ECONOMIC DECISION MAKING AND MACHINE LEARNING: A FIRST APPROXIMATION BY THE ECONOMIC ANALYSIS OF LAW

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Summary: Introduction. Economic Rationality and Artificial Intelligence. 2. Artificial economic agents and virtual economy. 3. Challenges of artificial economic decision. Final considerations. Bibliographical References.

INTRODUCTION

The accelerated development of Artificial Intelligence in all fields of society has generated several fundamental questions, about its impacts and challenges. The objective of this article is to verify one of the most intriguing aspects of the new economy: *the artificial economic decision.*

Herbert Simon, considered one of the founding theoreticians of the studies on Artificial Intelligence, adopted the motto that science had the purpose of knowing and understanding the wonders of the world, but without removing its enchantment[1] . Certainly, the unbridled technological development has left us

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[1] This was the motto of physicist Stevin, a scholar of the law of inclined planes, who noted that the phenomenon was "*wonderful, but not incomprehensible*", very well remembered by Herbert Simon in his work SIMON, Herbert Alexander. The sciences of the artificial. Cambridge: MIT Press, 1996, p. 01.

amazed, enchanted, surprised, but also confused and worried. After all, what is the impact of this change of context for fundamental and foundational phenomena in economic theory, such as economic decision?

The question to be analyzed in the present article is about the possibility of the emergence of *authentic artificial economic decisions* and their possible impacts, according to the economic analysis of Law.

1. ECONOMIC RATIONALITY AND ARTIFICIAL INTELLIGENCE.

Economic theories assume that economic behavior, and therefore human decisions, can be understood by means of models. These aim to describe patterns of behavior about activities that aim to satisfy needs and desires[2] .

The economic analysis of law (EDA) has precisely formulated these elements in the following postulates:

a)*methodological individualism*, that is, collective phenomena must be explained as the result of individual decisions;

b) *rational choice*, that is, individual decisions are understood as rationally directed to maximizing individual interests (*benefits over costs*). Whenever there is a choice there will be a choice between possible benefits (*tradeoff*);

c) *stable preferences*, it is postulated that in the short run there is preference stability;

d) *equilibrium*, it is understood that interactions in politics and law tend, as in the market, toward equilibrium.

The use of Artificial Intelligence presents several promising possibilities for behavior with artificial economic rationality. It would be a way of modeling decisions, capable of guiding the interaction of artificial agents with the environment. The use

[2] PARKES, D. C. *et* WELLMAN, M. P. "Economic Reasoning and Artificial Intelligence." Science, 2015. 349, 6245, p. 267-72. https://doi.org/10.1126/science.aaa8403.

of AI would allow efficient performance in fields as complex and distinct as autonomous military drones, autonomous vehicles, surgeon robots, robot judges, and investment robots in financial markets. The cases described, far from being future possibilities, have become part of the present and constantly evolving reality.

A first fundamental question is about the possibility of modeling in AI an economic rationality capable of guiding an artificial agent, with the ability to perceive and act in the world, with autonomous choices. The heart of economics is in rationality, which would be nothing more than a theory of rational choice, its consequences and limits[3] .

After all, would modeling in AI of rational choice be possible? A positive answer should consider two important aspects. The first is that AI should be able to model the economic environment with the same agility as a human agent. Second, it must be able to model rational choices directed to maximizing individual interests (*benefits over costs*).

Artificial rationality shares with human rationality some similar characteristics, such as abstraction, universality, and logic. But the main element of economic rationality lies in the instrumental sense of rational choices. Rationality is intended to achieve some results, whether these be desires, preferences, or realizing interests. For *David Hume* rational choice aims to satisfy desires, while other authors state differently that the intended goal is preferences. This is a field subject to different views about the intended end.

Another relevant aspect is that it is a utility maximizer, in the sense that it intends to *promote*, to the greatest extent possible, certain ends (desires, preferences or interests)[4] . *Amartia Sen* states that it is a relationship between goals and choices,

[3] GAUS, Gerald. On Philosophy, Politics and Economics, Wadsworth Philosophical Topics, 2008, p. 07.
[4] GAUS, Gerald. On Philosophy, Politics and Economics, Wadsworth Philosophical Topics, 2008, p. 08.

between options[5] . Thus, given our objectives, rationality presents the appropriate choice to achieve the intended end.

Another aspect to consider is that whenever there is a decision, there will be a choice between possible benefits (*tradeoff*). There are differences between the options to be chosen, but also about the intended ends themselves. Every choice is a decision about options, and every option chooses one preference over another. There is an opportunity cost involved, where every choice means giving up another preference, desire, or need.

An important distinction must be made between rational decision theory and rationality theory itself. The former has solid foundations in a notion of rationality formalized in mathematical models, which meet maximization and consistency requirements. But rationality itself cannot be understood in such narrow terms. It does not have all this normative force, and it is not always absolutely consistent. It cannot even be guided in an absolute way by maximization requirements.

Rationality is instrumental rather than normative, in a sense. It seeks to achieve ends, fulfill desires, satisfy needs, or obey self-interests, but these are themselves contradictory, imperfect, and partially opaque to reason itself[6] . *Amartia*[7] *Sen* states that an important aspect of volitional choice is that it is made on the basis of the substantial incompleteness of judgments.

