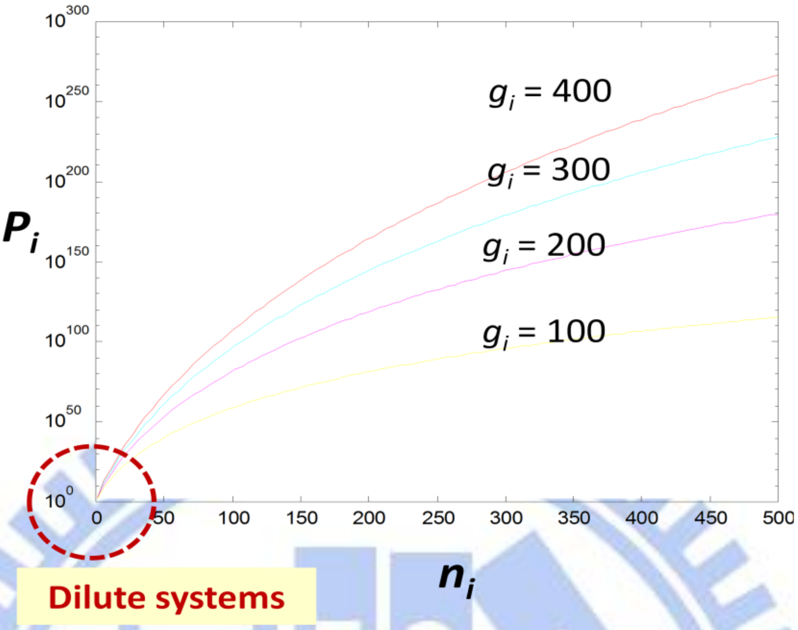


Figure 20 Bosons distribution

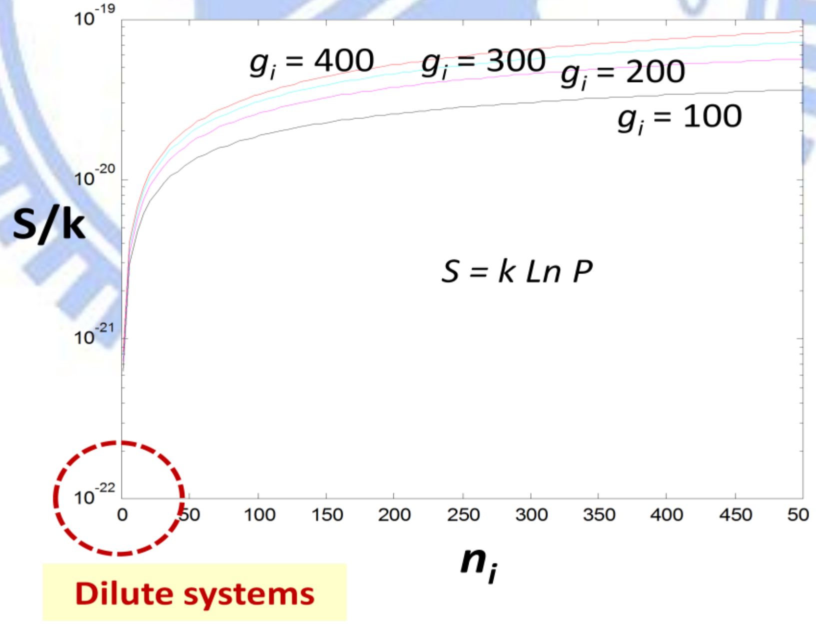


Figure 21 Entropy S - Bosons distribution

4.3.5 Properties of dilute systems

As defined in 3.2.4, systems which $g_j >> n_j$ are know as dilute systems. Under these conditions, although many bonsons can occupy the same wave function, it is very unlikely that they would ever do so with all the other wave functions available. The distingction between bosons and fermions then disappears.

