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Analysis of the impact generated by COVID-19 in banking institutions and possible economic effects

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Abstract. *From the perspective of early warning and the effects generated by the COVID-19 pandemic, this article deals with the impact that the COVID-19 pandemic has on the banking network. The 2019-nCoV coronavirus epidemic began in the Chinese city of Wuhan, which spread across the country and later in a very short period of time in several states, being seen as a global contagion effect that causes a large concern. The first part of the case study highlights that the behavior of agents greatly impacts the decisions they will make and this can cause financial and economic imbalances. The financial impact of coronavirus goes beyond the worst old scenarios, building the ideal framework for a possible economic crisis. Economic changes and their effects have also affected the stock markets. This is also analyzed in the first part of the case study and through the IT solution NetLogo we simulated the contagious economic effect that can be transmitted in the economy of a country that is built on the interactions between several economic agents, such as businesses, banks, institutions and even the government of a country. In the analysis performed in the second part of the case study, we collected data on the following stock market indices: S & P500, Dow Jones Industrial Average, FTSE but also indices related to the banking groups that include both Raiffeisen Bank Romania and Romanian Commercial Bank and we analyzed these data in the Altreva Adaptive software.*

Keywords: COVID-19, stock market, banking institutions, NetLogo, Altreva Adaptive Modeler.

JEL Classification: C02, C58, G17, G4.

1. Introduction

Mankind is nowadays situated at one of its thousands of key points which have left their footprint within history (either pandemics or wars, among other events resulting in mass deaths). This time, every grain of power on a global scale is focused on the occurrence of the novel coronavirus in Wuhan. Time and time again, there have been performed tests on the hypotheses assuming an influenza-related virus (even the 1918 Spanish flu), SARS coronavirus (Severe Acute Respiratory Syndrome) or MERS (Middle East Respiratory Syndrome) and the avian flu. Within one month from the occurrence of the first infection, the structure of the new strain has been discovered and named Wuhan or Coronavirus 2019-nCoV, after the city where it first made its mark. According to experts, respiratory disease in Wuhan is caused by a new type of coronavirus remotely related to SARS coronavirus (SARS-CoV). (Nica and Chiriță, 2020b)

After a period in which the increase in the impact of Fintech companies has been strongly supported, the United States investing over $ 18 billion in 2019 to finance venture capital for private Fintech, according to a report published by PwC, an unexpected event appears that disturbs the stability of the financial ecosystem and beyond. This is the pandemic caused by the SARS-CoV-2 virus, Coronavirus. By the way in which economic, political and legislative relations between countries and continents are conducted, they can be seen as a complex global network. Before analyzing the impact that COVID-19 has generated in the Banking Ecosystem, I will present some information about the concept of Fintech, Fintech companies being an important link in this ecosystem.

Fintech companies have benefited from more flexible regulations worldwide in both emerging and mature countries as organizations have sought to improve financial inclusion and serve a higher digital economy. According to an Ecosystm Report, five key trends that should have shaped the Fintech market in 2020 were presented:

- Greater investment in platforms that support financial inclusion.
- Increased collaboration and investments in Fintech companies by traditional banks.
- Awareness that Asia is the center of the Fintech universe.
- Increasing the importance of advanced data and analytical start-ups.
- Regtech companies ensure improved compliance automation.

Taking into account recent events in the financial system such as the appreciation of the Swiss franc against the euro and the dollar which has caused great difficulties to the economy, national and international companies, including people, or the phenomenon of "Brexit", studying methods to identify early effects affects an entire system, by diminishing negative events, is very important. The COVID-19 pandemic is an event that has taken the global economy by surprise, which has created and continues to create great difficulties. (Nica and Chiriță, 2020b)

2. Altreva Adaptive Modeler

Applying the concepts of virtual smart living to complex dynamic systems, such as stock markets, offers exciting new business opportunities. In the past, people have approached the task of modeling financial markets, trying to avoid complexity rather than capitalize on

it. Models resulting from simplified models usually predict rational results that do not correspond to the actual behavior of the markets. However, by creating an agent-based market model, i.e. a virtual market, I can capitalize on this complexity and use the functions it generates, such as emerging behavior, to forecast the time series based on a real financial model, and, of course, the ability to generate wealth. With the help of this software, agent-based financial market simulation models can be built, in order to predict the prices of shares traded on the real market or other securities, currencies, cryptocurrencies, which are traded in a specific market. The technology he uses is based on the theory of economy based on agents, the study of calculating economic processes modeled as dynamic systems of interaction with heterogeneous agents.

The adaptive model Altreva and other agent-based models are used to simulate financial markets to capture the complex dynamics of a wide variety of investors and traders with different strategies, different trading periods and different investment objectives. Agent-based, heterogeneous, and rationally delimited (learning) models have been shown to be able to explain the empirical features of financial markets better than traditional financial models that rely on representative rational agents. The software creates an agent-based model for a specific stock, consisting of an agent population and a virtual marketplace. Each agent represents a virtual trader/investor and has its own trading rule and funds. It can be downloaded free of charge for teaching purposes from https://www.altreva.com/download.htm.

Agent-based modeling is based on simulating the actions and interactions of several people or organizations in order to analyze emerging effects on a system.

An agent-based financial market model, for example, consists of a population of agents (investors) and a mechanism for regulating stock prices. Agent-based models have proven to be able to explain the behavior of financial markets better than traditional financial models. Financial markets have been studied using analytical mathematics and econometric models, most often based on the fact that market participants are generally considered to be rational. Altreva Adaptive Modeler uses computational intelligence and is primarily designed to actively trade stocks or market indices, i.e. using futures contracts.