Rationality cannot be confused with a normative vision of the maximization of expected utilities, after all, it would cease to be a rule for understanding rationality and would become the very objective to be reached[8] . The maximization of desires

[5] SEN, Amartya. Development as freedom. New York: First Anchor Books, 2000.
[6] BERMÚDEZ, José Luis. Decision Theory and Rationality. Oxford: OUP, 2009, p. 02.
[7] SEN, A. Maximization and the Act of Choice, Econometrica, Vol. 65, n. 4, 1997, pp. 745-779.
[8] BERMÚDEZ, José Luis. Decision Theory and Rationality. Oxford: OUP, 2009, p.

presupposes a clarity, a rigidity and a consistency that desires themselves do not possess in an absolute way. The understanding of utility maximization should be understood as being instrumental, as a means of analysis, formalization and modeling, but never as a logical law of rationality.

Thus, economic choice is instrumental and directed toward the realization of ends. This understanding is consistent with the economic premise that goods are scarce by nature. Thus, it is the goal of economic rationality to enter the best allocation of goods that are necessarily scarce (land, time, food, attention, etc.)[9] . In this way, a rational agent must adapt his internal rationality to adapt to the external environment in order to discover the best behavior aligned to his objective of conquering his goals.

An appropriate choice is one that is based on a consistent belief that among the various options it is rational to choose a particular action rather than another. Every choice represents the renunciation of an alternative option.

Unfortunately, there is no way to define a *priori* which is the best possible choice. Not even the best computing power imaginable today would be able to predict which is the most effective in all cases. Thus, every choice is to some extent based on a justified belief that this is the best option. Imagine an investor who wants to buy a certain asset or crypto-active, there are so many variables that influence the price (economics, politics, social and natural facts) that the choice will always act with an unavoidable margin of uncertainty.

For *Simon*, the human choice model is much more a matter of a *stimulus-choice pattern* decision than a choice between alternatives. This understanding derives from the recognition of the limitations of information processing for the agent to be able

02.

[9] SIMON, Herbert Alexander. The sciences of the artificial. Cambridge: MIT Press, 1996, p. 25.

to decide appropriately. Decision system *design* becomes very relevant in this case.

So far we have talked about rational choices and economic decision based on rationality. But would there be irrational choices that guide the decision of the economic agent. If so, could this choice be modeled computationally?

The idea of *ratio* appears in the tradition, since Seneca, in opposition to emotions[10] . The theory of rational choice is, in the classical tradition, above all, a normative theory. A rational agent must act in order to achieve his goals and it is possible to explain why an agent acts in a certain way and not in another[11] . Preferences and desires can be considered as reasons for acting in a certain way . [12]

The contradiction arises from the fact that desires can have within them a pragmatic contradiction. Desiring something can prevent the desire from being realized. *John Elster* testifies to the case that desiring paradise can be a cause for preventing your access to it[13] . Another important inconsistency lies in the fluidity of desires. In rational choice theory, desires are fixed, but in truth the internal structure of desires can subvert their fulfillment[14] . Emotions can produce a reversal or reversal of preferences . [15]

Nozick states that there must be a consistency between desires and ends[16] . It is not possible for someone to desire x and not desire x at the same time. However, the author admits that there can be conflicts between desires of different orders. And he presents as an example the case of the subject who wishes to drink, but at the same time wishes to stop drinking. This would

[10] ELSTER, Jon. Reason and Rationality, Princeton University Press, 2008, p. 01.
[11] ELSTER, Jon. Reason and Rationality, Princeton University Press, 2008, p. 14.
[12] ELSTER, Jon. Reason and Rationality, Princeton University Press, 2008, p. 16.
[13] ELSTER, Jon. Reason and Rationality, Princeton University Press, 2008, p. 19.
[14] ELSTER, Jon. Reason and Rationality, Princeton University Press, 2008, p. 20.
[15] ELSTER, Jon. Reason and Rationality, Princeton University Press, 2008, p. 42.
[16] NOZICK, Robert. The Nature of Rationality, Princeton University Press, 1993.

also be true for the case of the subject who wants credit and simultaneously wants to get out of the condition of credit taker. In this case the first order desires come into conflict with the second order desires. The desire and the desire not to desire would make up this inconsistency.

There are different projects for understanding rationality, on one side there is a prescriptive approach that analyzes from the decision theory and consistency and maximization norms. On the other hand, there is a project of understanding beyond the formalist model[17] .

The possibility of modeling rational choice in AI becomes possible given its normative and mathematical character. If AI still has difficulties reproducing or mimicking all dimensions of rationality, it is certain that it can adequately model the more normative, formalistic, and modeling facet.

An AI model should be able to verify how an artificial agent intends to accomplish specific ends, conditioned by observations of its environment. In this way, we can say that AI enables a significant advance in the methods of economic analysis. The foundations for this revolution are unquestionable, and the signs appear in several fields of economic investigation.

