The economic decision-making process in the context of Artificial Intelligence

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ABSTRACT

It is about the economic decision-making process, in the context of artificial intelligence, from the critical perspective of Amartya Sen, to conventional economic thinking, on the maximization of self-interest, as the only and exclusive form of Economic Rationality, in the "datacentrist" context of the economy. The diffusion of Artificial Intelligence (AI), in the context of economic choices autonomously, can activate homoeconomicus (a situation that is currently feasible). For this, it is proposed: (1) a qualitative analysis of the level of Economic Rationality (with fulcrum in three of the Economic Theories of Decision: the Prospect, the Limited Rationality and the Rational Choice), in the case of the Alpha-Zero AI (as a proxy variable of the homoeconomicus Intelligence) and the aforementioned critique of Amartya Sen; and (2) presentation of a theoretical econometric model, with direct application of the Coob-Douglas function and another multiple intertemporal linear function, to deal with the dynamic variables.

Keywords: Artificial Intelligence, Economic Rationality, Rational Choice, Bounded Rationality, Prospect Theory.

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INTRODUCTION

The research proposed to investigate and understand, within the scope of the economic decision-making process, the intertemporal impact of Alpha-Zero Artificial Intelligence (as a proxy variable of *homoeconomicus*) on the level of economic rationality of instantaneous choices, in the light of Amartya Sen's critique of conventional economic thinking. According to SEN (1987), there is a logical problem with the premise of maximizing self-interest, as the only and exclusive form of Economic Rationality.

According to the author, the premise that the maximization of self-interest implies economic rationality is correct and unquestionable. The problem, in his view, is the lack of proof that all economic rationality comes only from the maximization of self-interest, that is, all maximization of self-interest implies economic rationality, but the reverse has not been proven. For example, collective issues that do not maximize self-interest, according to SEN (1987), are real and are not contemplated in the premise of conventional economic thinking, about the decision-making process.

With the information on this topic, it was realized that the impact of artificial intelligence is transformative for the debate, because it has directly influenced economic choices and can make optimal instant choices feasible (do *homoeconomicus*). The case of the AI called Alpha-Zero, for example, which was able to learn strategic board games (from the rules alone), whose extraordinary performance, in a short time, demonstrated cognitive superiority and analysis (qualitative and quantitative; instantaneous and simultaneous; logical and holistic) optimized data, over human players and other AIs (without defeat in recent statistical records). For this reason, it was chosen, in a feasible way, as a proxy for homoeconomicus (the one who only makes optimal economic choices), in the context of maximizing self-interest.

Thus, the objective of the research was to develop a theoretical model, simple and rigid, to describe and understand the level of economic rationality of instant choices, associated with the use of Homo Sapiens intelligence versus Alpha-Zero AI, since this relationship can be: either "symbiotic" (when they are complementary), or "parasitic" (when they are substitutes) and, in the long run, *ceteris paribus*, in the parasitic relationship (substitution between inputs) the scenario will be chaotic, while if the relationship is "symbiotic" (complementary inputs), it will be harmonious.

There are also the dynamic variables of the process, such as ethical aspects and technological innovation, especially creative destruction and environmental economic problems with global effects, in the context of the Big Data Economy, in the global perspective of datacentrism, according to HARARI (2013), whose premise is that the Data is the center of thought, in this case, the economic one. Therefore, according to the author, one of the socioeconomic

challenges of the third millennium is the discussion about economic science alternatives and the maximization of self-interest, in the face of global economic challenges, according to HARARI (2023).

Amartya Sen's criticisms of conventional economic thought are about: the Maximization of self-interest, as the only and exclusive way to obtain Economic Rationality; and Pareto science, as the only reference for economic science and is related to an aspect of the dynamic variables, the ethical. Another aspect that is part of the debate is the creative destruction of J. Schumpeter, associated with certain dynamic variables.

The model intends to enable future scientific contributions (empirical and theoretical) on the subject, for example: remuneration of the social utility of homo sapiens, when its marginal productivity is less than or equal to zero; new forms of taxation and incentives, with a focus on the preservation, conservation and recovery of the environment, etc.

