Interpretations and Usages of Time in the Theory of Finance

Bálint Zsolt NAGY
Faculty of Economics and Business Administration,
Babeş-Bolyai University, Cluj

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Abstract: In the present article we attempt to give a general perspective on the role and usage of time generally in economics and specifically in different areas of the theory of finance as a sub-part of economics. After discussing time in economics in the first chapter, we turn to specific issues such as market timing of investments, timing of replacement decisions and the problem of intertemporal choice (discounting). In the last chapter we discuss controversies and issues related to econometric modelling and time series analysis in finance.

E-mail: balint.nagy@econ.ubbcluj.ro

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Time is an ancient, problematic concept, which has many interpretations in different fields of knowledge from philosophy, social sciences to natural sciences, especially physics. Time itself is not a central concept in economics and in finance but it does play a very important role in the theories of the time value of money, inter-temporal consumption and investment decisions, models of economic and business cycles and econometric forecasting models based on time series, just to name a few.

In the present article we attempt to give a general perspective on the role and usage of time generally in economics and specifically in different areas of the theory of finance as a sub-part of economics.

Time in economics

Before discussing time in finance in the next chapters, let us examine briefly some important aspects of time in economics. Time as a general notion is usually not rigorously defined in economic theory, instead the works in this field define only related concepts such as: time-value, waiting time, time series, time preference, etc.

To examine in detail the development of the relationship between time and economics throughout history greatly exceeds the scope of this paper therefore we will only refer briefly to the work of Mosselmans,[1] which explores the relationship of time and value in the history of economics and distinguishes several stages of the development of the economy. In the so-called "anthropometric stage" time and value are closely linked: value and time are not abstract and individual concepts, but they express a concrete process, which incorporates the social positions of individuals, hence the name anthropometric. In the "lineamentric stage" the concepts of time and value are

[1] B. Mosselmans, "Time and Value in the History of Political Economy", *Foundations of science*, 10, no. 3 (2005).

cyclical, because the origin of value – which in this stage is considered to be human labour – reproduces itself in each production period. In this stage the concepts of time and value become more abstract and disjoint. In the third and final, "syndetic stage" the cyclical conception of the economy is abandoned through the perception of a non-reproductive system. Time and value remain separated, and linear time becomes one of the main analytical tools of economics. This stage corresponds to the development of marginalism and neoclassical economics, which replaces the labour theory of value with subjective utility theory and the scarcity definition of economics.

In the history of economic thought in the 20th century, an interesting development came when J. R. Hicks in a 1976 book chapter[1] drew the attention to the difference between "economics in time" and "time in economics" referring to the way time was integrated into economic theory, mostly as a parameter (time in economics) without taking into consideration the most important characteristic of time: irreversibility. Moreover, viewing time merely as one more extra parameter does not solve the problem of developing dynamic economic models from static models. Hicks made references to Nicolae Georgescu Roegen, who initiated the so-called "thermoeconomics" science based exactly on the irreversibility of time which leads to the application of the Law of Entropy to the economic systems. Applying the second law of thermodynamics, the increase of entropy, would be a way of incorporating the irreversibility of time. Another way would be the application of evolutionary principles, which led to the development of evolutionary economics. To this date, thermoeconomics and evolutionary economics are considered heterodox approaches, the orthodox macroeconomics remaining with treating time as a simple parameter. Finally, time can be made endogenous in economic models using the concept of learning, because the process of learning assumes the irreversibility of knowledge and thus, the irreversibility of time.[2]

Turning now to the present, generally, neoclassical and Keynesian macroeconomics, which constitute the standard of economic literature, use the so-called Newtonian or linear time. Newtonian time describes an idea of time marked mainly by movements along a line (as either discrete or continuous units) in the same manner as space is made up of such units (economics as a science always aspired to achieve the rigorousness of physical science, hence the analogy with Newtonian mechanics). Austrian school theorists have criticized this conception and claim, Newtonian time has little relevance for economics.[3]

Specifically, O'Driscoll and Rizzo point to three elements of Newtonian time in standard economic theory:

- *Homogeneity.* All points in time are treated equally and therefore time passes without this necessarily meaning that the environment also changes. All changes in this case are exogenous; endogenous change in economic agents is not given, including learning.

[1] ***J. R. Hicks***, "Some Questions of Time in Economics", in *Evolution, Welfare and Time in Economics*, eds. A. M. Tang, F. M. Westfield, J. S. Worley (Lexington: Lexington Books, 1976), 263–280.