Another aspect to note is that there is a gigantic mass of data available, as never before in humanity. More data is produced in one year than was produced in all of previous history, and the volume is growing exponentially. Digitization of data allows it to be processed much more efficiently than previous physical archiving. Connectedness enables shared and distributed processing as never before. Not only is data being digitized, shared, and processed, but also media in voice, image, in the most varied formats possible. It is possible to understand with near-real-time capability the preferences of a consumer, the decisions of a taxpayer, the needs of a citizen, the interests of an

[17] BERMÚDEZ, José Luis. Decision Theory and Rationality. Oxford: OUP, 2009, p. 11.

investor in the stock market. Never before has so much empirical data been so available and so well formatted for processing.

Not only is there an immense amount of data available, but there are also very powerful new methods of analysis. Of particular note is the use of the machine learning branch of AI, which has developed rapidly over the past ten years thanks to its impressive processing power. *Machine learning* methods have become the subject of study by scientists, statisticians, and engineers, who have been developing increasingly sophisticated algorithms capable of understanding the nuances of individual preferences, analyzing or even discovering hidden patterns.

The problem of whether computers can learn is an old topic in computer theory and goes back to *Turing* and even *Ada Lovelace. In turn, the* concept of machine learning is much more recent, with its concept being attributed to *Arthur L. Samuel* in the 1960s[18] . He wondered how one could bring to computing the learning mechanisms present in humans and animals. Without dismissing the learning procedures or their philosophical aspects, his investigation was centered on machine learning techniques, in particular the development of computer learning applied to games. Considering the rudimentary knowledge of these techniques at the time, he applied them to the game of checkers, much simpler than chess.

The concept of machine learning will be well established by *Tom M. Mitchell* as a program that improves with experience. *A* formal definition proposed is: "*A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E*." [19]

The first and most impactful use of *machine learning* is in its ability to automate huge amounts of data or routine tasks.

[18] SAMUEL, Arthur. Some Studies in Machine Learning Using the Game of Checkers. IBM Journal of Research and Development, 1959, 3 (3), p. 210-229.
[19] MITCHELL, T. Machine Learning. McGraw Hill,1997, p. 02.

The use of *machine learning* holds the promise of making empirical economic research work more "*credible and* impactful"[20] . The ability to process large amounts of data quickly and make it public, networked, is truly amazing.

One example cited is its use in predicting economic growth. The use of traditional statistical techniques does not perform well in the presence of *missing data*. The efficient use of *Machine Learning* techniques such as "*surrogate variables*" can solve this problem of missing data. The predictive use of these variables aids in data handling and accurate analysis of predictions[21] . *Machine learning* techniques also allow for more effective handling of complex relationships, as well as the handling of *big datasets* .[22]

One of the prime examples is in the massive data handling in commerce. Large retail companies such as *Amazon* or *Ebay* sift through mountains of data in order to discover consumer patterns and preferences, with the intent of producing better shopping experiences. The clear advantages of segmentation, understanding the economic environment and predicting trends allows for more efficient market mechanisms[23] .

The use of AI has been relevant to another aspect neglected in classical economic theory, which is informational costs. This historical conception was based on the assumption that information has no relevant cost in market exchanges.

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[20] TANAKA, Katsuyuki et KAMIHIGASHI, Takashi. Machine Learning: New Tools for Economic Analysis," Discussion Paper Series DP2022-22, Research Institute for Economics & Business Administration, Kobe University, 2022.

[21] TANAKA, Katsuyuki et KAMIHIGASHI, Takashi. Machine Learning: New Tools for Economic Analysis," Discussion Paper Series DP2022-22, Research Institute for Economics & Business Administration, Kobe University, 2022.

[22] STEUER, Fabian. Machine Learning for Public Policy Making. How to Use Data-Driven Predictive Modeling for the Social Good. Mundus, Erasmus. 2017. Available at https://www.ibei.org/ibei_studentpaper46_162056.pdf. Accessed 21.07.2022.

[23] MILGROM, Paul R. *et* TADELIS, Steven How. Artificial Intelligence and Machine Learning Can Impact Market Design. In AGRAWAL, Ajay; GANS, Joshua et GOLDFARB, Avi. Prediction Machines: The Simple Economics of Artificial Intelligence. Chicago/London: The University of Chicago Press, 2019, p. 568.

Stigler demonstrated that one of the main costs in the dispersion of information is time[24] , it is obviously not the only one, but it is one of the most important costs. It is precisely in the reduction of search costs and approximation between buyers and sellers that one of the great examples of the efficient use of machine learning can be found. The possibility of bringing the consumer closer to the good that most closely matches his preference is one of the great efficiency mechanisms brought about by the use of AI[25] .

One of the most interesting and generally overlooked points of the use of machine learning mechanisms is in their role in reducing informational costs, more particularly in *Prediction Costs*[26] . We can conceptualize prediction as the ability to generate new information from pre-existing information, or as a means of formulating anticipated judgments about future states. Imagine the economic advantages of predicting a new pandemic, the climate and its effects on agriculture, the behavior of taxpayers with regard to new taxes, among so many possibilities. How many errors could be avoided, how much less waste of resources or efficient use of means.

The advantages of *Prediction Costs* reduction mechanisms are impressive. The economic agent able to predict economic facts before its competitor could have a decisive competitive advantage. Modern machine learning techniques have made predictive analysis more accessible, cheaper and safer.

