Hardwiring Sustainability into Financial Mathematics and Implications for Money Mechanics

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European Central Banks Event

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Abstract

This paper discusses the necessity to hardwire sustainability into financial mathematics for effective change of trajectory for humanity and planet. All initiatives that fall short of transforming our equations of value and return in financial and monetary economics, while positive and encouraging, will ultimately prove to be a distraction. To achieve the hardwiring of sustainability into financial mathematics, we start by introducing space as a dimension of analysis, and by entrenching our responsibility for impact on and in space, our physical context, into the value framework of finance theory and practice. This is necessary due to the omission of space and context parameters from our models and equations, a fact that may explain the current suboptimal outcome we face. As we introduce the analytical dimension of space, and its many layers, we define the nature of that relationship through the Space Value of Money principle, a complementary principle still missing in our framework: 'a dollar invested in space must at the very least have a dollar's worth of positive impact on space.' What follows is a set of new equations that complement the discounting of future expected cash flows, with the compounding of the space impact of cashflows. If investors must abide by the space value of money principle, and apply the equations that follow, then so must money creators, whether commercial or central banks. This implies a reassessment of instruments used by money creators and reveals a number of systemic implications for money mechanics. Specifically, a space-adjusted value framework and mathematics reveal three key challenges with debt-based money: calendar time, monetary gravity, and monetary hunger. The paper proposes an alternative money creation logic, space value creation, and proposes Public Capitalisation Notes (PCN) as a possible monetisation instrument – which leads to the concept of Value Easing, an alternative to Quantitative and Credit Easing, that can be used to fund the transition and other evolutionary challenges and investments.

Keywords: Sustainability, Financial Mathematics, Money, Value, Risk, Time, Space, Impact
JEL: E00, E58, G00, G30, Q51

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[1] This paper is a theoretical discussion built around the main propositions of 'The Space Value of Money: Rethinking Finance Beyond Risk and Time' (Papazian, 2022). https://doi.org/10.1057/978-1-137-59489-1

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Table of Contents

List of Figures

List of Tables

List of Charts

1. Introduction

The evidence confirming human responsibility for climate change has been overwhelming (IPCC, 2022, 2021, 2018, 2013). In a recent report IPCC (2023) summarises the challenge as follows:

> Human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals. (IPCC, 2023, 4)

Since 2015, the targets of the Paris Agreement (UNFCCC, 2015), to keep world temperature increases below *2°C* above preindustrial levels and ideally limit the temperature increase to *1.5°C*, have become an integral part of daily business and financial rhetoric. The operationalisation of sustainability in our daily institutional and organisational practices has become a defining theme across many fields and industries. Responding to the challenge, the finance industry and discipline have been actively developing a number of standards and frameworks for that purpose.

One of the key frameworks for the alignment of investment portfolios with our climate targets is the voluntary TCFD framework focused on the risks, opportunities, and financial impact of climate change, proposed by the Financial Stability Board – Task Force on Climate-related Financial Disclosures (TCFD, 2017). It is aimed at helping the industry self-regulate and adjust to the needs and requirements of the transition to a Net Zero economy (IEA, 2021). Simultaneously, going beyond emissions as such, growing attention is being rightfully directed at nature and biodiversity loss (IPBES, 2019; TNFD, 2021; CISL, 2020).

The initiatives are many, from summary buzz words like ESG (Environmental, Social, and Governance factors), to frameworks, standards, initiatives, and alliances, we are now faced with a plethora of acronyms to choose from: TCFD, TNFD, ISSB, SASB, NZBA, GFANZ, CDP, GRI, RTZ, NZIA, NZAOA, NZAMI, PRI, etc.[3] While all these initiatives are positive developments and aim to contribute to our transition to a more sustainable world, we are still, it seems, a few steps short of effective change of trajectory.

Indeed, just as an example, a bank that supports all the above mentioned acronyms and their initiatives, HSBC, was recently in the news for extending "a revolving credit facility to an energy

[3] Task Force on Climate-related Financial Disclosures, Taskforce on Nature-related Financial Disclosures, International Sustainability Standards Board, Sustainability Accounting Standards Board, Net-Zero Banking Alliance, Glasgow Financial Alliance for Net Zero, Carbon Disclosure Project, Global Reporting Initiative, Race To Zero, Net Zero Insurance Alliance, Net Zero Asset Owners Alliance, Net Zero Asset Managers Initiative, Principles of Responsible Investment.

company that is tearing down a German village to expand a large coal mine, despite its promise to 'phase down' fossil fuel financing" (Martinez, 2023).

At COP26 in Glasgow, in November 2021[4], the UK's Chancellor of the Exchequer at that time made the announcement that we must rewire the global financial system. Indeed, to truly rewire the global financial system, to reinvent human productivity, we must understand how we ended up in our current predicament - why we have tolerated such levels of pollution and waste in our air, rivers, oceans, land, and even outer space.

> One of the main reasons for such a suboptimal outcome can be found in our financial value framework, in the principles of finance that have governed financial education and training, our markets and investments. The root cause is in the value equations of core finance theory and practice, in the equations that have been, and still are, focused on risk and time, serving one stakeholder, the risk-averse return maximising investor. (Papazian, 2022, 3)

The recent momentum in sustainable finance, or ESG integration, or impact investing, or climate finance, has not yet transformed the core equations of value and return that we teach and apply in finance theory and practice, i.e., our financial mathematics. Moreover, no new equations of value seem to have been proposed that can replace our old models. Indeed, very often, ESG integration into the investment value chain has resulted in adjustments to variables in our existing models (PRI, 2016; Papazian, 2022).[5]

Moreover, neither ESG integration nor climate finance (or impact investing or responsible investing) consider money mechanics a relevant subject. The sustainability effort/rhetoric, in finance industry and academia, seems to be focused on standards, scores, ratings, and frameworks that aim to operationalise sustainability at the level of investments, instruments, portfolios, and businesses, public or private. The logic of the value of money, and the equations that define its creation, allocation, and deployment are not part of the discussion. Money creation is assumed to be exogenous to the sustainability or ESG challenge/opportunity.

Given the theoretical and practical traditions in the finance discipline and industry, and recent market history in 2008, and very recently in 2023, given more than half a century of financial education built around risk and time, we cannot expect consistent, effective, and global change across industry and business unless we rethink the mathematics that underpins our financial and monetary decisions across this planet.

This rethink must begin with a reassessment of our financial value framework. A framework built around the risk and time value of money, serving the risk averse mortal investor, where a pollution-averse planet and an aspirational human society are considered exogenously to the

[4] The UK hosted the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow between 31st of October and 13th of November 2021.

[5] The relevance and reliability of ESG ratings has been extensively debated in industry and academia from a variety of perspectives (Boffo, et al., 2020; Boffo and Patalano, 2020; Berg et al., 2022; and many others). Please see chapter three in Papazian (2022) for a detailed discussion of sustainable finance and ESG integration.

models, as externalities, or, through a qualitative addendum on corporate social responsibility. Our new financial mathematics, therefore, must begin by making humanity and planet equal stakeholders of our financial models alongside the mortal risk-averse return-maximising investor.

To address the evolutionary challenges we have created for ourselves, and climate change is only one of them, we need to redefine the value of money beyond risk and time. In truth, we have an entire analytical dimension missing in our financial value framework, i.e., space. Our equations, geared towards assessing the value of cash flows vis-à-vis risk and time, omit the space impact of cash flows and assets in the value equations of those cash flows and assets. In other words, with the omission of space as an analytical dimension our models have also ignored space impact, and absolved investments and investors of their share of responsibility.

The paper is divided into 4 main sections:

Section 2 explores our current value framework built around risk and time and identifies the key omissions in our mathematics of value and return that have led us to our current predicament.

Section 3 introduces the missing dimension of analysis, i.e., space, and the missing principle of value, i.e., space value of money, and proposes a set of new equations that could be used to hardwire sustainability into financial mathematics.

Section 4 addresses the implications of such a transformation for money mechanics. If investors must abide by the space value of money principle and ensuing equations, then so must money creators, whether commercial or central banks. The section considers the challenges of our current architecture given a transformed value framework.

Section 5 summarises the argument and concludes the paper.

2. The Risk and Time Value of Money

Since the early beginnings and for many decades, the value framework of the finance discipline has been built to serve the mortal risk-averse return-maximising investor. The human collective and the planet have been exogenous to our models, as externalities or corporate social responsibility. This focus is explained and mirrored by the two key principles of value that have shaped finance theory, practice, education, and research. Indeed, the analytical value framework of the discipline has been built around two key principles of value, 1) Risk and Return, and 2) Time Value of Money (See Table 2).

I have added the adjective 'mortal' to better describe the main stakeholder of finance theory and mathematics. This is so because Risk and Time are very mortal concerns. An immortal investor would be far less concerned with time and/or risk. This is important to note because from the perspective of the human collective, which can procreate and secure its continuous existence, evolutionary continuity in space would most likely take precedence to risk and time concerns.

Table 2 The core principles of finance theory and practice* *(Source: Author)*

Stakeholder	*Risk*	*Time*
Risk-Averse, Return-maximising, Mortal Investor	***Risk and Return*: The higher the risk the higher the expected return—**	***Time Value of Money*: A dollar ($1) today is worth more than a dollar ($1) tomorrow—**
	given the risk-averse nature of investors, higher risks imply higher expectations of reward.	because a dollar today can earn interest/return by tomorrow and be more than a dollar by tomorrow.

In truth, these principles of value discriminate against our evolutionary investments. The biases these principles introduce are revealed through a basic profiling of the risk and time features of our evolutionary challenges/investments – the Net Zero transition is one such challenge, but it is not the only one. All our evolutionary challenges require investments in the present that carry *very high risks* and *distant returns*. Two features that are negatively priced based on the current principles of value that underpin every equation we have and teach in the field.

A review of academic and industry literature can confirm the above observations. The Risk and Return and Time Value of Money principles have defined and continue to define the analytical content and equations of finance theory and practice. Brealey, Myers, and Allen (2020), a 13th edition core textbook in corporate finance, built on the wider academic literature, is a typical example. Similarly, in Pike, Neale, Akbar, and Linsley (2018), a 9th edition textbook on corporate finance and investment, and Watson and Head (2016), a 7th edition principles and practice handbook for corporate finance, we observe the same framework and principles at work.

In the professional banking and finance literature (Choudhry 2012, 2018) we can see evidence of the same. In investment valuation (Damodaran 2012, 2017), and company valuation (Koller et al. 2015, Koller et al. 2011), we encounter the same fundamental principles in action. In project finance (Yescombe, 2014), in investment banking (Rosenbaum and Pearl 2013), in property valuation and investment (Isaac and O'Leary 2013). All of the above are based on the foundational academic literature where the same can be observed in our models and equations of value and return (Williams, 1938; Graham and Dodd, 1934; Graham, 1949; Gordon and Shapiro, 1956; Markowitz, 1952; Modigliani and Miller, 1958; Ross, 1976; Sharpe, 1964; Lintner, 1965; Reinganum 1981; Lakonishok and Shapiro, 1986; Fama and French, 1992, 1996, 2004, 2015; and many others).