The research found that instant optimal choices of *homoeconomicus,* may be feasible. Considering the position of three of the economic theories on decision (Prospectus, Limited Rationality and Rational Choice), about economic rationality, based on the maximization of self-interest, three distinct perspectives can be observed: the first, with bias in choices (choices, poor suboptimal), the second with information asymmetry (suboptimal, satisfactory choices), the third (optimal choices). All this combined with the economic phenomenon of the diffusion of artificial intelligence and its consequences (such as cognitive superiority and optimized data analysis in the Alpha-Zero case) there was the possibility of translating the discussion about the aforementioned hypothesis applied to the concrete case, inserting the *homoeconomicus proxy*.

The proposal for the elaboration and formulation of a specific theoretical economic model was due to the novelty of the theoretical discussion and the possibility of testing it empirically. This model can describe and evaluate the phenomenon of the economic decision-making process in an intertemporal way, that is, its consequences over time.

It was established as a premise that the influence of Alpha-Zero in the economic decision-making process could be positive or negative. By checking the historiography of economic thought, it was possible to sustain this idea from the scientific point of view. The Prospect Theory, the Theory of Limited Rationality and the Theory of Rational Choice were used, with different positions on the applicability of the hypothesis of economic rationality in concrete cases, according to citations in the theoretical framework of this article.

The greatest theoretical and empirical discussions on the subject were from supporters and opponents of the models of each of the three theories: Rational Choice Theory, Limited Rationality Theory and Prospect Theory , evaluating whether or not there is a science of the integral , partial or non-applied application of the hypothesis of economic rationality. in concrete

cases involving choices of economic agents (consumers, governments or entrepreneurs) in the decision-making process.

Then, starting from the continuous impact of the event (occurrence of the diffusion of the use of Alpha-Zero AI), in the recursive increase in the level of economic choices, this model assumes different levels of economic rationality, for the use of each of the inputs (homo sapiens intelligence; Alpha-Zero AI, Proxy of *Homoeconomicus Intelligence*).

According to Souza Filho and Struchiner (2018), for the construction of theoretical models, it is necessary to be representative, review of the literature on the subject, concise and coherent elaboration of the theoretical model, validation and restructuring tests, and conclusion of the theoretical model. The model was proposed directly to the Coob-douglas function, ceteris paribus, adapted to the intertemporal form. Soon after, a multiple linear regression to capture the intertemporal impacts of the dynamic variables. This mathematical demonstration is in the chapter on Economic Modeling.

It is believed that it may be useful to verify, in the light of the ideas of SEN (1987), the intertemporal impact of the optimal rational choices of *homoeconomicus*, such as that proposed in the hypothesis of economic rationality . Thus, it is intended to provide the debate with initial elements to enable future scientific contributions (empirical and theoretical) on the proposed problem.

THEORETICAL FRAMEWORK

To understand the impact, intertemporal, on the level of economic rationality of instantaneous choices. The literature brings the diffusion of artificial intelligence, as a way to induce progressive improvements in the ability of choice of these agents. In addition, it is possible, through combined interactions of the use of basic inputs, Alpha-Zero AI and *homo sapiens intelligence*, it is possible that there will also be continuous improvement of these tools and systems.

The hypothesis of economic rationality has been the subject of much criticism and debate over the centuries. Some of the main consequences of this hypothesis include the idea that individuals are capable of making rational decisions and maximizing their own interests.

According to Arrow (1987), in his article "Economic Theory and the Hypothesis of Rationality", rationality acquires its strength and meaning from the social context in which it is inserted and is more plausible under ideal conditions. When these conditions cease to exist, assumptions of rationality become tense and possibly self-contradictory. The application in concrete cases depends on information processing and calculation that is far beyond what is feasible and that cannot be well justified as a result of learning and adaptation. By way of

illustration, Cavallini (2009) proposes, for example, a discussion of whether economic rationality is a legitimate scientific premise or an instrument to support the capitalist system of production.

On the one hand, The Theory of Rational Choice, proposed by authors such as Gary Becker (1976) and Milton Friedman (1953), and K. J. Arrow (1987), assumes that individuals are rational and make decisions based on their personal interests, enabling each economic agent to make his choice maximizing his utility, in the case of consumers, his profit in the case of companies and social well-being in the case of agents Government. In this case, full applicability of the hypothesis (based solely and exclusively on the maximization of self-interest) and optimal choices of the agents.