[2] L. Boland, "Applying Economic Methodology: Recognizing Knowledge in Economic Models", *Energeia: International Journal of Philosophy and Methodology of Economics*, 1 (2002), 22–31.

[3] Gerald P. O'Driscoll, Mario J. Rizzo, *The Economics of Time and Ignorance* (London and New York: Routledge, 1996): 55.

- *Mathematical continuity.* Because the points in time are regarded statically, each point is disconnected from all other points, therefore time does not "flow" from one period to the next, it jumps. "A Newtonian system is merely a stringing together of static states and cannot endogenously generate change."[1]
- *Causal inertness.* Because time is independent from its contents, the changes of the system must be traced back to the initial assumptions. Thus Newtonian models lack "genuine change" and "time literally adds nothing."[2]

Time in financial economics

Financial economics is the branch of economics concerned with "the allocation and deployment of economic resources, both spatially and across time, in an uncertain environment".[3] It is additionally characterised by its "concentration on monetary activities", in which "money of one type or another is likely to appear on *both sides* of a trade"[4]. The questions within financial economics are typically framed in terms of time, uncertainty, options and information.

- Time: money (cash flows) now is traded for money (cash flows) in the future.
- Uncertainty (or risk): The amount of money to be transferred in the future is uncertain.
- Options: one party to the transaction can make a decision at a later time that will affect subsequent transfers of money.
- Information: knowledge of the future can reduce, or possibly eliminate, the uncertainty associated with future monetary value.

The instances in which temporality plays an important part in financial economics are timing decisions, replacement or investment timing decisions and also the discounting (present value) models of financial mathematics. We will discuss these in the following three chapters.

Market timing

Market timing means in general choosing the optimal time for a certain financial decision. Sometimes it applies for decisions regarding at what time a company should issue stock, bonds or other assets (optimizing the company's financial structure). In the field of financial investments, timing the market is the strategy of making buy or sell decisions of financial assets by attempting to predict future market price movements. It is often cited as an opposed strategy to stock selection because timing involves switching between investments in broad classes of assets (from stocks to bonds or from real estate to stocks etc.) compared to stock selection where the careful picking of individual stocks and not the time of investment, is decisive. The prediction may be based on an outlook of market or economic conditions resulting from technical or fundamental analysis.

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[1] Rizzo O'Driscoll, *The Economics of Time and Ignorance*, 55.
[2] Ibid., 55.
[3] "Robert C. Merton – Nobel Lecture" (PDF). http://nobelprize.org/nobel_prizes/economics/laureates/1997/merton-lecture.pdf. Retrieved 2009-08-06.
[4] "Financial Economics". Stanford.edu. http://www.stanford.edu/~wfsharpe/mia/int/mia_int2.htm. Retrieved 2009-08-06.

Like many other topics in financial economics, the viability of market timing is very controversial. The Efficient-Market Hypothesis (EMH) claims that financial prices always follow a random behaviour and thus cannot be predicted with consistency, therefore market timing is considered gambling based on pure chance because undervalued or overvalued stocks cannot exist for a long time (the activity of speculators and traders ensures that even if there where mispricings on the market, these agents would buy or sell massively until the prices reach a new equilibrium). For all these reasons the efficient-market hypothesis says that market timing strategies cannot work. It says that investors cannot "beat the market", but also investors cannot do *worse* (on average) than the market either, when gross returns are measured. However, when net return is calculated after subtracting taxes and transaction costs, then most investors have a return less than the market average. EMH says that the investment return created by a strategy that is 50% of the time in cash and 50% of the time in stocks should be similar to a strategy that is 50% invested in stocks and 50% in cash *at all times* (plus variations for random error).

On the other hand, the fact that the stock market is subject to cyclical patterns and speculative bubbles, which contradict the efficient market hypothesis, many specialists try to find the optimal time to enter the stock market (e.g. at the beginning of a speculative bubble). However, because the economy is a complex system that contains the multilateral interaction of many factors, even at times of significant market optimism or pessimism, it often remains difficult to predetermine the local maximum or minimum of future prices with any precision; a so-called bubble can last for many years before prices collapse. Likewise, a crash can persist for extended periods, so in such times the rational expectation of market agents is for the trend in prices to continue (a so-called rational bubble forms).

