Equivalence of market models in economic fields with electromagnetic fields

Kenji Shirai[1] Yoshinori Amano[2], Takayuki Uda[3], Atsuya Ando [4]

Abstract

Profit margins in financial statements are constantly stochastic. That is, it is the result of interaction with the market. Hence, this is because the quality point of capital in the financial statements moves stochastically through space and time. Therefore, capital is constantly changing stochastically. What we propose is that the existing equity and liabilities on the balance sheet are electromagnetic fields when analysed from an electro-magnetic point of view. We also construct a mathematical model to analyze that prices fluctuate due to changes in the balance between supply and demand. Individual economic activities are constrained by the overall subject mass. Therefore, the behaviour of the entire system is considered to be bounded by the Schrödinger's wave equation in physics. The economic mass excited by the supply and demand information as economic information is considered to correspond to an electric field, the demand to a magnetic field, and the price flow or demand flow to a current. The equivalence with the Ampere-Maxwell electromagnetic equation, which exists in an electromagnetic field, is mentioned.

1 Introduction

A motive that the present writers and the like started to promote such kind of research during many years of experience of manufacturing operations of control equipment for general industrial machines is as follows. In our previous studies, all angles reported that schemes with superior rates of return were better synchronous processes than asynchronous processes. As a major contribution, we have proposed measures to improve the efficiency of production systems, backed by mathematical models of deterministic which is the advection-type diffusion equation, and stochastic systems which is lognormal-type stochastic differential equation[1, 2, 3, 4]. There are reports based on analytical mechanics, arguments in Riemannian space and general relativity to demonstrate the superiority of synchronous production processes[5, 6, 7, 8, 9, 10]. The process that concretely realizes the synchronous production system is called the production flow system. The production flow system is presented with real data in all the papers we have proposed. Also, Spin glasses are a group of materials that exhibit behavior different from that of normal magnets due to the inhomogeneity of interactions caused by impurities in the alloy. In this case, spin is thought to represent the natural behavior of particles[11, 12, 13]. Therefore, we have considered the critical state due to phase transition when economic factors particles with irregular interactions, which are assumed to have spin and impurities, are considered using the Spin Glass Theory for complex systems such as those mentioned above[14].

In this paper, we focus on the interactions that occur between individual economic agents and market actors in the economic field. The profit rate in the financial statements describing the behaviour of individual economic agents, i.e. profit-seeking organisational entities, constantly fluctuates stochastically. In other words, it is the result of interaction with the market. Interaction means that the rate of profit is determined in the context of demand and supply. In other words, this is because the quality point of capital in the financial statements moves stochastically through time and space. Therefore, capital is always changing stochastically. This can be constructed as a mathematical model. The problem is the mathematical model of the market. In our opinion, this market model could be an electromagnetic field (capital and debt). This is the subject of this paper.

2 Overview of the Schrödinger's wave equation

2.1 Wave function

The Schrödinger's wave equation is now the fundamental equation of the revolutionary new mechanics "quantum mechanics" that governs the microscopic world. It can be compared to Newton's equations of motion, which are

[1]Information and Culture Faculty
[2]Kyohnan Elecs co.,LTD
[3]Faculty of Business and Informatics
[4]Faculty of Business and Informatics

the fundamental equations of classical mechanics (Newtonian mechanics) governing the macroscopic world. In the microscopic world, a particle is both a particle and a wave. We describe the physical aspects of matter. Matter has a large number of acting particles under the mass of the overall acting entity. These particles are active particles and individually have energy. However, the behaviour of each particle has fluctuations $\sigma_i,\ i = 1, 2, \cdots$, and the overall behavioural entity is established as an aggregate of these. This is analogous to the behaviour of an electron acting stochastically around an atomic nucleus with a certain mass. In other words, the behaviour of the individual behavioural entities is bounded by the total entity mass. Hence, the behaviour of the whole system is constrained by the following equation.

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\Psi + V\Psi \tag{2.1}$$

2.2 de Broglie's material wave

Electrons and photons have both particle and wave properties. Its wave function has attributes in common with the particle properties of energy and momentum, which are rules of physics. Since de Broglie waves are also waves, we can use wave functions in the same way. The wave function representing de Broglie waves can be expressed as follows.

$$\Psi(x,t) = Acos2\pi\left(\frac{x}{\lambda} - vt\right) \tag{2.2}$$

where x is a location on the wave, t is time, A is amplitude, λ is wavelength, and v is frequency.

For light, energy E and momentum p are associated with its frequency v and wavelength λ, respectively, by the following equations.

If we rewrite the previous equation for the wave function Ψ, which was written using wavelength λ and frequency v, using momentum p and energy E, we obtain the following

$$\Psi(x,t) = Acos2\pi\left(\frac{px}{h} - \frac{Et}{h}\right) \tag{2.3}$$

Since the energy E of a substance is a quantity that combines kinetic energy T and potential energy V, it can be written as follows.

$$E = T + V \Rightarrow \quad T = \frac{1}{2}mv^2, \quad p = mv \Rightarrow \quad E = \frac{p^2}{2m} + V \tag{2.4}$$

In order to describe the quantum property of being both a wave and a particle, it is sufficient that the rewritten wave function satisfies the above equation. Multiplying equation A by Ψ yields

$$E = \frac{p^2}{2m} + V \Rightarrow \quad E\Psi = \frac{p^2}{2m}\Psi + V\Psi \tag{2.5}$$

Substituting $P^2\Psi$ and $E\Psi$ here yields the one-dimensional Schrödinger equation (Same as Equation (2.2). However,on the way, we use the following equations.

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\Psi + V\Psi \tag{2.6}$$

$$\Leftarrow \quad i\hbar\frac{\partial\Psi}{\partial x} = p\Psi, \quad -\hbar^2\frac{\partial^2\Psi}{\partial x^2} = p^2\Psi \tag{2.7}$$

In other words, it is assumed that each level has a volatility σ_N and that σ as Planck's constant is the average value of σ. In other words, if we assume that level n is the number of units of individual sets existing around the mass of the action aggregate, then, in this way, there exists a certain energy level around the action subject, which is bounded by the size of the action subject, and the individual subjects in each level are determined by a stochastic law.

If this holds, the following Schrödinger's wave equation holds if t is neglected. In other words, it is a constraint equation for x in the wave equation derived from disposable income. For example.

$$V(x)\Big|_{x=0} = \infty, \ V(x)\Big|_{x=L} = \infty \tag{2.8}$$

The solution to the following equation is obtained from Equation (2.8).

$$\Psi(x) = \sqrt{\frac{2}{L}} \sin \frac{n\pi}{L} x, \ \ x = 1, 2 \cdots$$
$$E_n = \frac{\hbar \pi^2 n^2}{2mL^2}, \ \ \Psi_n(0) = \Psi_n(L) = 0 \tag{2.9}$$

See Appendix A for the derivation of $\Psi(x)$.

