"*Constructive Skepticism*"
Volume 3 – Notebook #II: Ergodicity Economics

Introduction: The Historical Development of a Paradigm Shift

This series of workbooks, handbooks, and notebooks gathers thoughts, definitions, and sources focused on using "*Constructive Skepticism*" to make good individual decisions. As you can see from the first sentence in this paragraph, words with a specific "*Meaning*" anchored in the work of a referenced author show up in "*Italicized Quotes*" to alert the reader that these words have specific definitions in Volume 2 – Handbook #I: Glossary & "*Terms of Art*" Definitions. Additionally, author names in "***Bold Italicized Quotes***" indicate the presence of an entry in Volume 2 – Handbook #II: Authors Profiles. These italicized words lessen the confusion or "*Word Magic*" that may come from reading linearly through the text with an implicit, and different understanding of the "*Meaning*" of these words.

The workbooks collected in Volume 1 of this series of books, and the handbooks collected in Volume 2 document a large set of "*Tools, Checklists & Processes*" to help readers find the "*Meaning*" of research papers. Published on Substack in 2022 and 2023 at the request of CTRI members, and as a public peer-review process based on writing a two-page section each and every day, these workbooks and handbooks will remain available on Substack until their eventual print publication on Amazon, and include:

Volume 1: A Book of Connections in Four Workbooks

- Workbook #I: Our Shared Humanity
- Workbook #II: Making Good Individual Decisions
- Workbook #III: Making Good Business Decisions
- Workbook #IV: Making Good Investment Decisions

Volume 2: A Book of Collections in Four Handbooks

- Handbook #I: Glossary List and "Terms-of-Art" Definitions
- Handbook #II: Author Profiles
- Handbook #III: References
- Handbook #IV: The Template for Reading Research Papers

Publication on Amazon will begin in 2024 with the print version of the Template for Reading Research Papers as a stand-alone document so that readers can start with the end-product in hand, and use this collection of "*Tools, Checklists & Processes*" to "*See for Yourself*".

The ideas developed in the notebooks, written in long-form with no page limitation, and collected in Volume 3 will also become available on Substack until their eventual publication in print on Amazon. These notebooks cover topics suggested by CTRI members as well as Substack readers, and include the following at this time:

Volume 3: A Book of Illustrations with an Open-Ended Number of Notebooks

- Notebook #I: Model Risk
- Notebook #II: Ergodicity Economics
- Notebook #III: Business Ecosystems
- Notebook #IV: Asset Allocation
- Notebook #V: Behavioral Finance
- Notebook #VI: Terrain Theories
- Notebook #VII: Retirement Planning Processes
- …

This introduction to the Reading Note on ***Ergodicity Economics*** starts with the first three analytical steps from the Template for Reading Research Papers to describe the "*Perspective*", "*Domain of Knowledge*", and "*Historical Lineage*" of this new field, and summarizes the findings with the historical timeline that provides the chronological backbone for Volume 1 - Workbook IV: Making Good Investment Decisions. The writing of this timeline in 2021 was itself inspired by ***Ole Peters***' work on foundational papers such as "***Bernoulli 1738***". This timeline presents a synoptic view of the foundational authors behind the development of the "*Axioms, Assumptions & Hypotheses*" and resulting "*Theories, Rules & Laws*" in **Financial Economics**.

A "Perspective" on The "Historical Lineage" of Financial Economics including Expected Value Optimization, Growth Optimal Solutions (Generalized by Ergodicity Economics) & Client-Centric Planning (Generalized by the Household Balance Sheet)

The timeline shown on the right page comes from a draft paper published for public peer-review on RESEARCHERS.ONE in 2021, and titled "*A Centuries-Long, Three-Braided Conceptual Chronology: Expected Value Optimization, Client-Centric Planning, and Growth Optimal Selection*". The paper:

- Mapped the history of key concepts in the development of investment management by tracing each concept back to its earliest, published research paper,

- Structured the flow of the history of **Financial Economics** in four conceptual eras that include:

    o "*The 19th Century and Earlier: Expected Value*" (*shown in italics* in the Timeline)
    o "The 20th Century through World War II: Axiomatization" (in normal font)
    o **"The 20th Century, Post World War II: the Ergodic Fallacy" (in bold italics)**
    o **"The 21st Century: Time Average" (in bold normal font)**

- Summarized each concept in short paragraphs, including book & paper citations, and

- Illustrated the timeline as a one-page synoptic table.