On the other hand, the Theory of Bounded Rationality, developed by Herbert Simon (1955), recognizes that individuals have cognitive capacities limited by the instantaneity of the economic decision, that is, it proposes the partial applicability of the hypothesis of economic rationality in the same context, so that the choices of these agents (consumers, rulers and entrepreneurs) would be suboptimal satisfactory.

Finally, the Prospect Theory, proposed by Daniel Kahneman and Amos Tversky (1979), suggests that individuals make decisions based on heuristics and cognitive biases, taking into account potential losses and gains, so in this case economic choices would be suboptimal bad. It proposes the inapplicability of the rationality hypothesis for the same purposes, same context.

According to Fernandez Bêrni (2014), evaluating the principle of rationality in economic theories, according to Karl Popper, he proposed three possible answers to this question. They were examined, by the author, with their respective logical structures. The first proposes that the postulate of rationality plays the role of a general law of human behavior. The second requires that it function as an axiom of theory. Finally, the third proposal suggests that the postulate of rationality be understood as a methodological rule. Therefore, in this research, the last solution that satisfies the conceptual basis of the proposed three-step model to describe the diffusion of artificial intelligence is used.

According to Morais (2012), some variants of the Rational Choice Theory from the perspective of the applicability of the hypothesis of economic rationality, based on the use of instrumental reason, almost exclusively, differ in terms of the criteria for using this hypothesis, which raises the question of the viability of this theory. The author tests the operational limits of each proposal to estimate, in general terms , the extent to which rational choice serves as a tool for concrete cases .

In the context of the axiom of classical theory, it is plausible, according to Costa (2016), Herbert Simon's model of limited rationality for the economic choices of agents in complex

systems, under the prism of the notion of logically consistent suboptimal choices, due to the asymmetry of information the instantaneous choices are satisfactory".

Mendes da Silva, et al. (2013) proposed to identify the existence of a statistical relationship between rational choice and academic performance of undergraduate university students. According to the authors, the results show that Academic Performance is directly related to rational choice and alters cognitive biases in decision-making.

To support the new model, there is a study conducted by Agrawal, Gans, and Goldfarb (2018), which investigated how artificial intelligence can be used to improve decision-making in economic contexts. The authors argue that this technology can provide valuable information and accurate analysis, leading, over time, to more rational and efficient choices.

According to Varian (2010) The diffusion of artificial intelligence can have a significant impact on the hypothesis of economic rationality, in concrete cases. Since, with the aid of social tools and systems , individuals will increasingly seek to satisfy their needs in a rationally perfect way, taking into account available information, probabilities of events and potential costs and benefits in determining preferences.

According to Silva and Fleig (2019), artificial intelligence can promote great advances, but at the same time there are potential risks of this technology, which must be considered. Leading to believe that the diffusion of artificial intelligence can have a significant impact on the hypothesis of economic rationality, helping agents to make optimal choices. However, it is important to note that the ethical and responsible use of artificial intelligence is key.

Therefore, regulation and control to ensure that its applications are beneficial to society and that the development, implementation and use of this technology must be controlled, regulated and regulated, and are carried out in an ethical and responsible manner, taking into account issues such as privacy, security and social justice.

This warning is clear, according to França and Vasconcelos (2020), when discussing the growing use of technologies based on artificial intelligence in the development of systems and tools, which has the potential to reduce the need for human presence in many dangerous, monotonous, and tiring activities, while increasing existing risks and introducing new ones.

However, in practice, according to Kahneman and Tversky (1979), individuals do not always make optimal decisions due to the existence of cognitive and emotional limitations. In this way, artificial intelligence, according to Agrawal, Gans, and Goldfarb (2018) can help overcome these limitations by providing valuable information and accurate analysis to aid in decision-making.

So, in summary, there may be, in the long run, a significant impact on the hypothesis of economic rationality, caused by the diffusion of artificial intelligence, since by training human economic agents, they could also make optimal choices in the long run.

It is important to emphasize that the development, implementation, and ethical and responsible use of tools and systems are essential to ensure that their applications are beneficial to society. Therefore, regulation and social control should be included in this process, taking into account issues such as privacy, security and social justice, in order to be able to prove the hypothesis of this research.