The advocates of market timing usually point to the fact that if we look more closely, every trading activity on the stock market can be considered some form of market timing. So market timing can be as profitable or not profitable as trading on the stock market in general. The main adversaries of this point are the so-called passive (or buy-and-hold) investors who make no attempt to time the market: they just try to replicate the market average (market index) in order to obtain the stock market's long-term average return with average risks (although sometimes this strategy also implies changing, "rebalancing" the investment portfolio to reflect the changes incurred by market indexes).

The empirical evidence to support market timing is very controversial. On a large scale we have to look at the performance and money flows of mutual investment funds. These show that flows generally track the overall level of the market. For example, the largest inflows to stock mutual funds were in early 2000 while the largest outflows were in mid 2002. It is good to note that these mutual fund flows were near the start of a significant *bear* (downtrending) market and *bull* (uptrending) market respectively. A similar pattern is repeated near the end of the decade.[1] This mutual fund flow data seems to indicate that most investors (despite what they may say) actually buy high, and sell low although the profitable strategy would be the opposite. This leads to an increase in the number of buyers, which then drives the price even higher. However,

[1] B. G. Malkiel, "Can Predictable Patterns in Market Returns Be Exploited Using Real Money?", *Journal of Portfolio Management*, 31 (Special Issue) (2004): 131–141.

eventually, the supply of buyers becomes exhausted, and the demand for the stock declines and the stock or fund price also declines.

The most recent of the so-called Dalbar studies which analyze the behaviour of small investors, released in 2009, indicated that during the 20 years from 1989 to 2008, the average stock fund investor earned returns of only 1.87% per year, while the S&P 500 broad market average returned 8.35%.[1] The Dalbar studies reveal that the behaviour of average fund investors is an obstacle to reaching the published performance of the financial markets in which they are invested. Clearly, investor behaviour can have a far more negative impact on investment performance than investors realize.

Timing of replacement decisions

Another instance in which timing appears is found in corporate finance, namely in capital replacement decisions. These decisions are part of the so-called dynamic capital budgeting decisions, in which the task is to maximize the net present value of a collection of capital investments (e.g. the production facilities of a company). Timing decisions classically mean calculating the net present value in each scenario of prolonging the lifetime of a production unit and selecting the scenario with maximal present value (ex-ante decisions). Ex-post replacement decisions involve the comparison of an asset, which has already been in utilization with a new asset, comparing the annuities obtained from their present value.

While traditional financial theory considers risk and uncertainty as factors that decrease the value of any investment or asset, more modern theories, such as the theory of real options suggest the opposite: under certain circumstances, uncertainty and risk may add to the value of an investment or asset, especially when this investment is not a rigid, fixed decision, but can be timed, i.e. deferred or postponed to some point in the future where the investment could be more profitable. Flexibility either in time of implementation or in the product variety obtained with that asset can add to the value of the investment project.

It is still controversial whether these types of replacement and timing decisions properly integrate the concept of the irreversibility of time. Boland argues that in the case of investment decisions dynamics are exogenous but the source of the dynamics is unknown. "When one is optimistic an early investment decision will be made but when one is pessimistic the investment might be postponed. In this sense timing of an investment is endogenous so long as one builds into the model the explanation as to how one might choose to view the future."[2]

Discounting models

Time value of money is a groundstone in all valuation models used in finance. The theory, although attributed to Irving Fisher[3] in most microeconomics textbooks, was analytically formulated for a multi-period general framework by Paul Samuelson.[4] Any

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[1] www.qaib.com

[2] L. A. Boland, *Economics in Time Versus Time in Economics: Building Models so that Time Matters* (working paper, Simon Fraser University, 2005).

[3] Irving Fisher, *The Theory of Interest* (NY: Macmillan, 1930).

[4] Paul Samuelson, "A Note on Measurement of Utility", *Review of Economic Studies* 4 (1937): 155–161.

amount of value or asset (money, consumption, material goods) is worth more in the present than in any time in the future. It is important to note that future consumption or money is not worth less because the future is always uncertain. The difference between present and future value remains even in the case of complete certainty of future consumption or money. In cases where we have risk in or uncertainty about the future, then these future cash flows are worth even less.

From these considerations the concept of interest rate has evolved, which in most textbooks is defined as the price of money. However, if we take into consideration that the interest rate is exactly the "difference" between future value and present value, then we can say that the interest rate is the price of time.