This table maps the "*Three Braids*" of best practice developments in **Financial Economics** as follows:

- "*Expected Value Optimization*", the historical foundation of **Financial Economics**, based on the collective "*Rationality*" of the **Logic & Statistics Program,** and shown in the right column in the matrix on the right page

- "*Growth Optimal Selection*", the historical refocusing from **Financial Economics** and the collective "*Rationality*" of "*Expected Value Optimization*" to **Ergodicity Economics** and the "*Time Average*" growth rate of the typical individual, shown in the middle column in the matrix

- "*Client-Centric Planning*", the historical evolution from the "*Bias, Framing & Aversions*" of the **Heuristics & Bias Program** to the "*Ecological Rationality*" of "*fast & Frugal*" **Heuristics Program**, and shown in the left column in the matrix

In 2022 on Substack, this timeline became the backbone for the flow of the two-page sections in Volume 1 - Workbook #IV: Making Good Investment Decisions.

Timeline of the foundational authors behind the development of the "Axioms, Assumptions & Hypotheses", and matching "Theories, Rules & Laws" in Financial Economics

Client Centric Planning	Growth Optimal Solutions	Expected Value Optimization
	Euclid (3rd. Century BCE)	*Euclid (3rd. Century BCE)*
		Leonardo Fibonacci (1202)
		Huygens (1657)
	Euler (1730)	*Bernoulli (1738)*
		Bayes (1763)
		Cournot (1838)
	Euler (1862)	
		Devas (1883)
	Boltzmann (1884)	
		Galton (1886)
		Edgeworth (1888)
		Bachelier (1900)
		Fisher (1925)
Ramsey (1931)		
		Neyman/Pearson (1933)
		Kolmogorov (1933)
		Wald (1939)
Koopman (1942)		
Wald (1945)		
	Samuelson (1947)	*Von Neumann/Morgenstern (1947)*
	Shannon (1948)	
		Graham (1949)
Roy (1952)		*Markowitz (1952)*
Simon (1957)		*Bellman (1957)*
		Herrenstein (1961)
Kogan/Wallach (1964)	*Mandelbrot (1964)*	*Sharpe, Fama (1964)*
		Modigliani (1966)
	Merton (1969)	
		Merton (1972)
		Treynor/Black, Black/Scholes (1973)
		Ross (1976)
		Lucas (1978)
Kahneman/Tversky (1979)		
	Bell, Cover (1980)	
		Brinson/Hood/Beebower (1986)
Black/Litterman (1992)		*Fama/French (1992)*
Tversky/Kahneman (1992)		
	Merton (1993)	
Bengen (1994)		
	Fernholz (1995)	
Fehr/Schmidt, Gigerenzer (1999)		
Shegrin/Statman (2000)		
		Lo/MacKinley (2002)
Qian (2005)		
Hovernaar (2008)		
	Peters (2009)	
Gadenne/Zwecker (2010)		

Having positioned **Ole Peters** (2009), thus **Ergodicity Economics** in the "*Historical Lineage*" of **Financial Economics**, the next page uses all analytical steps from the Template for Reading Research Papers – including "*Perspective*", "*Historical Lineage*", "*Purpose*", "*Methodology*", "*Methods*", "*Axioms, Assumptions & Hypotheses*", and "*Meaning*" – to develop an Author Profile that describes the on-going role and growing importance of **Ole Peter** and **Ergodicity Economics** in **Financial Economics**.

Author Profile: Ole Peters

"Perspective": Decision-Making Under Uncertainty based in Physical Operations
Ole Peters applies insights from Physics to decision-making theory, and his results generalize findings in several fields that include ***Financial Economics***, ***Behavioral Economics***, and ***Decision Theory***.

"Historical Context": From Physics to Decision-Making
In 2001, ***Peters*** earned his B.Sc. in Physics from the Imperial College London, followed by a Ph.D., also in Physics, in 2004. His career took him to the Santa Fe Institute as well as UCLA before he became the intellectual founder of the ***Ergodicity Economics*** program (***EE***) in 2012, and its organizational leader, in 2018, at the London Mathematical Laboratory (LML).

"Purpose": Fixing Foundational Errors
EE resolves many "*Puzzles, Paradoxes, & Anomalies*" in ***Financial Economics*** by fixing the "*Feet of Clay*" of foundational "*Axioms, Assumptions & Hypotheses*" in "*Rational*" theories of decision-making in general, and EUT in particular.

"*Methodology*": Ergodically Consistent Closed-From Equations
EE develops equations with explicit ergodic consistency, starting with "*Growth Dynamics*" with matching growth formulas, and ergodic transformation functions.

