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Mathematics in economics.
A perspective on necessity and sufficiency

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Abstract. *The age of maturity in any science is marked by epistemological debates. This paper focuses on the controversy surrounding the use of mathematics in economics. The role of language, tools and appropriateness of methods is discussed within the borders set by empirical and rational approaches. An odyssey through schools of thought unveils creative oppositions, from naive neo-classical assumptions to literate praxeology and unexpected Bioeconomics. The main debate drifts away from the discussion on the necessity of mathematics in economics and concentrates more on the degree in which this abstract science should infiltrate on the highly empirical field of social sciences, in particular, economics. The dissertation includes opinions on the intrusion of yet another discipline in economics, namely computer science and the consequences thereof, especially related to possible imbalances. In conclusion, economics is a melting pot of other domains and it requires the craftsmanship of the highly literate.*

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1. Titanomachia

Economics has led an ideological struggle to achieve a respectable status among other sciences and, for a long time, it was considered to belong to an inferior level of purity amid ideas. In fact, economics needs to be rediscovered, reconsidered from an interdisciplinary perspective and handled with the tools of a Renaissance inspired Homo Universalis, because, in reality, it simultaneously incorporates politics, mathematics, psychology, law, philosophy, art and religion.

Illustrious figures, representing both economists and mathematicians, entered in the debate over the role of mathematics in economics, their views ranging from fierce Puritanism to unprecedented fusion.

The advocates of mathematics in economics are mainly neo-classics, the pioneer of which is Auguste Cournot (1801-1877), who, in 1838, with simplistic mathematical tools, opened a new path for understanding the economy. The same course is followed by Leon Walras (1834-1910), Francis Y. Edgeworth (1845-1926), William S. Jevons (1835-1882) and Vilfredo Pareto (1848-1923). The logical paradigm and mathematical construction used by them are further developed by Alfred Marshall, J.M. Keynes, and numerous Nobel Prize winners such as P. Samuelson, G. Debreu and K. Arrow. Note that the latter had a mathematical culture, a deep understanding of the mathematical concepts, but, sometimes, fascinated by the aesthetic beauty of the results, ceased to question the models' accuracy in terms of economic significance.

From the neo-classical school a new thinking and philosophy branch emerged, which vehemently fought against the mathematical approach to economics, claiming the dominance of the verb over the symbol, the word over the equation. They called themselves the Austrian School and were introduced by Carl Menger (1840-1921), a fierce critic of the marginal theory, which had a significant influence on the other followers of this school of thought, such as: Ludwig von Mises, Friedrich Hayek, both practitioners of praxeology. Their echo stretches from the classical John Stuart Mill to the contemporary Kenneth Galbraith, who both regard the mathematical tools as means that lead to a departure from the truth.

More opinions are expressed in strictly epistemological works, dedicated specifically to these issues, of which we note those of Imre Lakatos(1980), Roy Weintraub(2002) and the work of Ludwig von Mises (1978).

2. Empirical and rational

The relationship between mathematics and economics is enclosed in the epistemology of both sciences; thus it should not be regarded as an antagonism, but as a permanent exchange of information, methods and results.

In order to understand the fusion between these two disciplines, we begin by capturing opinions about the fundamental characteristics of the two sciences, namely rationalism and empiricism. Our goal is to refute the common concept that each of these is an inherent characteristic of mathematics, respectively economics.

In order to talk about empiricism in mathematics it is useful to invoke the historical roots of this science and to observe that mathematics was born out of practical need, as the result of certain tangible experiences. Even the very abstract theories such as the infinitesimal and differential calculus are rooted in practical physics problems, thus, in experiment. Yet, the definition and learning of some basic concepts of mathematics, such as Riemann’s integral, arise from approximations. However, many mathematicians show a real aversion to the idea that mathematics be among the empirical sciences, arguing that such restrictions would lead to the very degradation of its scientific status; this inclusion would contradict the perfection of the axiomatic systems on which it is based. Perhaps it was such a judgment of value that was the starting point of the reasoning that has denigrated economics, which is essentially empirical, dealing with experiments on a macro scale, with the observed reality. We mention in this context von Neumann's view expressed in "The Mathematician" (Neumann, p. 177) according to which the criterion of success of a mathematical theory also has an aesthetic component, based on the "beauty" and "elegance" of the final formula, a factor most often missing to the empirical approach.