Behavioural models of intertemporal choice – hyperbolic discounting

As we have mentioned earlier, discounting is a natural assumption for human decision makers. But the question is how intensely do people in general prefer present utility more than future utility? In other words what types of mathematical functions must we use to determine the present equivalent (present value) of a future unit of utility? The mainstream financial theory states that we should use exponential discounting, because that is consistent with the Neumann-Morgenstern axioms[1] of rational decision-making and it leads to consistent time preferences: the preference relation between two different quantities of utility will be the same in any given point in time. On the contrary, more modern approaches such as behavioural economics and finance advance the hypothesis of *hyperbolic discounting*. Hyperbolic discounting has been widely documented in humans and animals.

Regarding the technical differences between exponential and hyperbolic discounting, we can observe that in hyperbolic discounting, valuations fall very rapidly for small delay periods, but then fall slowly for longer delay periods. This contrasts with exponential discounting, in which valuation falls by a constant factor per unit delay, regardless of the total length of the delay.

A subject using hyperbolic discounting has a tendency to make inconsistent choices over time. This *dynamic inconsistency* happens because hyperbolic discounting discounts future rewards much more than exponential discounting. The simplest example for dynamic inconsistency is the following: when offered the choice between $100 now and $200 a year from now, many people will choose the immediate $100 payoff (which means that these decision makers possess a subjective time preference rate of at least 100%). In contrast, given the choice between $100 in ten years and $200 in eleven years almost everyone will choose $200 in eleven years, even though that is the same choice seen at ten years' greater distance.

George Ainslie pointed out[2] that if we plot the value assigned to choices by delay (time index), this would result in a hyperbolic shape, and that this shape produces a reversal of preference from the larger, later to the smaller, sooner reward only for the reason that the delays to the two rewards got shorter. A large number of subsequent experiments have confirmed that spontaneous preferences by both human and

[1] J. von Neumann and O. Morgenstern, *Theory of Games and Economic Behavior* (Princeton, NJ: Princeton University Press, 1953). Originally published in 1944.
[2] G. W. ***Ainslie***, "Impulse Control in Pigeons", *Journal of the Experimental Analysis of Behavior* 21 (1974): 485–489.

nonhuman subjects follow a hyperbolic curve rather than the conventional, "exponential" curve that would produce consistent choice over time.[1, 2]

Since then, a great body of literature has developed around the role of hyperbolic discounting in the domain of self control: a variety of studies have used measures of hyperbolic discounting to find that drug dependent individuals discount future benefits more than the nondependent control group.[3] Another area of addiction in which hyperbolic discounting plays a great part is that of pathological gambling[4] and that of procrastination (the tendency of people to postpone important decisions, especially postpone the quitting of a bad habit such as smoking). The direction of causality between hyperbolic discounting and addiction is not precisely determined: it is unclear whether high rates of hyperbolic discounting precede addictions or vice-versa.

The financial studies concerned with hyperbolic discounting examine the discounting of specific rewards such as money (measured in temporal cash-flows). There are many factors that influence the rate of discounting such as age,[5] the species being observed, experience, and the amount of time needed to consume the reward.[6] Furthermore, even for a given delay, discount rates vary across different types of intertemporal choices: gains are discounted more than losses (sign effect), small amounts more than large amounts (magnitude effect), and explicit sequences of multiple outcomes are discounted differently than outcomes considered singly (sub-additive discounting).[7]

The main explanation of this phenomenon is evolutionary: the human survival instinct has evolved to appreciate that one cannot enjoy a conserved resource tomorrow if one does not survive today. This deeply imprinted tendency may be the bias behind our temporal myopia, leading us to decisions, which could cause short-term happiness and long-term disaster.

Another manifestation of hyperbolic discounting is when people over-commit their future schedules. Researchers documented that most people tend to make commitments for the far future that they would never make if the commitment required immediate action.

Apart from the classical economic theories of capital and production factors there is also a psychological reason for which financial institutions such as banks and credit card companies developed and exist: they build their businesses on hyperbolic discounting, because borrowing money and paying interest are actions that spend future

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[1] Leonard Green, Astrid Fry, and Joel Myerson, ''Discounting of Delayed Rewards: A Life-Span Comparison'', *Psychological Science* 5 (1994): 33–36.

[2] Kris N. Kirby, ''Bidding on the Future: Evidence Against Normative Discounting of Delayed Rewards'', *Journal of Experimental Psychology*: *General* 126 (1997): 54–70.