"Methods": The Mathematics of Physics
EE uses the mathematics of theoretical & applied Physics to model individual behavior based on the specific "*Growth Dynamics*" in the decision-maker's "*Task Environment*". In the case of ***Financial Economics***, ***EE*** models the stochastic processes that governs the growth of wealth to enable the description of individual as well as population behaviors. This reveals emergent behaviors such as "*Winners-take-all*" trajectories, the value of cooperation between individuals, justifications for optimal taxation, and the value of minimum investment holding period. It also reveals regularities in the price trajectories of traded, risky assets, optimal leverage (strategic asset allocation) across types of financial assets, and the development of ***EE***'s theory of noisy growth in stock prices resolves many "*Puzzles, Paradoxes & Anomalies*" such as the Equity Premium Puzzle.

"*Assumptions & Hypotheses*": Life Seeks to Maximize Rates of Change Over Time
Decision-making has a structure that maps into mathematical models with physical interpretations. Past theoretical & empirical research suggests that most real-life situations have decision-making circumstances with non-ergodic observables. In the few situations that have decision-making circumstances with ergodic observables, the expected value provides a relevant summary of the situation for individual decision-making. Current empirical research shows that individuals may sense ergodicity-breaking circumstances where the "*Time Average*", instead of the "*Ensemble Average*", provides the relevant summary of the situation for individual decision-making. Life seeks to maximize rates of change over time, and "*only in the case of processes with ergodic increments do inferences based on group-level data generalize to individual experience*".

Author Profile: Ole Peters (Continued)

<u>*"Meaning":*</u> The Relevance of Ergodicity Economics

While the first **EE** papers show publication dates that start around 2010, **EE** conferences started in 2021. The table shown below presents the conference speakers in their order of appearance for the four EE conferences to date. The color coding shows the returning speakers over time as a proxy for the topics that continued to have relevance from one conference to the next.

EE Conferences 2021 to 2024: Speakers and Returning Speakers

2021	2022	2023	2024
Alex Adamou	John Kay	Ole Peters	William Poundstone
Ole Peters	Ole Peters	Nicholas Underwood	Ole Peters
Marc Elsberg	Umberto Cherubini	James Price	Colm Connaughton
David Meder	Carlos Raposo	Carlos Raposo	Simon Steinkamp
Arne Vanhoyweghen	Andrew Fleck	Rory Sutherland	Dominik Baumann
Remy Levin	Lorenzo Fant	Lorenzo Fant	Gabriel J. P. Pinto
Mark Kirstein	Veronica Poor	James King	Jerome Garnier-Brun
Ollie Hulme	Mark Kirstein	Athena Aktipis	Marleen Van Der Weij
Peter P. Wakker	Luciano Andreozzi	Colm Caunnaughton	Hugo Fleming
Hans Geboers	Ollie Hulme	Julie Freytag	Emilie Soysal
Mishael Milakovic	Thomaz Kopczewski	Bert Verbruggen	Aaron Fisher
Nils Bertschinger	Jean-Philippe Bouchau	Dominik Baumann	Oliver Hulme
Yonatan Berman	Ivonee Schwartz	Stepahnie Kelton	Erica Thompson
Victor Stojkoski	Giulia Liveri	Benjamin Skjold	Veronica Poor
Jamil Civitarese	James Price	Matthew Ford	Graham Boyd
Ihor Kendiukhov	Victor Stojkoski	Maria de la Laviada	James King
Diomedes Mavroyianni	Rory Sutherland	Joshua Lawson	Simon Blothner
Anthony Britto	Harry Crane	Ollie Hulme	Benjamin Skjold
Erica Thompson	Andrea Taroni	Benjamin Skjold	Tobias Wand
Alex Kacelnik	Anand Sahasranaman	Cathy Macharis	Pavel Chvykov
Madhur Mangalam	Fahimeh Najafi	Madhur Mangalam	Jerome Nikolai Warren
Michael Bell		Erica Thompson	
Ravi Kanbur		Luca Dellanna	
Samuel Forbes		Emilie Soysal	
Roger Farmer		Arne Vanhoyweghen	
Francois Gadenne			
Christian Mueller			
Andrew Fleck			

EE's "*Historical Lineage*", and its developing theoretical & practical ecosystems paint the picture of the development of **EE** as a new Program that stands alongside the ***Logic & Statistics Program***, the ***Heuristics & Bias Program***, and the "*Fast & Frugal*" ***Heuristics Program***. Since its foundation, nearly 15 years ago, the ***Ergodicity Economics Program*** has moved from theory, to empirical validation, and to best practice implementations as shown on the next page.

