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Thermodynamic Approach to the Discount Rate and Discounted Cash Flow Method

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Abstract: Current theories of the discount rate have a theoretical basis focused on risk; risk-free rate and risk premium. The basic component of the discount rate, the risk-free rate as purely empirical has a natural infirmity which consequently weakens the final theory. Similarly, the risk premium category is not theoretically perfect. The fundamental shortcoming is that the theory of the discount rate does not relate to fundamental knowledge of capital and the natural rate of its potential growth. Therefore, the purpose of the discussion is to justify the discount rate structure with the constant of potential growth of capital; a = 0.08 [1/year] as the main component. It is proven that the theory of the discount rate is linked to the essence of time and the pace of its passage and is an essential component of the capital–labor–time triad.

Keywords: risk premium; capital; thermodynamics; discount rate; natural constant; time flow rate

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1. Introduction

The economy is a game with nature, and it is a non-zero positive sum game (Wright 2001). This game is played for the possibility of existence of life. The author recognizes that the possibility of winning is a force that stimulates economic and non-economic activities. Non-zero-sum means that in this game, all participants, i.e., economic actors seeking profit, can win with different results. Since this is the case, there must be energy inflows to the earth system of life, otherwise capital would have to be created from nothing. It is natural to conclude that the source of capital is solar energy and the common phenomenon of photosynthesis. But is this the only one? The growth of the plant kingdom enables the growth of the animal kingdom and humans. The payoff must be significant since for its achievement, economic units are organized in pursuit of profit constantly rationalizing management.

We hypothesize that the average value of the winnings approaches eight percent of the invested capital, unless some devastating calamity occurs during the period. By economic units we mean enterprises as well as employees with their personal human capital. As is well known, achieving profit at an adequate level requires competent, careful management of every area of economic activity.

Very responsible decisions are made in the field of capital investment (capital budgeting). Investment projects are usually long-term, so methods of their evaluation are a significant part of economic knowledge. Methods for evaluating economic projects are an enduring legacy of economic thought. It is known that in economic projects, it is necessary to assess the rate of multiplication of the capital invested in the project and determine the internal rate of return. Then, the resulting assessment can be compared with a standard value. There are many variations of this procedure generally referred to as discounted cash flow (DCF); the main ones are known as internal rate of return (IRR) and net present value (NPV). But what is the main premise and purpose of these methods? The rationale is the belief in the extraordinary importance of capital and the need to grow its invested value. The purpose of this study is to give an unambiguous opinion as to whether the rate of capital multiplication meets the elementary requirements of conducting economic activity in the earth system of life (ESL).

The above submission poses the following questions: (i) what is this capital and why is it so important? The question is legitimate because difficulties in understanding capital still exist, and there is no clear definition of this important concept. The second question (ii) has to do with the benchmark value of the rate of capital expansion on an annual basis, the basic astronomical cycle at the end of which economic evaluations of ongoing ventures are made.

Note that the above questions are avoided in practice and education. Instead, two rather enigmatic categories are introduced, such as the change in the time value of money and the risk of the project being evaluated. Damodaran (2012, p. 27) explains that in the DCF approach, we determine the value of a valued asset by discounting the expected flows it generates at a discount rate that reflects its risk. In other words, we measure the intrinsic value of the asset. Should discount rate theory only consider risk and empirical facts? Scientists like Mazur (1976, p. 43) recognize that nothing in a theory should be justified by empirics. A theory in which even one link of evidence is drawn from empirics is weak and questionable.

The purpose of the study is to obtain a scientific answer to the questions posed; to define capital unambiguously, to establish a benchmark value for the rate of capital multiplication, and to determine the structure of the discount rate while specifying the risk component. The category of capital is an abstract concept, so mathematical tools and physical principles are needed to describe it. Capital does not arise from nothing, nor does it multiply spontaneously, so the first principle of thermodynamics is indispensable here. As is also known, capital undergoes spontaneous dissipation, so the application of the second principle of thermodynamics is indispensable in explaining the title topic.