The current principles of value in finance theory leave our evolutionary investments in a blind spot. By negatively pricing distant returns and high risks, our financial value framework misprices our evolutionary investments. In fact, today, our evolutionary investments become plausible and 'affordable' only when they can be made to make sense within the preference framework of the mortal risk-averse return-maximising investor. A theoretical and practical misconception that could well explain our current predicament.

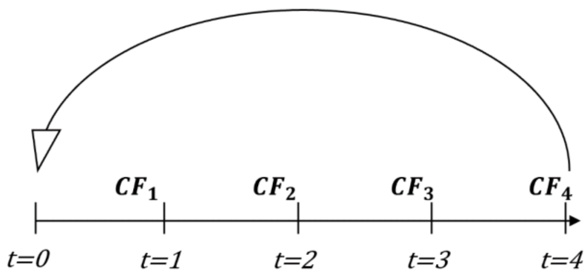
2.1. Equations without Space, without Context or Impact

The internal biases introduced by the current principles of value in finance identify the need to revise the framework and the resulting equations with a much broader perspective. After all, how can we even begin to address sustainability (in ESG form or other), if our core principles and equations are working against our very own purpose, human evolution and planetary sustainability.

To identify what is missing in our framework and mathematics of financial and monetary value, this section takes a closer look at our equations. To start at the very beginning, we must consider one of the most commonly used methods of valuation in finance, i.e., cash flow discounting. This, interestingly, takes us to the 13th century. While financial mathematics uses discounting in almost all value models across different lines of application, it does not always reveal the origin of this key valuation method.

A recent working paper by Goetzmann (2004) tracks the discounting method to Leonardo of Pisa or Fibonacci in 1202. Goetzmann finds evidence that in his Liber Abaci, *The Book of Calculation*, Fibonacci (1202) was the first to develop the present value analysis for comparing the economic value of alternative contractual or expected cash flows.

Fig. 2.1 Discounting Future Expected Cash Flows



Today, across stock, bond, asset, project, firm, and all cash flow valuation equations taught and used in the finance discipline and industry, discounting is used to measure the time and risk value of money. The risk is introduced and 'quantified' through the use of a discount rate that represents the market rate or rate of return on an alternative investment with the same level of risk as the instrument/opportunity being assessed.

In Table 2.1 you can find a sample of bond, stock, asset, firm, option, and cash flow valuation equations. Naturally, this is not a comprehensive list of models and equations in finance, but it is a representative one. Indeed, many of them have defined the course of theoretical development in the field. While not all use discounting (like CAPM and other asset and option pricing models), they are all built around risk and time, using proxies for both to value the expected future cashflows.[6]

The equations in Table 2.1 reveal a financial mathematics without any contextual parameters. Our financial mathematics seems to be missing the analytical dimension of *where*. Cashflows are assessed in a risktime universe, abstracted from our physical context, serving the risk-averse mortal investor, without any direct mathematical reference to planet and humanity. In truth, our financial value framework is missing the analytical dimension of *Space* - our physical context stretching from subatomic to interstellar space and every layer in between and beyond. By and through this omission, our equations have also abstracted away responsibility of space impact.[7]

This is the theoretical and mathematical junction where we have ignored our context and our responsibility of impact, causing unprecedented environmental degradation, a climate crisis, and a host of socioeconomic challenges. It is the level and degree of this misconception that also explains why adjusting variables with ESG considerations will prove to be an ineffective strategy and a poor conceptualisation of sustainability in finance theory and practice.

[6] In parallel to the equations in Table 2.1, the risk and time focus of the discipline is also revealed through the vast literature on stock market predictability, discussing market efficiency, random walks, and overreaction in the context of risk-adjusted returns (Papazian, 2022; See also Fama, 1970; Malkiel, 1973, De Bondt and Thaler, 1984; Dissanaike, 1994,1997, Xi et al., 2022; and others)

[7] A similar omission can be observed in company valuation literature. Please see Koller et al., 2015, Koller et al., 2011.

Table 2.1 Sample Core Finance Equations: Bonds, Firms, Stocks, Assets, Options

Sample Bond Valuation Equations

$$Bond\ Price = \sum_{i=1}^{n} \frac{C_i}{(1+r)^n} + \frac{F}{(1+r)^n}$$

$$Bond\ Price = C \times \left(\frac{1 - \left(\frac{1}{(1+r)^n} \right)}{r} \right) + \frac{F}{(1+r)^n}$$

$$Bond\ Price = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} + \frac{P}{(1+r)^n}$$

$$Bond\ Price = \sum_{t=1}^{n\times m} \frac{CF_t}{\left(1+\left(\frac{r}{m}\right)\right)^t} + \frac{P}{\left(1+\left(\frac{r}{m}\right)\right)^{n\times m}}$$

$$Bond\ Price = \left(\frac{C}{m}\right) \times \left(\frac{1 - \left(\frac{1}{\left(1+\frac{r}{m}\right)^{n\times m}} \right)}{\left(\frac{r}{m}\right)} \right) + \frac{P}{\left(1+\frac{r}{m}\right)^{n\times m}}$$

Sample of Stock and Firm Valuation Equations

$$P_0 = \frac{D_1}{r-g}$$

$$P_0 = \sum_{t=1}^{\infty} \frac{D_t}{(1+r)^t}$$

$$P_0 = \sum_{t=1}^{n} \frac{D_t}{(1+WACC)^t} + \frac{P_n}{(1+WACC)^n}$$

$$P_0 = \sum_{t=1}^{n} \frac{D_t}{(1+WACC)^t} + \frac{D_{n+1}}{(WACC-g).(1+WACC)^n}$$

$$Firm\ Value = \sum_{t=1}^{n} \frac{D_t}{(1+WACC)^t} + \frac{FCFF_{n+1}}{(WACC-g).(1+WACC)^n}$$

Sample of Asset Pricing Models

$$R_i = R_f + \beta_i \times (R_m - R_f) \qquad Beta_i = \beta_i = \frac{Covariance_{R_i,R_m}}{Variance_{R_m}}$$

$$E(R_i) - R_f = b_1\big(E(R_M) - R_f\big) + s_i E(SMB) + h_i E(HML)$$

Modigliani Miller Corporate Value and Capital Structure Model

$$V_j = \left(S_j + D_j\right) = \frac{\overline{X}_J}{\rho_k}$$

$$i_j = \rho_k + (\rho_k - r)\frac{D_j}{S_j}$$

Black and Scholes Option Pricing Model

$$C = SN(d) - Le^{-rt}N(d - \sigma\sqrt{t})$$

$$d = \frac{\ln\frac{S}{L} + \left(r + \frac{\sigma^2}{2}\right)t}{\sqrt[\sigma]{t}}$$

NET PRESENT VALUE CASH FLOW VALUATION MODEL

$$NPV = \sum_{t=0}^{T}\frac{CF_t}{(1+r)^t} \qquad NPV = CF_0 + \sum_{t=1}^{T}\frac{CF_t}{(1+r)^t}$$

$$\boldsymbol{N}et\ Present\ Value = -\ II + \sum_{t=1}^{n}\frac{CF_t}{(1+r)^t}$$

See Brealey, Myers, and Allen (2020), Pike, Neale, Akbar, and Linsley (2018), Watson and Head (2016), Fama and French (1996, 2004, 2015), Gordon and Shapiro (1956), Modigliani and Miller (1958), Ross (1976), Sharpe (1964), Lintner (1965), Merton, 1973; Nobel Prize (1997) and others.

2.2. Discounting the Non-Actual, while Omitting the Actual

Our current financial value framework built around risk and time, serving the mortal risk-averse return-maximising investor, has inbuilt biases against our evolutionary investments, and has an entire dimension of context, i.e., space, missing from the equations of value and return it teaches and applies in theory and practice.

Interestingly, our financial mathematics, through our models and equations, reveals yet another key architectural shortcoming - a bias towards the non-actual figures, i.e., cash flows in the future. While this in itself could be considered a harmless focus, combined with the omission of space and responsibility from our models, it can further explain our current predicament.

Taking as an example the Net Present Value (NPV) equation, which epitomises a risk and time-based financial mathematics, we notice as in Eq. 1, that the mathematical focus is on the imaginary future expected cash flows rather than the actual space impact of investments – which are treated only with a '-' sign to denote an outflow. [8][9]

$$\boldsymbol{N}et\ Present\ Value = \boxed{-\ II} + \boxed{\sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}} \tag{1}$$

$n = Time\ Horizon$

$t = Moving\ time$

$r = Discount\ Rate$

$II = Initial\ Investment$

$CF_t = Future\ Expected\ Cash\ Flows$

Actual Non-Actual

There are two parts to this equation. The first part, the actual part, which is what we would be investing to be able to expect the future expected cash flows, the initial investment (*II*), and the second part, the non-actual part, the expected future cash flows. Future expected cash flows are non-actual or imaginary because they have not happened yet. They may happen, or they may not (as expected or agreed). If these cash flows were guaranteed, there would be no need to discount

[8] The NPV equation is sometimes written in the below formats, where the first cashflow CF_0 (II) is included in the right-side term as the first cash flow at t=0, or excluded but without the negative sign as the negative sign of the first cash flow CF_0 is assumed:

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \qquad NPV = CF_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t}$$

[9] The Net Present Value equation (NPV) is one of the most commonly used equations. Indeed, Graham and Harvey (2002) reveal that Net Present Value (NPV) is one of the most frequently used capital budgeting techniques by CFOs, along with the internal rate of return (IRR), which is the discount rate that equalizes NPV to zero.

them into the present to account for their riskiness. Naturally, applying a discount rate to the future expected cash flows does not make the cash flows any less non-actual, or more real.

The certain element in the NPV equation is the initial investment (II), and it is treated with a negative sign. This indicates an outflow for the investor. Meanwhile, the non-actual part is mathematically treated for time and risk. This reveals a mathematical attention entirely focused on the expected cash flows in the future, while the investment, that which is most certain in the present, is treated simply with a minus sign. The impact of the initial investment is abstracted away along with the dimension of context and space.