Further, we establish that the logical-deductive and axiomatic systems in mathematics denote an age of maturity of this science, a culmination of her progress, while its living segment, where new theories are born, stands on empiric grounds, pending a further distillation to purely abstract notions.

Among denigrating ideas it is worth mentioning the status of rationalism in economics. The emergence of the neoclassical inspired Homo Oeconomicus is the materialization of rationalism in economics, which was met with tremendous enthusiasm by the followers of Ricardo and great retention by the members of the Austrian School (Ludwig von Mises, Frederich Hayek).

The intrusion of mathematics was revealed by the appearance of various models built on simplifying assumptions, up to the loss of essence. The desire to introduce axiomatic systems of economics similar to those from mathematics was overwhelming. The almost forced mathematical characterization of the economic market's equilibrium (general equilibrium, dynamic equilibrium, etc.), the characterization of the consumer and the producer, the preferences expressed by inequalities, the development of countries' economies as functional relations, all draw-up an image of unrealistic, scholastic, utopia. Inside this abyss, becoming denser and more populated with equations, it is only natural for members of socio-political or humanistic currents to lose their ability to distinguish the reason that leads man to perform economic action, as Mises notices.

The critique of mathematical tools in economics is not unfounded, especially concerning the application of these tools. Many mathematical models are built under some strict assumptions about the variables (ex. Cox-Ross-Rubinstein model to assess the financial derivatives), any relaxation of either of the assumptions must be also operated in the content of the model, which otherwise loses all validity. Blind application of models without prior authentication of the underlying assumptions leads to false conclusions, which in economic context translates into financial losses. Thus, advocates of rationalism in economics must also borrow the mathematical rigor specific to work with hypotheses, not just state the results; otherwise it all comes to a problem of form without substance.

Also, due to the nature of the economy as a rapidly transforming reality, it is almost impossible to define an imperturbable structure, of an axiomatic type, that, implemented in a logical-deductive system, produces a set of economic "theorems". Each science must make use of their own methods and should only borrow tools and techniques specific to other areas of research, useful for discovering results, the tight fit into a pattern is not desirable.

The need for mathematics in economics can be justified by its usefulness in order not to be accused of verbosity, though, according to Paul Samuelson (Samuelson, p. 52), "*Mathematics is a language*" and any mathematical text can be expressed with sufficient explanations in natural language. So, one can understand the use of mathematics in economics as an evidence of culture and concision but not as a tool to provide a scientific garment to an otherwise empty speech. Therefore, when one decides to use this special and specialized language, one must fully commit to its rules, i.e. to determine the exact assumptions under which one works, to ensure that the terms used are well defined mathematically (for instance, exclude division by zero). In short, the use of mathematics in economics is similar to the use of quotations from foreign languages; one must ensure that they are context appropriate and that the "grammar" is correct.

About sufficiency, discussions are much more nuanced, starting with the idea that almost any economic concept can be expressed in natural language. Erudition in many fields is necessary in order to be able to select those aspects that deserve illustrated using mathematical concepts, from others, which can be better explained by appealing perhaps to politics, to doctrines, to philosophy or to culture.

Experience has previously shown that the limitation to simple arithmetic is not desirable but, simultaneously, the use of extremely abstract concepts such as functional analysis can lead to artificial results, elegant, but subject to paradoxes (in reality the preference relationship may not be transitive: A> B, B> C does not necessarily imply A> C).

Of course, any radical position such that of Cairnes (Samuelson, p. 60), which states that "economic truths are not discoverable through the instrumentality of mathematics", is not desirable, since such an approach to mathematics' sufficiency becomes more hilarious with each new discovery. History has shown that mathematics is a useful tool in solving economic strategy dilemma (game theory, von Neumann, Morgenstern, Nash Jr.), computational problems (Dantzig-simplex algorithm), etc.