Enduring EE Topics in the Conference Programs

EE's framing of decision problems in terms of the "*Time Average*" growth rate instead of the "*Expected Value*" of rates of return provides quantitative explanations that bring closure to a large number of the "*Puzzles, Paradoxes & Anomalies*" in **Financial Economics** & **Behavioral Economics** theories based on the **Logic & Statistics Program** For instance, it solves problems related to discounting and utility as intrinsic properties of ***EE's*** "*Growth Dynamics*". These intrinsic properties do not require an appeal to "*As-if*" models, or hidden forces external to the model.

The continuity of conference topics presented by speakers from ***EE***2021 to ***EE***2024 includes:

- ***EE*** as a generalization of Expected Utility Theory (EUT)
- ***EE*** Micro, Meso, and Macro-Economic models,
- ***EE*** validation through empirical experiments,
- ***EE*** validation of inferences from Models
- ***EE*** and the value of Cooperation,
- Insurance as an Ergodicity Problem,
- Absorbing Barriers as a source of non-ergodicity, and
- ***EE***'s value for Reinforcement Learning

Above and beyond the conference presentations based on these continuing topics, ***EE***2024 included a review of ***EE***'s "*Historical Lineage*" by ***Ole Peters***. The next page presents a side-by-side timeline comparison between CTRI's 2021 paper and this ***EE***2024 presentation.

Comparing Column 1 (***Ole Peters*** presentation at EE2024), and Column 2 (***Francois Gadenne***'s 2021 paper, and Volume 1 – Workbook #IV), and looking for both added and missing authors shows the similarities of the "*Historical Lineage*" timelines, and the differences that come from developing such timelines with an academic **Physics** "*Perspective*" vs. a business **Financial Economics** "*Perspective*".

Comparing the 2021 Timeline of the foundational authors behind the development of the "Axioms, Assumptions & Hypotheses" and resulting "Theories, Rules & Laws" in Financial Economics with Ole Peters' EE2024 Timeline for Ergodicity Economics

Ergodicity Economics (EE2024)	Growth Optimal Solutions	Expected Value Optimization
	Euclid (3rd. Century BCE)	*Euclid (3rd. Century BCE)*
		Leonardo Fibonacci (1202)
Pascal/Fermat (1650s)		*Huygens (1657)*
Bernoulli: Nicolas (1710)/Daniel (1738)	*Euler (1730)*	*Bernoulli (1738)*
		Bayes (1763)
		Cournot (1838)
	Euler (1862)	
Withworth (1870)Galton/Watson(1875)		*Devas (1883)*
Botzman/Maxwell/Gibbs	*Boltzmann (1884)*	
		Galton (1886)
		Edgeworth (1888)
Bachelier/Hilbert (1900)		*Bachelier (1900)*
		Fisher (1925)
		Neyman/Pearson (1933)
		Kolmogorov (1933)
		Wald (1939)
Von Newmann/Birkhoff (1932)	**Samuelson (1947)**	***Von Neumann/Morgenstern (1947)***
Ito (1944)	**Shannon (1948)**	
Schrodinger		***Graham (1949)***
		Markowitz (1952)
John Kelly (1956)		***Bellman (1957)***
Aitchison/Brown (1957)		***Herrenstein (1961)***
	Mandelbrot (1964)	***Sharpe, Fama (1964)***
Samuelson (1968)		***Modigliani (1966)***
	Merton (1969)	
Anderson (1972)		***Merton (1972)***
		Treynor/Black, Black/Scholes (1973)
		Ross (1976)
		Lucas (1978)
Arthur/Davidson/Derrida/Kauffman, Santa Fe Institute(1980)	**Bell, Cover (1980)**	
		Brinson/Hood/Beebower (1986)
		Fama/French (1992)
	Merton (1993)	
	Fernholz (1995)	
Marsili/Maslov/Zhang (1998)		
Bouchaud/Mezard (2000)		
		Lo/MacKinley (2002)
	Peters (2009)	
Peters (2011)		
Gell-Mann/Peters (2016)		
Adamou/Peters (2018)		
Meder, et al. (2021)		
Carr/Cherubini (2022)		

The next chapters in this notebook on ***Ergodicity Economics*** will build up on these similarities and differences to describe **EE**'s "*Purpose*", "*Methodology*" choices, "*Methods*", "*Axioms, Assumptions & Hypotheses*", and "*Meaning*".