[3] W. K. Bickel, M. W. Johnson, "Delay Discounting: A Fundamental Behavioral Process of Drug Dependence", in *Time and Decision*, eds. G. Loewenstein, D. Read, and R. F. Baumeister (New York: Russell Sage Foundation, 2003).

[4] Nancy M. Petry, *Thomas* Casarella**,** "Excessive Discounting of Delayed Rewards in Substance Abusers with Gambling Problems", *Drug and Alcohol Dependence* 56 (1999): 25–32.

[5] Leonard *G*reen*, Astrid F.* Fry*, Joel M*yerson, *"*Discounting of Delayed Rewards: A Life-Span Comparison", *Psychological Science*, 5 (1994): 33–36.

[6] George Lowenstein*, D.* Prelec*,* "Anomalies in Intertemporal Choice: Evidence and Interpretation", *Quarterly Journal of Economics*, 57 (1992), 573–598.

[7] Shane Frederick, George Loewenstein, Ted O'Donoghue, "*Time Discounting and Time Preference: A Critical Review*", *Journal of Economic Literature*, 40 No. 2 (2002): 351–401.

wealth for present utility. Of course, crediting is an activity that would be present even in the case of exponential discounting, but the virtually zero savings rate of many developed societies and economies (such as the USA) suggest that people value present consumption much more than what exponential discounting suggests: the more intense the hyperbolic discounting, the higher interest rates have to be in order for people to save more and borrow less. Unfortunately monetary policy in the US has acted contrary to this, lowering interest rates in much of the 2000s decade, leading to the housing bubble on the US market.

Psychologists offer a few ways to ameliorate the effects of hyperbolic discounting. Because at the core of the problem lies the excessive self-focus of individuals, the best theoretical approach is to take an objective view of any decision that has future consequences. Some imaginative exercises can help in these circumstances e.g. the subject should imagine that the decision belongs to someone else (suitably a close friend) and that the subject has been asked for advice. Removing oneself from consideration makes one less blind to the future consequences, but this is only in theory because acting rationally after these insights can still be very hard (awareness is only a necessary but not a sufficient condition in this case). Therefore it can be even more useful if the individuals affected by this bias are advised by a third person (but close to the subject) who can be even more objective.

Therefore the hyperbolic discounting model is an eloquent example of how the interpretation of time becomes non-linear: from the point of view of practical (financial) decisions, it appears as if time had a giant singularity (accumulation point, or a metaphorical black hole) around the time of the present and any utility or cash flow which is beyond the immediate, subjective horizon of this "black hole", were a matter of much less significance.

Economists are forced to intuit, to the best of their abilities, which considerations are likely to be important in a particular domain and which are likely to be largely irrelevant. When economists model labour supply, for instance, they typically do so with a utility function that incorporates consumption and leisure, but when they model investment decisions, they typically assume that preferences are defined over wealth. Similarly, a researcher investigating charity might use a utility function that incorporates altruism but not risk aversion or time preference, whereas someone studying investor behaviour is unlikely to use a utility function that incorporates altruism. For each domain, economists choose the utility function that is best able to incorporate the essential considerations for that domain, and then evaluate whether the inclusion of specific considerations improves the predictive or explanatory power of a model. The same approach can be applied to multiple-motive models of intertemporal choice. For drug addiction, for example, habit formation, visceral factors, and hyperbolic discounting seem likely to play a prominent role. For extended experiences, such as health states, careers, and long vacations, the preference for improvement is likely to come into play. For brief, vivid experiences, such as weddings or criminal sanctions, utility from anticipation may be an important determinant of behaviour.

To sum up, we believe that economists' understanding of intertemporal choices will progress most rapidly by continuing to import insights from psychology, by relinquishing the assumption that the key to understanding intertemporal choices is finding the right discount rate (or even the right discount function), and by readopting the view that intertemporal choices reflect many distinct considerations and often involve the interplay of several competing motives.

One of the main open questions is whether hyperbolic discounting could replace exponential discounting in the valuation formulae used in the financial literature and practice. We believe the answer is negative because the discounting of future cash flows is based not on psychological features but on the institutional practice that investing in safe assets such as bank deposits and government bonds results in pay-offs calculated exponentially (through the compound interest formula).