The debate over the usefulness of mathematics in economics should be regarded as a matter of degree and the appropriateness of the instrument for the intended use.

3. The waltz of knowledge

Economics is primarily a philosophical topic, and is only secondarily a tangible matter, thus an essentially practical approach, without a prior understanding of its subtle mechanisms encourages the use of templates, without the possibility of development, thus submerging the economic science in the ordinary or causing stagnation.

Therefore, an understanding of the ideas that were floated around economy in the past centuries is necessary in order to navigate to new horizons.

In terms of mathematics' intrusion into economics, beyond simple arithmetic calculations required for accounting purposes, that accompanied the economics since the birth of trade, even before the advent of money, Schumpeter (Schumpeter, Schumpeter, p. 202) indicates the German author Gottfried Achenwall (1719-1772) as a pioneer in the use of mathematical tools in economics (which he called "statistics"), followed by the Englishman Sir William Petty.

Classical school, represented by David Ricardo, makes use of logic in the exposure of free trade theory and employs numerical examples, but one may not speak of a mathematical model in the current meaning of the term. Note the position of John Stuart Mill, who advocates against the use of long strings of logical deductions, arguing the dissipation of truth behind this approach.

The first economic models resembling the modern ones are that of Thomas Malthus on demography and that of von Tuhnen, developed in 1826, using marginal analysis to calculate land rent.

During the nineteenth century, economics is greatly influenced by the mathematical modeling method inspired by natural sciences, particularly physics, adopted by the neo-classical school. It sought that economics became an exact science based on laws of Newtonian origin, clear, unruffled and providing easily quantifiable and replicable results.

This idea was followed by the introduction of the concept of equilibrium in economics; the pioneer in this field is Cournot, who, in its very simple model of duopoly, attempted a characterization of the equilibrium of an oligopolistic economy. His successors were Walras, who believed in a general static equilibrium, Jevons, a supporter of the marginal utility and Edgeworth, which uses infinitesimal calculus and introduces the idea of indifference curves. Reactions to this new trend did not fail to appear, backed by the founder of the Austrian School, Carl Menger, which, although had some contributions to the utility theory, addressed another point of view, one which puts the individual at the center, the subjective preference of the man, thus militating for a more human entity.

The transformation of economics towards a science deeply based on mathematical reasoning is made by Alfred Marshall, a mathematician at the core, which sets the limits to the use of mathematics as a tool for argument compression, necessarily followed by explanations and examples, the lack of which would be synonymous to the destruction of the whole edifice.

In the interwar period and subsequently, in the '50s comes into attention the question over the purity of sciences, their clear definition of instruments and their limitations.

Thus, a disciple of Marshall, John Maynard Keynes, although familiar with statistical terms, with game probabilities, is reserved about the application of econometric methods, as he thoughts necessary a prior discussion about the adequacy of those to their goals.

On the other hand, theorists of pure mathematics, such as the French group organized under the pseudonym Nicholas Bourbaki, develop during this period a growing revulsion for applied mathematics in various fields, being outspoken about the need of purity in this science and condemning its use in other areas (Bourbaki, p. 221).

In these circumstances flourishes a new approach to economics, which extensively makes use of mathematical tools and will eventually even develop new ones.

This is the emergence point of game theory, introduced by von Neuman and Morgenstern(1944) and developed by Nash Jr. Also, the idea of equilibrium is not abandoned: Paul Samuelson used differential calculus, John von Neumann employed fixed point theorem while Arrow and Debreu introduced functional analysis theorems in order to achieve a characterization of this notion.

Optimization problems are discussed by means of linear programming, studies for which the Nobel Prize was offered to Leonid Kantarovich and Tjalling Koopmans.

Among the economists previously mentioned, some of them felt the need to justify the proximity of economics and mathematics in essays, as is the case of von Neumann, and Samuelson.