> The omission of space happens when we ascribe an abstract negative sign to the initial investment, disregarding it entirely as a real process with a space impact. Indeed, the assessment of impact can be achieved by digging deeper into the many aspects of the investment and its deployment. In other words, the omission of space and space impact occurs when our treatment of the initial investment is defined and limited to ascribing a negative sign to denote an outflow for the risk-averse investor without further analysis or consideration of its utilisation and impact on the environment, on society, on space. (Papazian, 2022, 24)

Given the omission of context from our financial mathematics, given the omission of space from our equations, given the biases against our evolutionary investments, given the focus on the mortal risk-averse return-maximising investor as only stakeholder, given the mathematical attention of our models on the future non-actual expected returns and the abstraction of actual space impact, can we be surprised with the current state of the world?

It is very hard to visualise a sustainable world when the equations that underpin billions of financial and monetary decisions across the planet are still based on risk and time alone, without context parameters and without consideration of impact. Indeed, this is why ESG ratings, Implied Temperature Rates (TCFD-PAT, 2021, 2020; CISL, 2021a, 2021b), and similar misalignment indicators cannot lead us to a transformed human productivity. We need to attend to the climate crisis and reinvent our value chains to not only reduce emissions, but also all pollutants and waste we have left behind (here) in every environment we have come to touch.

The carbon in our air, the plastic on our oceans, the sewage in our rivers and beaches, the chemical waste in landfills, the radioactive waste under the ocean bed, and the debris in orbit, etc., require a radical rethink of our value paradigm and financial mathematics so that we can effectively change trajectory and ensure the sustainability and continuous expansion of human productivity.

3. Introducing Space into RiskTime Finance

As the previous discussion revealed, the finance discipline and industry have operated in a world without 'space', without context, and without considering the impact of investments on and in space as an integral element of the value of investments. This section begins by defining space as our context, and goes on to introduce the new, and yet missing principle, the space value of money – the principle that ushers in the space-adjusted financial mathematics where responsibility and sustainability are hardwired in our equations of value and return.

3.1. Space

Space is the dimension of 'where' and refers to our physical context. A physical context of matter that stretches from the world of atoms, inside matter, to the planet, its core, surface, atmosphere, and outer space. Indeed, space is defined as our physical context from subatomic to interstellar space and every layer in between and beyond. Fig. 3.1 provides a broad overview of the layers of space we affect and have interacted with (Papazian, 2022, 130).

Fig. 3.1 Space Layers *(Source: Papazian, 2022)*

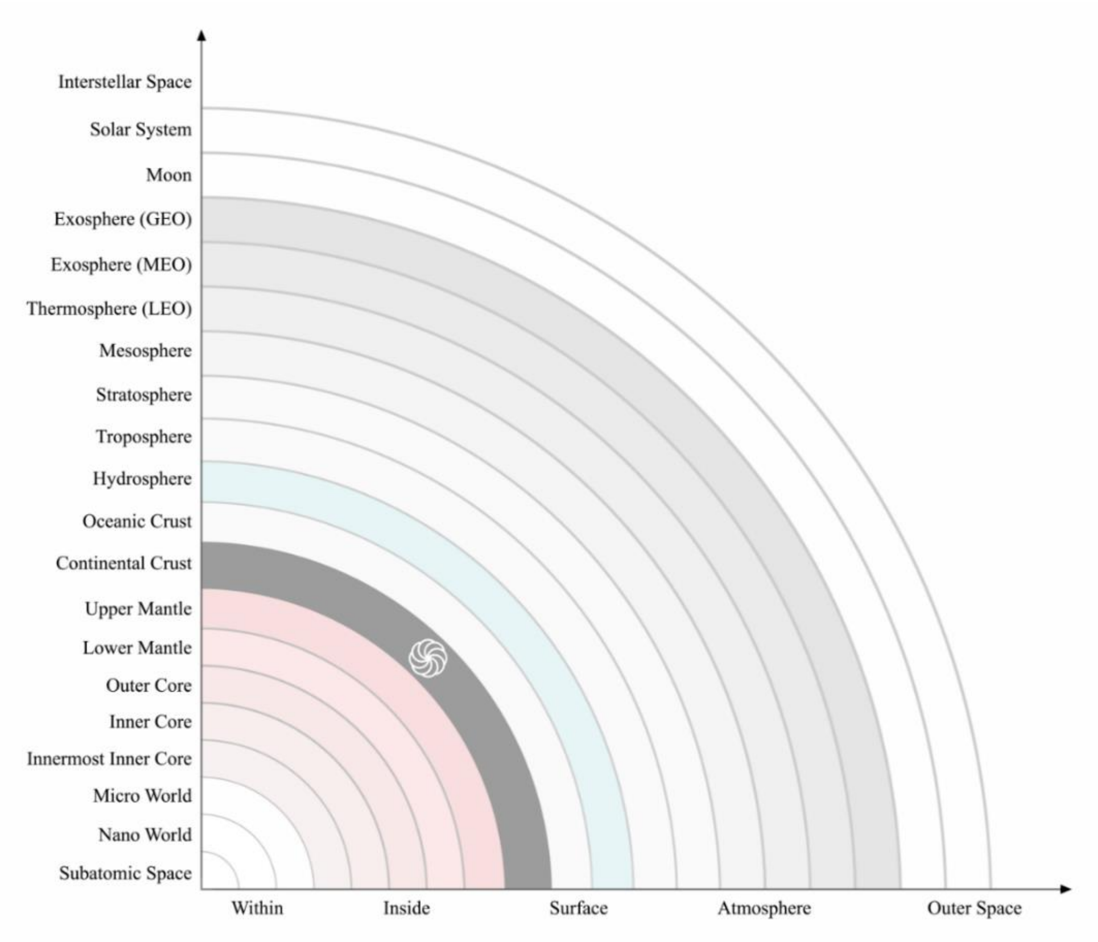


Table 3.1 Space layers further details: hydrosphere and continental crust
(Source: Papazian, 2022)

Space Layers	Sub-Layers		Sub-Layer Type Examples
	Seas, Lakes, Rivers, Ice Sheets		Tectonic lakes
			Volcanic lakes
	Oceans		Glacial lakes
		Epipelagic Zone - The Sunlight Zone	Fluvial lakes
Hydrosphere		Mesopelagic Zone - The Twilight Zone	Solution lakes
		Bathypelagic Zone - The Midnight Zone	Landslide lakes
		Abyssopelagic Zone - The Abyss	Aeolian lakes
		Hadal Zone - The Trenches	Shoreline lakes
			Organic lakes
			Anthropogenic lakes
			Meteorite lakes
	Land Surface		Tundra
		Mountains	Taiga
		Built Up	Temperate broadleaf and mixed forest
			Temperate steppe
			Subtropical moist forest
		Vegetation	Mediterranean vegetation
			Tropical and subtropical moist forests
Continental Crust		Cropland	Arid desert
	Soil		Xeric shrubland
		O Horizon - Organic Layer	Dry steppe
		A Horizon - Top Soil Nutrient Layer	Semiarid desert
		E Horizon - Eluviation Layer	Grass savanna
		B Horizon - Subsoil Mineral Layer	Tree savanna
		C Horizon - Regolith Layer	Tropical and subtropical dry forest
		R Horizon - Bedrock Layer	Tropical rainforest
	Deep Crust		Alpine tundra
			Montane forest

It is important to note that every space layer noted in Fig. 3.1 can be further divided into sub-layers. As in Table 3.1, we can see how the continental crust and hydrosphere (which includes the cryosphere) can be further broken down into sublayers as and when they are relevant to consider. The table provides further details on 'lakes' and 'vegetation' revealing that a fine-tuned understanding of each sublayer is also possible and should be considered when relevant.

Now that we have conceptualised the analytical dimension of space, of our physical context, its introduction into our models requires that we define the space value principle, which would define our relationship with space, just like the existing principles of finance define our relationship with risk and time.

3.2. The Space Value of Money

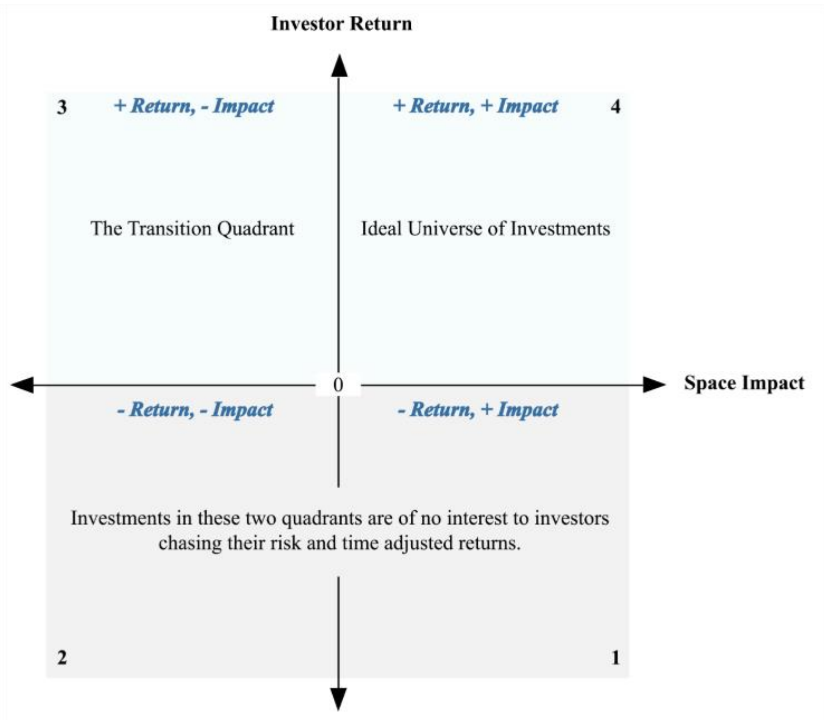
Indeed, we have a missing principle in finance, a principle that establishes the value of cash flows vis-à-vis space. I have proposed the introduction of a third principle into core finance theory and practice, the Space Value of Money.

> The space value of money principle complements time value of money and risk and return. It establishes our spatial responsibility and requires that a dollar ($1) invested in space has at the very least a dollar's ($1) worth of positive impact on space. (Papazian, 2022, 104)

The space value of money (SVM) is the first step in transforming our value framework, and it leads to new equations of value and return where the responsibility of impact is integral to our models and equations. Indeed, while risk and return and time value of money define our relationship with risk and time from the perspective of the risk-averse mortal return-maximising investor, the space value of money introduces planet and humanity as equal stakeholders into our value framework.

The space value of money establishes a bottom threshold of investment acceptability because it requires that any dollar invested in space has at the very least a dollar's worth of positive impact on space, taking into account all its many layers. To demonstrate the theoretical and practical relevance of the principle, consider the Transition Return Impact Map (TRIM) in Fig. 3.2.1. It denotes Space Impact and Investor Return and helps us visualise the transition challenge.