Figure 1 shows the state of $P_n(\sigma)$ with respect to m by the energy level E_n. In other words, the cost $P(\sigma)$ has fluctuations due to σ. Figure 2 shows the $P(\sigma)$ state for m by the energy level E_n. That is,

$$P_n(\sigma) \approx E_n = \frac{\hbar \pi^2}{2mL^2} n^2 = \frac{\pi^2 \sigma}{2L^2} n^2 \tag{2.10}$$

Assuming that the wavenumber k is normally distributed, the general solution of Equation (2.1) is Equation (2.11).

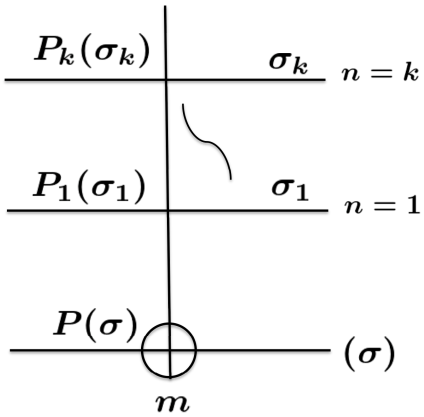


Fig. 1: Individual entities at individual levels

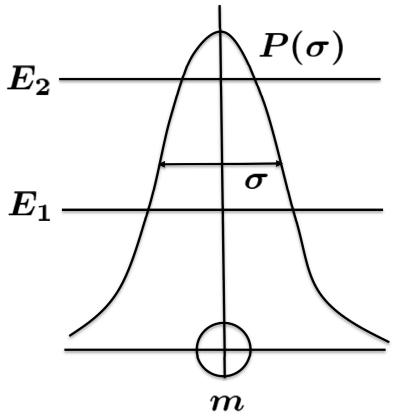


Fig. 2: Cost $P(\sigma)$ for energy level E_n for m

Furthermore, if $V(x) = 0$, then

$$\Psi(x,t) = \int_{\infty}^{\infty} q(k) e^{ikx} e^{-i\frac{E(k)}{\hbar}} dk \tag{2.11}$$

When Equation (2.11) represents the general solution, $\Psi(x)$ is

$$\Psi(x) = \int_{\infty}^{\infty} q(k) e^{ikx} dk \tag{2.12}$$

Let $q(k)$ be a normal distribution.

$$q(k) = e^{-\frac{a^2k^2}{2}} = e^{-\frac{1}{2}\left(\frac{k}{1/a}\right)^2} \tag{2.13}$$

$$\Psi(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}\xi^2}, \ \ \xi = \frac{x}{2\pi} \tag{2.14}$$

Therefore, $\Psi(x)$ is represented by a standard normal distribution.

3 Equivalence of electromagnetic and economic fields

3.1 Electromagnetic equation

Maxwell's equations are described collectively as follows[15].

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t} \, (Electromagnetic\, induction\, law) \tag{3.1}$$

$$\nabla \times \boldsymbol{H} = \boldsymbol{J} + \frac{\partial \boldsymbol{D}}{\partial t} \;\; (Ampere - Maxwell's \;\; law) \tag{3.2}$$

$$\nabla \cdot \boldsymbol{D} = \rho \;\; (Gauss's\, Law\, on\, Electric\, Flux\, Density) \tag{3.3}$$

$$\nabla \cdot \boldsymbol{B} = 0 \, (Gauss's\, law\, on\, magnetic\, flux\, density) \tag{3.4}$$

where $\boldsymbol{E}$: Electric field $[V/m] = [N/C]$, $\boldsymbol{B}$: Magnetic Flux Density $[T] = [Wb/m^2]$, $\boldsymbol{H}$: Magnetic field$[A/m]$, $\boldsymbol{D}$: Electric flux density $[C/m^2]$, $\boldsymbol{J}$: Current density $[A/m^2]$, ρ : Charge Density $[C/m^3]$

Equation (3.1) represents the rotation (left side) of the electric field $\boldsymbol{E}$ caused by the time variation of the magnetic flux density. With a minus on the right side, the direction of the electric field rotation $\nabla \boldsymbol{E}$ is opposite to the direction of the time-varying magnetic flux density. Figure 3 represents the rotation of the electric field E (left side in Equation (3.1)) caused by the time variation of the magnetic flux density $\boldsymbol{B}$ (right side in Equation (3.1)). Figure 4 illustrates Faraday's law of electromagnetic induction. The inductor power e produced in the coil is expressed by $e = -d\phi_0/dt$. Figure 5 illustrates that there is no single magnetic charge. For Figure 6, we have a picture of vector potentials. Suppose that physical space is filled with a highly viscous liquid (like syrup). Suppose there is a long stick in the liquid and the stick is moving in the direction of current flow. The viscous liquid around the rod will then be dragged by the rod and move in the same direction, faster for those near it and slower for those far away. This is the magnitude and direction of the vector potential in the case of Figure 6[16].

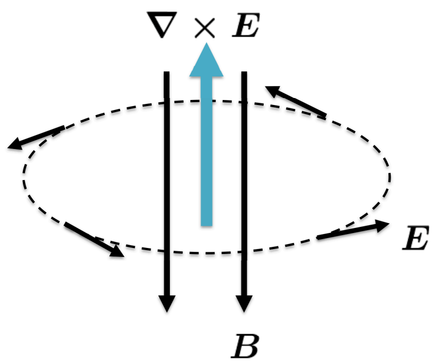


Fig. 3: $\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}$

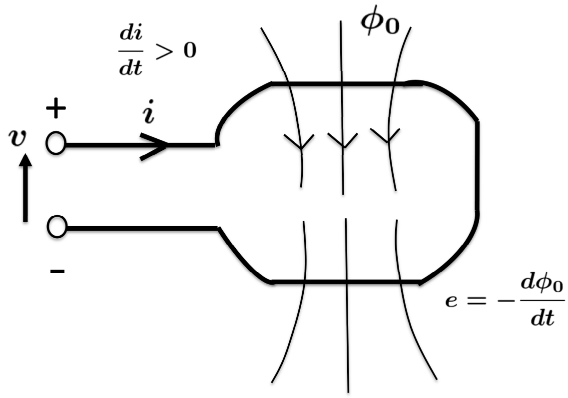


Fig. 4: Faraday's law of electromagnetic induction

We derive Faraday's law of electromagnetic induction from Equation (3.1). Integrate both sides of Equation (3.1).