The generation of economic relationships of trust is

[24] STIGLER, George. The Economics of Information. ... George Stigler - Journal of Political Economy, 1961, vol. 69, 213, p. 216.
[25] MILGROM, Paul R. *et* TADELIS, Steven How. Artificial Intelligence and Machine Learning Can Impact Market Design. In AGRAWAL, Ajay; GANS, Joshua et GOLDFARB, Avi. Prediction Machines: The Simple Economics of Artificial Intelligence. Chicago/London: The University of Chicago Press, 2019, p. 582.
[26] AGRAWAL, Ajay; GANS, Joshua et GOLDFARB, Avi. Prediction, Judgment, and Complexity. In AGRAWAL, Ajay; GANS, Joshua et GOLDFARB, Avi. Prediction Machines: The Simple Economics of Artificial Intelligence. Chicago/London: The University of Chicago Press, 2019, p. 92.

another key economic advantage of using machine learning. Usually the debates about the use of intelligent systems are based on the performance of these programs. On one hand, the automation of routines allows massive data processing, and on the other hand the accuracy of the predictions generates more efficient solutions. But the generation of quality relationships is something fundamental. Reliable *marketplaces* sell more, sellers with a good reputation make more money, and the whole system benefits from a network of trust[27] .

The use of *machine learning* to track the exchange of messages in the sales process in e-commerce has been a promising field of analysis of cases in which there is a frustrated sale. Through the use of NLP (Natural Language Programming) it is possible to track the exchange of information without responses, with negative feedback or with the presence of dissatisfaction on the part of the consumer.

The economic uses of *machine learning* in the economy are the most diverse, ranging from public policy architecture, designing price auction mechanisms or e-commerce of goods, preventing business conflicts, and many others. But the most impactful sector of *machine learning* use is in its ability to shape authentic artificial economic agents.

It is no longer just a matter of modeling and studying the behavior of a virtual *homus economicus*. It is not just an exercise in mimicking or imitating the human agent in the marketplace. But of a real artificial agent acting in the market as an authentic participant.

Obviously, by the mass of data generated and stored it is possible to make robust modeling about the behavior of agents in different markets, whether they are in the financial market,

[27] MILGROM, Paul R. *et* TADELIS, Steven How. Artificial Intelligence and Machine Learning Can Impact Market Design. In AGRAWAL, Ajay; GANS, Joshua et GOLDFARB, Avi. Prediction Machines: The Simple Economics of Artificial Intelligence. Chicago/London: The University of Chicago Press, 2019, p. 577.

healthcare, industry[28] or the public sector. The advantages of analysis mechanisms and, especially, behavior prediction is very promising.

The heart of the AI revolution, however, lies in the *design of* artificial agents, capable of perceiving the world, deliberating, and acting.

2. ARTIFICIAL ECONOMIC AGENTS AND VIRTUAL ECONOMY.

One of the great challenges of AI is the construction of intelligent agents, capable of acting rationally, within the limits of existing computational power. Some call this project laying the foundations of a *machina economicus* similar to *homo economicus* .[29]

Considering as valid the hypothesis of the current or future existence of intelligent artificial agents endowed with an artificial rationality, then it is possible that several artificial agents coexist and have to interact with each other. The possibility of machines interacting autonomously with each other is something already given by the current technological reality. Mechanisms connect with other mechanisms, and this fact has become commonplace in several areas of social life. Life tends to become more connected and hopefully better. Well-designed solutions have emerged in sectors as diverse as smart homes, smart cities, industrial, and medical applications. Other sectors of concern have also been impacted by new ways of connecting machines, such as in the military and in security .[30]

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[28] NIKOLIC, B. et al. Predictive manufacturing systems in industry 4.0: trends, benefits and
challenges. Annals of DAAAM & Proceedings, v. 28, 2017 and ZHONG, R. Y. et al. Intelligent manufacturing in the context of industry 4.0: a review. Engineering, v. 3, n. 5, p. 616-630, 2017.

[29] PARKES, D. C. *et* WELLMAN, M. P. "Economic Reasoning and Artificial Intelligence." Science, 2015. 349, 6245, p. 267-72. https://doi.org/10.1126/science.aaa8403.

[30] OECD. The Internet of Things Seizing the Benefits and Addressing The Challenges.

The possibility of artificial agents interacting with each other is a reality that is not only possible, but very likely in the not so distant future. The emergence of a world populated by interacting artificial agents will require an architecture for multi-agent systems. These, in turn, may give rise to intelligent artificial economies, where not only will there be multi-agent interaction, but also with firms and people .[31]

Such a complex economic system, composed of artificial agents, firms and people will demand a new economic science[32] . The learning capacity of machines and the possibility of processing immense amounts of data will be able to generate new and sophisticated market structures.

In some markets the massive presence of intelligent mechanisms is already a reality, such as in the financial market, where they account for more than 70% of the trades.

The emergence of *machina economicus* will bring new economic and social challenges, among which we can mention learning for multi-agent systems and voting procedures to align decisions of intelligent systems.