Refer to Figure 22 and Figure 23 below, as n is approaching zeor, that is, approaching the case $g>>n$, the possible permutations P is approaching the curve $g_n/n!$ in both bosons and fermions case. In summary, the number of microstates for fermions and bosons are related as

$$W_{FD} \le \prod_j \frac{g_j^{n_j}}{n_j!} \le W_{BE} \qquad [25]$$

The equalities hold only in the limit of **infinite dilution**. That is, when systems are approaching to such limit of high dilution, fermions and bosons are both approaching to similar behavior.

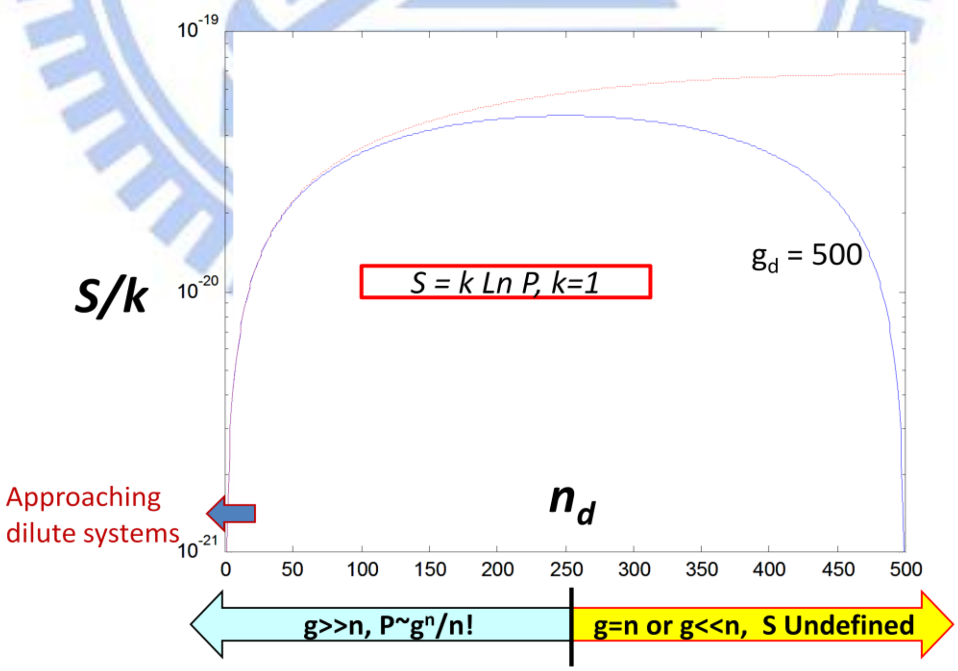


Figure 22 Scenario: Fermions, g_d = 500

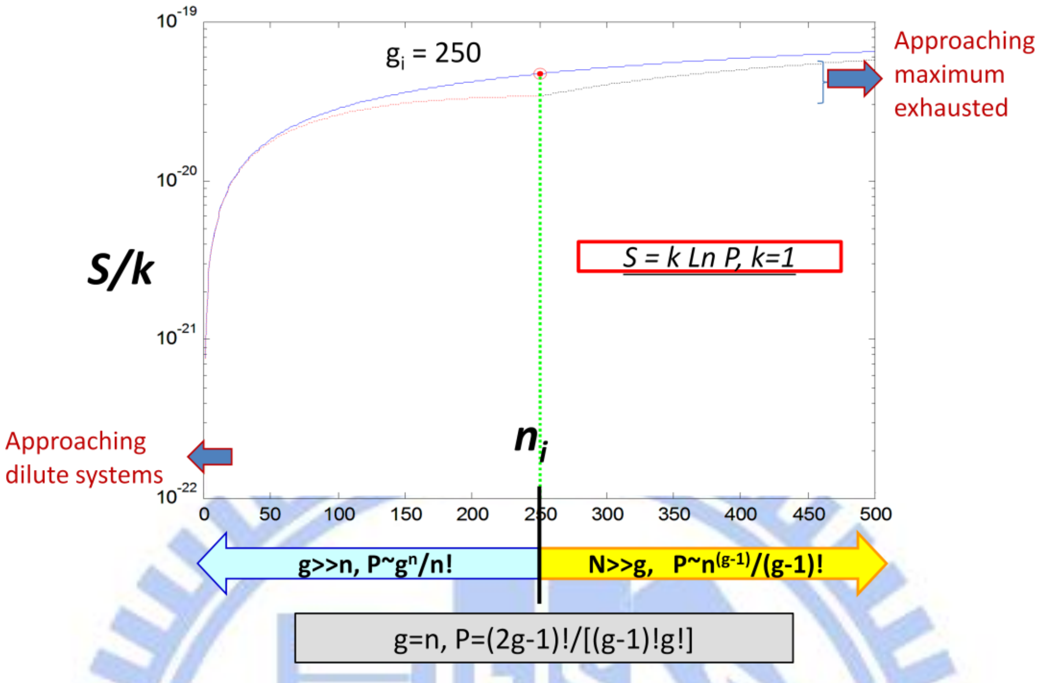


Figure 23 Scenario: Bosons, g_i= 250

4.3.6 Market implications from thermodynamic analysis

Check entropy S distribution of **fermions** at g_d = 500, as show in Figure 22.

We can find that:

- Entropy maximization and exhaustion is found when $n \geq g/2$
- Entropy is undefined when $n \geq g$
- **Entrepreneurial innovation is only likely to occur when $n < g$**
- While creating greater rooms for entrepreneurial innovation, more coded channels are needed, **favoring the markets of distributed capitalism**

Check entropy S distribution of **bosons** at g_i = 250, as show in Figure 23, we can find that:

- Entropy is a continuous function of n, and no universal maximum is found.