$$\int_S \nabla \times \boldsymbol{E} \cdot dS = -\frac{\partial}{\partial t} \int_S \boldsymbol{B} \cdot dS = -\frac{\partial \phi}{\partial t} \tag{3.5}$$

Here the magnetic flux is given by the area of the magnetic flux density. In other words,

$$\phi = \int_S \boldsymbol{B} \cdot dS \tag{3.6}$$

Applying Stokes' theorem to the left-hand side of Equation (3.5).

$$\int_S \nabla \times \boldsymbol{E} \cdot dS = \oint_C \boldsymbol{E} \cdot dS = e \tag{3.7}$$

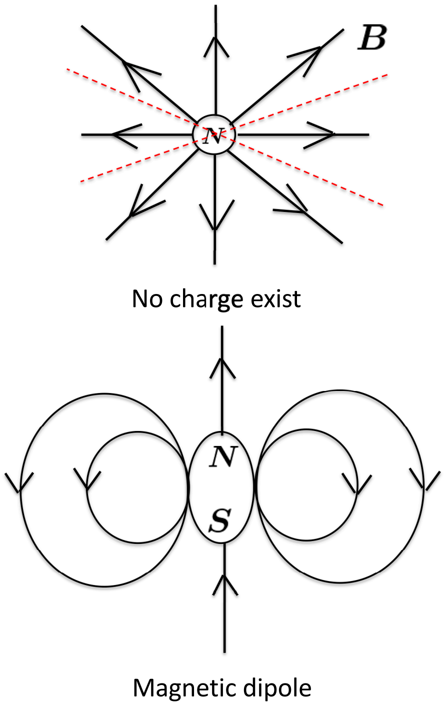


Fig. 5: Single charge and magnetic dipole

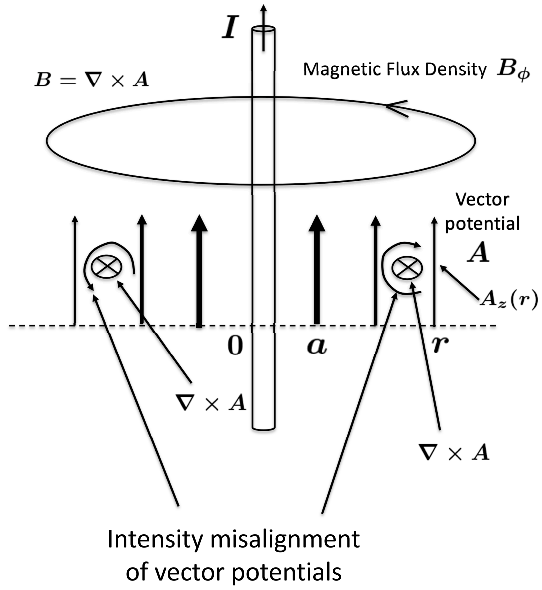


Fig. 6: Vector potential $\boldsymbol{A}$

where C derives the path of integration along the perimeter of the area region $\boldsymbol{S}$. From the above, Equations (3.5) (3.7), Faraday's electromagnetic induction law is obtained as follows.

$$e=-\frac{d\phi}{dt},(Faraday's\ electromagnetic\ induction\ law) \tag{3.8}$$

Kirchhoff's Voltage Law (KVL) can be derived from Equation (3.1). Here, we consider the case where the magnetic field does not change with time (static magnetic field).

$$\nabla\times\boldsymbol{E}=0 \tag{3.9}$$

Applying Stokes' theorem to Equation (3.9), we obtain

$$\int_S \nabla\times\boldsymbol{E}\cdot dS=\oint_C \boldsymbol{E}\cdot dS=0 \tag{3.10}$$

Equation (3.2) means that the rotation of the magnetic field (left side) is caused by the time variation of the current and flux density (right side). The details of Equation (3.2) is omitted here.

From Equation (3.2) we obtain Kirchhoff's current law. Let us consider the electrostatic field and denote it as $\partial\mathbf{D}/\partial\mathbf{t}$. From the vector analysis, the following holds in the canonical form.

$$\nabla\cdot\nabla\times\boldsymbol{H}=0 \tag{3.11}$$

Consider the right-hand side of Equation (3.11).

$$\nabla\times\boldsymbol{J}=0 \tag{3.12}$$

This means that the current gushing from any region is zero. Equation (3.3) means that there is a gushing of electric field from a charge. For a positive charge, there is gushing; for a negative charge, there is sucking. Equation (3.3) corresponds to the differential form of Gauss' law. The integral type is as follows.

$$\int_v \nabla\cdot\boldsymbol{D}dv=\int_v \rho dv=Q \tag{3.13}$$

where Q is the algebraic sum of charges in the integration domain.

$$\int_v \nabla \cdot \boldsymbol{D} dv = \int_S \boldsymbol{D} \cdot dS \quad (Gauss's \ \ law) \tag{3.14}$$

where S is the surface of the domain of integration.

Thus, we obtain Gauss's Law on electric flux density of Equation (3.3). Equation (3.4) is Gauss's law on magnetic flux density, also means that no single magnetic charge exists. Restated, the equation is as follows.

$$\nabla \cdot \boldsymbol{D} = \rho \tag{3.15}$$

$$\nabla \cdot \boldsymbol{B} = 0 \tag{3.16}$$

3.2 Mapping from electromagnetic field to economic field

The following table shows which matters that play an important role in the electromagnetic field correspond to what role they play in the economic field.

Table. 1: Electromagnetic field and Economic field

Electromagnetic field	Economic field
Electric field ($\boldsymbol{E}$)	Supply or market cost
Magnetic field ($\boldsymbol{H}$)	Demand or Market debt
Current ($\boldsymbol{J}$)	Price $\boldsymbol{P}$ flow or demand flow
Lorentz force ($\boldsymbol{F}$)	Price fluctuation force

In Figure 7, ρ is the market capital density and $\{\boldsymbol{E}_0, \boldsymbol{H}_0\}$ is the electromagnetic field for the supply and demand of goods in the market. There exists here a virtual excited particle ρ excited by the above. The virtual electromagnetic field $\{\boldsymbol{E}_0, \boldsymbol{H}_0\}$ in the market induces $\boldsymbol{E}$ (market costs) and $\boldsymbol{H}$ (market liabilities) from economic individuals (quality points) with capital density ρ. This $\{\boldsymbol{E}, \boldsymbol{H}\}$ is called the electromagnetic field due to economic behaviour.