The methodology of the considerations and research carried out is determined by the epistemology of Imre Lakatos. Considerations are carried out within the framework of a natural research program, the hard core of which is the correct theory of capital. As is well known, a well-defined core endowed with the attribute of truth naturally stimulates positive heuristics. In this case, understanding the abstract nature of capital invokes thermodynamic knowledge and the natural constant a = 0.08 [1/year], which can be thought to be determined by the natural cycles occurring in the Solar System, is revealed. Thus, it can be thought that natural annual capital gains have limited variance, and are even determined by a natural constant.

A nested narrative develops (Sheldrake 2020) and comes to an understanding of time that manifests itself in all its glory in the economic sciences when in physics the duration–element of time–is sufficient. The operationalization of present and future value, in addition to the number that determines the duration of the process, requires adequate knowledge of the capitalization and discount rate. Thus, a theory is formulated that is fully integrated with the subsequent achievements of the scientific program. Understanding of the time category made it possible to move on to the study of capitalizing and discounting rates.

2. What Is Capital?

This question must be asked because there is evidence that economists frequently define capital according to their own thinking, such as Piketty (2015, pp. 63–64), who assumes that it is a type of asset. At the same time, one may suspect that some scholars are not aware that capital is the most important economic concept, so the lack of understanding presages the failure of the proclamations. Trying to answer this question also requires realizing that there are two actually separate systems of knowledge, in which scholars do not confront their achievements and do not seek to agree on the perception of capital. They are, as it were, in separation.

One of these areas of knowledge is accounting theory, which deals with the measurement of capital and the reporting of its periodic growth in economic units. This knowledge serves economic units, tax and budget systems, and many government agencies, such as the

Statistics Office, and it also serves prosecutors and expert witnesses when the need arises. It's worth mentioning that the economists who created the GDP measurement system abandoned the cost method, which would have been based on reports from accounting systems. This is one of the reasons for the lack of integration. The second field is economics with its numerous sub-disciplines; in particular, the theories of human and intellectual capital.

In economics, there is a well-known "Cambridge capital controversy" or "the capital controversy" that has surfaced over the understanding of capital. We have marked our position on this issue, most recently in an article (Dobija and Renkas 2023). Instead of agreeing with one side's views, a theory of capital derived from the relevant foundational principles was presented. However, the perception of capital as an intangible category was, in our case, a consequence of work in accounting theory. There had already been articles explaining the belonging of accounting to the natural sciences (Dobija 2013; Dobija and Renkas 2020). As can be seen, there is a strong analogy in natural sciences and accounting theory, a similar paradigm, i.e., matter-energy dualism in physics and asset-capital dualism in accounting. The principle of dualism, according to which economic measures are considered dualistically as assets and the capital dense in them, is absolutely fundamental to accounting theory (Mattessich 1995, p. 62). From it derives the necessity of dual recording, from which in turn derives the principle that capital does not arise from nothing.

There are many interpretations of the duality principle, but a particularly useful one is presented in the articles (Dobija 2013, 2016). The division of capital by ownership (liabilities and owner's capital) was abandoned as irrelevant, leading to the simple equation $A_0 = C_0$, where A stands for the value of assets, C stands for for the value of capital, and the number zero is an index indicates that the value is considered at the same point in time. From this equation, one obtains the natural conclusion that the value of capital as well as capital itself are abstract categories; capital is embodied in tangible and intangible assets. Thus, descriptions of capital require mathematical tools such as number systems, functions, etc.

Moreover, as previously noted by Ijiri (1995), assets are heterogeneous and capital is homogeneous. These unambiguous and indisputable characteristics (capital is abstract and homogeneous) are significant for the further development of cognition, in particular, the introduction of an adequate definition of capital. Since it is homogeneous, capital embodied in a device, cash, and a person is the same medium. One can also conclude that capital embodied in an object defines its essence (noumen).

At this level of cognition, there is still much relevant information about the nature of capital. Note that capital embodied in assets, tangible and intangible objects, as well as living things is a potential category. For example, a car has the ability to drive and transport objects. More generally, assets embodied in capital have the ability to do work. Similarly, an educated adult has the capacity to do useful work. In addition, a tree has the ability to provide wood and more. The thing is that this capacity is potential and, in addition, does not persist indefinitely. It undergoes random, spontaneous, and unidirectional change; potential decreases over time. This causes the assets in which capital is embodied to undergo physical, adverse changes over time. The phenomenon (everything ages) is commonly manifested in reality and is subject to an explanation known as the second law of thermodynamics. Since the principle specifying that capital does not arise from nothing is called the first principle of thermodynamics, therefore, these two principles are the foundation of accounting theory and not just natural science.