A history of the ideas from that time, and new disputes can be found in Weintraub's(2002) dissertation.

Criticism of this new trend also comes out of the Austrian School, by Hayek's speech on the irrelevance of mathematical models especially due to their assumptions, both on the micro and the macro economy and through the work of von Mises and his disciple, Rothbard. Anchored in praxeology, they bring three major accusations to the use of mathematics in economics.

The first critique refers to the fact that statistics is suited to recall economic history and not to make predictions, given that the "ceteris paribus" hypothesis may not always be true. The following charge relates to the tacit acceptance of the use of money in any economic relationship, as the sole expression of value. The last, and perhaps the most important charge, relates to the desire of the neo-classical and neo-Keynesian inspired economists to develop a scientific approach to economy similar to that of physics, which is deemed impossible because economics studies human beings, which are, in essence, unique with a non-replicable behavior.

A new paradigm about the role of mathematics in economics is introduced by Nicholas Georgescu-Roengen, as Bioeconomics (Georgescu-Roengen, Legea entropiei și procesul economic, 1970). Inspired by the neo-classics, a mathematician, he managed to overcome the simple equation modeling of economic phenomena and advanced the idea that the economic system is a whole, in a permanent exchange of information with the surrounding environment, in constant evolution towards equilibrium. He borrows from both the Neoclassical

School and the Austrian School, merging, under the physical Law of Entropy, the mathematical instruments with the interest for the individual's motivation.

Thus, knowledge is emerging as a waltz in three steps: modeling economic processes using the resemblance to physics, denial of this vision by the Austrian School's rejection towards mathematical models and the idea of reconsidering concepts that originated in physics to describe the transitions of the economic processes.

4. Use and abuse

Discussion about the use of mathematics in economics gave birth to controversy, has set up schools of thought and has animated researchers to debate the necessity of such a step, more than for any other science. This ensemble even gets grotesque accents because, caught in the verve of arguments in favor and especially against these practices, proponents of a camp or the other tend to forget that this war goes on the sacred ground of philosophy of science, where invectives do not stand for persuasion.

A first methodological issue to be taken into consideration is related to the definition of "mathematics". It is important to emphasize what one understands in this paper through the use of this word. This term refers to any logical-deductive reasoning based on a set of axioms, any model built using existing mathematical operations and out of which are excluded the trivial arithmetic operations used by economic practice for accounting purposes. We also include in this category any relationships (equation/inequality) whose terms are defined as symbolic expressions of economic concepts.

Following broadly the exposure from the work of Beed and Kane (2007, p. 583), we enunciate and analyze the most important criticism to be made against the use of mathematics in economics, while, in parallel, we go through Morgenstern's argument on the limitations thereof (Morgenstern, 1963, pp. 8-11).

The first and most frequently used accusation against mathematics in economics is the fact that it employs implausible assumptions, inconsistent with the reality which the economic model derived from these assumptions attempts to capture.

Heads of accusation relate, in particular, to Friedman's instrumentalism, which is described as *theories are neither true nor false, but rather prediction tools*. The exponent of the Chicago School has taken on neo-classical ideas used to construct mathematical models for over half a century. Relying on simplifying assumptions, these often distorted completely the phenomenon under study.

The neo-classical models have offered an extraordinary broad topic for attack by the followers of the Austrian School who rightly considered that such an approach lacked the essential component, namely the subject: the individual. Neo-classical Homo Oeconomicus is a simplification to the essence, and even beyond that, it is schematic to dissolution.

Furthermore, the mathematics thought appropriate for the study of economic phenomena is, in turn, a simplification of techniques available, a simplification of the working assumptions, in order to obtain an easy handling tool, devoid of economic meaning, and sometimes, even of the mathematical one. One recalls in this context, the opinion of Morgenstern (1963, p. 10), that, in the works of Walras and Pareto it is not discussed neither the uniqueness, nor the stability of the proposed solutions, which shows a complete lack of approximations, the mere existence is not considered sufficient not even in the austere mathematical circumstances.