In Figure 8, in terms of profit flows, profit flows generated from current assets and profit flows generated from net assets are interconnected with each other. Also, the sine wave in Figure 8 assumes an oscillating field of revenues and costs. In Figure 8, $\boldsymbol{D}$ and $\boldsymbol{B}$ also satisfy the following equations[17].

$$\boldsymbol{D}(t) = \boldsymbol{X} e^{j\omega t}, \quad \boldsymbol{B}(t) = \int \boldsymbol{D}(t) dt = \int \boldsymbol{X} e^{j\omega t} \tag{3.17}$$

Figure 9 illustrates that the economic field is equivalent to the electromagnetic field as a physical field. The specifics are discussed below. In the Schrödinger's field in the previous section, individual economic agents and market agents interact with each other. Since the economic field is equivalent to the electromagnetic field, the electromagnetic equations formed in the electromagnetic field are valid in the economic field. In an economic field, what corresponds to the electromagnetic equation is equivalent to economic demand and supply. In the following, we will analyze this mathematically. Figure 8 illustrates Fleming's left-hand rule in electromagnetism. It is assumed that Fleming's left-hand rule holds true for economic fields. This is shown here based on single-year accounting data. In other words, assuming the $\boldsymbol{D} - \boldsymbol{B}$ curve as an orthogonal curve. $\boldsymbol{D}$ and $\boldsymbol{B}$ are always orthogonal at this point, no matter what point the equilibrium point moves to.

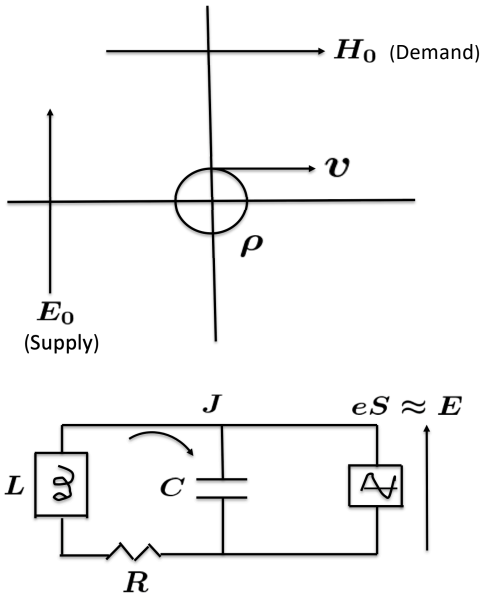


Fig. 7: Market potential

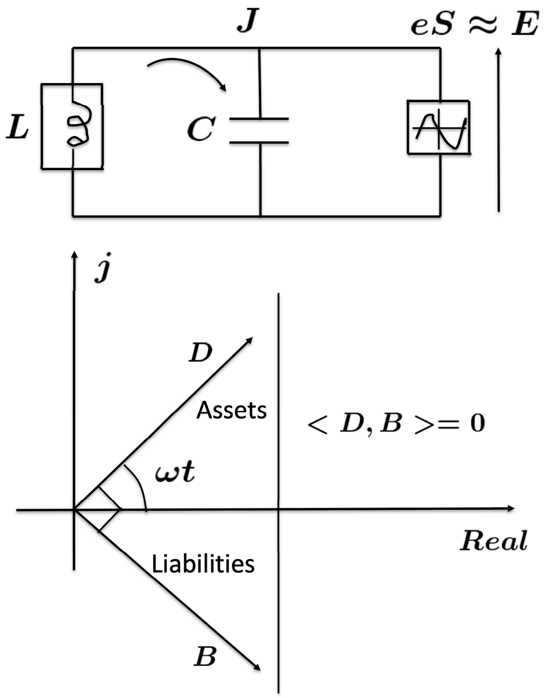


Fig. 8: Asset-liability relationships correspond to electrical and magnetic relationship

3.3 Maxwell's equations expressed in terms of electromagnetic potential

Change $\boldsymbol{D}$ and $\boldsymbol{H}$ out of the four physical quantities $\boldsymbol{E}$, $\boldsymbol{D}$, $\boldsymbol{H}$, and $\boldsymbol{B}$ in Maxwell's equations in Equations (3.1)-(3.4) into equations for only electric field E and magnetic flux density $\boldsymbol{B}$ using $\boldsymbol{D} = \varepsilon\boldsymbol{E}$, $\boldsymbol{H} = \boldsymbol{B}/\mu$.

$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t}\,(Electromagnetic\,induction\,law) \tag{3.18}$$

$$\nabla \times \boldsymbol{B} = \mu \boldsymbol{i} + \varepsilon \boldsymbol{i}\frac{\partial \boldsymbol{E}}{\partial t}\;\;(Ampere - Maxwell's\;\;law) \tag{3.19}$$

$$\nabla \cdot \boldsymbol{E} = \frac{\rho}{\varepsilon}\;\;(Gauss's\,Law\,on\,Electric\,Flux\,Density) \tag{3.20}$$

$$\nabla \cdot \boldsymbol{B} = 0\,(Gauss's\,law\,on\,magnetic\,flux\,density) \tag{3.21}$$

Next, $\boldsymbol{E}$ and $\boldsymbol{B}$ in these equations are replaced by the electromagnetic potentials ϕ (scalar potential) and $\boldsymbol{A}$ (vector potential). Equation (3.21) becomes

$$\boldsymbol{B} = \nabla \times \boldsymbol{A} \tag{3.22}$$

Substituting Equation (3.22) into Equation (3.21), the vector formula becomes zero identically. Substituing $\boldsymbol{B}$ in Equation (3.18) into $\boldsymbol{A}$, we obtain the following equation.

$$\nabla \times \left(\boldsymbol{E} + \frac{\partial \boldsymbol{A}}{\partial t}\right) = 0 \Rightarrow \boldsymbol{E} = -\nabla\phi - \frac{\partial \boldsymbol{A}}{\partial t} \tag{3.23}$$

$\boldsymbol{E}(x,t)$ represents the electric field, $\boldsymbol{H}(x,t)$ the magnetic field and $\{\boldsymbol{E}(x,t), \boldsymbol{H}(x,t)\}$ the market electromagnetic field. Also, ρ has spin and particle nature. $\boldsymbol{A}(x,t)$ is a vector potential, a vector excited by the magnetic field in the market. It is also transformed to Equation (3.23) from the Lorentz force due to the interaction. In terms of profit flows, the current production number profit flows interoperate with each other.