Fig. 3.2.1 The TRIM: Transition Return Impact Map *(Source: Papazian, 2022)*

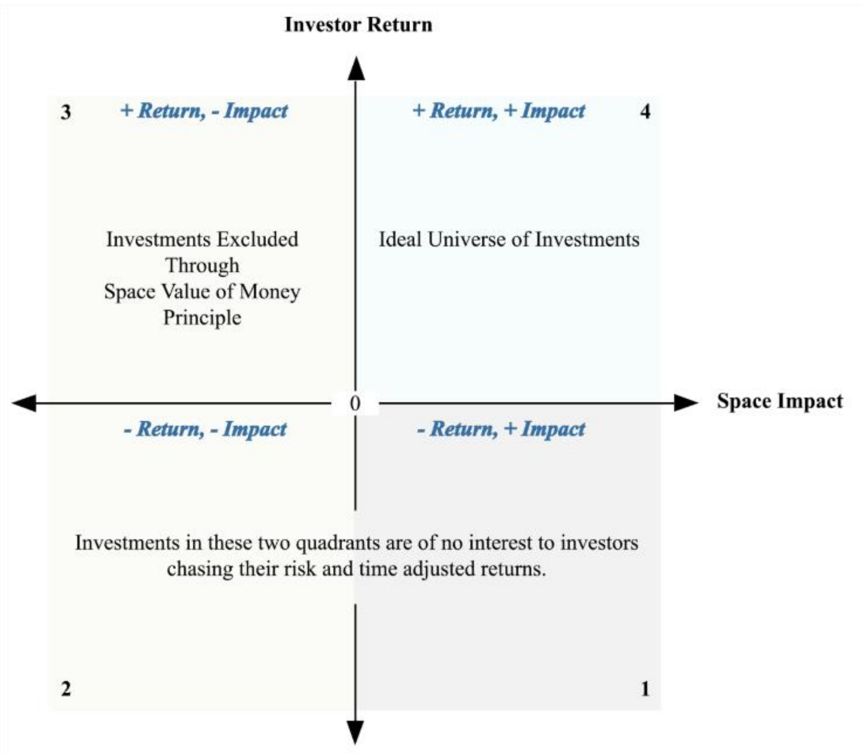


The challenge of the transition is to ensure that investments, assets, projects, and companies do not have a negative space impact— whether we are considering emissions or other types of pollution and waste, or biodiversity loss. Our current financial value framework focuses on risk and time and does not require investors to have a positive impact. Indeed, our current challenges and the many environments we have come to litter reveal that our framework and equations have to date absolved negative impact because of the very omission of space and our impact on it.

In other words, our current value paradigm in finance does not prevent investors from investing in opportunities or projects that are in the top left quadrant in Fig. 3.2.1 (Quadrant 3), where returns are positive, but impact is negative. This is the transition quadrant, and it exists because we do not yet have a principle or financial mathematics that prevents investments with negative space impact. Based on the current value framework taught and applied in finance, the bottom two quadrants in Fig. 3.2.1 (Quadrants 1 and 2) are automatically dismissed by investors as unattractive – expected returns being negative, there is no reason to invest.[10]

Space Value of Money*: A dollar ($1) invested in space must at the very least have a dollar's ($1) worth of positive impact on space.*

Fig. 3.2.2 The TRIM with Space Value of Money *(Source: Papazian, 2022)*



[10] Note that actual returns could be negative post investment, and this is referring to expected and required returns. Also, some public investors may initiate investments in the bottom two quadrants for a variety of reasons, amongst them is the provision of public goods, paid through tax revenue.

The introduction of the space value of money, therefore, acts as a bottom threshold of investment acceptability, as it represents investments in projects and assets and investments that have a negative space impact. In doing so, it also requires that space impact is calculated and compounded into the future in parallel to the discounting of projected future expected cash flows.

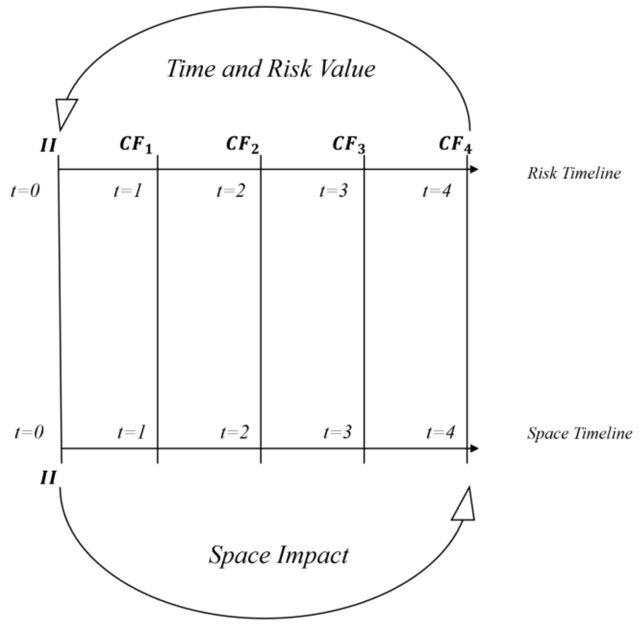
Based on the above, the space value of money facilitates the introduction of new equations and a new financial mathematics that hardwires sustainability, and allows us to, at the very least, prevent the inception of new investments that have negative space impact. In doing so, it also provides a framework through which existing investments with negative space impact can transition into a healthier value chain.

The space value of money includes far more than just E, S, and G (environmental, social, and governance factors). It includes T and M as well, (technology and money), and offers a systematic method that allows a thorough and authentic measurement of space impact across the many layers of space an investment may be affecting. Space value of money could be considered the theoretical link between sustainability and finance, and the principle that makes finance inherently sustainable.

3.3. The Financial Mathematics of Space Impact

Once we have introduced space as an analytical dimension, and established our responsibility of space impact, and complemented our current principles with the space value of money, the next step is to devise a systematic method through which we can map and quantify space impact. To do so, we can start by expanding a commonly used tool in finance, the cashflow timeline. I have introduced the double timeline to depict the Risk and Space timelines that allow us to assess the space impact/value of cash flows along with their risk and time value.

Fig. 3.2.3 The Double Timeline *(Source: Papazian, 2022)*



Given our new framework and the new principle, as we discount future cashflows to assess their time and risk value, we must also measure and compound the space impact of cash flows across all affected space layers.

The minimum space value condition is that a dollar invested in space, has at the very least a dollar's worth of positive impact on space. The below concepts and equations provide a conceptual summary of space impact using the Gross Space Value and Net Space Value equations, which measure the aggregate space impact of cash flows (Papazian, 2022).

The minimum space value of money condition is met when Net Space Value (NSV) is equal to zero, and thus the Gross Space Value is equal to the initial investment – when a dollar invested has a dollar's worth of positive space impact.

$$Gross\ Space\ Value_{T,S} = \mathrm{NSV} + II \tag{2}$$

$$NSV + II = GSV \mid NSV = 0$$

$$\boldsymbol{GSV = II}$$

Where the Net Space Value is defined as the Planetary, Human, and Economic impact of the investment or cashflows - summarised as:

$$\boldsymbol{NSV_{T\&S} = Net\ Space\ Value\ of\ Investment}$$
$$\boldsymbol{NSV_{T\&S} = \{Planetary,\ Human,\ and\ Economic\ Impact\}_{All\ S\ Layers\ \&\ T\ Periods}}$$

$$T = Total\ Number\ of\ Years\ of\ Investment\ being\ Considered$$

$$S = All\ Space\ layers\ Involved\ in\ the\ Investment$$

$$\begin{aligned} NSV_{T\&S} = & \sum_{t=1}^{T}\sum_{s=1}^{S} Pollution\ \&\ Biodiversity\ Impact \\ & + \sum_{t=1}^{T}\sum_{s=1}^{S} Human\ Capital\ \&\ R\ and\ D\ Impact \\ & + \sum_{t=1}^{T}\sum_{s=1}^{S} New\ Asset\ \&\ New\ Money\ Impact \end{aligned} \tag{3}$$

Where each of the elements, planetary, human, and economic are further defined as the pollution, biodiversity, human capital, R & D, New Money and New Asset impacts of the investment (See Table 3.3).

Table 3.3 The equations of impact (*Source: Papazian, 2022*)

Impact Aspect	Net Space Value	$\boldsymbol{g \times (PI_{T,S,P} + BI_{T,S,B} + HCI_{T,S} + RDI_{T,S,N} + NAI_{D,S,A} + NMI_T)}$	(4)
PLANETARY	**Pollution Impact**	$PI_{T,S,P} = \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{p=1}^{P} Q_{pst} \times C_{pst}$	(5)
	Biodiversity Impact	$BI_{T,S,B} = \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{b=1}^{B} A_{bst} \times R_{bst}$	(6)
HUMAN	**Human Capital Impact**	$HCI_{T,S} = f \times \sum_{t=1}^{T}\sum_{s=1}^{S} E_{st} + T_{st} + H_{st} + I_{st} + C_{st} + S_{st}$	(7)
	R and D Impact	$RDI_{T,S,N} = \sum_{t=1}^{T}\sum_{s=1}^{S}\sum_{n=1}^{N} h_n \times RD_{tsn}$	(8)
ECONOMIC	**New Asset Impact**	$NAI_{D,S,A} = \sum_{s=1}^{S}\sum_{a=1}^{A} k_a \times BVA_{asD}$	(9)
	New Money Impact	$NMI_T = (II \times DR \times BLR) + mm \times (II + X_T - M_T)$	(10)
Coefficients	**Fairness** **Health** **Transition** **Governance**	f h k g	

The derivation and logic of each of the component equations in Table 3.3 can be found in Papazian (2022). A few important explanations are due here. Pollution and biodiversity elements consider the clean-up costs (C_{pst}) and restoration costs (R_{bst}) in order to quantify the projected costs of the cash flows and investments across all time period, space layers, and types of pollutants and biodiversity losses, and they do so for prevention purposes, they are not to be confused with direct and/or indirect encouragement of post event treatment.

Given the space value principle, negative impacts must be identified across all categories and prevented, and positive impacts do not absolve the investment from its negative impacts – no off setting or trade-offs are considered viable. Furthermore, across all these component equations, the main purpose is the development of a comprehensive aggregation tool, as such, other approaches and impact assessment frameworks, like Life Cycle Approach, can still be used.

All the coefficients, fairness, health, governance, and transition, naturally involve a certain level of subjective assessment – in other words, the framework does not pretend to be 'subjectivity free'. However, unlike ESG Ratings and other proposed metrics like Implied Temperature Rates (ITR), the space value equations offer a framework through which marginal new information can be interpreted by the market, even if traders may sometimes reach contradictory conclusions given their subjective assessments - a key component missing in the ESG ratings-based approach, where neither equations nor framework allow the market to interpret, and potentially act upon, a new piece of information as its effects on scores is neither immediate nor necessarily obvious.