Moreover, marginal analysis makes use of differential calculus, which assumes a perfect divisibility of the quantities involved, a utopia to say the least.

Beyond the clumsiness of these assumptions, one should not forget about another hypothesis for which the neo-classical models are often blamed, namely the economic rationality.

The economic rationality is invalidated by marketing – a branch of economics that appeals to the irrational side of the consumer, but one admits that this perspective was not predicted in the nineteenth century.

The former idea introduces the second accusation of the economic science, namely that only a part of economics is quantitative and thus suitable to mathematical approach. Contrary to Samuelson's belief that *the economy is naturally quantitative*, there are certain branches of economy that are free from the need of quantification. This statement, which, probably, according to the author, referred solely to some quantifiable branches of economics, by generalization, loses its scientific value and becomes obsolete. Economic policies are not quantifiable; doctrines are beyond the barrier of number. One may not put into figures the aspirations of liberalism, not even the socialist plans are fully characterized by number, nor equation. In addition, ignoring economic policies is synonymous to ignorance.

On the other hand, the discussion about the role of mathematics in economics includes a sub-theme related to language. Even if, according to Gibbs, quoted by Samuleson (1952, p. 56) "*Mathematics is a language*", and any array of mathematical symbols can be expressed in natural language, mutual conversion does not always have a satisfactory result. Furthermore, it is neither necessary, nor desirable. There are many mathematical models of economic phenomena which abuse the symbolic language of mathematics, often distorting their meaning completely, emptying them of their mathematical substance.

Economics is a discipline that belongs to social sciences, thus is concerned with events that appeal to cultural, social, historical and psychological influences, called, according to Georgescu-Roegen, "*dialectical terms*", opposed to ”*aritmomorphic models*”. Mathematical symbolism does not intend, nor have the tools to illustrate these influences that often prove crucial for understanding the cause-effect relationships. It is therefore necessary that, whenever a mathematical tool is used in economic exposure, to use the natural language, to employ explanations, or interpretations of the numerical results deducted from the equations, whereas mathematical language is highly specialized and based on logical inference, therefore conclusions are not always clearly expressed and one may not appeal to the reader's comprehension to recreate exactly the thinking thread of the author.

It is also important to clearly understand the limitations of mathematical language, because it has not been created and is not used to express emotional states, desires of consumers and producers, briefly, a whole range of feelings that govern economic decision.

In this context, one can provide an example of mathematics' limitations by discussing the theory of utility. According to this, consumers can assign any quantity of a given good a certain score. In order to achieve a classification of preferences, it is necessary for a consumer (group of consumers) to be able to compare any two quantities of any two goods and, moreover, the relationship needs to be transitive. These requirements imply that the utility function thus created to be continuous (any quantity of goods may be requested). It was previously demonstrated that there exist preference relations which arise in economic practice and do not meet these requirements, such as lexicographic preference (Ingersoll, 1987).

According to Morgenstern, although this utility theory bundles in artificiality, it is still taught and used. He follows that the assumption of a "cardinal" utility, known a priori and able to be subjected to arithmetic operations is at least naive. Even an ordinal classification, leading to indifference curves, has no greater chance of proving to be a significant scientific achievement. Morgenstern's conclusion is that economists who wish to use mathematical tools must first reach a deep understanding of the phenomenon treated, otherwise a poorly defined problem, garnished with mathematical means, results in nonsense and it is always easier to accuse the method and not the thinker.

Neo-classical theory brings to the fore Homo Oeconomicus, a figment located at the intersection of many economists' imagination, a prototype of the alleged excessive rationality of either the producer or consumer. This individual is described as extremely rational, totally selfish and holder of a special ability to solve optimization problems.

Born from the use of mathematics in economics area, the existence of Homo Oeconomicus is threatened by the appearance of just another branch of mathematics, also developed alongside its application in economics: game theory.