Figure 10 represents the balance sheet as a rational method of financial notation in a capitalist economy. This is a table that can be obtained for any macro or micro economy.

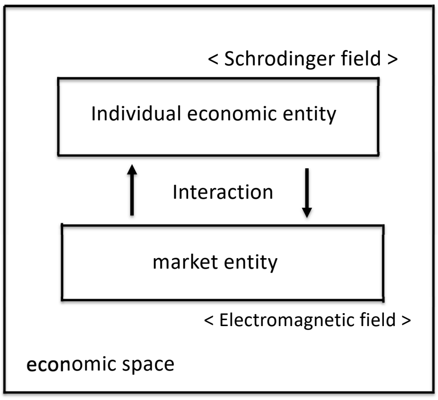


Fig. 9: Individual subjects in individual standard

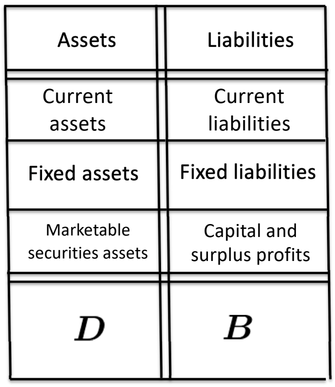


Fig. 10: Balance sheet

- Faraday's law : time variations in the magnetic field produce an electric field.
- Anperer-Maxwell's law : relationship between magnetic field and current density (displacement current).
- Gauss's law : divergence of electric fields and charge density

These must be established in the economic field.

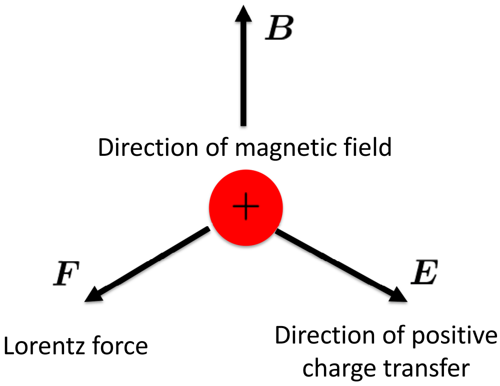


Fig. 11: Lorentz force

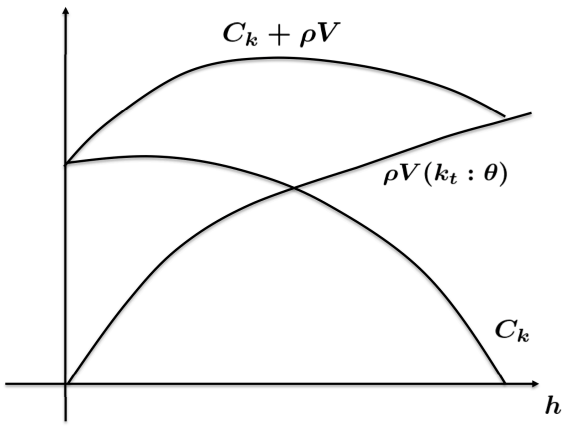


Fig. 12: Curve of $\boldsymbol{C}_k$ and $\rho\boldsymbol{V}$

3.4 Lorentz force in an economic field

Electromagnetism consists of Maxwell's equations, which are a series of four laws. The laws are the force acting on an electric charge (Electric force; Coulomb force), the force acting on an electric current (Magnetic force). The laws are derived from the forces acting on electric charges (electrostatic force; Coulomb force) and electric currents (magnetic force; Ampere's force), and are the theory of electric and magnetic dynamics. However, the four equations in current electromagnetics are based on the relationship between electric and magnetic fields, or fields, and do not explicitly show the action of forces (= Electromagnetic mechanics). The equation responsible for this dynamics is called the Lorentz force. Like Maxwell's equations, this equation is also invariant to inertial systems. Figure 11 illustrate Lorentz force in line with Fleming's left-hand rule.

Now, consider a point $\boldsymbol{P}$ in an electromagnetic field where the electric field is $\boldsymbol{E}$ and the magnetic flux density is $\boldsymbol{B}$. A particle with electric quantity e and velocity $\boldsymbol{v}$ that eventually comes to this point $\boldsymbol{P}$ will be subject to an electromagnetic force $\boldsymbol{F}$ such as follows.

Definition 3.1 *Lorentz force*

$$\boldsymbol{F} = e(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B}) \tag{3.24}$$

In Figure 11, the Lorentz force is the force that a charged mass point in an electromagnetic field receives from the electromagnetic field, and that it moves with a certain velocity v. In an economic field, the Lorentz force is considered to be the fluctuating force of market prices. So, P_t is determined by following equation[18].

$$\boldsymbol{P}_t = \rho \frac{\partial \boldsymbol{V}}{\partial h} = -\frac{\partial \boldsymbol{v}(\boldsymbol{P}, \boldsymbol{k}_t, \boldsymbol{\theta})}{\partial h} \tag{3.25}$$

where $\boldsymbol{P}_t$ is the price in an economic field. $\boldsymbol{\theta}$ is an equilibrium dynamic system.

Hence, we denote the equilibrium dynamic system by $h(\boldsymbol{k}_t : \boldsymbol{\theta})$ in Figure 12. That is, $\boldsymbol{C}_k$ represents the trade-off between social utility u_1 and the output level of capital $\boldsymbol{k}_1$ in the current period under a given initial capital k_t. Also, $\rho\boldsymbol{V}$ represents the social welfare sum after the second period, and the vertical sum of $\rho\boldsymbol{v}$ and $\boldsymbol{C}_k$ is $(\boldsymbol{C}_k + \rho\boldsymbol{v})$. These $\boldsymbol{C}_k$ and $(\boldsymbol{C}_k + \rho\boldsymbol{V})$ depend on $\boldsymbol{k}_t = h(\boldsymbol{k}_{t-1} : \boldsymbol{\theta})$. Therefore, the demand curve $\boldsymbol{D}_k$ takes $\partial(\rho\boldsymbol{V})/\partial h$ and the supply curve $\boldsymbol{S}_{t-1}$ takes $|\partial\boldsymbol{C}_k/\partial h|$, and the point $\boldsymbol{D}_{k_t} = \boldsymbol{S}_{k_{t-1}}$ where these coincide on $\boldsymbol{C}_k$ is the point of dynamic equilibrium at $\boldsymbol{E}$ and the point of dynamic equilibrium is obtained as in Equation (3.25) in Figure 13. As can be seen from the two balance sheets, each item is stochastically variable in relation to supply and demand in Figure 14[18].