An important problem in economics and finance is the topic of moral hazard, which describes situations when different actors interacting in an economic entity or system have incentives and motivations that are in contradiction. One example of such a moral hazard is put forward by Kahneman in the case of different time horizons: many moral hazard problems in firms arise from the fact that the paradigm of maximizing the market (or shareholder) value of a company is an objective for the long term, whereas the individual managers who take responsibility for it, typically have short term motivations due to the short term of their individual life. The same can be applied to public decision makers such as politicians who have to act for the long-term development of an economy but they face the same short-term contradicting motivations that company managers do.

Econometrics and time series analysis as principal tools for financial modelling

Before turning to the empirical aspects of time based analysis in finance (statistics and econometrics), we have to understand exactly why statistics and econometrics based on probabilities and estimations play such an important role in economics and finance.

A much-cited specialist in formalizing the analytical tools of software programming, Jan Bergstra formulates a very strong hypothesis: "*logic and the formalization of reasoning play no role in economic thinking and theory, neither do they in finance! There is an incredible dominance of statistical and probabilistic analysis suggesting that analytic models simply cannot exist*." [1] In his research project Bergstra tries to explain this dominance calling it a "major research problem".

We tend to agree to some extent with this point of view, indeed the role of statistics and probability increases when analytical, deterministic modelling does not lead to the expected results. Of course analytical, deterministic modelling still exists in many models developed in micro- and macroeconomics. However, the research field of economics and finance is so wide and the interactions between the economic agents are so complex that analytical modelling necessarily has far more limitations than in the case of physical sciences. Therefore the mathematical paradigms visible in the economic literature are heavily biased towards quantitative description and analysis of risk and uncertainty. This is interestingly in certain contrast with the everyday practice of economic organizations, especially private companies. Most organizations combine advanced accounting and financial analysis with qualitative and often intuitive decision-making performed by financial experts. Very often biased, prejudiced thinking and so-called heuristics, quasi-rational decision algorithms are applied by the executive

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[1] Jan Bergstra, Financial Logic
http://www.phil.uu.nl/~janb/phloofin/top.html retrieved 2010-01-10

management of companies. In these applications of financial thinking much less probability and statistics is used than we should expect from standard economic literature. Most management textbooks written by practitioners or teaching staff from universities use a much more simplistic approach to financial and strategic decision problems, often focusing on proper visualization of their categorizations (in 2*2 matrix forms, flowcharts, coloured graphs, etc.) rather than formalizing or proving them with rigorous mathematical tools. This is precisely the reason why there is a huge gap and distance between economic theorists (who use mathematics and statistics) and practitioners in many fields of economic and financial decision-making.

Among the main causes for the absence of financial logic and financial algebra in the field of finance, we can list the following:

1. The preference of economic thinking for quantification is in contradiction with the difficulties of this quantitative approach. The methodology used for financial modelling and forecasting is more and more complicated and wide, causing considerable disputes within the academic world upon which methods to use. There are no universally accepted mathematical tools that have no limitations or disadvantages. These complicated mathematical procedures then produce numerical results, which depend on subjective interpretation affected and many times biased by political doctrine or moral hazard.
2. Another reason why formal, deductive logic and reasoning in economic analysis cannot rise to dominance is that this field is characterized by highly practical people who have in most cases a case-study based education. Such persons often do not acknowledge the essential virtue of logic and deduction, and feel that rigorous decomposing and algorithmic thinking takes too much time and does not deliver superior results
3. Financial systems have more links with accounting than with economy, and, although accounting is a standard discipline at all economic faculties, it is also a part of the study of law. The logical formalization of law is a very clear direction of work in the theory of law and therefore accounting, as a part of law, could move into this direction of rigorous formalization.

One of the main methodological tools and frameworks in the field of economics and finance is econometrics, a discipline which evolved from statistics and mathematics in the first half of the 20th century based on the works of Ragnar Frisch and Jan Tinbergen (the winners of the first Nobel prize in economics in 1969). At the centre of econometrics lies regression analysis, which aims at identifying mathematical relationships between different variables. Social and economic processes are rarely deterministic therefore regressions always contain a differing degree of error. Econometric data can be classified as cross-sectional (when we analyse a certain statistical population with different parameters at a fixed point in time) and time-series (when we analyse the same statistical population at different points in time) or a combination of the two (panel data).