Game theory is perhaps the first branch of economic mathematics developed by mathematicians, among which the most important to date are John von Neumann, Oskar Morgenstern and John Forbes Nash Jr. They studied the classical and neo-classical literature and managed to transpose, in a coherent mathematical language, an action, if not a specifically human trait, which, until then, was excluded from the economic models: cooperation.

Another important merit of game theory is that it can eliminate, to some extent, unrealistic assumptions from economic models. Thus, the hypothesis of total information available to the entity, a typical case of neo-classic utopia, is reinterpreted as a non-cooperative game with a participant who embodies the nature, the unknown. This was the turning point when mathematics took an important step towards acceptance of economic reality, whereas on the real market, agents never have complete information available and market conditions are not static. The idea of strategy, reflected by successive movements of the entity that depend on the move of the opponent, brought the model of the market much closer to reality. Moreover, neo-classical theory does not explain growth of firms, whereas the equilibrium provides only marginal subsistence, a state that, in real economic world, is not the ultimate goal.

Let us descend for a moment from the sphere of ideas and plunge into the ordinary, inside the micro-economy dictated by the consumer to the producer. At this simple level, without being a mathematician, the producer expresses goals in precise numerical terms, wanting to minimize/maximize the percentage of cost/profit.

This is exactly the counter-argument to the charge of extreme abstraction of mathematics, resulting in a break from reality. Without the help of mathematics, the use of data, the manufacturer will have no clue about the consumer's desires, about the volume of production; he would have no tool on which to base his daily decisions. And, finally, as seductive as the discussion about economics might be at a purely intellectual level, one must not forget that economy is a vivid organism that lives by its billions of cells: producers and consumers.

In the real world of the voracious market, separated from discussions of epistemological nature, mathematics is used in economy especially through input-output analysis and linear programming that provide numerical answers to everyday problems, as required by various industries. Economy, from this perspective, is mainly quantitative, at both micro and macro level. Decisions (even qualitative) are taken using figures and the figures result from algorithms and mathematical models. Their adequacy to reality and the possible disastrous consequences of the lack thereof generated the idea that mathematics is a subject that should not leave the abstract area.

Recently, mathematical models have been accused by Krugman to be the source of the economic crisis that begun in 2007 in the United States of America, but nobody accused the chaotic use, nor the lack of adjustment of the model to match reality. In practice, valuation models of financial derivatives which are called responsible for the economic crisis have been developed based on options and forward contracts on certain real property. When one applies the same models to derivatives, it obtains derivative contracts on derivatives, and sometimes even repeats this process several times. This is a severe violation of the model's assumptions, and the result is only a formal calculation, a mental exercise, which, unfortunately, translated into reality led to financial disaster. It is not enough to apply the algorithm, to introduce data into the computer and press the button to get results. It is necessary to understand that model's assumptions are the cornerstone of the foundation, without which the whole assembly has zero resistance.

Just as the mathematical model does not fully dictate the action of the trader, but man, in the same way, not the mathematical model caused the financial crisis, but man, who has used it chaotically, thus breaking the first hypothesis: rationality.

Another charge made to the use of mathematics in economics is that it leads to formalization, to the introduction of symbols sometimes vaguely understood that, instead of having to clarify the role of exposure, have the opposite effect. This criticism may be allowed under certain circumstances: either the transmitter or the receiver of the message are to blame and the condition relates to the impossibility of establishing a common code of communication, due probably to poor training in the field of at least one of them.

The use of mathematics in economics does not automatically ensure a privileged status for the author of those ideas, because, as the phrase in natural language can be either virtuous or babbled, similarly, in the symbolic expression of mathematics, there may be crystal clear exposures or trivial attempts.

What is noteworthy is that although the introduction of equations in economic discourse can facilitate acceptance of ideas by the scientific community, mathematics is an "ornament" difficult to match and should only be flown by connoisseurs, otherwise, the thinker may be blamed of arrogance by both mathematicians and economists.

To those who support the eradication of mathematics in economics, we further propose a mental experiment, which aims to demonstrate, at least partially, the need of mathematics in economics. To be consistent with the theme, we use the method of reduction to absurdity, specific to mathematical demonstration.