Now we define the connection vector between $\boldsymbol{D}_{k_t}$ and $\boldsymbol{S}_{k_{t-1}}$ at this equilibrium point. In Figure 12, $\boldsymbol{C}_k$ is the utility summable curve and $\rho\boldsymbol{V}$ is the present value of the total utility thereafter generated from initial capital.

$$\boldsymbol{k}_t = h(\boldsymbol{k}_{t-1} : \theta), \quad \boldsymbol{V} = \sum_{\tau=1}^{\infty} \rho^{\tau-1} \sum_i \boldsymbol{\theta}_i u_{i_{\tau+1}} \tag{3.26}$$

where k_t is the capital level in period. Δt is a function of carryover from period $t-1$ and imputed value.

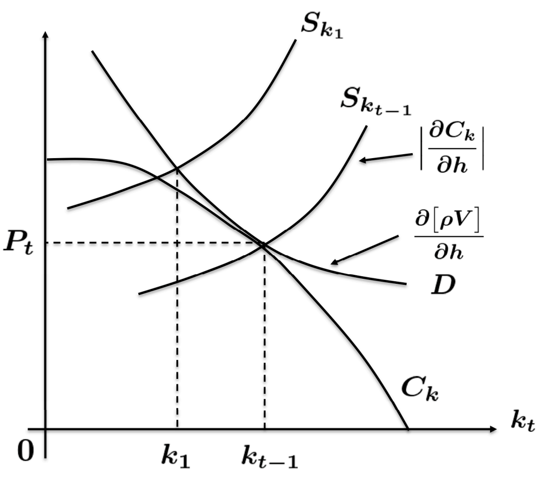


Fig. 13: Demand and Supply curve

E	H
55.1	3.6
44.0	51.7
0.9	44.7

Balance sheet for year A

E	H
54.1	4.4
44.9	42.8
1.0	52.8

Balance sheet for year B

Fig. 14: One year balance sheet

We analyze for $\partial(\rho\boldsymbol{V})/\partial h$.

$$\frac{\partial \boldsymbol{V}}{\partial h} = \frac{\partial \boldsymbol{V}}{\partial P} \cdot \frac{\partial \boldsymbol{P}}{\partial \theta} \cdot \frac{\partial \boldsymbol{\theta}}{\partial h} \tag{3.27}$$

Therefore,

$$\rho \boldsymbol{V}_P = -\boldsymbol{V}_P \cdot \boldsymbol{P}(h, \boldsymbol{\theta}) \tag{3.28}$$

where, $\frac{\partial \boldsymbol{V}}{\partial P} = \boldsymbol{V}_P$ is the value of marginal demand relative to price, and $\boldsymbol{P}(h, \boldsymbol{\theta})$ is the marginal value coefficient of the allocation function. Also, $\rho \boldsymbol{V}_P$ denotes the marginal future value for price displacement.

In Equation (3.24), $e\boldsymbol{S}$ is as follows

$$e\boldsymbol{S} = -\Big[\big(\frac{\partial \boldsymbol{D}}{\partial P}\big) \cdot (e\boldsymbol{N}) \Big] \tag{3.29}$$

where, $e\boldsymbol{S}$ is the variable value of capital. $\left(\frac{\partial \boldsymbol{D}}{\partial \boldsymbol{P}}\right)$ is the marginal coefficient of demand on price. $e\boldsymbol{N}$ is the value of quantity demanded, in other words, the utility value of consumption.

If we now put $e\boldsymbol{S} = \boldsymbol{e}_L$.

$$\boldsymbol{e}_L = -L \frac{\partial \phi}{\partial t} \tag{3.30}$$

Equation (3.31) implies that capital volumes are excited and generated by distribution flows. Distribution flows are the density of accumulated capital volume relative to market capacity. In other words, distribution flows represent changes in market size and capital density.

Now, we derive F as the volatility of prices at a given market size as follows.

$$\boldsymbol{F} = e\boldsymbol{S} + e(\boldsymbol{D} \times \boldsymbol{N}) \tag{3.31}$$

This $\boldsymbol{F}$ is called the Lorenz force in the economic field. This force disappears at t_1, but income $e\boldsymbol{S}$ is realised under the new price $\boldsymbol{P}$. Therefore, at t_1,

$$e\boldsymbol{S} + e(\boldsymbol{D} \times \boldsymbol{N}) = 0; \quad e\boldsymbol{S} = -e(\boldsymbol{D} \times \boldsymbol{N}) \tag{3.32}$$

where $\boldsymbol{D}$ is the rate of change in demand (rate of change) and $\boldsymbol{N}$ is the quantity supplied.

This means that the income $e\boldsymbol{S}$ is the demand (strength of magnetic induction) generated by the market excitation. This expression is isomorphic to the quantitative expression of the law of electromagnetic induction. Therefore, all units of trade can be converted into e-unit quantities by this price system.

$$\boldsymbol{F} = e\boldsymbol{S} + e\boldsymbol{N} \cdot \boldsymbol{D} \longleftrightarrow \boldsymbol{F} = e\boldsymbol{E} + e\boldsymbol{B} \cdot \boldsymbol{v} \tag{3.33}$$

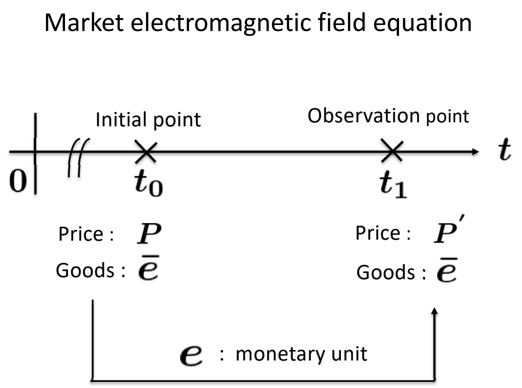


Fig. 15: Market electromagnetic field

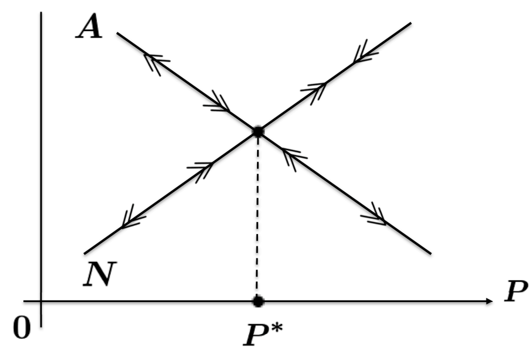


Fig. 16: Demand and supply curve

The price equation is given by setting the field space variable to x.

$$\frac{\partial \boldsymbol{P}(x,t)}{\partial t} \cong \Big[-\mathscr{L}_x \boldsymbol{P}(x,t) + (\boldsymbol{D}(x,t) - \boldsymbol{q}(x,t)) \Big] \tag{3.34}$$

where $\boldsymbol{D}$ is the demand volume and $\boldsymbol{q}$ is the supply.