Thus, capital is an intangible medium, it is a potential embodied in an object, the presence of which determines its permanence as a specific entity. When the level of capital in an object is exhausted, what remains is scrap and waste. We have received an answer to the question of why capital is so important. It is what determines the existence of an animated entity or economic assets.

The process of asset depreciation, the disappearance of capital, is measurable when taking into account the exchangeable market value. The fact of inevitable disappearance of capital potential in an object is described by an equation, the solution of which determines the periodic rate of depreciation:

$$V_p \times e^{-d \times t} = V_k \quad (1)$$

where V_p is the initial value of the object, V_k is the value at the end of its useful life, t is the number of years of operation, and d is the periodic rate of depreciation of the fixed asset.

With the state of knowledge presented, capital appears as an abstract ability to do work, subject to the principles of thermodynamics, so a category analogous to energy in the physical sciences. This is actually not an analogy, but an understanding that energy and its transformations constitute the foundation of knowledge about reality, and the principles of thermodynamics, constitute the laws that drive the universe (Atkins 2007). The aforementioned author points out another feature of energy and capital. Since they cannot be created, they can serve as currency in cosmic accounting (Atkins 2005, p. 118). Therefore, the narrative about the change in the value of money over time is worth replacing with statements about the rate of capital growth and asset depreciation.

In modern history, there are recorded important facts of the existence of knowledge of capital and the measurement of capital growth in management, or profit, such as the work of L. Pacioli published in print in 1494. L. Pacioli recognizes capital as a type of economic power (Ijiri 1993). An important indicator of return on equity (ROE) appears, which, considered over many periods, leads to the formula of compound interest $E_n = E_0 [1 + r]^n$, where E is invested capital, r is average value of ROE, and, n is number of years. This formula is the basic model of economic growth, which respects the fact that capital is not created from nothing. A little later comes physiocratism, in which the role of nature, photosynthesis is the basis of economic considerations. The farmer's work is supported by photosynthesis, and the laborer's work is idle, it is only the transfer of human capital to the object of labor. The farmer usually has no special benefit from this because photosynthesis is a natural good that the free market does not value.

Since the creation of human capital required expenditures, labor, as a transfer of capital, contributes to its preservation in objects, thus stopping the destruction attributed to the second principle. But it is idle; paid at fair value, it does not directly produce a profit. Thanks to the Physiocrats, deep thought about the source of capital growth is revealed. There is also an opportunity to qualitatively define capital.

3. The Relationship of Capital and Time

One may think that the relationship between capital and time is determined by the formula of compound interest. However, this is an over-simplification due to the tacit identification of the number of periods of a process usually denoted by the letter t (like time) with the category of time. It also ignores the problem that time is as puzzling as capital (Dobija and Renkas 2022). There is a simple formula linking capital and time. It is the formula of compound interest. Albert Einstein reportedly said (Inglis 2023) that the compound interest formula is the greatest mathematical achievement of mankind[1]. This shows the good scientific sense of this scientist, but this simple formula only becomes meaningful after replacing duration (t) with the category of time, which leads to a capital growth model. This problem has been solved as a result of studies of the sources of profit earned in the activities of enterprises (Kurek 2012; Dobija and Kurek 2013; Renkas 2016, 2022; Dobija and Renkas 2021).

As a result of this research, a capital growth model derived from the formula of compound interest with continuous capitalization was formulated. Thus, it was assumed that the formula $C_t = C_0\, e^{rt}$ is a key element of the overall capital model. To arrive at a complete model of capital, it is necessary to recognize the structure of the rate (r), which determines the changes in the initial capital C_0. Consideration and theoretical analysis allowed us to arrive at the following rate structure $r = a - s + m$, where s is the rate of capital disappearance, m is capital inflow through labor, a is a natural constant quantifying positive natural influences. Thus, the general model of capital is presented:

$$C_t = C_0 \times e^{-st} \times e^{mt} \times e^{at} = C_0 \times e^{(a - s + m)t}, \; a \geq E(s) = 0.08\ [1/\text{year}] \quad (2)$$

Model (2), among other things, points to the essence of time, which is determined by the trinity (s, m, t), not just the number of periods t (Dobija and Renkas 2022; Dobija and Renkas 2023).