We intend to "remove" economists who have made use of mathematics in their writings. Suppose (by reduction to absurdity) that they have not existed, have not published and, therefore, have not influenced other generations of thinkers.

Thus we begin by erasing Walras, Jevons, Edgeworth, also Pareto and Marshall will disappear automatically. Thus the worthless theories of utility and equilibrium are gone, which may seem a gain. Economics would be free to build on other foundations, to be closer to human nature, to the empirical approach, lacking the bodice of equations.

However, through this step one has just canceled Keynes, Schumpeter and Georgescu-Roengen. Moreover, by this movement one may have even cancel the Austrian School because, by abolishing the neo-classical thinking, the Austrians would have no ideas to oppose their own, without the stimulation produced by the crude neo-classical models, the Austrians would not find the motivation to conceive elegant counter-arguments.

One continues the decimation with the exponents of game theory and dissolves their influence on political economy, on behavioral economics, and on all discussions about equilibrium.

Looking now towards economics devoid of mathematics, one has a bleak picture, the erasure has succeeded the regression of economics at the stage of plain trade from the Middle Ages, before the demon of mathematics became interested in the soul of this discipline, which, now, during the XXI century, seems to have completely captured.

5. Quod erat demonstrandum

The previous experiment has demonstrated the necessity of mathematics in economics. Just as physics, chemistry, biology have known for centuries how to use mathematical tools without fearing a comparison with the "Queen of sciences", in the same way, economy can take advantage of mathematics, without feeling that this intrusion has a denigrating role.

Mathematics, used correctly in economy, is a tool of thought; it is a way of quickly reaching the goal, without becoming mandatory to be itself a goal of economic science. It is necessary, as long as it brings services to the thinker; yet, if one chooses this weapon from his arsenal of methods, one should be a master in handling assumptions, formulas and especially consistent interpretation of data obtained. Otherwise, it is preferable for one only to watch the exciting game of others in the realm of symbols, in order to protect himself and his readers from the false and ridiculous.

The Austrian School had denied the benefits of mathematics in economics, however, Mises believes that these sciences share a common method: "*Mill places logic, mathematics, and the «moral sciences» in the category of disciplines for which the appropriate method is the «method a priori»*" (Mises, 1978, p. 21). In the same paper (p. 127) the author states that only great thinkers of economics have not used mathematics to arrive at their findings and only afterwards did they try to translate them into a mathematical form. Mises even invites, even if on a slightly ironic note, to make use of mathematics in economics, if a better tool in not known.

Samuelson, although he was a fervent user of mathematics in economic approach, concludes (Samuelson, 1952, p. 65) that "*mathematics is neither a necessary nor a sufficient for a fruitful career in economic theory*", but this statement should be seen strictly in context, i.e. referring to the orientation of a young man who wants such a career, to give him choices.

Talking about the sufficiency of mathematics in economics is a more delicate matter, since such a discussion, not substantially argued, could lead to utopia: that one can draw a clear border.

Taking back to Morgenstern's admonition in this regard (Morgenstern, 1963, p. 2): "*let the point (if it exists) be discovered by evolution, the point from whereon there is no further room for mathematics in economics*".

Sufficiency in this context is synonymous with choking; a sign of this is the lack of transparency of the economic message under the guise of equations. This is the moment when the thinker must appeal to other sciences to polish his speech, since mathematics can prove sometimes too abrasive.

One may regard the notion of sufficiency from another point of view, namely as the panacea to economy's problems. This approach, born from the desire to find in economics a resemblance with the natural sciences poses a threat. It threatens the freedom of thought, the development of economics in a multidisciplinary framework and even the confidence enjoyed by the mathematical instruments in other sciences. This approach may be compared to an operation on which only the scalpel is used, arguing that this is the most important instrument, forgetting the need for others.

The discussion on the dangers or benefits of mathematics in economics had gone on for decades, but since the mid twentieth century, and especially during the twenty-first century, a new discipline makes its presence felt: computer science.