In other words, prices are affected by the supply-demand balance. Therefore, if the change in the amount of capital resulting from the above is $\boldsymbol{S}$, then

$$e\boldsymbol{S} \approx -\frac{\partial \boldsymbol{P}}{\partial t} = -L\frac{\partial \phi}{\partial t} \tag{3.35}$$

where ϕ is the demand flow and L is the proportional constant.

Let $\phi_\alpha(x,t)$ denote the quantity of economic grass, and the following electromagnetic equation is established. In other words, it is excited by the supply and demand information as economic information. The economic mass corresponds to the electric field, the demand (flow) to the magnetic field, and the price P flow or demand flow to the electric current.

The next section considers the Lorenz force as applied to economics. In Figure 15, the price P changes to P' due to changes in the supply-demand balance.

- e : monetary unit
- $\bar{e}$: The unit of transaction of the commodity on which the conversion is based and the price is equal to e.
- $e\boldsymbol{S}$: Unit of trade of the commodity on which the conversion is based and the price is equal to e.
- $\boldsymbol{S}$: Amount of capital in the market
- $\boldsymbol{N}$: demand
- $\boldsymbol{A}$:supply
- $\boldsymbol{A}'$: Variable part of supply A
- $\boldsymbol{D}$: Percentage of demand satisfied by supply

From these,

$$\boldsymbol{D} = \frac{\boldsymbol{A}' - \boldsymbol{N}'}{\boldsymbol{N}'} = \frac{\boldsymbol{A}'}{\boldsymbol{N}'} - 1 \tag{3.36}$$

Therefore, according to Maxwell's electromagnetic equations are described in Equations (3.1) (3.4). Here, we set $\boldsymbol{F} = 0$ at the observation point.

$$e\boldsymbol{S} = -e(\boldsymbol{D} \times \boldsymbol{N}) \tag{3.37}$$

This considers that market capital (income) eS is excited by the rate of change in demand. In other words, if we consider that it is proportional to the rate of change in market prices and the market constant, we obtain the following equation.

$$e\boldsymbol{S} \equiv -L\frac{d\boldsymbol{P}}{dt} \Longleftrightarrow \boldsymbol{e_L} = -L\frac{d\boldsymbol{i}}{dt} \tag{3.38}$$

Hence, market prices are considered to be derived from demand. Therefore, prices are flows in the market, analogous to currents in electromagnetic fields.

The above definitions are considered as follows.

- $\boldsymbol{P}$: Market price
- $\boldsymbol{A}$: Supply
- $\boldsymbol{N}$: Demand
- e : Trading unit of commodity
- $\boldsymbol{S}$: Market capital (income)

Supply moves in a manner consistent with demand. The price fluctuation force (pressure) in the market is determined when the market price is observed and the force disappears. Therefore,

$$\boldsymbol{F} = e\boldsymbol{S} + e(\boldsymbol{D} \times \boldsymbol{N}), \quad \boldsymbol{D} = \frac{\Delta \boldsymbol{A}}{\Delta \boldsymbol{N}} - 1 \tag{3.39}$$

That is, considering that $\boldsymbol{D}$ is the turnover rate of demand.

$$\boldsymbol{F} = e\boldsymbol{E} + e(\boldsymbol{v} \times \boldsymbol{B}), \quad \boldsymbol{B} = \mu \boldsymbol{H} \tag{3.40}$$

This is isomorphic to the Lorentz force in electromagnetic fields.

Again, to confirm, as illustrated in Figure 8, eS represents the electric field $\boldsymbol{E}$, $\boldsymbol{J}$ is the displacement current and obeys Anpere-Maxwell's law.

$$e\boldsymbol{S} = L\frac{d\boldsymbol{J}}{dt} \ \ (Faraday's \ \ law), \quad \boldsymbol{J} = \frac{1}{c}\int (e\boldsymbol{S})dt \ \ (Ampere - Maxwell's \ \ law) \tag{3.41}$$

where c is the speed of light.

Furthermore, if we assume that the mass density in the region ρ,

$$\sum_{u^i n[\Omega]} e\boldsymbol{S}(u,t) \cong \sum_{u \in [\Omega]} \rho(u) \tag{3.42}$$

where, $e\boldsymbol{S}$ is the change.

$$\nabla[e\boldsymbol{S}] \approx \kappa\rho, \quad \boldsymbol{S} \in [\Omega] \tag{3.43}$$

From the above considerations, the equivalent circuit in the economic field can be expressed by Figure 8. According to this, the fundamental laws of electro-physics are established. From Figure 8,

$$\boldsymbol{v} = L\frac{d\boldsymbol{i}}{dt}, \quad \boldsymbol{i} = \frac{1}{c}\int \boldsymbol{v}dt \iff \quad \boldsymbol{H} = \oint_{x \in \Omega} \boldsymbol{A}(x,t)dx \tag{3.44}$$

Figure 8 is an electric circuit model of an economic quality point. Here, in the economic field, the L and C parameters in Figure 8 are, for example, disposable income, interest rates and labour variables, v is economic mass (capital) and i is the various types of distribution in the economy (Potential). The loss in the economic field can then be defined by cascading the resistance R to L and C. This loss is equivalent to the consumption of free energy by the dissipative term. This will be discussed in detail in the next issue. Equation (3.28) is then a general dynamic equilibrium model. Alternatively, Equation (3.29) is an electromagnetic field model for fluctuations in market capital (income) and demand. Alternatively, it is considered as the variation of market prices and demand. Hence, it is organized as follows.