The well-known definition of time given by Isaac Newton (1999, p. 54), before the emergence of knowledge of thermodynamics, is as follows:

> Absolute, true, and mathematical time, in and of itself and of its own nature, without reference to anything external, flows uniformly and by another name is called duration. Relative, apparent, and common time is any sensible and external measure (precise or imprecise) of duration by means of motion; such a measure—for example, an hour, a day, a month, a year—is commonly used instead of true time.

The modified definition of time (Dobija and Renkas 2023) stems from the belief that time in its general sense is a constant process of transformation of the primordial energy of life in the environment of planet earth into resources embodying energy, i.e., the abstract ability to do work. Examples of such resources are trees, coal seams, animals, plants, people, etc. This general definition of time is applicable to all living creatures. But like "money", for example, time is a human concept that is essential to the development of civilization. Consequently, the transformation of the energy of life relating precisely to people is concretizing the definition of time and determining this most important time arrow. Thus, the complete definition, which we believe integrates the convictions of Kant, Leibniz, Newton, and others, presents itself as follows:

> Time is the process of transformation of the stock of primary life energy of modern man into the ability to perform work, i.e., personal human capital. The rate of passage of time is constant and independent of anything. This rate is determined by the natural constant a = 0.08 [1/year].

In this determination, an important element appears; the initial energy of life of modern man and its steady transformation at a rate of 8% per year, resulting in an end of existence of fewer than 120 years as confirmed by scientific research by gerontologists (Vijg and Le Bourg 2017) and others. Taking the maximum of the initial life energy $E_0 = 1.0000$, it is obtained that after the first year $E_1 = 0.9231$, after the second year $E_2 = 0.8521$, after the third year $E_3 = 0.7866$, . . . , while $E_{65} = 0.0055$, and so on. As you can see, this even transformation produces highly nonlinear effects. This transformation makes an infant after the first year of life already look like an adult one-year-old child. The following years also show the rapid growth of a person's capital C, but slowing down. After reaching the age of 65, E is already quite small, which involves some changes in the physical body, as Doctor Ki Bo informed the Yellow Emperor (Maoshing 2012, pp. 22–23). But with this residual E, some people even reach an age close to 120 years, when $E_{120} = 0.000068$. This is because humanity can still use at least two accessible sources of life energy: food and air. For humans, the value of $E_{120} = 0.000067$ sets the biological zero for the function $E(t) = e^{-0.08t}$ at t = 120 years.

As you can see, the category of capital appears in the modern definition of time, and the definition declares that there is a constant transformation of the energy of life into the energy (capital) of man–the source of labor. Labor, in turn, transfers human capital into labor products. In the case of grain cultivation, tree plantations, and other crops, energy from two sources is embodied in the final products; solar energy and the human capital of workers. This composition defines a qualitative explanation of the nature of capital, its sources, and its impressive significance in economic thought.

4. The Natural Constant of Potential Capital Growth

Capital cannot be created. Profitable companies acquire it and accumulate it through revenues from product sales. Human capital grows with the participation of the primary energy of life. Numerous empirical studies make it possible to estimate the average annual rate of capital growth obtained through economic activity. Due to thermodynamic conditions, the rate of growth is determined by a natural constant, extremely important in economic thought. This is the same constant that occurs in the determination of time. Empirical studies have been conducted in various settings: stock market returns when investing in stocks, corporate profits, measurement of human capital, determination of fair labor compensation, the study of wage expectations, level of interest rates when borrowing, as well as biomass and phytomass growth.

Average annual growth of capital invested in stocks. The rate of capital multiplication is limited by the operation of the efficient market and does not exceed the magnitude of 8% per year with a tendency to decrease. This is evident from studies made on the ground of the U.S. economy with regard to the rate of return achieved on stocks and bonds. Relevant data for calculations appeared in the assessment of the "risk premium". This figure, being determined by the difference between the level of the real rate of return and the size of the return on U.S. Treasury Bills, is a component part of the CAPM model (Goetzmann and Ibbotson 2006), which has lost a lot of its appeal at this point.

