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Abstract: The purpose of this work is to highlight the epistemological proximity between Nietzsche's philosophy of science and the underlying philosophical principles of fractal geometry, as illustrated in the main work of its creator, the French mathematician Benoit Mandelbrot. This work also aims to find the end of this philosophical continuity, finding an important divergence between Nietzsche's philosophy of risk taking and Mandelbrot's legacy in risk management.

Keywords: Nietzsche, Mandelbrot, epistemology, mathematics, fractal geometry, finance, risk

Nietzsche, physics, and faith

Friedrich Wilhelm Nietzsche refused to structure an epistemological framework throughout his work, leading to different readings of his view on the philosophical significance of the practice of science. In an earlier set of works, which scholars define as the 'middle period' (1878-1882), the German philosopher praises the scientific method mainly as opposed to religious faith (in particular, Christianity) in what is generally considered a pro-Enlightenment stance (Garrard 2008). Nietzsche undertakes a major reversal through the works of the 'later period' (starting from 1882), in which he strongly condemns the concept of causality and other deterministic principles, reserving his most heated criticism to the practitioners of physics and mathematics.

Scholars (such as Campa 2007) have highlighted that Nietzsche never abandoned the idea that the scientific method is superior to religious faith, mainly because it does not aim to offer absolute truths. This idea is introduced briefly in *Human, All Too Human* (1878), in which the philosopher claims that the promises of science concern 'as little pain as possible, as long a life as possible' (HH, I, 128), adding that science's goals are 'very modest as compared with the promises of religions.' The characterization of science as 'modest' is resumed in *Antichrist* (1888), where Nietzsche states that science has less appeal than religion precisely because the scientific method – that is 'quiet, cautious, distrustful' (AC, 13) and forces scientists not to make unsubstantiated claims – does not offer the same certainty as religion, which instead has a 'picturesque effectiveness'.

It is key to note that Nietzsche's praise of science has always been related to process rather than results: 'The value of strictly pursuing science for a time does not lie precisely in its results' (HH, I, 256); mathematicians are praised for their 'subtlety and rigour' (GS, 246) and physicists for being 'creators' (GS, 335).

Negri (1994) speculates that Nietzsche's distrust of physics (and by proxy mathematics and logic) was prompted by the success of Newton's law of universal gravitation and its impact on the scientific method: gravity and forces of attraction are often mentioned in the philosopher's fragments and in *Thus Spoke Zarathustra* (1883), the German philosopher goes so far as defining the 'spirit of gravity' (I, On the Vision and the Riddle) as his 'devil' and 'arch-enemy.'

In the late XIX century, the British scientist's legacy was so powerful that his theories were being used as a base for virtually all new development in physics: the German physicist and philosopher Ernst Mach would mention in his *Science of Mechanics* (1893) that Newtonian theories were being used 'as points of departures' and that 'the impulse to inquire after their origin soon disappeared almost completely'. Kuhn (1962) would later define the Newtonian revolution as a 'paradigm shift', a scientific theory that constituted the basis of later scientific development. This paradigm shift had triggered a period of 'normal science', a phase in which science was being carried out based on 'achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice' (Kuhn 1962, p. 10).

Nietzsche is ostensibly disappointed by the fact that physicists could 'not get rid of the effect [action] at a distance' (FP, 36 [31], June-July 1885) - of which gravity is a prime example - and that the 'belief in even the ability to explain' these forces (FP, 36 [34], June-July 1885) had been lost. Physicists had become guilty – pretty much like the priests – of offering 'safety' against 'fear of the incalculable' (FP, 5, 10, 1886). In Garrard's (2008) words, he came to see the scientific research carried out in that period as 'just another herd mentality'. Negri (1994) concludes that it is not unlikely that the study of Newtonian theories appeared the equivalent of a theology in Nietzsche's eyes.