Since, in a summarized way, Ludermir (2021), Ribeiro (2011) and Fiorin et.al (2011), postulate that artificial intelligence is a broad and interdisciplinary field that includes many subfields. Machine Learning is a subfield of artificial intelligence that involves developing algorithms that can learn from data and make predictions or decisions without being explicitly programmed to do so. Another well-known subfield is neural networks: a type of machine learning algorithm modeled after the structure and function of the human brain.

Neural Networks are made up of layers of interconnected nodes or neurons that can learn to recognize patterns in data. Natural Language Processing (NLP) is also a field of artificial intelligence that focuses on enabling computers to understand, interpret, and manage human language. We still have as a large subfield associated with this technology the agent-based and multi-agent systems: the area of artificial intelligence that consists mainly of creating agent-based systems, where an agent is an autonomous entity capable of perceiving its environment, reasoning and making decisions to achieve its goals.

In addition, Search is also a subfield of artificial intelligence that focuses on developing algorithms to find solutions to complex problems. There is also: Automated Planning, which focuses on developing algorithms to automatically plan actions to achieve a specific goal; Knowledge Representation, which focuses on representing knowledge in a way that can be used by artificial intelligence systems to reason and make decisions; Probabilistic Reasoning and Reasoning which focuses on developing algorithms to reason about uncertain or incomplete information; and Robotics and Perception, which focuses on developing robotic systems capable of perceiving their environment and making autonomous decisions.

The authors are categorical about establishing that these are just a few of the many subsets of artificial intelligence, and each of these subsets can be broken down into even more specialized subfields. It is important to note that these subsets are not mutually exclusive and often overlap with one another, with many techniques and algorithms being used in a number of different areas.

For example, deep learning is a subset of machine learning and artificial intelligence, which is considered a core technology of today's Fourth Century.

Industrial Revolution (4IR or Industry 4.0). Due to its data-driven learning capabilities, deep learning technology, which originated from artificial neural networks, has become a vital topic in

the context of computing and is widely applied in various areas such as healthcare, visual recognition, text analytics, cybersecurity, and many others.

Knowing that the objective of the research was to develop a simple, rigid and seminal theoretical model to describe and understand how the diffusion of artificial intelligence could influence the behavior of economic agents. This model format intends to promote initial elements in order to enable future scientific, empirical and theoretical contributions on this specific subject.

To develop this economic model, according to Souza Filho and Struchiner (2021), seven steps are necessary: Identification and Delimitation of the Object of Study (Stage 1); Cognitive Rescue and Brainstorming (Stage 2); Representation of the Theoretical Model (Stage 3); Review of the Literature on the Subject (Stage 4); Structuring of the Theoretical Model (Stage 5); Submission of the Theoretical Model to Experts (Stage 6); to the Restructuring and Finalization of the Theoretical Model (Stage 7).

In addition, it is necessary to answer a questionnaire for internal validation of the premises, according to Günther (2006), this analysis would be used as a technique to internally validate, in a qualitative way, the hypotheses. So, it seemed useful to initially verify in a qualitative way the impact of both the combined use of basic inputs (Homo Sapiens intelligence and Alpha-Zero AI) and the dynamic variables.

The Theory of Creative Destruction, according to Schumpeter (1942), consists of understanding the transformations inherent to capitalism. Destruction, the essence of this theory, consists of the dynamics of capitalism, where new technologies emerge as waves, in a random way. These innovations not only disrupt the market, but also increase the productivity of capital and labor.

In this sense, innovative entrepreneurs introduce new products and methods that have competitive advantages over existing ones (the second term, Creative, is related to the evolution that occurred after destruction). From there, according to the author, it occurs: either the gradual or the disruptive replacement of the old methods or products. This category of innovation causes significant disruptions in the market and can often lead to the extinction of companies or even productive sectors. Disruptive innovation is not limited to incremental improvements, it can also network entire sectors, creating new patterns of consumption and business behavior.