Decision-making, also in economy is transferred ever more frequently to high-power computing devices. Statistical analysis of large volumes of data that are available today is left to machines. Computer software built on mathematical models is increasingly used, especially by novices in economics.

The real danger comes not from mathematics, or, even less, from the mathematicians. The difficulty of this discipline, if properly understood, ensures enough logical thinking as not to be used chaotically.

In today's society, the danger comes from computing power, unimaginable a few years ago, which now develops at an exponential pace, is widely available and extremely low cost, and may be freely used by the uninitiated. We live in a society where everyone, regardless of training, has access to trading on financial markets, we dispense of accountants' services and trust in the computing machine, without questioning its capabilities and limitations.

We have not discarded Homo Oeconomicus amongst us, we have only gave him a heart and soul of CPU and hosted him in the virtual environment, daily entrusting him with our savings, our hopes, only to be desperate and helpless when the machine "does what it is told to do, not what you would like it to do" (Weizenbaum J.).

Faced with this new threat, the use of mathematics in economics seems a nineteenth century parlor game, a game of mind among intelligent people, a pleasant past time, which is not meant to blunt the honor of any of the participants, while using a software without knowing what lies behind it is a degenerate game, a poker in the darkness that no one can win.

The need of mathematics in economics is a personal choice, which occurs as a result of in-depth insight into a certain branch of economics.

For this decision to be an appropriate one, it is necessary for the economist, the researcher, to know the mathematical tools that he can use and the alternatives from other areas of spiritual cultivation, such as sociology, philosophy, law. Also, he must sustain his preference of a certain method with solid arguments.

This choice comes as a result of culture; it emerges from reading classical works in economics, knowing the trends that have influenced economic thinking, recognizing the mistakes that were made in the economic approach.

The economist who chooses to use mathematics in his speech assumes the responsibility of proper use, including the terms thereof, the retention of rigor during demonstrations, hoping for a clear exposure, aiming at a beneficial simplification of explanations and hoping to achieve a significant step towards abstraction. It is fundamentally necessary to know exactly the meaning of terms, to have a sense of measure concerning the mathematical techniques introduced, in order to correctly outline the studied economic phenomena.

It is tempting for those who have access to mathematical tools to make use thereof, hoping that their thoughts will have an aura of science. It is also known that many prestigious journals choose papers rich in mathematics, even the Nobel Memorial Prize in economics has been awarded repeatedly to those who use mathematics extensively. Again, it requires a discussion about the extent and sufficiency. Mathematics is welcome if it brings logical value to the approach, if the proposed models are fully harmonized with the explanations given in natural language.

Personally, I admire the fact that those researchers who could, by their academic background, to act as advocates of mathematics in economics, are retained in statements, campaigning for moderation, even support the idea that mathematics is not a scientific panacea, but just another tool that can be used.

Georgescu-Roegen, Morgenstern, von Neumann, people who have changed paradigms in universal thinking, are reserved, precisely because they are fine connoisseurs of the limitations of mathematics in economics.

It is obvious that not all economists should be required to be simultaneously talented mathematicians, but this condition is mandatory for those venturing into the realm of symbols.

Moreover, in the twenty-first century, I believe one has to pay attention to the use of software in economics, since these are all built based on mathematical tools. The difference lies in the fact that the mathematics is hidden, is not directly accessible to user, who often forgets the substrate of such software and makes use of it without fully understanding the results produced or ignoring the possible problems raised by the mathematical model behind the program.

I believe in the utility of mathematics in economics, in the power of statistical analysis, and in the mathematical models' ability to explain economic mechanisms, up to a certain level of trust.

Also I argue that these abstract tools must be supported by economic theories, should be subject to the test of reality and should be placed in a feedback system to be continually rethought according to market dynamics.

Economics lives, it may not be reduced to universal equations, those who wish to do so can be likened to collectors, who admire their entomological, arguing that within is contained all the grandeur of nature.

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