The Space Value framework introduces the necessity and tools to assess the impact of cash flows across *all the layers of space* that the considered cashflows may be affecting. This is a unique and an important distinction for a variety of reasons:

a) Value Chain: because the value chains of investments affect different layers of space – a shipping company that uses aeroplanes affects the stratosphere, while a shipping company using ships affects the hydrosphere.
b) Impact Intensity: because the intensity of impact differs across space layers, GHG emissions in the stratosphere have a different impact from GHG emissions in busy densely populated cities with high rise buildings.
c) Clean-up Technology: because cleaning the same pollutant in different space layers involves different technologies – cleaning plastic from our oceans, from our rivers, from our streets, and from our food chain require different technologies.
d) Costs: given all of the above, the costs of impact differ across different layers of space, even for the same pollutant or type of waste.

$$\sum_{s=1}^{S}$$

Another key contribution of the space value framework is the introduction of three intensity measures which allow a more granular assessment of impact. The planetary, human, and economic impact intensities of investments and cash flows introduce the opportunity to identify the specific footprint involved.

$$Planetary\ Impact\ Intensity_t = PI\ and\ BI\ per\ Expected\ Cash\ Flow_t$$

$$PLANETII_t = \frac{PI_{t,S,P} + BI_{t,S,\,B}}{Expected\ Cash\ Flow_t} \tag{11}$$

$$Human\ Impact\ Intensity_t = HCI\ and\ RDI\ per\ Expected\ Cash\ Flow_t$$

$$HUMANII_t = \frac{HCI_{t,S} + RDI_{t,S,N}}{Expected\ Cash\ Flow_t} \tag{12}$$

$$Economic\ Impact\ Intensity_t = NAI\ and\ NMI\ per\ Expected\ Cash\ Flow_t$$

$$ECONOMICII_t = \frac{NAI_{d,S,A} + NMI_t}{Expected\ Cash\ Flow_t} \tag{13}$$

Having mapped and identified and measured the space impact of cash flows, the next step is to make sure that negative impacts are prevented and avoided. In order to entrench sustainability into our value equations, investments and cash flows must be valued considering their impact. This implies that when negative impacts are possible and part of the impact of an investment, then those negative impacts must be included in the equations of value used, for prevention purposes. Eq. 14 is one example using the Net Present Value formula. The equation uses the absolute value of the negative space impacts and adds the negative external to the total for theoretical clarity.[11]

$$Negative\ Impact\ Adjusted\ NPV = -\left|NNSV_{T,S}\right| - II + \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t}$$

$$NNSV_{T,S} = The\ Sum\ of\ Negative\ Impacts\ Across\ All\ Years\ and\ Space\ Layers \tag{14}$$

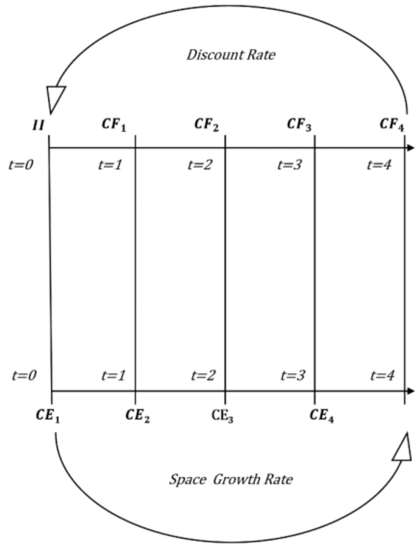
> The negative space impacts involved in the investment are summarised by the NNSV element of the equation and reflect the sum of all negative impacts across the years of the investment. This is not the negative of the total NSV figure, but the sum of the negative elements within NSV. NNSV identifies the negative impacts that will take to achieve those cash flows on top of the initial investment.
>
> Potentially, given the time sensitivities of the NPV model and the risk and time conscious investor, we could also consider the present value of the negative impacts. We can rewrite the above by discounting the future negative impacts into the present to reveal the time value of the negative impacts using the same discount rate used for the expected cash flows. (Papazian, 2022, 179)

$$-\sum_{t=1}^{T} \frac{|NNSV_t|}{(1+r)^t} = The\ Sum\ of\ Negative\ Impacts\ Discounted\ to\ Present$$

[11] See Papazian (2022) for additional examples and a more extensive discussion.

Another key contribution of the space value framework is the Space Growth Rate (SPR), which measures the implied periodic rate of growth that takes us from the Initial Investment (II) to the aggregate Net Space Value of the investment across the T periods of the investment. The Space Growth Rate is a summary rate that, in a way, mirrors the discount rate. As depicted in Fig. 3.3, and given the space value of money principle, while investors can continue pursuing their risk and time adjusted returns, their impact must be accounted for and compounded into the future when relevant. Equations 15 and 17 reveal the relationship between the space growth rate and the Net Space Value of an investment, where the investment is considered as a series of cash expenditures, and the SPR is used to compound them into the future.

Fig. 3.3 The double timeline and the space growth rate *(Source: Papazian, 2022)*



$$\boldsymbol{SPR = \sqrt[T]{\frac{NSV_{T,S}}{II}} - 1} \tag{15}$$

$$SPR = The\ Space\ Growth\ Rate\ per\ period$$

$$II = Initial\ Investment$$

$$T = All\ Time\ Periods\ involved\ in\ the\ Investment$$

$$S = All\ Space\ Layers\ Involved\ in\ the\ Investment$$

$$NSV_{T,S} = Net\ Space\ Value$$

$$\boldsymbol{Net\ Space\ Value_{T,S} = g \times \left(PI_{T,S,P} + BI_{T,S,B} + HCI_{T,S} + RDI_{T,S,N} + NAI_{D,S,A} + NMI_{T}\right)} \tag{16}$$

$$Net\ Space\ Value = NSV_{T,S}$$

$$\boldsymbol{NSV_{T,S} = \sum_{t=0}^{T} CE_t (1 + SPR)^{T-t}} \tag{17}$$

In truth, just like benchmark discount rates being used in markets, we could also have benchmark space growth rates >0 that would set the minimum required positive space impact required for public and private investments.

4. Implications for Money Mechanics

If investors must respect the space value of money principle, and earn their returns with a positive space impact, then money creators, whether they are commercial or central banks, must also follow the same principle. This means that every instance of contractual financial engineering that results in new money creation must apply the same financial mathematics, where the value/return of the instruments must be considered not just in terms of time and risk, but also space, and space impact.

The hardwiring of sustainability into financial mathematics as discussed in the previous section will naturally require a comprehensive reassessment of instruments and investments executed by money creators. While this in itself will have a variety of technical implications for money mechanics, in this section I focus on broader systemic considerations given our debt-based monetary architecture.

4.1. Debt-based money

In an article published in the Bank of England Quarterly Bulletin, our current debt-based architecture is best described by McLeay et al. (2014a):

> There are three main types of money: currency, bank deposits and central bank reserves. Each represents an IOU from one sector of the economy to another. Most money in the modern economy is in the form of bank deposits, which are created by commercial banks themselves (McLeay et al. 2014a, 4).

Table 4.1 provides examples of instruments, portfolios, and transactional engagements that lead to or are used for debt-based money creation within our current architecture. Fig. 4.1 further elaborates the debt/loan-based money mechanics structured around IOU transactions/instruments between central banks, commercial banks, and consumers. Chart 4.1 depicts the Asset side of the Federal Reserve balance sheet denoting key QE/CE periods of money creation.

Table 4.1 Commercial and Central Bank Sample Debt Instruments, Portfolios, and Transactional Engagements (*Source: Author*)

	Commercial Banks	**Central Banks**
Instruments	Consumer Credit Business Credit Residential Mortgages Commercial Mortgages	Discount Loans (FED) TLTRO Loans (ECB) Subsidiary Loans (BOE)
Portfolios	Loan Portfolios Mortgage Portfolios	Government Bond Portfolios Corporate Bond Portfolios MBS and CDO Portfolios Commercial Paper (FED)
Transactional Engagements	Loan Approvals Mortgage Approvals	Currency Issuance Reserve Issuance - Quantitative Easing - Credit Easing

Fig. 4.1 Bank of England Money Creation *(Source: Adapted from McLeay et al. 2014b)*

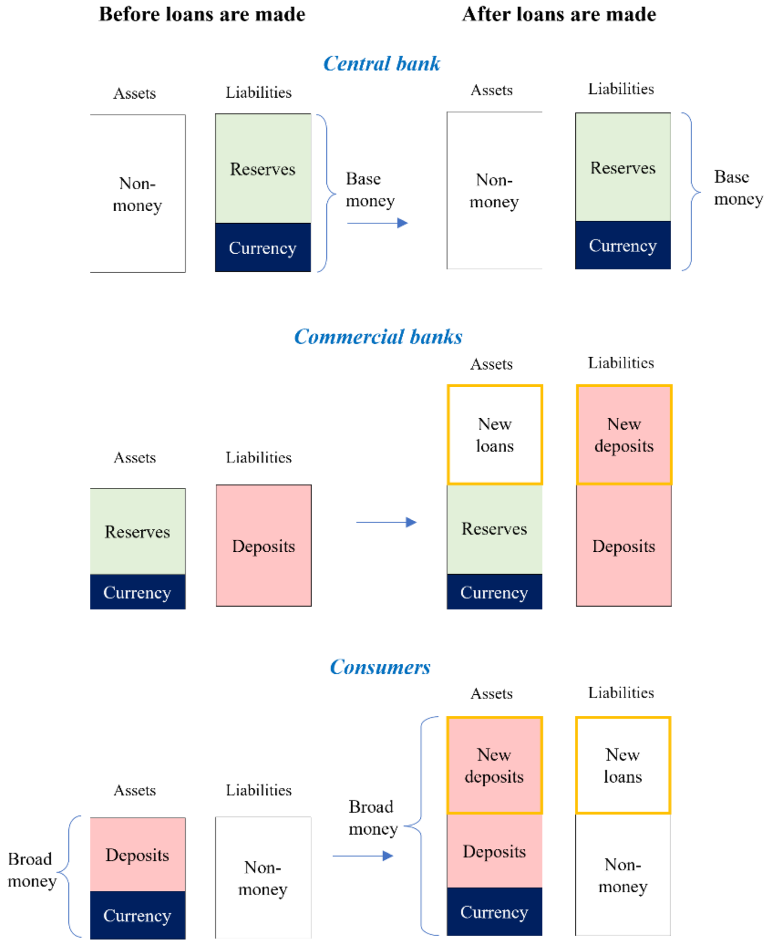
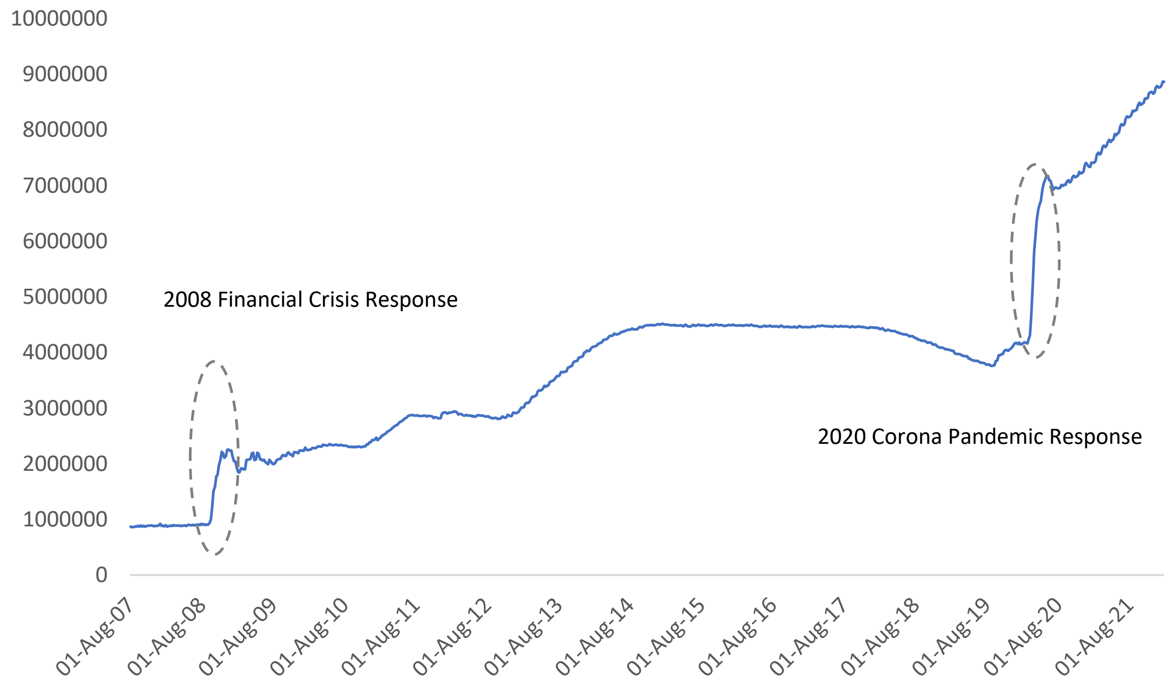