There have been several attempts to simulate the construction of a virtual economy through simulations and computer games[33] . This economy, besides predicting the interaction between multi-agents, performance and economic results, must pay attention to the difficult task of measuring "*virtual wealth*". This is understood to be a special kind of virtual good that can be stored, measured and exchanged for other goods or virtual

2016 Ministerial Meeting on the Digital Economy. OECD Digital Economy Papers, n. 252, 2016.

[31] PARKES, D. C. *et* WELLMAN, M. P. "Economic Reasoning and Artificial Intelligence." Science, 2015. 349, 6245, p. 267-72. https://doi.org/10.1126/science.aaa8403.

[32] PARKES, D. C. *et* WELLMAN, M. P. "Economic Reasoning and Artificial Intelligence." Science, 2015. 349, 6245, p. 267-72. https://doi.org/10.1126/science.aaa8403.

[33] GAZDA, V., GRÓF, M., HORVÁTH, J. et al. Agent based model of a simple economy. J Econ Interact Coord 7, 209-221 (2012). https://doi.org/10.1007/s11403-012-0097-2

currencies[34] . This is an innovative and important approach, especially in times of research on virtual worlds and especially the impact of the *Metaverse* on business.

The rules of this virtual economy must be established in its own institutions, capable of regulating the conduct of thousands of participants. One of the most unique aspects of such economies is in the prominent role of the developers or program architects. They are the "*Institution*" that can *actually* control this virtual environment .[35]

The development of virtual reality has entailed important studies on the economics of virtual worlds[36] , the measurement of virtual wealth in virtual worlds[37] , and multi-agent organization[38] .

Several pioneering studies have attempted to build multi-agent market models. Some sought to replicate the economic model to better understand virtual and real business[39] and the possibilities of multi-agent systems in the e-business domain. The focus of the studies also turned to specific industries, such as finance[40] , insurance, or healthcare.

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[34] GUO, J., GONG, Z. Measuring virtual wealth in virtual worlds. *Inf Technol Manag* **12,** 121-135 (2011).

[35] MILDENBERGER, C.D. The constitutional political economy of virtual worlds. Const Polit Econ 24, 239-264 (2013).

[36] MILDENBERGER, C.D.: The Constitutional Political Economy of Virtual Worlds. In: Constitutional Political Economy. Springer Science+Business Media, New York, 2013.

[37] GUO, J., GONG, Z.: Measuring Virtual Wealth in Virtual Worlds. In: Information and Technology Management 2011, pp. 121-135. Springer Science + Business Media, LLC, Heidelberg, 2011.

[38] THABET, I., BOUSLIMI, I., HANACHI, C., GHÉDIRA, K. A Multi-agent Organizational Model for Grid Scheduling. In: O'Shea, J., Nguyen, N.T., Crockett, K., Howlett, R.J., Jain, L.C. (eds.) KES-AMSTA 2011. LNCS (LNAI), vol. 6682, pp. 148-158. Springer, Heidelberg, 2011.

[39] MANDI, Riteesh M. 2021. "Artificial Intelligence: The Technology That Changes Business." International Journal for Research in Applied Science and Engineering Technology 9 (5), pp. 54-57.

[40] SUN, Zhaohao et WU, Zhiyou. Handbook of Research on Foundations and Applications of Intelligent Business Analytics. Bokus, 2022.

The construction of a virtual market architecture simulating a real market is a long-standing hope that seeks to harness all the elements of AI to better understand market dynamics. One way has been to use an architecture for a virtual market-based agent that includes all the necessary elements: communication, infrastructure, storage, finance, exchange, and transfer of goods.

Such a model could couple some specific issues such as the question of environmental protection and sustainability. Thus the model could include the analysis of the behavior of agents in the face of the climate challenge and energy sustainability.

Some profitable paths were directed to the various aspects of e-commerce such as online services, shopping, and *virtual catalogs*. The same was thought for the study of online stores, price search engines, and online products. The shopping experience could thus be studied, anticipated, and catered more closely to consumer preferences.

The OECD has seriously addressed the phenomenon of so-called "*virtual worlds*" and their impact on the global economy in a series of studies. A virtual world, according to the OECD, is considered to be a persistently simulated computing environment where a large number of users interact in real time through *avatars* on a computer network, such as the Internet[41] .

The growth in the use of virtual worlds has received particular increase in the entertainment, networking, *e-commerce* or *e-business,* education and training, teleworking and teleconferencing, research and development, and government sectors.

The *Metaverse* can be considered a technological advance in relation to the very definition of virtual worlds. It is characterized by immersive experiences in augmented, virtual and mixed reality. It is this immersive character that characterizes this experience, where the user is "*present*" and not just

[41] OECD. Virtual Worlds. OECD Digital Economy Papers, June, 2011, p. 04. Available at https://doi.org/10.1787/5kg9qgnpjmjg-en.

looking at a computer screen[42] . Metaverse envisions a sophisticated human-computer interface based on *augmented reality (AR), virtual reality (VR), mixed reality (MR), extended reality (XR), blockchain and non-fungible tokens (NFTs* or *"tokens"*)[43] . Metaverse has yet to be measured, in terms of wealth created, but there is a tendency for it to have a substantial economic impact .[44]

The role of AI in the Metaverse infrastructure is unquestionable, as well as other techniques present, such as: brain-computer interface; *data-driven* modeling; sophisticated communicational *networking;* natural language processing (NLP); machine vision; use of *blockchain* and cryptoactive[45] .