For the calculation of the rate of return from the data in Table 1, the following procedure will be followed. The value of inflation is subtracted from the values determining stock returns. This gives the value: 12.39% − 3.12% = 9.27%, which is calculated according to the arithmetic mean. In turn, according to the geometric mean, it is 10.43% − 3.04% = 7.39%. It is within this range (7.39–9.27%) that the multi-year average rate of return achieved in the U.S. equity market falls. In the next step, the arithmetic average of these two numbers is calculated, and a value of 8.285% is obtained. As is known in the case of stock market information, as well as corporate earnings reporting, the data specify the value at the end of the year. If the capital multiplies at a rate of 8% on an ongoing basis, then at the end of the year it will reach a multiplication of $e^{0.08} - 1$, or about 8.33%. Therefore, the estimation specifies a = 0.08 [1/year].

Table 1. Summary statistics for returns on stocks, bonds and Treasury Bills in the U.S. (1926–2004).

Specification	Shares	Long-Term Government Bonds	Treasury Bills	Inflation	Real Rate of Return
Arithmetic average	12.39%	5.82%	3.76%	3.12%	9.27%
Geometric average	10.43%	5.44%	3.72%	3.04%	7.39%
Standard deviation	20.31%	9.30%	3.14%	4.32%	8.33%

Source: own compilation based on (Goetzmann and Ibbotson 2006, p. 35).

Returns on invested capital in business units were studied by B. Kurek (2012). He conducted the study on a sample of financial statements of companies belonging to the Standard & Poor's 1500 index over a consecutive 20-year period. The components of the index, i.e., companies clustered in the Standard & Poor's 1000, Standard & Poor's 900, Standard & Poor's 600, Standard & Poor's 500, Standard & Poor's 400 indexes, were taken into account. The study analyzed 22,952 reports. The results of B. Kurk's statistical tests confirmed the hypothesis of a mean risk premium of 8.33% (ex post), which is equivalent to 8% ex ante. The study yielded a confidence interval of 8.25–8.89%, with the mean estimated at 8.57%. Due to the low relative random error (3.75%), the inference was considered completely safe. B. Kurk was concerned with the rate of capital multiplication in entrepreneurship. Therefore, unlike Ibbotson and Goetzmann, who looked for a risk premium by setting their targets, B. Kurek examined the real rate of return, confirming the magnitude of a = 0.08 [1/year].

The economic constant is also revealed in the human capital account, as M. Dobija (1998, 2015) found. He confirmed this on calculations of the minimum wage for a 17-year-old teenager starting work in the U.S. Another study of the size of the economic constant was conducted by W. Kozioł (2011), who, analyzing the wages of a large number of employees of the ABM Solid SA company, statistically confirmed the size of the constant at a = 0.08 [1/year]. Similarly, a study of salary expectations by J. Renkas (2022), conducted on the basis of questionnaires from job seekers in Ukraine, confirmed the existence of a constant at a level very close to a = 0.08 [1/year]. This study also showed that the economic constant manifests itself in the human capital account regardless of the country studied.

Thus, the research initiated by one author in measuring human capital, the results of which now serve in explaining the nature of time, has attracted a large number of researchers, authors of dissertations, books, and articles, such as (Kurek 2012, 2021; Renkas 2013, 2016, 2022; Kozioł 2011; Cieslak 2008; Holda and Renkas 2015; Kurek and Górowski 2020; Kozioł and Mikos 2019; Oliwkiewicz 2020) and others. The studies of these authors repeatedly revealed the constant a = 0.08 [1/year], which, as it turned out, has many applications, particularly in the areas of measuring the growth of employees' human capital, the theory of fair labor compensation, sources of profit and periodic measurement of this figure, and a fair and equitable price for agricultural products.

The main result in human capital measurement theory is manifested by the equation:

$$W(a) = a \times H(a,n,T,b) \tag{3}$$

where W is labor remuneration, a = 0.08 [1/year], n is the number of years of professional education, T is number of years of professional work, b is the learning parameter, and H is human capital. For a person entering his first professional job at the age of 17, Equation (2) takes the form: W(a) = a × H(a). Empirical testing uses the legal minimum wage prevailing in economically developed countries under the law. The correspondence between the calculated wage and the legally established wage is examined.