An interesting philosophical aspect of econometrics concerns the relationship between the underlying reality and the regression models used to describe this reality. The performance of regression analysis methods in practice depends on the form of the so-called *data-generating process*, and how it relates to the regression approach being used. The data-generating process is axiomatically seen as an "almost platonic" objective entity in econometrics, which can never be known with 100% certainty, therefore regression analysis depends on making assumptions about this process. One of the most widely tested of these assumptions is the one regarding the statistical distribution of data (mostly the testing of the normal distribution). Other essential assumptions used in the classic linear regression framework are the assumptions of no autocorrelation, no multicollinearity and homoskedasticity (the discussion of these assumptions greatly exceeds the scope of this paper). Regression models for prediction (forecasting) are often useful even when the assumptions are moderately violated, although they may not perform optimally. However when carrying out inference using regression models, especially involving small effects, structural breaks or questions of causality based on observational data, regression must be used very carefully because it can lead to mistaken results, especially in case of time series data.

At the beginnings of econometric modelling the so-called *destructive* approach was used which means that analytical macroeconomic theories were tested on empirical data through the method of falsification. Later, influenced by the works of Hendry,[1] *constructive* econometrics took over, which develops models starting from the empirical data, by trial and error methods (reduction theory). Although Hendry's reduction theory provides a comprehensive and general framework for the analysis of the relation between social reality and econometric models, it nevertheless has several shortcomings.

Hendry's theory lacks proper theoretical background and therefore econometrics has two contradicting views of social reality at its base. The first view is the theory that social reality is made up of indeterministic, historically inherited particulars. The course of history is indeterministic (indeterminism), history does not repeat itself (particularism), and the future depends on the past (historical inheritance). The second view is that there are permanent laws regarding the relationship and interaction between variables, an idea, which underlies most econometric practice. In constructive econometrics the economic mechanism under study (represented by the econometric model), is an entity of interactions that *can* change over time. According to the theory of social reality, however, there is no *a priori* reason for stable or persistent regularities to exist, so their existence is an empirical question. Conceptually this is not necessarily incompatible with constructive econometrics but since the latter does not give a probabilistic account on why and how the economic mechanism changes, this theory is unable to provide probabilistic reduction analysis with reference to the same initial or fundamental probability space. As a solution Sucarrat[2] proposes that the outcome set in the fundamental probability space is specified as consisting of indeterministic worlds made up of historically inherited particulars. This means that reduction analysis can be undertaken with reference to the same initial probability space throughout all reductions and the (conditional) existence of models across time and/or space can be obtained as (conditional) reductions.

In constructive econometrics there exists a complete set of theoretic variables relevant to the economy under investigation. If the course of history is indeterministic, if history does not repeat itself and if the future depends on the past, the number of theory

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[1] D. F. Hendry, *Dynamic Econometrics* (Oxford: Oxford University Press, 1995).

[2] G. Sucarrat, "Econometric Reduction Theory and Philosophy", forthcoming in the *Journal of Economic Methodology*.

variables of objective relevance for any economic event is likely to be infinite, because each cause has in the background its own causes, and so on. On the other hand in practice, every econometric model only focuses on a relatively small number of variables that may be of relevance for the purpose of the analysis.

In the models of financial economics time is a continuous variable, which is a convenient tool for the mathematical operations. Economics is at its foundation a normative science; it is always concerned with finding optimal values for certain variables – minimizing cost or maximizing profit, maximizing market value (or shareholder value), and finding these extreme values involves differentiating these continuous functions. On the other hand, general equilibrium models and behavioural economics and finance can be considered as part of a positive, descriptive science. Constructive econometrics is also problematic in its approach towards discrete versus continuous time models, because any econometric time series is based on a finite sample and therefore it can never be truly continuous the way theoretical, analytical models are.

Finance in general, and financial economics in particular uses extensively the methodology of time series analysis. That is because most financial phenomena take place in time and the quantities, variables analysed by financial economics (stock prices, interest rates, rates of return, money supply, etc.) are mostly time series.

Time series present the particular feature that they are affected by the irreversibility of time. While other types of data (e.g. cross-sectional data) can be arranged in any order we like, time series data can only have one direction: from the past towards the present and the future. In most methods applied time is viewed in a linear manner.

This leads to certain issues such as autocorrelation, which only affect time series. Therefore from the point of view of finance, irreversibility is the most distinctive and defining characteristic of time.