Chart 4.1 Federal Reserve Balance Sheet, Assets in $ Millions (*Source: FED, 2021*)



4.2. Challenges with debt-based money

When we consider our debt-based money mechanics within the context of a transformed analytical value framework and financial mathematics, a number of key challenges become evident. Specifically, in an analytical framework with space, and responsibility of impact on space, three primary challenges become apparent.

a) Calendar time
b) Monetary gravity
c) Monetary hunger

I briefly discuss and summarise these challenges next.

4.2.1. Calendar Time

Creating money based on debt instruments involves calendar time obligations. While this is taken for granted within our monetary and financial architecture, in truth, linking money creation to an artificial concept like calendar time poses serious constraints. Due to this calendar time-based conceptualisation of money creating instruments, governments, government agencies, municipalities, small businesses, households, individuals, corporations, and even banks are all chained to calendar time payments.

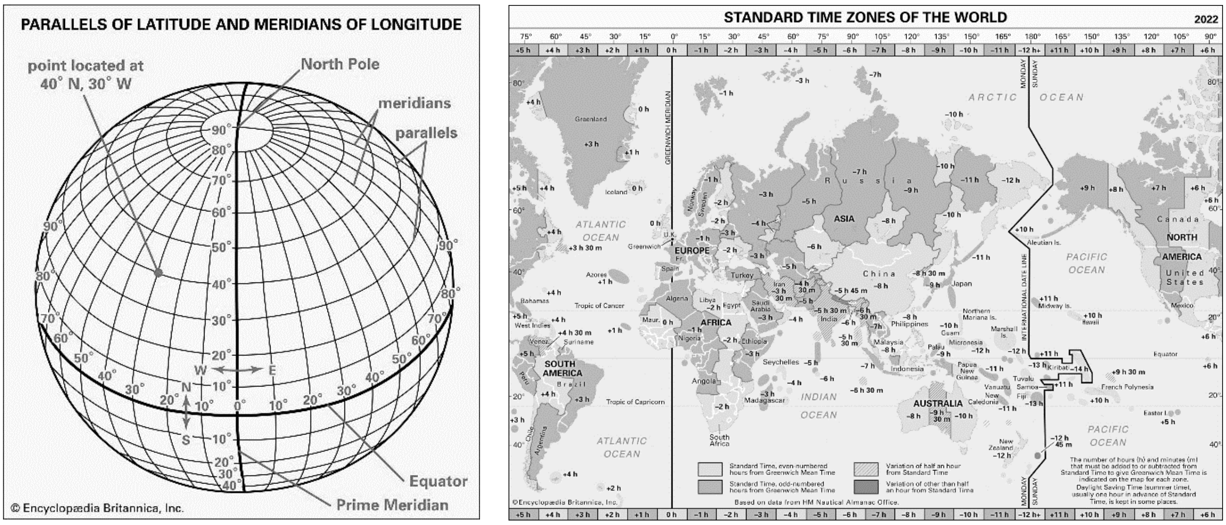
> Debt, which involves time obligations in terms of scheduled interest and principal repayments, chains everybody involved to calendar time payments. Indeed, whatever the actual shape of the repayment schedule involved, our debt-based money creation methodology chains our entire productive and creative potential to calendar time (Papazian, 2013a).

It is very important to note here that I do not use the term time, but calendar time. While the nature of time is a debateable subject (Rovelli, 2006, 2018; Smolin, 2006; Greene, 2004) and economists have discussed the relevance of psychological and real time to the performance of investments (Blanqué, 2021), the time used and applied by banks and central banks in debt transactions is simply calendar time.

Calendar time is central to the functioning of the world economy. Calendar time gives structure and direction to our days and our productive activities, and it is a human invention that helps us structure and navigate our productive life on the planet. The conceptual mapping of space and time on Earth makes use of the Prime Meridian, epitomised by the Greenwich laser beam, at 0° longitude (See Fig. 4.2.1).

> The Prime Meridian is the line and the point at which the world's longitude is set at 0°. It does not exist in any strict material sense, yet through maps and clocks, the prime meridian governs the life of every human on Earth. (Withers, 2017, 5)

Fig. 4.2.1 Prime Meridian and Standard Time Zones (*Source: Encyclopaedia Britannica*)



While this imaginary point/line on Earth, in space, is an important element and structural pillar of the entire world economy, using an artificial point and line and the resulting fixed paced calendar time as a foundation of money mechanics limits our ability to invest in space timelessly, beyond the limitations of the structural construct. This is one of the key issues with calendar time and debt-based money.

4.2.2. Monetary Gravity

Debt-based money creation, at the central bank level and at the commercial bank level, is achieved through credit and debt instruments that require the repayment of principal and interest to the original source within a specific calendar time window. In other words, debt-based money involves a backward loop to the creator of money within specified calendar time windows and intervals. While this is taken for granted in our current systems, it is also the source of a unique type of artificially created force that I call monetary gravity (Papazian, 2022, 216).

Debt-based money is a human invention, and it acts as a powerful constraint on how far in space an investment can reach before it must return to pay back principal and interest to some bank. Indeed, this is true even if payments are done electronically without a physical return to the bank because the structure of the instrument imposes the necessity to earn the income and make the payment within the time frame required. Even if the debt can be rolled over, or postponed, and refinanced, the foundation of debt-based money imposes a limit on how far in space a process can go before having to return to some bank.

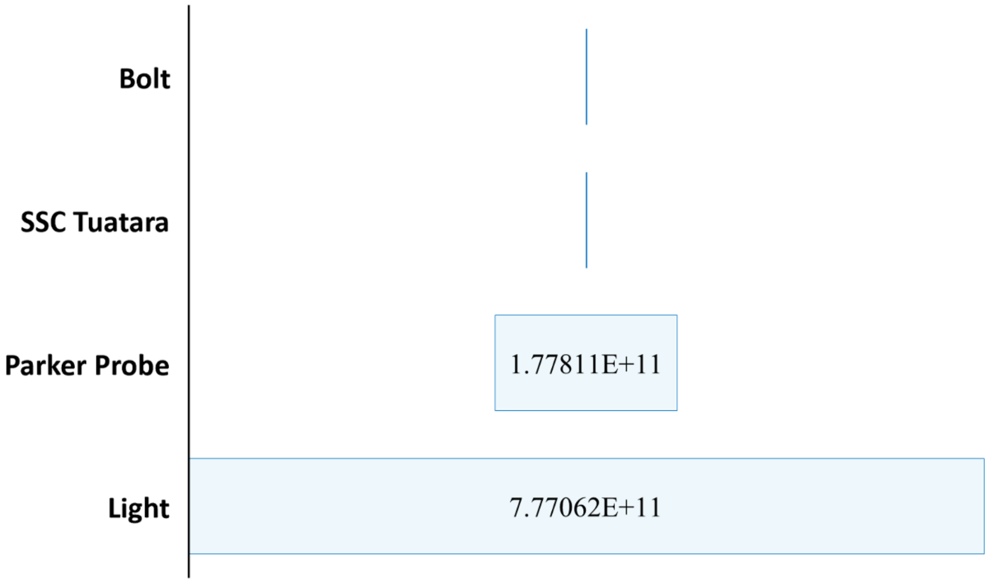
The below conceptual equation (Eq. 18) can be used to calculate the limit on distance travelled when a monthly interest payment must be paid on a money creating instrument. Chart 4.2.2

provides the limits on distances given the speed of Usain Bolt, the SSC Tuatara, the Parker Probe (NASA, 2018), and light.[12]

$$Maximum\ Distance_{Light} = Speed\ of\ Light\ \frac{m}{s} \times Time\ Interval\ in\ s \tag{18}$$

These are hypothetical examples in order to argue that we and our fastest tools and inventions, and light itself, will experience a limit on distance travelled given an interval of calendar time.