- In the regime of n>g, entropy is increased to exhaustion where

entrepreneurial innovation becomes unlikely.

- In the regime of n<g, entropy reaches a minimum, having a pattern resembling that of Fermions.

The interpretation of these partition functions is arranged as Table 5, which is based on the supply-side perspective for maximum entrepreneurship & innovation, a stochastic view of entrepreneurship on an overthrow of equilibrium economics.

Table 5 Interpretation of Partition Functions

	Scenario	**Supply Side Entropic Loss**	**Demand Side Entropic Transmission**	**Channel Structure**	**Competitive Advantage**
Indistinguishable	n<< g	Minimum	New segments, ***Dilute systems***	Amorphous	Innovation
	n = g	Moderate to High	Single Commodity	Monopoly	Efficiency & Cost Effectiveness
	n >> g	**Exhausted**	Multiple Commodities	Oligopoly or Monopoly	Economies of Scale
Distinguishable	n << g	Minimum	***Dilute Systems*** & Rooms for New Additions of Disorder	Platform-based Specialization; Marshallian Mesh-Network	Supply-side Entrepreneurial Curation & Price Effectiveness
	n = g/2	Moderate to High	Pre-determined channels	Customization or Personalized Services	Total Solution
	n >> g	**Exhausted**	N.A.	None-existing	N.A

Apply to analytic model developed by this research group, namely, Platfroms of Innovation Intensive Service, combined with implication of communication technologies is arranged as Figure 24.