Table. 2: Asse and Liabilitities

Assets	Capital
aa	*cc*
bb	*dd*

- Capital value (capital density) : supply $\iff$ Electric field $\boldsymbol{E}(x,t)$
- Demand$\iff$ Magnetic field $H(x,t) \Longrightarrow \boldsymbol{A}(x,t)$
- Market price (excited by demand) $\iff$ Current $\boldsymbol{i}(x,t)$ or demand flow
- Electric potential (electric) $\iff$ Excited from the electric field $\phi(x,t)$ (scalar potential)

In Table 2, aa is current assets (current assets) and bb is fixed assets. cc is current liabilities + fixed liabilities. dd is capital stock + retained earnings

$$(aa + bb) - (cc + dd) = 0 \tag{3.45}$$

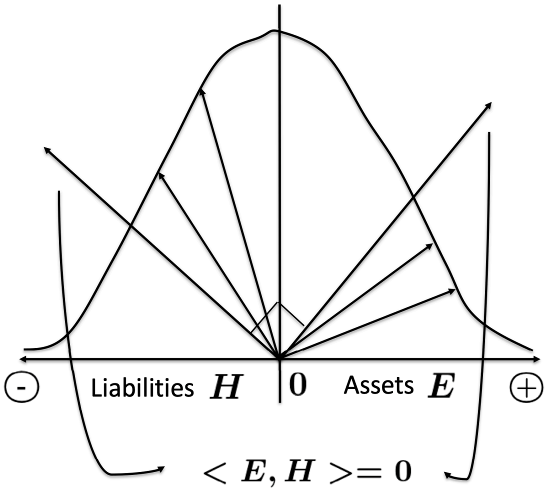
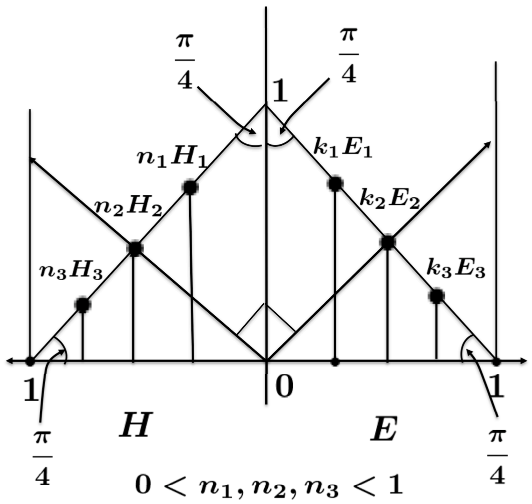


Fig. 17: Graphing the balance sheet



$$0 < n_1, n_2, n_3 < 1$$
$$0 < k_1, k_2, k_3 < 1$$
$$k_1 + k_2 + k_3 = 1$$
$$n_1 + n_2 + n_3 = 1$$

Fig. 18: Relationship between equity and debt

E	H
0.5	0.03
0.4	0.5
0.1	0.45

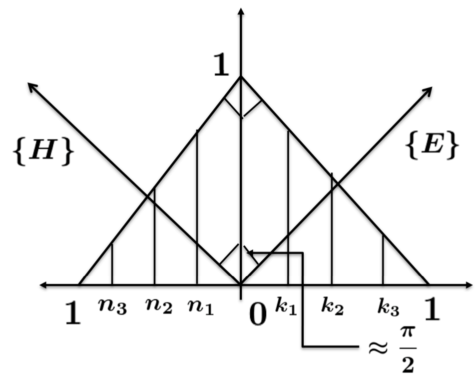
Balance sheet for year A (normalization)

→

E	H
0.5	0.04
0.45	0.4
0.1	0.55

Balance sheet for year B (normalization)

Fig. 19: One year balance sheet (normalization)



One year balance sheet (normalization) A and B

$$E = k_1 E_1 + k_2 E_2 + k_3 E_3 \approx 1$$
$$H = n_1 H_1 + n_2 H_2 + n_3 H_3 \approx 1$$
$$< E, H >= 0$$

Fig. 20: $< \boldsymbol{E}, \boldsymbol{H} >= 0$

4 Numerical examples

Figure 19 is the normalized data for $\boldsymbol{E}$ and $\boldsymbol{H}$ described in Figure 14. $\boldsymbol{E}$ and $\boldsymbol{H}$ locations extracted from the normal distribution map are linearly approximated in Figure 18. In Figure 18, we use two balance sheets for each single year in Figure 19. Calculating each value from $\boldsymbol{E}_1$ through $\boldsymbol{E}_3$ and from $\boldsymbol{H}_1$ through $\boldsymbol{H}_3$ according to the calculation method described in Figure 18, the angle of intersection with the vertical axis is approximately $\pi/4$ as shown in Figure 18. Therefore, the intersection angle of $\boldsymbol{E}$ and $\boldsymbol{H}$ is $\pi/2$ in Figure 20. That is, $<\boldsymbol{E},\boldsymbol{H}>=0$. It can be seen that the relationship between capital and debt in the economic field maintains Fleming's left-hand rule in electromagnetism.

5 Results

We proposed that equity and debt on the balance sheet are electromagnetic fields in an electric magnetic field. We also used a mathematical model to explain that prices fluctuate due to changes in the balance between supply and demand. We suggested that it is equivalent to Ampere-Maxwell's electromagnetic equation existing in an electromagnetic field. We further assumed that equity and debt are electromagnetic fields and therefore go straight through each other. Calculated from two simple balance sheets, they are not perfectly straight lines, but they intersect at an angle close to a right angle. In our next article, the proof that the electromagnetic equation in the economic field holds is left to time.

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Appendix

A Derivation of $\Psi(x)$

For simplicity, we consider it in terms of a one-dimensional wave equation.

$$-\frac{\hbar h^2}{2m}\frac{d^2}{dx^2}\Psi = \boldsymbol{E}\Psi$$

A trigonometric function appears in this solution. and is -1 times the original function after two differentiations. Therefore, Let $\Psi = A\sin bx$. A and b are undetermined coefficients. Schrödinger's boundary and normalization conditions are as follows. For $x = 0$ and $x = L$,

$$\Psi = A\sin(b\times 0) = 0, \quad \Psi = A\sin(b\times L) = A\sin bL$$

To satisfy $A\sin bL = 0$,

$$bL = n\pi, \quad (n = 1,2,3,\cdots) \quad \Rightarrow \quad b = \frac{n\pi}{L} \quad (n = 1,2,\cdots)$$

The normalization condition then states that the probability that a particle exists in the region from $x = 0$ to $x = L$ is 1.

$$\int_0^L \left|A\sin\frac{n\pi}{L}x\right|^2 dx = |A|^2\int_0^L \sin^2\frac{n\pi}{L}xdx = |A|^2\left[\frac{1}{2}x - \frac{1}{2}(\frac{2n\pi}{L})^{-1}\sin\frac{2n\pi}{L}\right]_0^L = |A|^2\frac{L}{2}$$

The result of the above equation must be 1 (normalization condition)

$$|A|^2\frac{L}{2} = 1, \quad A = \sqrt{\frac{2}{L}}$$

Therefore, the wave function to be sought is,

$$\Psi = \sqrt{\frac{2}{L}}\sin\frac{2n\pi}{L}$$