Chart 4.2.2 Limits on distance travelled in space in a month in m *(Source: Papazian, 2022)*



> Debt-based money acts as a leash on our species, chaining us to a self-created calendar, to a self-created system that ultimately chains us to the surface of the planet. Given that calendar time is a human concept, artificially created to manage human activities, linking money creation to an artificially limited concept such as a month or a year, artificially limits the distance we can travel before we need to return to the bank. (Papazian, 2022, 218)

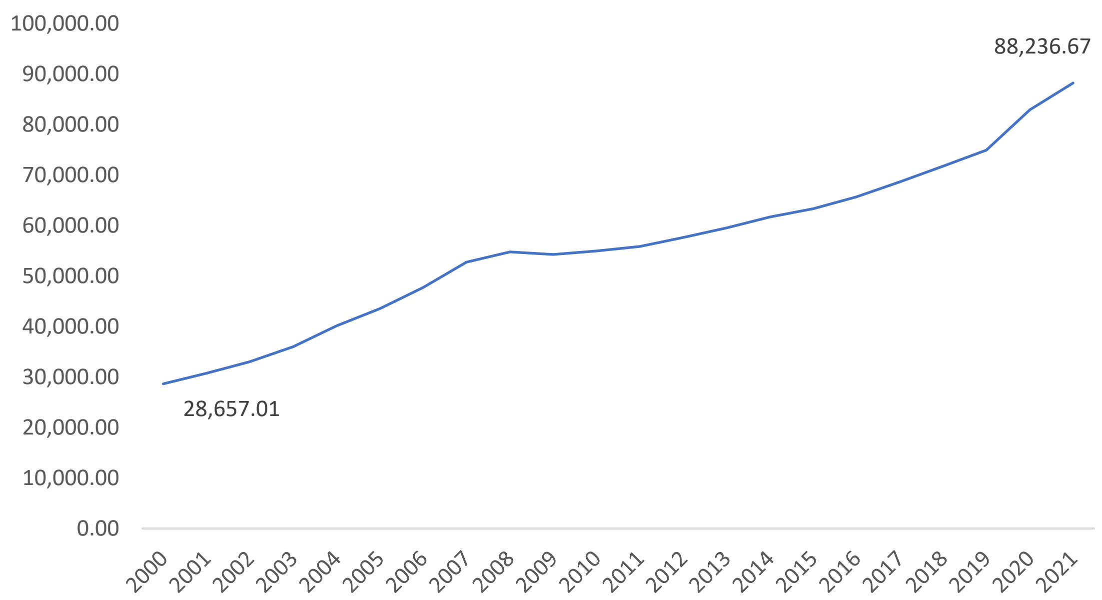
[12] Please note that the calculations assume uniform terrestrial conditions for simplicity and the purpose of the argument.

4.2.3. Monetary Hunger

The third key space impact challenge posed by debt-based money is what I call monetary hunger. In any debt-based economy, irrespective of past or current capital accumulation, a large segment of society, including households, municipalities, governments, corporations, and banks, is chasing available cash and deposits to pay calendar time-linked debt obligations. Debt-based money creates monetary hunger in any debt-based economy, and whatever the actual levels of debt to GDP ratios. This is so given that money is continuously created via debt.

As a numerical example of monetary hunger, in the United Stated, between 2000 and 2021, the total outstanding public and private debt across all sectors increased from 28.7 trillion U.S. dollars to 88.2 trillion U.S. dollars (See Chart 4.2.3 from Statista).

Chart 4.2.3 Total outstanding public and private debt USA, 2000-2021in billion U.S. dollars (*Source:* [*Statista*])



While a significant driver of growth, monetary hunger can also explain personal, business and investment practices. After all, the threat of default and loss of ratings and assets are existential threats for businesses and households and avoiding them is naturally a priority. In other words, given a voluntary framework, and the threat of default, businesses will always choose the alternative that costs less, whatever the environmental impact.

Before moving to the next section where I propose an alternative money creation logic that integrates space impact and addresses the above discussed challenges, it is important to discuss the relatively recent phenomenon of cryptocurrencies, or cryptoassets.

4.3. Cryptocurrencies

It is important to open this parenthesis and discuss cryptocurrencies[13] given the popular misconception about their relevance and importance as an alternative form of money (to debt-based fiat money). Indeed, this is particularly relevant from a sustainable finance perspective.

As of March 2023, there were 9021 cryptocurrencies listed on coinmarketcap.com (CoinMarketCap, 2023). Bitcoin is the first on the list and is used as an example in this discussion. There are many features of Bitcoin and other cryptocurrencies that require attention. The first is their labelling as currency. The Bank of England refers to them as cryptoassets:

> Put it this way, you wouldn't use cryptocurrency to pay for your food shop. In the UK, no major high street shop accepts cryptocurrency as payment. It's generally slower and more expensive to pay with cryptocurrency than a recognised currency like sterling. Development is underway to make cryptocurrency easier to use, but for now it isn't very 'money-like'. This is why central banks now refer to them as "cryptoassets" instead of "cryptocurrencies". Today cryptocurrencies are generally held as investments by people who expect their value to rise (Bank of England, 2021c).

This raises an equally serious concern, they do not have any intrinsic value, and they do not involve any return accruing to holders. Prasad (2021) refers to this by referencing the 'greater fool' theory. He writes: "The valuations of meme currencies seem to be based entirely on the "greater fool" theory—all you need to do to profit from your investment is to find an even greater fool willing to pay a higher price than you paid for the digital coins." An alternative interpretation is that the attractiveness of Bitcoin and other cryptocurrencies is in their lack of transparency, as 'dark money' (Economist, 2022).

Another critical aspect is the energy consumption attached to the mining process that generates the coins. The Cambridge Bitcoin Energy Consumption Index (CBECI) estimates that the yearly average annualised electricity consumption of the Bitcoin Network is around 118.3 TWh per year, which is higher than the yearly consumption of the Netherlands at 113.3 TWh per year (CCAF, 2023).[14] Moreover, a recent study reveals the electronic waste generated due to the consumption of electronic hardware used in mining the coins. The authors estimate that Bitcoin's e-waste is 30.7 metric kilotons per annum as of May 2021 (De Vries and Stoll, 2021).

While the above raised issues are all relevant and important to sustainability and sustainable finance, the most critical, however, is the very logic of their creation. While central bank and commercial bank money are created via debt transactions, crypto coins are created after a mining process through powerful computers performing specific mining operations which consist in solving complex mathematical puzzles.

[13] Cryptocurrencies should not be confused with Central Bank Digital Currencies (CBDC) which are now being considered by the Bank of England and other central banks (Bank of England, 2024)

[14] For a relative understanding of the numbers, note that the two highest consuming countries, China and USA, use respectively 7805.66 TWh and 3979.28 TWh per year (CCAF, 2023).

> Anybody can become a Bitcoin miner by running software with specialized hardware. Mining software listens for transactions broadcast through the peer-to-peer network and performs appropriate tasks to process and confirm these transactions. Bitcoin miners perform this work because they can earn **transaction fees paid by users for faster transaction processing, and newly created bitcoins issued into existence according to a fixed formula**.
>
> For new transactions to be confirmed, they need to be included in a block along with a mathematical proof of work. **Such proofs are very hard to generate because there is no way to create them other than by trying billions of calculations per second**. This requires miners to perform these calculations before their blocks are accepted by the network and before they are rewarded. As more people start to mine, the difficulty of finding valid blocks is automatically increased by the network to ensure that the average time to find a block remains equal to 10 minutes. As a result, mining is a very competitive business where no individual miner can control what is included in the block chain (Bitcoin, 2021a).[15]

The underlying process through/for which Bitcoins are created/awarded involves and is dependent on '*trying billions of calculations per second*'. In other words, to put it in the most benign way possible, minors get rewarded with bitcoin for mathematical guesswork. Basically, from a debt logic, we have now moved to a more preposterous logic of money creation, mathematical guesswork.

The above discussion aimed at clarifying an important aspect of the debate, and to remove all doubts regarding the popular misconception that cryptocurrencies are an actual alternative to debt-based money. From a sustainability perspective, they in fact offer no real solutions to the challenges discussed in the previous sections, and in truth, they add a host of new ones that further undermine a sustainable trajectory.

4.4. Money Mechanics with Space Value Creation

Previous sections discussed the key challenges of debt-based money from a systemic perspective, and revealed why cryptocurrencies are not the alternative a sustainable world needs. Indeed, from debt to mathematical guesswork with a heavy carbon and electronic footprint, we seem to be in dire need of a money mechanics that is built on and delivers positive space impact.

This section elaborates on an alternative money creation logic and instrument that are aligned with the space value of money principle and can provide the blueprint for a mechanism that can fund the transition to Net Zero, and other evolutionary challenges we have created for ourselves. Given the many trillions of dollars we will need to fund the transition (HSBC-BCG, 2021; McKinsey-GI, 2022), and the absence of a reliable framework to create and deploy these funds, this proposition is of critical relevance.

[15] Emphasis added.

It is important to start by stating why it is and should be possible to improve and fine-tune our money creation methodology. Indeed, it is very much a plausible opportunity and necessity to introduce a new channel of money creation that is not debt-based, and addresses the challenges discussed in the previous sections. The below quote and Table 4.4 reveal as to why we should and must consider this avenue as a veritable opportunity for innovation and improvement in money mechanics.

> If the Bank of England can create and back banknotes by a deposit in the banking department of the Bank of England, if the Bank of England can create new money by loaning to its own wholly-owned subsidiary, if the Federal Reserve can create new money by buying toxic Collateralised Debt Obligations and Mortgage-Backed Securities, or by buying commercial paper, there is no reason why they cannot back or create new money through an alternative equity like instrument that shares risks, shares the ownership of the assets created through the instrument, has a tangible and inspiring positive space impact, and helps resolve our evolutionary challenges. (Papazian, 2022, 223)

Table 4.4 BOE Balance Sheet, Issue Department (Source: *Bank of England, 2021b)*

	2021	2020
	£m	£m
Assets		
Securities of, or guaranteed by, the British Government	2,093	2,726
*Other securities and assets including those acquired under reverse repurchase agreements	82,599	71,696
Total Assets	**84,692**	**74,422**
Liabilities		
Note Issued		
In Circulation	84,692	74,422
Total Liabilities	**84,692**	**74,422**
*		
Other securities and assets including those acquired under reverse repurchase agreements		
Deposit with Banking Department	78,524	66,552
Reverse repurchase agreements	4,075	5,144
	82,599	**71,696**

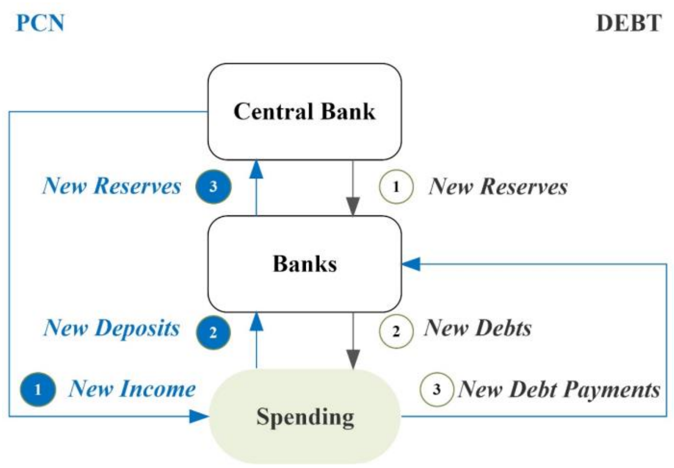
While an important systemic change, the idea and proposition put forward here is quite simple and straightforward and amounts to the introduction of a new financial instrument within our existing monetary architecture. The proposition is to introduce a new instrument of money creation, Public Capitalisation Notes (PCN) which will have a different logic and different locus of injection from previously used debt instruments through quantitative and/or credit easing by the Federal Reserve, Bank of England and the European Central Bank (Bernanke, 2009).