It is worth noting that Nietzsche's rejection of a systematic approach to science should be read in conjunction with his underlying critique of the epistemological system of Descartes. Burgess (2013) sees Descartes as an inspiration, although mostly as an antithesis, to Nietzsche throughout his works dedicated to science. The very first Cartesian principle 'ego cogito, ergo sum' is directly mentioned by Nietzsche (in WM, 484), who noted the pleonastic use of 'ego', an emphasis meant to highlight the subject of the thought: Nietzsche sees in this grammatical addition an 'ungrounded metaphysical assumption'.

This becomes a recurring theme throughout Nietzsche's work, in direct opposition with Descartes'. Burgess found that Descartes is 'not terribly interested in developing his thoughts in the order of being', which brings him to the conclusion that mathematical truths appear beyond all doubt. Nietzsche's is much more interested in the underlying forces behind reason (Burgess calls it the 'genealogy' of reason), concluding that rational insights are intertwined with the underlying values or desires of the agent. In BGE, 2 Nietzsche demands: 'From these "beliefs" they [metaphysicians] try to acquire their "knowledge," to acquire something that will end up being solemnly christened as "the truth."[…] It has not occurred to even the most cautious of them to start doubting right here at the threshold, where it is actually needed the most – even though they had vowed to themselves "de omnibus dubitandum"' (one should doubt about everything).

Scholars have defined Nietzsche's approach as 'Perspectivism', after an important excerpt (GS, 374) in which the German philosopher claims that 'human intellect cannot avoid seeing itself in its own perspectives.' Wallace (1973), citing Arthur Danto's *Nietzsche as Philosopher*, summarizes Nietzsche's position on the nature of mathematics and logic as follows: not inherent in nature, nor in the human mind, but 'useful conventions', just a conceptual scheme that is as dubitable as any other assumption.

Far from being a widely adopted notion in science, Nietzsche's perspectivism has been studied as an interesting influence in the history of mathematics. Hussain (2004), referring to Mach again, finds Nietzsche's ideas substantially in line with those of the German physicist with respect to 'taking science and the senses quite seriously'. Neves (2019) goes as far as calling Nietzschean perspectivism as a good option to interpret the modern results in physics.

Nietzsche and mathematical formalism

A related element of Nietzsche's critique of science is his position against mathematical formalism. The German philosopher could not conceive of science as 'an indoor diversion for mathematicians' (GS, 373) and believed that mathematics was 'too crude' (FP, 34 [124], April-June 1885) to be used to interpret the world. In what is probably his clearest contribution to the philosophy of mathematics, Nietzsche recognised that 'mathematics is only the means to general and final knowledge of humanity', but only to 'ascertain our human relation to things' (GS, 246). In a period when physicists and mathematicians indulged in formalism to illustrate mechanical principles, the German philosopher warned that 'our knowledge has become scientific to the extent that it is able to employ number and measure' (WP, 710). Steinhart (1999) found that Nietzsche's thought was 'squarely in line with those of intuitionism', a philosophy of mathematics based on the idea that mathematics is a languageless activity, that is, discerning mathematical intuition from mathematical formality.

A glimpse into Nietzsche's own epistemology can be found in 'On truth and lies in a nonmoral sense' (Nietzsche [1873] 2020), a short essay in which Nietzsche discusses the pursuit of knowledge, the philosopher attributes the power to reach the truth to '(forbidden) metaphors' and 'metonymies': the knowledge seeker (here called 'intuitive man') is 'guided by intuitions rather than concepts' and avoids taking a 'regular path'. In this world, mathematical formalism binds the truth through the 'cool breath of logic' into 'concepts', which are 'merely the residue of a metaphor'.

Nietzsche believes that the 'reduction' of phenomena into formulae is a 'human' activity and necessary for their interpretation, but he emphasizes that scientific formalism is a sub-optimal lens for understanding the world. 'How much of a piece of music is understood' (WP, 624) by the formulae that describe it, i.e., musical notation?

Mandelbrot and a crisis of intuition

In an essay published in the second edition of 'The Fractal Geometry of Nature' (1982), the Polish mathematician and father of fractal geometry Benoit Mandelbrot explains the circumstances under which fractal geometry was developed, with particular reference to the crisis related to the role of intuition in the development of mathematics, which served as the backdrop for the development of his theories.