The UN estimates that most of the 3D images, animations, and speech in the Metaverse will be generated by AI. Smart contracts will be automated through *machine learning*; distributed wallets and blockchain will enable virtual transactions[46] . The entire ecosystem will make up a very complex new virtual economy.

Imagine all this technology applied to a specific sector of the economy, such as the healthcare sector. Medicine will be greatly aided by the immersive reality of the Metaverse. Among

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[42] CHRISTENSEN, Lau and ROBINSON, Alex. The potential global economic impact of the Metaverse. Analysis Group, 2022, p. 05. Available at https://www.analysisgroup.com/globalassets/insights/publishing/2022-the-potential-global-economic-impact-of-the-metaverse.pdf.

[43] KACZYNSKI, Steve *and* KOMINERS, S. D. How NFTs Create Value. Harvard Business Review, November 10, 2021. Available at https://hbr.org/2021/11/how-nfts-create-value.

[44] CHRISTENSEN, Lau and ROBINSON, Alex. The potential global economic impact of the Metaverse. Analysis Group, 2022, p. 12. Available at https://www.analysisgroup.com/globalassets/insights/publishing/2022-the-potential-global-economic-impact-of-the-metaverse.pdf.

[45] HUYNH-THE, Thien; Pham, Quoc-Viet; Pham, Xuan-Qui; Nguyen, Thanh; Han, Zhu *et* Kim, Dong-Seong. n.d. Artificial Intelligence for the Metaverse: A Survey. Available at https://arxiv.org/pdf/2202.10336.pdf. Accessed on 28.07.2022.

[46] UN. AI: The Driving Force behind the Metaverse? - ITU Hub. 2022. ITU Hub. June 30, 2022. Available at https://www.itu.int/hub/2022/06/ai-driving-force-metaverse/.

some contributions we could mention[47] : *remote surgery, telepresence, augmented reality surgery; 3D human anatomy models for education; visualization diagnosis, and planning; architectural design for healthcare facilities; preventive medicine and patient education; haptic aided rehabilitation; visualization of massive medical databases; treatment planning; medical therapy; pain control; psychotherapy through Virtual Reality; virtual patients and surgery simulation*.

There are so many complex and sophisticated technological aspects, that to expose them in this article would become very tiresome and superficial. Take, for example, the revolution in augmented reality technology. It has the potential to greatly advance the industry in many ways. It is possible to receive computer-generated virtual content, with multiple information, not only visual, but also audio, scents and *haptics*. This is a technology that emerged in the 1990s and has developed impressively.[48]

The economy in the Metaverse has some very important pillars. The first of these is the presence of its own monetary system, with decentralized financial governance or a virtual banking system. The use of cryptocurrencies and their mining is an important feature of this system.

Another characteristic is the concentration of this market in a few gigantic technology companies, configuring a true worldwide oligopoly in this virtual world. The barriers to entry for new participants are high, due to technological complexity,

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[47] MOZUMDER, M. A. I.; SHEERAZ, M. M., ATHAR, A., AICH, S. *et* KIM, H. -C. Overview: Technology Roadmap of the Future Trend of Metaverse based on IoT, Blockchain, AI Technique, and Medical Domain Metaverse Activity. 2022 24th International Conference on Advanced Communication Technology (ICACT), 2022, pp. 256-261.

[48] LIK-HANG, Lee; BRAUD ,Tristan, ZHOU, Pengyuan *et* HUI, Pan. All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda. ResearchGate. unknown. October 11, 2021. https://www.researchgate.net/publication/355172308_All_One_Needs_to_Know_about_Metaverse_A_Complete_Survey_on_Technological_Singularity_Virtual_Ecosystem_and_Research_Agenda.

the concentrating market power and the scale required to create these virtual universes. The governance of the virtual economy tends to be centralized in the hands of these major *players*.

Commerce in the Metaverse tends to be another relevant aspect. It is not a mere transposition of electronic commerce, already traditional, to the virtual world. The goods to be traded will be specific to the virtual world and may be interoperable in other virtual worlds. The trade of virtual goods will be based on *non-fungible tokens*, which will become an even more relevant and powerful business[49] .

3. CHALLENGES OF ARTIFICIAL ECONOMIC DECISION.

The challenges of understanding artificial economic decision are immense. On the one hand, economic theory has advanced greatly and in parallel with the development of machine learning technology and virtual worlds. Establishing a correct understanding of the various and possible connections between these two worlds is somewhat challenging.

It is given that we can build artificial agent models to try to understand the behavior of economic agents. These models can be descriptive, mimicking the behavior of economic agents and demonstrating their explainability, or they can be prescriptive, in order to try to understand future decisions based on incomplete information about the economic environment.