More recently there is a growing concern among economists that the above presented treatment and usage of time is not appropriate and has many implicit dangers. These controversies were further fuelled by the eruption of today's global financial-economic crisis, which in itself constitutes a proof of the fact that financial modelling was not able to foresee and prevent such a catastrophic phenomenon. One of the most vocal critics of standard time series analysis is the best-selling author, university professor and financial philosopher, Nassim Thaleb who in his two most successful books, *Fooled by Randomness* and *The Black Swan* makes several attacks on mainstream financial theory.[1]

First of all, he defines "black swans" as metaphors for events, which are *extremely rare*, *highly consequential* and *explained post-hoc.* Then Taleb defines himself as a "skeptical empiricist", but unlike other skeptics, his doubts are only directed to the fundamental incomputability of the probability of "Black Swan" events, and not towards regular events, which can be described with the Gaussian (normal) distribution. Taking the trial and error methods of medieval medicine as a model, Taleb's empiricism implies resisting generalization and induction from data and limiting the derivation of general rules from particular observations. Thus he believes that economists and

[1] Nassim Nicholas Taleb, *Fooled by Randomness: The Hidden Role of Chance in Life and in the Markets* (New York: Random House, 2001/2005). Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Improbable* (New York: Random House, 2007).

financiers in particular (but other categories of decision-makers as well) are victims of the so-called illusion of pattern: financial theorists and practitioners overestimate the value of rational explanations of past data, and underestimate the unexplainable randomness in those data. This assertion is in accordance with the much popularised results of cognitive psychologists Kahneman and Tversky, who demonstrated in many questionnaire-based surveys and psychological experiments the heuristics of recognizing patterns, representativity, myopia, etc.[1]

In his books, Taleb takes a multidisciplinary approach arching from mathematics through psychology, to philosophy. He defines himself primarily as a philosopher and a follower in certain sense of skeptical philosophers, among whom he makes the most numerous references to Socrates, Sextus Empiricus, Michel de Montaigne, David Hume, and Karl Popper in believing that we know much less than we think we do, and that the past should not be used naively to predict the future. The aim of his research is to make the world "Black-swan robust" i.e. resistant to these unpredictable and therefore uncontrollable events.

Taleb believes that most people ignore "black swans" because they are more comfortable and accustomed to perceiving the world as well-defined, structured, ordinary, and comprehensible. Taleb calls this blindness "the Platonic fallacy" and further discerns three sub-categories within that:

1. *Narrative fallacy*: Causality is not just an essential attribute of physical phenomena, but also a basic attribute of the way humans think, discovering stories, narratives post-hoc so that an event will seem to have an identifiable cause.
2. *Ludic fallacy*: With the advent of game theory, operations management, and stochastic finance, financial theorists suggested that this mathematical apparatus is capable of replicating the unstructured, "wild" randomness found in the social-economic sphere.
3. The *triplet of opacity*, which consists of an illusion of understanding current events, a retrospective distortion of historical events, and an overestimation of factual information, combined with an overvaluation of the intellectual elite.[2]

Taleb, an anti-Platonist, supports experiments and fact collecting, because knowledge and technology are generated by what he calls "stochastic tinkering", from the bottom-up and rarely by top-down directed research. Consistent with this anti-Platonism, Taleb stands against grand theories in social science and does not like to see his ideas called "theories"; instead, in his 2007 book, *The Black Swan*, he calls this an "anti-theory" or the "Black Swan idea".

This point of view is highly controversial in academia, mostly because apart from criticising almost every achievement of statistics and time series analysis, Taleb so far has failed to provide a framework which is better than standard statistics. In closing we must comment that time series analysis and especially financial forecasting remain among the most controversial topics in financial methodology.

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[1] Amos Tversky*, Daniel* Kahneman, "*Judgment under Uncertainty:* Heuristics *and Biases", Science,* New Series, Vol. 185, No. 4157 (Sep. 27, 1974).

[2] Nassim Nicholas Taleb, A. Pilpel, "Epistemology and Risk Management", *Risk and Regulation*, 13, Summer 2007.

Conclusions

We have tried to analyse certain aspects of time in financial methodology and theory. We have seen that time and timing decisions play a crucial role in financial economics, we have discussed the issues of market timing versus efficient market hypothesis (still an ongoing debate), replacement decisions and discounting. One of the most interesting scientific novelties is hyperbolic discounting which is just one of those transdisciplinary models that were developed by psychologists and later successfully applied by economists and financiers. Finally we have analysed extensively the issues of econometric forecasting and time-series analysis, one of the most controversial areas of financial methodology.