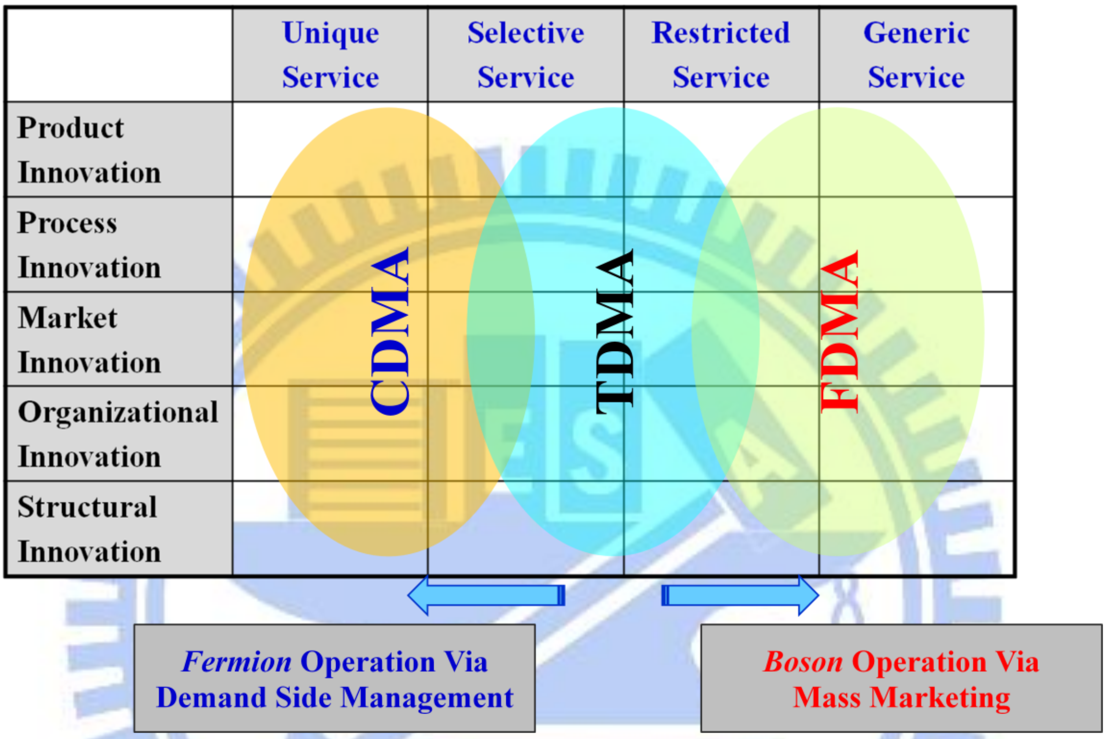


Figure 24 Arranged with the IIS analytic matrix

A brief summary of marketing implications from thermodynamic analysis

Supply-Side Perspective:

- Entrepreneurial randomness and externalization of network platforms demand multiple channels for reconfiguring and curation of supply-side randomness
- **Lateral collaboration** of sibling and multiple specializations requires a low-entropy carrier (platform) to reduce system entropy
- When system entropy is exhausted, little entrepreneurship can further be granted

Demand-Side Perspective:

- System optimization demands specialization of effectively coded channels, which yield larger rooms for additions of **disorder in the markets of distributed capitalism**
- **Demand-side management** is key for the dilute systems of entrepreneurial innovation

5. Conclusions

Forerunning forwards to topic about thermodynamic over marketing behavior. The research provided essential background knowledge and tools. And, tools that derived from information theory were proved useful to analyze variables/information in specified series, namely, time series. These tools/metrics can be used to judge randomness of a series information and dependency of two (or more) series information.

- The distribution like Bose-Einstein statistics via mass market
  1. Represented a conventional indistinguishable market which is close to centralized/aggregated market in generic static and equally partitioned with chances.
  2. If number of possible markets in specified industrial is much bigger than number of participators, which means the market is in new segments (a dilute system). The channel structure is in amorphous and the competitive advantage is innovation.
  3. If number of possible markets is equal to or smaller than number of participators, that is, the channel structure is under monopoly or oligopoly which efficiency and cost effectiveness are the key to success, and the

competitive advantage is economies of scale.

- The distribution like Fermi-Dirac statistics via demand side management
  1. Represented a progressive distinguishable market which is close to distributed market in non-equiprobable states for maximum effectiveness with full of chances.
  2. If number of possible markets in specified industrial is much bigger than number of participators, which means the market is still in uncertain state. There are still rooms to be success with new additions of disorder and innovation. The channel structure is platform-based specialization with supply-side entrepreneurial **curation**.
  3. If number of participators close to half of possible markets, that is, the market structure is full with customization or personalized services under pre-determined channels. A platform should be well prepared for re-ordered the market in advance for preventing the market is exhausted, that is, number of participators close to or bigger than possible markets in specified industrial.

According to description above, this study provides strategical suggestions for policymaker to develop corresponding strategies for entrepreneurship facing modern distributed markets.

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