These decisions can be fed complete information in a fully controlled environment, keeping all other variables at bay, or they can be based on the idea that information is incomplete and the rationality of the artificial agent is limited, and it must

[49] LIK-HANG, Lee; BRAUD ,Tristan, ZHOU, Pengyuan *et* HUI, Pan. All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda. ResearchGate. unknown. October 11, 2021, p. 35. https://www.researchgate.net/publication/355172308_All_One_Needs_to_Know_about_Metaverse_A_Complete_Survey_on_Technological_Singularity_Virtual_Ecosystem_and_Research_Agenda.

decide based on existing information.

The decision architecture can also be based on a *top down* model, where the economic decision or choice is based on general premises or guidelines that guide the concrete decision, or on the contrary, it is based on the experience of the artificial agent that learns how to behave in the economic environment, called the *bottom up* model.

Many of the theories in AI start from the erroneous premise that the real environment is static, deterministic, discrete and fully observable. The real world is actually dynamic, stochastic, *continuous, and* partially observable[50] .

All these possibilities have been analyzed and have been thoroughly tested by economists and computer scientists.

One of the most promising possibilities is the use of evolutionary algorithms, with reinforcement learning[51] . In this case, autonomous agents start to decide based on new information coming from the environment, without the intervention of an external programmer, about the model of the decision to be taken or that influences the architecture of preferences[52] .

The notion that artificial agents can behave

[50] RUSSELL, Stuart. Learning agents for uncertain environments (extended abstract). In Proceedings of the eleventh annual conference on Computational learning theory (COLT' 98). Association for Computing Machinery, New York, NY, USA, 1998, p. 101-103. Available at https://doi.org/10.1145/279943.279964. Accessed 07.28.2022.

[51] Reinforcement learning uses algorithms that seek to solve "Markov Decision Processes (MDP). These are nothing more than reward feedback systems that establish transition states based on probabilities for each possible action. See *in* RUSSELL, Stuart. Learning agents for uncertain environments (extended abstract). In Proceedings of the eleventh annual conference on Computational learning theory (COLT' 98). Association for Computing Machinery, New York, NY, USA, 1998, p. 101-103. Available at https://doi.org/10.1145/279943.279964. Accessed 07.28.2022. Agents should learn by constraints implicit in the system and not just by rewards. See *in* R. Noothigattu *et al*., Teaching AI agents ethical values using reinforcement learning and policy orchestration. *IBM Journal of Research and Development*, vol. 63, no. 4/5, pp. 2:1-2:9, 1 July-Sept. 2019.

[52] CHEN, Shu-Heng; KAO Ying-Fang et VENKATACHALAM, Ragupathy. Computational Behavioral Economics, 2016, p. 16. Available at https://core.ac.uk/download/pdf/74246198.pdf.

autonomously in the face of incomplete information and decide with bounded rationality brings them much closer to human decisions. Artificial agents learn from their experience, just as economic agents do. Obviously they must use a pre-installed architecture, a pre-defined input, as well as an already installed database. It is on this initial baseline that the system must establish its unsupervised learning, under given circumstances .[53]

An artificial economic environment will start from a model where there is an infinitely repeating pricing game, where firms act simultaneously and condition their actions based on history[54] .

The possibility of *automated decision-making systems* (ADMS), that is, autonomous systems capable of self-learning, by collecting and processing data for the purpose of artificial decision making without human intervention, has been spreading throughout society. Strategic decisions such as investment in the financial market, purchasing choices, medical decisions, or judicial sentences have been some of the sectors in question[55] . The autonomous, complex, and scalable nature of ADMS translates into its unpredictability, opacity, and the difficulty of managing the risks arising from artificial autonomous decisions. It becomes a fundamental issue, in the AI agenda, the structuring of artificial ethics audits (*Ethical Based Auditory* - EBA) .[56]

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[53] HOOG, Sander Van Der Der. Deep Learning in Agent-Based Models: A Prospectus. Faculty of Business Administration and Economics Working Papers in Economics and Management, 2016, p. 04. Available at http://www2.econ.iastate.edu/tesfatsi/DeepLearningABM.SVanDerHoog2016.pdf. Accessed 27.08.2022.

[54] CALVANO, Emilio; CALZOLARI, Giacomo; DENICOLÒ, Vincenzo *et* PASTORELLO, Sergio. Artificial INTELLIGENCE, Algorithmic Pricing, and Collusion. American Economic Review 110 (10), 2020, p. 3267-97. Available at https://doi.org/10.1257/aer.20190623. Accessed on 28.07.2022.

[55] MÖKANDER, J.; MORLEY, J; TADDEO, M *and* FLORIDI, L. Ethics-Based Auditing of Automated Decision-Making Systems: Nature, Scope, and Limitations. Sci Eng Ethics. 2021, Jul 6; 27:44.

[56] MÖKANDER, J.; MORLEY, J; TADDEO, M *and* FLORIDI, L. Ethics-Based Auditing of Automated Decision-Making Systems: Nature, Scope, and Limitations. Sci

The ethical and behavioral complexities of the decisions of artificial economic agents have raised the inquiry about a new field of research, called *behavioral artificial intelligence* (BAI), distinct from classical or symbolic AI[57] . The artificial decision process would be guided not only by rational guidelines, but also by biases and other limits arising from bounded rationality.