According to the author, it is possible to identify the recurring patterns: (1) competitiveness and market dynamics, whose competition drives innovation and constant adaptation; (2) technological advancement, where new technologies transform the economic context of the market; (3) the transformations in the consumption pattern, consists of the evolution of consumer preferences, which drives the demand for new products and services. So,

the Theory of Creative Destruction treats capitalism as a dynamic and adaptable system, in which innovation and transformations are inevitable.

According to KISSINGER, SCHIMIDT, and HOTTENLOCHER (2021) the AlphaZero AI, developed by Google's DeepMind, represents a remarkable milestone in the field of AI. With a reinforcement learning approach, AlphaZero's AI was able to learn how to play chess, Go, and shogi at an advanced level with no prior knowledge beyond the basic rules of the games.

Regarding the speed of learning, according to the authors, AlphaZero, in just 24 hours, reached a level of knowledge sufficient to face the best chess players in the world; in four hours, it developed skills that surpassed human performance and, after three days, defeated the previous version of the program, AlphaGo, by 100 to 0 in Go games.

Regarding the results of Games, the authors reveal that, in chess, AlphaZero played 100 games against the Stock sh program (considered the best at the time) and the results were: 28 (twenty-eight wins), 62 (seventy-two draws) and no defeats. In this case, Alpha-Zero's game strategy is robust because it continuously adapts and evolves.

In addition, AlphaZero creates new tactics and approaches, some of which have never been seen before.

Therefore, Alpha-Zero AI offers new perspectives and possibilities to network the potential for learning and strategy. In this case, it is feasible that it can be applied to the economic decision-making process, used as a proxy for *homoeconomicus*, with regard to instantaneous economic choices, with a focus on maximizing self-interest (Optimal choices, as in the Rational Choice Theory).

QUALITATIVE ANALYSIS

Thus, based on the intertemporal impact of the combined use of Homo Sapiens Intelligence (attributed to the Theories: Prospect and Limited Rationality, with suboptimal choices) and Alpha-Zero AI proxy of Homoeconomic Intelligence, changing the level of Economic Rationality of instantaneous economic choices, based on the maximization of self-interest, as advocated, the Rational Choice Theory (where choices are always optimal).

Associating the previous perception that it is possible to establish an intertemporal evaluation of the situation presented, based on the scientific discussion on the applicability of the hypothesis of the economic rationality of the agents contained especially by the theoretical debate of three of the economic theories of the economic decision-making process: (1) Prospect Theory, associated with bad choices (due to the proposal of inapplicability of this hypothesis); (2) Theory of Bounded Rationality, related to satisfactory choices (due to the proposal of partial applicability of this hypothesis); and (3) Theory of Rational Choice, which postulates, for any

rational economic agent, optimal choices (due to the full applicability of the premises of this hypothesis).

The empirical discussion of these theories revolves around the level of economic rationality due to the extraordinary success of the use, development and implementation of Alpha-Zero artificial intelligence, in the field of strategic board games, in the same context, maximization of self-interest, whose cognitive superiority and optimized data analysis, over Homo Sapiens intelligence and other AIs, in the games (no defeats).

The discussion would be as follows: in the initial period of the intertemporal evaluation of the use of inputs, as economic agents are all human, then the foundation is given by the Prospect Theory: bad choices because agents are not trained to make good economic choices, the expectation is that the impact of the insertion of Alpha-Zero will be positive.

As a result, as time passes, agents are subjected to the positive effect of the event of the diffusion of artificial intelligence, and, therefore, will make suboptimal, incremental, instantaneous choices, starting to behave as recommended by the Theory of Bounded Rationality. And in the long run, in the end, the choices would be optimal, because the agents were subjected to the effect of the event recursively, until they were able to make optimal choices.

If the relationship between the inputs is "symbiotic" (complementary inputs) then, ceteris paribus, in the long run the effect would be found in a "harmonic scenario", but there may be a "parasitic" relationship (substitute inputs), in this case, ceteris paribus, in the long run, there will be a "chaotic scenario", due to the prevalence of the replacement of Homo Sapiens intelligence, by Alpha-Zero AI, as demonstrated in similar performance in strategic board games, Whose latest statistics recorded 73.5% wins; 26.5% draws; no defeats. In addition, the scores, innovation, novelty, etc. grows at an increasing rate.