4.4.1. Public Capitalisation Notes (PCN)

Public Capitalisation Notes are conceived as instruments that can be used by any central bank to inject new money into the economy. A number of key features make PCNs very different from conventional debt instruments. These features are designed to address the challenges discussed with debt-based money and introduce a new logic of money creation and injection founded on space value creation. If the trigger of money creation in debt transactions is the agreement to repay, in PCNs, the trigger is the commitment to create necessary positive space value and share the returns when they occur.

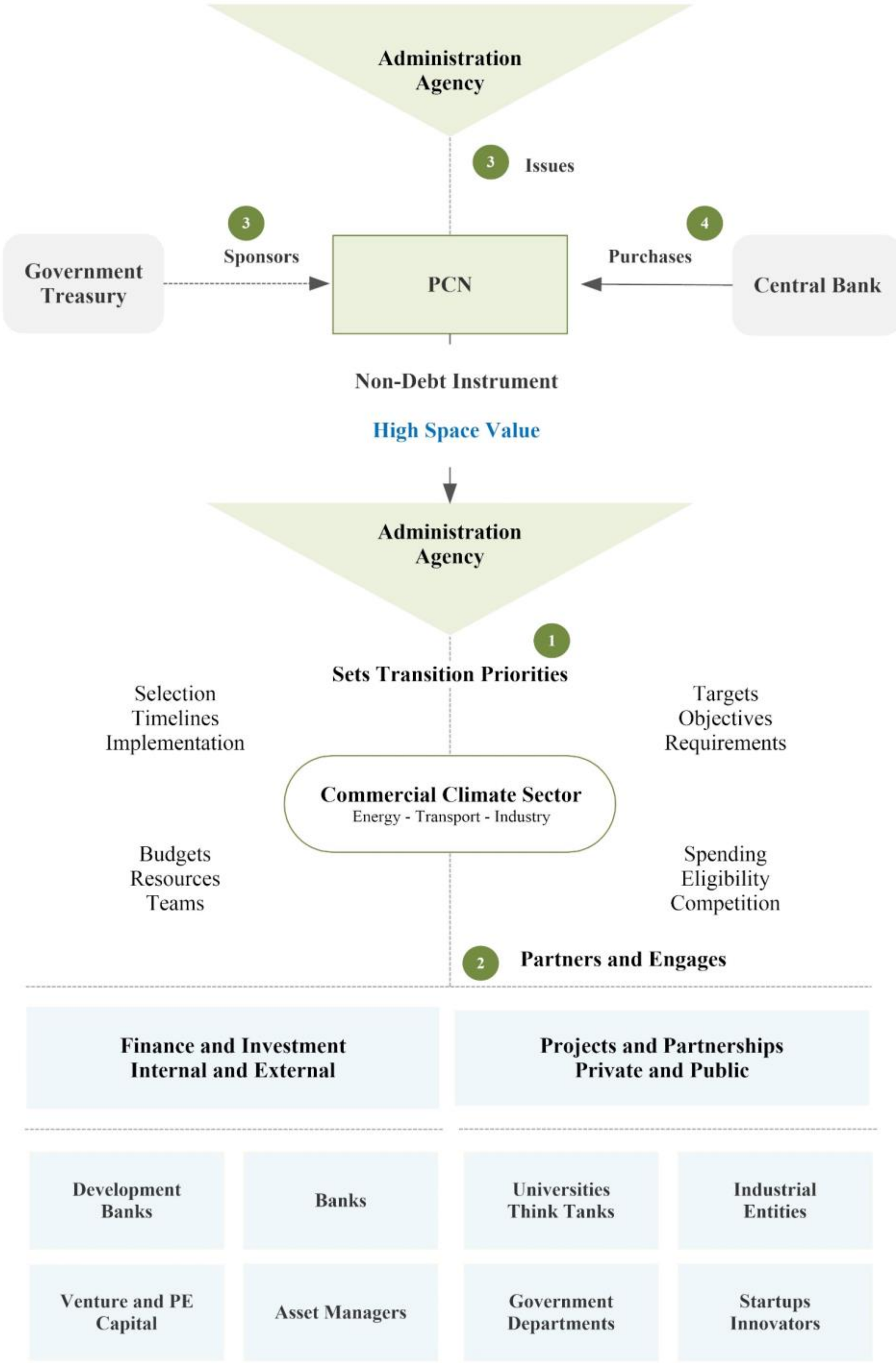
Fig. 4.4.1 expands the rationale behind the change of locus of the injection. PCNs do not condition the space impact of the created new money by further or next round lending by banks. The injected liquidity is outside the banking system and is therefore spending before it becomes bank reserves. In the case of Quantitative Easing and Credit Easing, the starting point are bank reserves and credit conditions, and subsequent availability and direction of credit is dependent on bank lending.

Fig. 4.4.1 PCN vs Debt Money Injection *(Source: Papazian, 2022)*



As discussed above, introducing a new logic of money creation through the introduction of a new instrument that can be used in parallel allows systemic flexibility and the opportunity to address many of the bottlenecks we face. Most importantly it allows the funding of evolutionary challenges and economy wide investment programs that cannot be sustained through debt financing alone.

Fig. 4.4.2 Climate PCN *(Source: Adapted from Papazian, 2022)*



The key features of PCNs:

Non-debt (addresses monetary hunger), no-maturity (addresses monetary gravity), equity-like (shares risks & assets and returns when due), high space value/impact (addresses challenges like transition), issued by qualified government agencies (as administrative HQ), in collaboration with private sector (Public Private Partnerships), with Treasury sponsorship (shares risk & assets and returns when due), increase the central bank's balance sheet (like QE and CE), inject new liquidity outside the banking system (unlike QE and CE).

It is important to note that the suggestion here is not to ‘print’ or create new money indiscriminately. The proposition is to change the logic of creation for the amounts already being created in order to balance the system and address the challenges of debt-based money. I call this new approach of monetisation Value Easing (VE).

4.4.2. Value Easing

Value Easing: The transactional process undertaken by a central bank that consists in purchasing non-debt no-maturity equity-like high space impact value creating instruments from qualified government agencies and/or public private partnerships (PPP) with relevant Treasury sponsorship that increases the central bank’s balance sheet and injects new liquidity outside the banking system.

Note that VE is far less inflationary than the recently used Quantitative Easing and Credit Easing, and it allows the injection to be directed where it is most needed, thus alleviating business cycle pressures, investment gaps, evolutionary challenges, and other strategic objectives. It addresses productivity and output gaps and enables the targeted injection of new liquidity that can alleviate supply shock driven price inflation, without relying on further bank lending. Which, as previous experience has demonstrated post 2008 and 2020, can lead to asset price inflation rather than productive output growth.

Indeed, Value Easing is perfectly suited to fund those economy wide transformations that cannot be appropriately addressed by our current risk and time focused models and instruments.

4.4.3. From Debt Ceiling to Wealth Floor

Another brief parenthesis is appropriate here. This concerns the United States where the debt ceiling has been a central institutional bottleneck and the subject of intense debate (Austin, 2015). The US Department of the Treasury describes the Debt Limit/Ceiling as follows:

> The debt limit is the total amount of money that the United States government is authorized to borrow to meet its existing legal obligations, including Social Security and Medicare benefits, military salaries, interest on the national debt, tax refunds, and other payments (US Treasury 2021).

The introduction of Value Easing using PCNs can actually allow the opportunity to transform the debt ceiling into a wealth floor. While this would be a gradual transformation, it can begin the balanced rehabilitation of an entirely debt based public expenditure architecture (Papazian, 2022).

5. Conclusion

> A logic of value built vis-à-vis risk and time alone, with the risk-averse investor as only stakeholder, has contributed to the environmental, ecological, and social crises we are facing today. This omission of space and our responsibility for space impact from our analytical framework and equations of value can explain why so many need to transition to a responsible future, why the flow of new firms requiring transition is still going strong, and why sectors like coal are still attracting investor attention and funds. (Papazian, 2022, 102)

Finance theory and practice, through the omission of space - our physical context stretching from subatomic to interstellar space and every layer in between and beyond - and our responsibility of impact in it and on it, through an entirely risk and time-based conceptualisation of money and its valuation, have been directly and indirectly complicit in causing the many environmental and social crises we face today.

To achieve effective change, to truly change trajectory, we must change and reform our financial value framework and rethink the financial mathematics that defines our markets and investments. This involves a change in the very principles that define the value of money. It also involves the introduction of new equations where impact is integrated into value, where the discounting of future expected cashflows is accompanied by the compounding of their space impact into the future.

Indeed, the equations that govern the creation, allocation, and deployment of money are key to any true and effective conceptualisation and operationalisation of sustainability. Sustainability must be achieved at the level of our monetary architecture as well as our products, businesses, investments, and instruments, public or private. Money mechanics is central to a sustainable financial and monetary reality.

Achieving a Net Zero world and addressing the many evolutionary challenges we have created for ourselves require a transformed weave of our value chains, our energy systems, productive infrastructures, and institutional architectures. To meet this challenge, which is nothing short of an evolutionary leap, we must hardwire sustainability into the very financial mathematics that underpins billions of financial and monetary decisions on this planet.

The space value of money and the financial mathematics it ushers in may very well be one plausible avenue that can lead to a transformed value framework that could, in turn, secure the sustainability as well as future expansion of human productivity across time and space.

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Is the fulfilment of these ideas a visionary hope? Have they insufficient roots in the motives which govern the evolution of political society? Are the interests which they will thwart stronger and more obvious than those which they will serve?

… At the present moment people are unusually expectant of a more fundamental diagnosis; more particularly ready to receive it; eager to try it out, if it should be even plausible. But apart from this contemporary mood, the ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually the slaves of some defunct economist. Madmen in authority, who hear voices in the air, are distilling their frenzy from some academic scribbler of a few years back. I am sure that the power of vested interests is vastly exaggerated compared with the gradual encroachment of ideas. Not, indeed, immediately, but after a certain interval; for in the field of economic and political philosophy there are not many who are influenced by new theories after they are twenty-five or thirty years of age, so that the ideas which civil servants and politicians and even agitators apply to current events are not likely to be the newest. But, soon or late, it is ideas, not vested interests, which are dangerous for good or evil.

John Maynard Keynes
The General Theory of Employment, Interest and Money, 1936, 383-384