To illustrate the calculation, we will apply Equation (3) to an American teenager who takes his first job at age 17. Thus, t = 17 years old, the monthly cost of living = $585/mc.

Value of human capital: $C(17) = (12 \times 585)\frac{\exp(0.08 \times 17) - 1}{0.08} = \$254,141$.

Having the calculated value of a person's human capital, the value of a fair wage is calculated. It can not be less than the level of energy loss (s) that naturally occurs in the body of an adolescent. The relationship s ≈ a is taken and the wage is calculated:

Calculated annual salary: W = s × C = a × C = 0.08 × $254,141 = $20,331.

Calculated hourly wage = $20,331: 12 mc: 176 h = $9.63/h.

Adjusting the hourly rate to the employer's contribution to social security (6.2%) and medicare (1.45%), we arrive at a theoretical hourly rate of $8.95/h. This rate is in line with the federal government's rate, which is set at $9.00/h.

The manifestation of the economic constant a = 0.08 [1/year] in economic life is also found throughout history. According to Pikulska-Robaszkiewicz (1999, pp. 41–42), in the Roman Republic, the interest rate on lending was legally limited and defined as 1/12 of the capital, or 8.33% per year. As Litewski (1994, p. 242) writes, "At the end of the Republic, the highest interest rate allowed was 12% per year". Emperor Justinian's reforms introduced the rule that bankers could charge a maximum of 8% and others 6% except for the magnates called "illusters," who should not demand more than 4%. In addition, overdue interest could not exceed the principal. There was also a ban on charging interest on interest. Large risks could be included in sea loans (Litewski 1994, p. 267). In ancient times, these were determined by contract, with no limit on the amount. Emperor Justinian also limited the rate to 12%.

It is worth noting in these examples, the existence of a distinguished rate referring to the constant a = 0.08 [1/year], which explicitly takes into account natural growth through the forces of nature. By introducing these restrictions, Emperor Justinian exempted contracts from ruinous, unreasonable interest. It took into account, consciously or not, natural laws, in particular, the potential rate of capital growth realized by the forces of nature with the participation of the factor of human labor. As is well known, human labor largely offsets the destructive impact of the second principle. Painting a car body significantly extends its life. As is well known, J.B. Clark considered capital as a permanent fund that automatically generates productivity in the form of interest (Huerta de Soto 2009, pp. 386–89). The concepts of capital as a homogeneous fund that automatically and synchronously generates income were supported by I. Fisher and F.H. Knight. These are indications of the existence of a natural rate of interest, as written about by Garrison (2006).

Thinking in terms of thermodynamics requires respect for the principle of conservation. It is necessary to identify the source of this fund and its growth, which will justify the occurrence of the interest rate. The current understanding of capital as a composition of life energy and solar energy explains the sources of its origin. We even know that celestial (high-energy) photons reach the planet earth and infrared (low-energy) photons depart, the number of which was calculated by Greene (2020, p. 141). The author writes: " . . . Photons from the Sun are low-entropy food that plants absorb and use for life processes, and then release as degraded high-entropy waste. For every photon received from the Sun, the Earth sends back into space less ordered and more dispersed two dozen energetically degraded infrared photons . . . "

What rate of capital growth is revealed in the earth's living system? We know how human capital increases, but what is it like in the plant kingdom? It turns out that natural annual increments in nature also refer to a constant as the lower end of the growth rate. As an example, we will use data from biomass growth studies (Sporek 2013). The author describes the results of research conducted on the rate of forest biomass formation and its bioenergetic potential. The purpose of the study was to determine the value of energy that is accumulated in the biomass of Scots pine (*Pinus sylvestris L.*) in the first-age class. Within the framework of the field research, stands with different numbers of years were established. Model trees were felled after 5, 8, 12, 15, 17, and 19 years. The calculation resulted in the following measurement of the energy potential in units (MJ): 15, 19, 69, 96, 94, and 146 (MJ).

Based on the above values, we determine the average annual growth rate. To do this, we create three subgroups from the years (5,8), (12,15), and (17,19). For the first subgroup, the result is 19/15 = 1.26666667, which gives an average annual biomass growth of 0.0888888889, or about 9%. For the second subgroup, the result obtained is 96/69 = 1.391304348, which gives an average annual increase of 0.130434783 (or 13%). For the third subgroup, the result is 146/94 = 1.553191489, which gives an average annual increase of 0.184397163 (or 18%). The calculations presented here support the view that the average growth rate of biomass in the plant kingdom exceeds the value of a constant magnitude set at a = 0.08 [1/year].