In the case of the dynamic variables, they can be of two types: those that contribute to the symbiotic relationship (complementary) between the inputs and, consequently, to the harmonious scenario in the long term. On the other hand, those that contribute to the parasitic relationship between inputs (substitutes), that is, to the chaotic scenario in the long term.

According to Almeida (2021), calibration usually requires the use of data, whether primary or secondary. The data is used to estimate the values of the model parameters so that it fits the observed data. Without data, it would be difficult to calibrate a model accurately and comably. However, in some cases, the parameters may be defined based on theoretical assumptions or on values commonly accepted in the economic literature, but this may limit the accuracy and reliability of the model.

Due to the incipience of the occurrence of AI for this purpose and the absence of statistical data outside the strategic board games, the AI Alpha Zero was presented for future contributions, without econometric tests. The reason for adopting the Cobb-Douglas function was for its

versatility, convenient and realistic properties for economical models. Widely used in models to represent, for example, the relationship between two (or more) factors of production and the product.

This function is important because it allows you to associate different amounts of Capital and Labor, in order to obtain the same level of production. The function for intertemporal capture of the impacts of independent variables, at the level of economic rationality of instantaneous choices (based on the maximization of self-interest) was adapted to the Alpha-Zero case as a proxy variable of *homoeconomic intelligence*.

This function is used in economic science to model the output of a firm (or an economy as a whole), taking into account the contribution of different factors of production.

So in the long run, in the case of a symbiotic relationship (complementary inputs), there would also be, in the long run, a probable reasonable improvement in the development indicators of the countries, especially the poorest ones (reduction of multidimensional poverty, increase in income, better labor relations, improvement in the environment, reduction of crime, remuneration of the social utility of homo sapiens, when his marginal productivity is less or equal to zero, etc.) since ethical precepts would be associated with the level of rationality, rather than just maximized self-interest.

PROPOSAL FOR QUANTITATIVE ANALYSIS

The intertemporal and stochastic econometric model that can be used to capture the impact of the combined relationship between the use of basic inputs: *homo sapiens* intelligence and Alpha-Zero AI (proxy variable of *homoeconomic intelligence*), at the level of Economic Rationality of instantaneous economic choices (based on the maximization of self-interest). This relationship can be

"symbiotic" (when these inputs are complementary) or "parasitic" (when these inputs are substitutes) between human intelligence and artificial intelligence in the economic context. The simplified model where IHS represents Homo Sapiens intelligence and IHE represents *homoeconomicus* intelligence (AI Alpha Zero as proxy).

The symbiotic relationship was modeled as a Cobb-Douglas production function, which is to represent the level of instantaneous economic rationality, where inputs are complementary:

$$Yt = At \, . \, IHS\alpha t \, . \, IHEt \, (1-\alpha)$$

Where: Yt is the level of economic rationality of instantaneous choices, the economic imput in time (t); A_t is a factor of total productivity that can vary over time; α is the elasticity of production

of human intelligence, ($0 < \alpha < 1$); and IHSt and IHEt are the levels of human intelligence and AI over time (t), respectively.

For the parasitic relationship, when inputs are substitutes, we can introduce a substitution term (θt), which varies over time and represents the ease with which AI can replace human intelligence:

$$Yt = At \,.\, (\theta t \,.\, IHSt + IHEt\,)\beta$$

Where, β represents the elasticity of substitution between inputs.

In both cases, intertemporal dynamics can be introduced through stochastic differential equations that model the evolution of At; IHSt and IHEt, over time, considering random shocks that can affect productivity and intelligence levels:

$$d\,At = \mu A \,.\, At\,dt + \text{ɤ}A \,.\, A_t \,.\, dWAt\; dIHSt = \mu HS \,.\, IHSt\,dt + \text{ɤ}HSt \,.\, I\,IHSt \,.\, dWHSt$$
$$dIHEt = \mu HE \,.\, IHEt\,dt + \text{ɤ}HEt \,.\, I\,IHEt \,.\, dWHEt$$

Where: (μ) and (ɤ) are the drift and volatility parameters, respectively; and dW, are Wiener's terms that represent stochastic shocks.

This is a simplified example and many other factors can be included to make the model more realistic, such as the interaction between HSI and HSI, the dependence of time on (θt), and the introduction of exogenous variables.