Not only that, artificial agents start deciding based on biases initially installed by the programmer or by the system architecture, but immediately (some would say frighteningly) they can learn from the environment, mimicking or even creating them[58] .

The study of possible algorithmic biases, their ethical problems of unfairness and discrimination is a major focus of the legal analysis of the topic.

On the other hand, the analysis of the artificial agent decision has moved from the individual aspect to the general aspect. After all, to what extent will a system with the presence of multiple artificial agents create a "*decision architecture*" or pattern of economic decisions based on rules created by "*populations*" of virtual agents in a virtual exchange environment.

Finally, when we think of an artificial agent we generally think of an isolated agent, endowed with corporeality, but nothing would prevent the system itself from having an autonomous or emergent "*will*" and "*intentionality",* distinct from its original programmers, by deep learning or evolution.

Increasingly, however, the focus is shifting from the artificial agent to the environment where multiple artificial agents

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Eng Ethics. 2021, Jul 6; 27:44.

[57] CHEN, Shu-Heng; KAO, Ying-Fang *et* VENKATACHALAM, Ragupathy. Computational Behavioral Economics. Available at https://core.ac.uk/download/pdf/74246198.pdf. Accessed 07.28.2022.

[58] MEHRABI, Ninareh; MORSTATTER, Fred; SAXENA, Nripsuta; ANI, Kristina Lerman et GALSTYAN, A. G. A Survey on Bias and Fairness in Machine Learning. ACM Computing Surveys (CSUR) 54 (2021), pp. 01 - 35. "Semantic Scholar." 2022. Semanticscholar.org. 2022. https://www.semanticscholar.org/reader/0090023afc66cd2741568599057f4e82b566137c.

interact in an autonomous and decentralized manner. They act on the basis of internalized data and behavioral rules, through adversarial or cooperative behavior. Not only does each agent end up learning how to act, according to the stimuli from the economic environment, but also the multiplicity of agents acts in an unintentional manner to bring forth a model that evolves with the learning of the group of intelligent agents[59] . This is a *bottom-up model*, in that the system emerges from the interactions of the individual agents and not the other way around.

There are so many challenges in this new area of the economics of artificial behavior, that an economic analysis of law must take seriously the challenge of an urgent agenda of studies on the subject. After all, the consequences of what is being built, intentionally or artificially, more than matter to humanity.

FINAL CONSIDERATIONS.

The present article analyzed the possibility of the emergence of authentic artificial economic decisions and their possible impacts on the economic analysis of Law.

The economic analysis of law (AED) has accurately formulated some classical postulates, such as: *methodological individualism*, *rational choice*, *stable preferences*, and *equilibrium*. One of the conclusions is that studies on AI have allowed a better understanding of economic rationality, through its computational modeling.

It is also possible to conclude that an artificial agent can seek to accomplish specific ends, conditioned by observations of its environment. On the other hand, an artificial intelligence system is capable of processing a gigantic mass of available data. On the other hand, the use of *machine learning* allows the

[59] TESFATSION, Leigh. Agent-Based Computational Economics." Scholarpedia 2 (2) 2007. Available at https://doi.org/10.4249/scholarpedia.1970 . Accessed 07.28.2022.

automation of huge amounts of data or routine tasks, enabling such important results as prediction and massive data processing.

But the most amazing thing is not the amazing automation and processing of data, but the possibility of a complex economic system composed of artificial agents, firms and people. The emergence of virtual universes, which have as one of their pillars a virtual economy, with interaction between multi-agents, will be a new reality.

The digital economy has expanded beyond software applications and platforms to digital ecosystems. These can be thought of as digitally connected, decentralized organizations, often spontaneously forming, bound together by connections of trust, expertise, and mutual collaboration[60] .

The growth in the use of virtual worlds, and especially nowadays the Metaverse, can be considered a technological advance in relation to the very definition of virtual worlds. It is characterized by immersive experiences in augmented, virtual and mixed reality. It is the immersive nature that characterizes this experience, where the user is "*present*" and not just looking at a computer screen.

The challenges of understanding artificial economic decision are immense. It is given that we can build models of artificial agents to try to understand the behavior of economic agents. But it is possible to state that artificial agents learn from their experience, just as economic agents do.

The possibility of *automated decision-making systems* (ADMS), that is, autonomous systems capable of self-learning, through the collection and processing of data for the purpose of

[60] JACOBIDES, Michael G.; SUNDARARAJAN, Arun *et* ALSTYNE, Marshall Van Van. Platforms and Ecosystems: Enabling the Digital Economy. Briefing Paper: World Economic Forum. Cologny/Geneve: World Economic Forum, 2019. Available at https://www3.weforum.org/docs/WEF_Digital_Platforms_and_Ecosystems_2019.pdf. Accessed 04.04.2022.

artificial decision making without human intervention is a present reality, which has shown itself to be promising and challenging, especially for its ethical impacts.

It is also worth investigating carefully the limits and controls of biases in the decision of artificial agents, as well as the possibility of the emergence of an intelligent, autonomous, decentralized system in multiple artificial agents.

Understanding the economic rationality of the new artificial agents and their regulation requires revisiting the foundations of the classical theory of economic analysis and building new theoretical models of study.

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