In particular, Mandelbrot reports several excerpts from Felix Klein's lectures at Northwestern University: Klein was a German mathematician, known for his work on non-Euclidean geometry, and his classes focused on whether the cultivation of abstract mathematics, which, in Klein's own words, lack 'any practical application', had to be separated from applied sciences. Klein's conclusion is that it is not possible to base science on axioms alone and discard intuition entirely, stating that 'splendid [theoretical] researches' would have been impossible without the 'constant use of geometrical intuition'.

Mandelbrot quotes a second set of lectures, this time from Hans Hahn, mathematician known for the study of vector spaces, to comment on an opposite view. Hahn believed that 'intuition is a wholly unreliable guide' and called for a 'task of completely formalizing mathematics'. In Nietzsche's words, Hans believed that understanding the world was indeed an 'indoor diversion for mathematicians'.

Mandelbrot expresses his disdain for Hans' theories in his comment on the lectures, claiming that Hans' theories had provided for 'excesses of pure mathematics' and that his own research on fractal geometry showed that 'intuition is not invariable but can and must be trained to perform new tasks'. Nietzsche would agree: 'the extent to which we possess science today is precisely the extent to which we have decided to accept the testimony of the senses and learned to sharpen them' (TWI, Reason in Philosophy, 3).

The Polish mathematician was surprised of the 'visual barrenness' of the 19 c. mathematics works, and comfortably stated that 'a rough drawing is a more adequate geometric model of a thread than the mathematical line itself.' He was proud that fractal geometry had allowed 'the eye to link mathematics with concrete work in economics and physics, and even with everyday experience', which is consistent with Nietzsche's interpretation of the goals of mathematics - 'making phenomena more comprehensible' (FP, 5, 16, 1886).

After more than a century of mathematics developments after Nietzsche's death, Mandelbrot claimed that 'Clouds are not round, mountains are not cones, coastlines are not smooth' (2008). Nietzsche was equally unimpressed by Galilei (1623, p. 4), who could see triangles and circles in the universe, and Descartes ([1641] 1911), who saw in mathematics firm and solid fundamentals, stating that in Nature there are no exactly straight lines, no real circle, no absolute standard of size (HH, I, 11).

The mariner lost at sea

Perhaps the most striking similarity between the mathematician's and philosopher's works is the usage of an image that represents a cornerstone of Nietzsche's epistemology: the mariner.

First introduced in 'The Birth of Tragedy' (1872) – and inspired by the works of Schopenhauer and Leopardi – the sailor is depicted as sitting 'peacefully' in a 'weak craft [boat]' navigating in a 'stormy sea'. Mandelbrot (1999) described fractal geometry as a tool reflecting the 'mariner's warning that on even the calmest sea, a gale may be just over the horizon' and scientists making use of it as able to 'prepare for inevitable sea changes'.

Nietzsche is clearly more radical here: the mariner is in a 'weak craft', i.e., it is not equipped with the means of certainty (faith, logic, or mathematics) and this is the condition of a true knowledge seeker. Mandelbrot instead believes that the mariner is not equipped enough for the risk they are facing, and fractal geometry is the adequate tool to prepare.

Risk management is indeed central in the application of Mandelbrot's tools, with a particular focus on financial markets [1]. Through the use of fractal geometry, Mandelbrot was one of the first critics of commonly used risk management models in finance, proposing (2008) the use of alternate metrics which would not rely on the assumption of normally distributed (i.e., highly predictable) prices for financial assets. The hidden flaws of such formally correct models were exposed by Mandelbrot, who described at length the 'benign neglect' (1999) of their underlying assumptions, claiming that they 'embraced continuity'; or as Nietzsche would say, expected to find 'regularity in phenomena in order to apply abbreviation formulae' (FP, 5, 10, 1886).

Nietzsche's philosophy of risk taking

The philosophical continuity between Nietzsche and Mandelbrot is evident when it comes to warning against the faith in pure mathematical formalism and emphasizing the essential role of intuition in the pursuit of knowledge, but their thoughts diverge on the necessary role of risk.