Another proposal for subsidiary modeling to verify the impact of the dynamic variables of the economic decision-making process would be, by means of multiple linear regression, to evaluate how these variables behave in relation to the dependent variable level of economic rationality of the instantaneous choices, inserting them in the model as dummies variables:

$$Yt = \alpha + \Sigma\,\beta\,nt\,Xnt + \Sigma\,\beta\,mt\,Xmt + \varepsilon t$$

Where: Yt is the level of economic rationality of instantaneous choices in time; α is the basic level of economic rationality of instantaneous choices; β represents the elasticity of substitution between the dynamic dummies variables, which can be symbiotic Xn when they have a positive impact, because they contribute to the harmonic scenario: and parasitic Xn when they have a negative impact, because they contribute to the chaotic scenario, in the long run, *ceteris paribus*.

However, the calibration and estimation of this model requires empirical data and further analysis. It is important to note that the construction of econometric models is complex and

must be adapted to the specificities of the phenomenon studied. I hope this example provides a basis for developing a more detailed model that is tailored to your research needs.

DISCUSSION OF THEORETICAL RESULTS

As this is a theoretical research, the discussion and outcome chapter included a qualitative analysis on how the level of economic rationality of the instantaneous choices from: the review of the specic literature and the Case Study of AlfaZero AI, applied to strategic board games (based on the maximization of self-interest); and from there, Due to the incipience of the occurrence and the absence of relevant statistical data, elaboration of proposals for econometric models.

The implications of these results with regard to the ethical development of artificial intelligence were also discussed, based on Amartya Sen's critique of conventional economic thinking. First, a previous qualitative analysis was carried out, we present three possible scenarios: (1) relationship between the inputs: Homo *Sapiens intelligence* and Alpha-zero AI, homoeconomicus proxy. This relationship can be symbiotic (when the inputs are complementary), or parasitic (when they are substitutes; (2) Economic scenarios of this relationship in the

that can be diametrically opposed: either chaotic, caused by the parasitic relationship between inputs (or by dynamic variables), or harmonic, with a symbiotic relationship between inputs or by dynamic variables; or (3) the presence of dynamic variables of the economic decision-making process, which can have an impact, either positively (contributing to the symbiotic relationship and harmonious scenario), or negatively (diametrically opposite situation).

As for the classification of the relationship between inputs, in Symbiotics (when the IHE and IHE inputs are complementary) there will be harmony between the inputs and a science weighted by ethical issues, as proposed by Amartya Sen when questioning conventional economic thinking.

On the other hand, the Parasitic (when the inputs are substitutes), the economic decision-making process will take place as recommended by the Rational Theory of Choice, with the prevalence of maximizing self-interest, and without ethical precepts involved, ceteris paribus, in the long run, the Chaotic scenario would occur.

As for the long-term scenarios, in Chaotic: the cognitive superiority and data analysis of the IHE input over human intelligence, demonstrated in the performance of the Alpha-Zero AI (in strategic board games, reaching superhuman levels, with no percentage of defeats in the last games, not even for other AIs), without weighting by ethical precepts, will provide for the replacement of IHs by IHE in the long run, ceteris paribus, the scenario will be: extreme poverty and hunger, due to the decreasing marginal productivity (at increasing rates) of IHS

employment; absurd concentration of income; increased crime, social tensions and wars; destruction of the environment; Problems especially in the third world of Education and Public Health, due to lack of investments in this area; etc.

On the other hand, in the harmonic scenario, the situation is diametrically opposite because the IHE and IHS inputs are complementary and the dynamic variables contribute positively to socioeconomic development, so investments will be focused mainly on issues such as: preservation of the environment, fight against hunger, medicine and collective health, technological innovation, world peace, fight against crime, income distribution (remuneration of the social utility of the IHS when its marginal productivity is less than or equal to zero); and so on..

In the first scenario, chaotic as to whether IHE can replace IHS can occur quickly, as there will be no regulatory barriers to prevent or slow down its adoption. However, the lack of regulation can also lead to ethical and social concerns, such as privacy and security issues. This can affect individuals' trust in the technology and make them less willing to adopt it.