A broad field of research is the weight gain of phytomass in forest crops. Phytomass stock represents the quantitative estimate of the total weight of all plant organisms or individual plants in a given area at a given time (Fitomasa 2023). Gabdelkhakov (2005) in his research showed that the annual production (growth) of phytomass of linden stands measured in tons per hectare averaged 15.56 t/ha/year. With an initial phytomass value of 172.82 t/ha, the annual increment is 9%. This ratio in forest communities reaches 9–10% per year. As can be seen, the annual growth rate of phytomass is not less than 9%.

In the absence of a full understanding of capital, labor, value, and money, one could think, as Aristotle and St. Thomas Aquinas did, "Money is sterile and cannot give birth to new money". Taking interest on borrowed capital, Aquinas considered *maxime praeter naturam*–against nature. Metaphors do not always relate to reality. Money is an asset whose value is determined by the content of the capital it represents. Capital is uncreated but flows into the earth's living system thanks to the sun. Active economic activity is the way to acquire it, but it cannot be started without initial capital and conducted without adequate working capital. Therefore, borrowing is necessary, and honest banking is the basis of the economy and its development.

5. The Natural Structure of the Discount Rate

The discount rate is mainly necessary for accounts lasting for many periods. Then the calculation must be reduced to a fixed point on the time axis (we should say; on the duration axis). These are familiar issues, but to illustrate discounting, let's consider an example. Here, a man with the competence of a professional driver decides to start a transportation business. He has a capital of 100,000 euros. He acquires a vehicle, adequate working capital, a parking space, pays the appropriate fees, and starts the business. As an employee in the business, he records the cost of maintaining himself as a business expense. In the first year, he achieves a cash-flow of 20,000, and in the second year his cash flow is 15,000. Disappointed somewhat, he sells the business for 73,000 and terminates the business.

The internal rate of return (IRR) equation is derived from the data:

$$100(1 + p)^2 = 20(1 + p) + 15 + 73 \quad (4)$$

That is, $100z^2 = 20z + 88$ and $z^2 = 0.2z + 0.88$, $z = 1 + p$, where p is the interest rate.

Solving Equation (4) ($\Delta = 3.56$, $\sqrt{\Delta} = 1.8868$) yields z = 1.0434, so p = 0.0434, or (4.34%). The investor's disappointment was justified, though not striking. After all, he had no losses, and his living expenses were covered, which means he was getting paid and earned a not inconsiderable profit. However, the profits deviated from the natural 8% achieved in business, resulting in the undervaluation of the fund to cover risks (reduced opportunities for growth and duration in the market).

Note that Equation (4) was written for a specific point in time; the end of the second year, so capitalization factors are present. Dividing this equation by $(1 + p)^2$ we get a formula with the discount factors used to calculate present values. Of course, the magnitude of p is identical to that previously calculated.

$$100 = \frac{20}{1+p} + \frac{88}{(1+p)^2} \quad (5)$$

On the basis of the considerations presented about the economic constant of potential growth, the general theoretical form of the discount factor obtains the form $[1 + p(a)]^{-t}$ or $e^{-p(a)t}$ if capitalization is continuous, where a = 0.08 [1/year], and t is the number of periods of the economic process. The function p(a) indicates the fundamental dependence of the discount rate on the constant a = 0.08 [1/year]. This function can take the form p(a) = a + b, where b is the percentage of increase or decrease due to project risk assessment.

Thus, the proposed capitalization or discount rate is a function of natural forces, its constant part is not the risk-free rate but the natural constant that determines the rate of capital growth in the earth's living system. This fixed part contains an element of uncertainty, the existence of which follows from the second law of thermodynamics. Adjusting the constant part for the personal risk of a given project cannot have a strict theory, so it is not considered here. The amount of "b" added to the prime rate represents this increase in the discount rate, which forces the selling price of products to increase so that a fund is created for the emergence of losses due to increased risk. The sum of experience in this regard is enormous, so the procedures used in practice to increase the discount rate due to various risks do a good job. Excessive increases in the capitalization or discount rate limit the competitive free market. Similar opinions apply to reducing the base rate. It is known that a deposit made in a law-abiding country in a well-run bank, with virtually no risk of losing the deposit, cannot count on an interest rate of 8% because the risk of achieving a multiplication of capital has been assumed by the bank, and it is to the bank that the 8% is due. Another thing is that it is difficult to find such states nowadays.