Mandelbrot's legacy is that risk can be managed – and still with formal mathematics: fractal geometry triggered a new phase in the use of models (in particular, risk management models) in finance, based on the refusal of assumptions on the regularity of variables that affect markets. The overreliance on abstract models and theoretical formulae in finance is now part of the academic debate, through the work, among others, of Goldstein and Taleb (2007) and Derman (2010) [2]. Among these, Peters (2019), who aims to resolve 'many puzzles besetting the current economic formalism [..] in a natural and empirically testable way'.

Nietzsche's intuitive man, instead, 'suffers more intensively and more frequently' (OTL) yet is rewarded with 'a harvest of continually inflowing illumination, cheer, and redemption'. The image of the harvest and the reference to physical suffering is used again in one of the most vivid excerpts of *The Gay Science* (1882), in which we read:

> '[…] the secret for harvesting from existence the greatest fruitfulness and the greatest enjoyment is - to live dangerously! Build your cities on the slopes of Vesuvius! Send your ships into uncharted seas! Live at war with your peers and yourselves! Be robbers and conquerors as long as you cannot be rulers and possessors, you seekers of knowledge! Soon the time will be past in which you had to be content living bidden in forests like

shy deer! Finally the search for knowledge will reach for its due; it will want to rule and possess, and you with it!'. (GS, 283)

Berry (2011) synthesised the epistemological significance of such metaphors that describe physical risk that ultimately describes this precarious, dangerous state as a never-ending quest to 'intellectual honesty'.

The importance of GS, 283 is substantiated by the fact that it is curiously titled 'Preparatory human beings', almost hinting at the creation of a new form of human beings that will later become the Übermensch. This new human being – which Nietzsche would alternatively call the 'intuitive man' - is someone who 'does not hesitate to offer human sacrifices, to risk every danger, to take upon oneself whatever is bad and worst' (WP, 26) and seeks 'life raised to a higher power, life lived in danger' (WP, 929). Exposure to risk must be voluntary ('building on the slopes of the Vesuvius') and its consequences must be a necessary means of achieving scientific conclusions: Empedocles throwing himself into the crater of Etna is the absolute 'form of science' (FP, 7 [101], April 1871). Bubbio (2008) and Ercole (2019) extensively cover the significance of the adoption of self-sacrifice, in particular in opposition to the critique of Christianity, described as 'sacrifice of all freedom' in BGE.

Kuehne (2018) goes as far as defining Nietzsche's philosophy as a 'philosophy of danger', concluding that throughout Nietzsche's works 'there is no mention of reaching solid ground again'. Contrary to Mandelbrot, Nietzsche did not believe that there could be new or better ways (or mathematics) that could constitute the basis for more robust science. The German philosopher's legacy is that risk is embedded in knowledge seeking and that this constant motion itself (e.g., navigating the storm) is the state in which the intuitive man will find himself.

Conclusions

Nietzsche's philosophy has been associated in the past with complex systems and fractal geometry (see Douglas, 1996) due to his dynamic interpretation of forces and the relationship between time and space.

The purpose of this work is to highlight the epistemological proximity of Nietzsche's thought to the underlying philosophical principles of fractal geometry. In particular, Mandelbrot and the German philosopher shared their view on the limits of mathematical formalism, especially when not substantiated by inputs coming from intuition and observation.

The work aims to find the end of this philosophical continuity, finding a relevant divergence in their approach to risk management. In particular, fractal geometry triggered a radical overhaul of the use of mathematical models, and Mandelbrot himself presented a series of tools for the management of (financial) risk. When it comes to Nietzsche, exposure to risk became a central component of his epistemology, turning the philosopher into a theorist of taking risks for knowledge's sake.

Endnotes

[1] According to Taleb (2007, pp. 268-9), Mandelbrot was particularly interested in the application of fractal geometry to finance markets because he could rely on vast data sets.

[2] The reader will recognize that Derman (2010) uses the word 'metaphors' to describe financial models with a completely opposite meaning to Nietzsche's, i.e., to deem them imprecise and far from scientific standards.

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Conflict of Interest Statement

The author declares that there are no conflicts of interest.

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