In the second scenario, harmonious, there would be the presence of strong ethical precepts (preservation of the human species, the environment, water, etc.; search for peace, and ethical investments in health, education and equity. Therefore, there would be guarantees that artificial intelligence would be used ethically and responsibly, taking into account issues such as privacy, security and social justice, etc.

In the case of the dynamic variables of the economic decision-making process, they are basically related to the aspects of ethics in the economy and to the aspects of technological innovation. They can contribute positively or negatively to the harmony of the combined ratio of inputs and consequently to the long-term scenarios. As described in the qualitative analysis, and in future empirical tests, when relevant data are available.

In addition to projections regarding the scenarios, there was the presentation of theoretical models, based on theories and other similar models existing in the speci c literature on this subject. This could help to contextualize the results of the qualitative evaluation and to identify possible gaps in the current research, with the aim of improving it both empirically and theoretically.

There is a growing body of scientific literature on the social and ethical impact of artificial intelligence. Most of these publications discuss the ethical concerns raised by artificial intelligence systems and most of the topics are associated with the potential for misuse of predictive models for decision-making. Another frequently identified topic is the analysis of the social and ethical impacts of the use of artificial intelligence in specific sectors of the economy.

Therefore, the model is only an incipient contribution to translate the debate to evaluate the impact of the phenomenon of the incidence of artificial intelligence, as a proxy for the

idealized *homoeconomicus*, in the economic decision-making process in relation to its optimal choices, in the long run. Due to all the limitations found in relation to primary and secondary data, the theoretical model is suggested in order to initiate discussions and tests on this possibility.

The proposed model is an attempt to integrate different theories and approaches to understand and improve Economic Theories on decision. It is important to note that the model is only a first attempt and is subject to criticism and improvement. However, it represents an important step towards better understanding how artificial intelligence (as a proxy) can intertemporally affect the economy and society.

CONCLUSION

This article examined economic rationality in the context of the decision-making process, considering three economic theories: the Prospectus, by Daniel K. and Amos T., the Limited Rationality, by Hebert S., and the Rational Choice theory, by Gary B. From the premise that the maximization of self-interest is not enough to determine economic rationality, as proposed by Amartya Sen in the critique of conventional economic thought, when the maximization of self-interest is not the only and exclusive form of economic rationality and neither is Pareto's science the exclusive reference of economic science.

From there, the combination of the use of two basic inputs was explored: Homo *Sapiens Intelligence* – IHS and Homoeconomicus Intelligence – IHE. The theoretical econometric model that uses Alpha Zero AI as a proxy for *Homoeconomicus*. In addition, the dynamic variables of the process were also considered, especially those related to ethical precepts and technological innovation.

Our conclusions indicate that the Prospect Theory describes the economic behavior of Homo Sapiens, with choices marked by bias, therefore suboptimal and considered "bad". The Theory of Bounded Rationality, in turn, results in choices marked by information asymmetry, then suboptimal, considered "satisfactory". Rational Choice, an attribute of Homoeconomicus Intelligence, leads to choices (with a focus on maximizing self-interest) considered "optimal".

When applying the Cobb-Douglas function, in this economic decision-making process, considering HEI (Homoeconomic Intelligence, Alpha-Zero AI as *a proxy*) for K (Capital in the original function) and HSI (Homo *Sapiens Intelligence*) for L (Work, in the original function), it is observed, ceteris paribus, that, at the level of economic rationality Y, the intertemporal combination of the use of these inputs can lead to a parasitic or symbiotic relationship in the long run. This dynamic can result in chaotic or harmonic qualitative scenarios.

Another theoretical model presented in a subsidiary way was regarding the dynamic variables, which through multiple intertemporal linear regression, applying a dummy variable to

each of them, to intertemporally capture the positive (contributing to harmony) and negative (contributing to chaos) impacts.

Based on the impressive results of Alpha Zero AI in strategic games, demonstrated in the case study, the cognitive and analytical superiority of this AI over Homo Sapiens Intelligence and other AIs stands out, which allowed us to propose the use of this variable as a proxy for IHE, Homoeconomic Intelligence, in the context of the Process Conventional decision-making (based on maximizing self-interest). However, it is relevant to consider, in the economic models presented, the ethical aspects, and technological innovation, in order to avoid tendencies to chaotic parasitism.

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