There is another important difference between the well-known discount theory and the one proposed here. Note that the letter "t" in the discount factor, traditionally referred to as the passage of time, actually stands for the number of periods of the process. Time is revealed in all its glory in the thermodynamic approach to the discount rate theory. Only the new formula $[1 + p(a)]^{-t}$ takes full account of time since it includes a pair of variables (a, t); the time-lapse constant and the number of periods. As can be seen, the constant plays a dual role; it quantifies the effect of natural forces on the economy and the passage of time, and these are important elements that shape the discount rate and the theory called "capital budgeting". This theory is an important part of economic knowledge and has served humanity well, as also evidenced by the UNIDO "Manual for the Preparation of Industrial Feasibility Studies" published in 1991 by Behrens and Hawranek (1991). Enriched with a thermodynamic basis, the discount rate theory makes this knowledge similar in meaning and precision to natural sciences.

6. Conclusions

Understanding time introduces new possibilities for the development of economic thought, so the modification of the discount rate structure is a natural example. Note that time in the earthly system of life results from the transformation of the energy of life into capital, that is, in general, the abstract ability to do work. It is natural that in the definition appeared the arrow of time of man, the most conscious being on the earthly plane. Nevertheless, every living being contributes to the growth of capital. Even bacteria contribute to the fact that we have cream and butter. The authors (Bejan and Tsatsaronis 2021) describe thermodynamics as the science of the driving force of fire. Let's note that burning wood or coal fire brings out the energy inside it thanks to the processes of life, a transformation that locates there the compositions of solar energy and life–seen in economic science as capital.

The constant as the main component of the interest or discount rate brings a lot of content and meaning to this quantity. It defines the lower end of the rate of growth in the plant world, the rate of growth of man's capital, gives a good approximation of the rate of dissipation of this capital, determines the level of possible fair profit from economic activity, and also determines the course and end of time for man. As Lagos writes (Lagos 2012, p. 333), the exchange of matter with nature and society is a source of pleasure and joy for man. Since this exchange has a limited duration, time for man is a fundamental value, and such a value is also existence. The above statements are the main axis of scientific and philosophical considerations in terms of the triad: ethics–economics–time and the fragments of economic knowledge using the discount rate are among the momentous and lasting theoretical and practical achievements.

The recommendation to entrepreneurs from the above considerations regarding the practical determination of the discount rate for capital budgeting decisions is simple and straightforward. Take 8% as the starting rate, since in nature we see growth at least at this level, and it is also the percentage that determines fair wages for labor. Capital providers also expect to be paid at this level. Increase the rate further by analyzing the project. Increase production capacity to meet existing demand? Increase by 2–4%. A new product? Increase by another 2–4%. Extra risks, like threatened embargoes, sanctions, or broken supply chains? Add another 4–5%. A political threat, possible warfare? Rethink whether to abandon the project. The validity of these recommendations is underscored by the fact that entrepreneurs have long developed such pragmatics using the experience of existing and operating in the earthly system of life.

The development of evolutionary knowledge is changing many of the stagnant views of reality. Moving away from notions of nature as a constructed machine opens the way for the formulation of the theory of evolutionism, which introduces a changed picture of the world. One element of this picture is the understanding that present constants are not absolute. In fact, as Sheldrake (2020, p. 113) writes, the values of constants are subject to periodic changes and specialists periodically adjust them. It is natural that the constant of potential capital growth, which affects many important economic issues (wages, profits) can evolve. This requires various studies with a great awareness of the complex role of labor in the processes of profit creation and the formulation of principles of fair remuneration. It is a fact, however, that this constant at 8% has been manifesting itself in economic matters since the days of Republican Rome and continues to reveal itself at this level until now.

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Note

[1] Albert Einstein is credited with discovering the compound interest rule of 72. Referring to compound interest, Albert Einstein is quoted as saying, "It is the greatest mathematical discovery of all time".

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