The simulator works as follows: it is divided into 2 main areas of analysis, agent-based modeling and trading system. In short, the agent-based model receives quotes and produces price forecasts, and the trading system decides when it should give a new trading signal based on the user's forecasts and trading preferences. The IT solution offers a modern simulation framework, frameworks on statistics of developments over time, being also highlighted the dynamic framework of financial markets. Also with the help of this program you can do statistical simulations such as historical simulation or Monte Carlo simulation. In addition, it is a good stock market modeling and value at risk program (Benefit at Risk, in English) beneficial for any investor to know how to position themselves in the market.

3. Case study and discussion

The beginning of 2020 was not a great one, affecting the above desired trends because another major trend appears as a result of the existing pandemic. This has an impact on

investments in Fintech companies, leading to a greater use of digital banking. The rapid geographical spread of coronavirus and high rates of contamination (over 100,000 infections in about 80 countries by March 4, 2020) have spread fear worldwide and disrupted global economic activity.

From the perspectives of early warning and risk identification, risk quantification and analysis, as well as risk management, I propose the following recommendations, which include the analysis of the behavior of the panicked citizen and the cooperation of Romanian institutions.

The 2019-nCoV coronavirus epidemic began in the Chinese city of Wuhan, which spread across the country and later in a very short period of time in several states, being seen as a global contagion effect that causes a large concern. As the virus approached Romania, the situation became worrying, and citizens were already panicking.

Mankind is currently located in one of the thousands of key points that have left their mark on history (either pandemics or wars, among other events that have resulted in mass deaths). This time, every gram of power on a global scale is focused on the emergence of the new coronavirus in Wuhan. Again, tests were performed on hypotheses involving an influenza-related virus (including the Spanish flu of 1918), coronavirus SARS (severe acute respiratory syndrome) or MERS and avian influenza. Within a month of the first infection, the structure of the new strain was discovered and named Wuhan or Coronavirus 2019-nCoV, after the city where it left its mark. According to experts, respiratory disease in Wuhan is caused by a new type of coronavirus remotely related to SARS coronavirus (SARS-CoV). Aggressive human-to-human transmission has led to a large number of coronavirus infections that have killed more than tens of thousands of people in several countries. According to official figures from the World Health Organization, there were 2,918 deaths out of a total of 81,109 confirmed cases worldwide. Most were registered in China (2,718 out of 78,191). These figures indicate a mortality rate of just over 3%. (Karuc et al., 2020)

Managing the risks of potential Coronavirus in Romania can pose many problems. The major potential impacts on Romanian society could be: public panic, lack of medical supplies and food, insufficient beds and medical staff. Confirmation of the coronavirus pandemic among the Romanian population could also have an impact on the functioning of economic units, such as banks. The initial spread of the virus in as many European countries as possible near Romania and the confirmation of the appearance of the coronavirus in Italy had already caused panic among the population. Access to the Internet, social networks such as Facebook and international news makes it easier for panic to grow and for citizens to behave in chaos.

With the panic, the economic problems will become even greater in the short term. Emotionally, consumption can increase, but only artificially. This could also lead to a shortage of goods, which is based on popular perception of a certain danger. For example, due to the fear that the virus has been confirmed in Romania, people have started to buy a lot of food such as flour, pasta, water, oil and canned food to prepare with supplies. Thus, a chaos has already been created that does nothing but amplify the panic even more. The

head of the Supervisory Board of the National Bank of Romania, Mr. Nicolae Cinteză, said that the situation can become worrying for Romanian banks if it does not provide a working scenario in case of unforeseen events, such as coronavirus, regarding business continuity.

From an economic point of view, in the context of investors who fear that the new coronavirus epidemic will slow the economy, European and Asian stock markets have been on a downward trend. The panic created among the citizens leads to as many purchases as possible regarding non-perishable food, hygiene and protective materials. People need to be aware that this exaggerated fear can lead to a lack of food and hygiene materials, and this is a potential danger to life, health and basic survival. The population must be rational in these moments regarding the choices and decisions they make.

Most EU Member States have developed risk assessment methodologies, adopted in national legislation and already operational. These developments are taking place in the context in which, since 2010, in order to improve the capacity of Member States to respond to the identified risks through prevention, preparedness and response measures, the European Commission has initiated a process of creating a methodological framework for risk assessment to enable the development of common European strategies and policies, based on comparable results at EU level. A common European framework aims at better management and distribution of resources, with the aim of effectively and efficiently preventing and managing the negative effects of disasters and other risks at EU level. Several epidemics and pandemics in recent centuries have originated in China. In 1781-1782, an influenza virus killed many people in China and other countries. The Asian crisis of 1957 killed more than 1 million people. This was followed by SARS in 2002 and bird flu in 2013.

An important measure for the prevention and control of the epidemic could be the analysis of possible risks and their monitoring. Risk monitoring, combined with knowledge based on the analysis of larger amounts of data and certain information, combined with artificial intelligence and data science could be a factor that would contribute to improving citizens' motivation and behavior. Due to the high rate of the spread of an epidemic, a small amount of data is used and little research is needed to make quick decisions so that the spread of the contagion is prevented. From the point of view of risk management, several parties need to be involved, as follows: medical resources, political departments, emergency departments, patient, coronavirus suspected patient, research institutions, citizen, media and international community. You need to create a complex network of interactions so that the best decisions can be made. When it comes to a contagious disease, many people face panic.

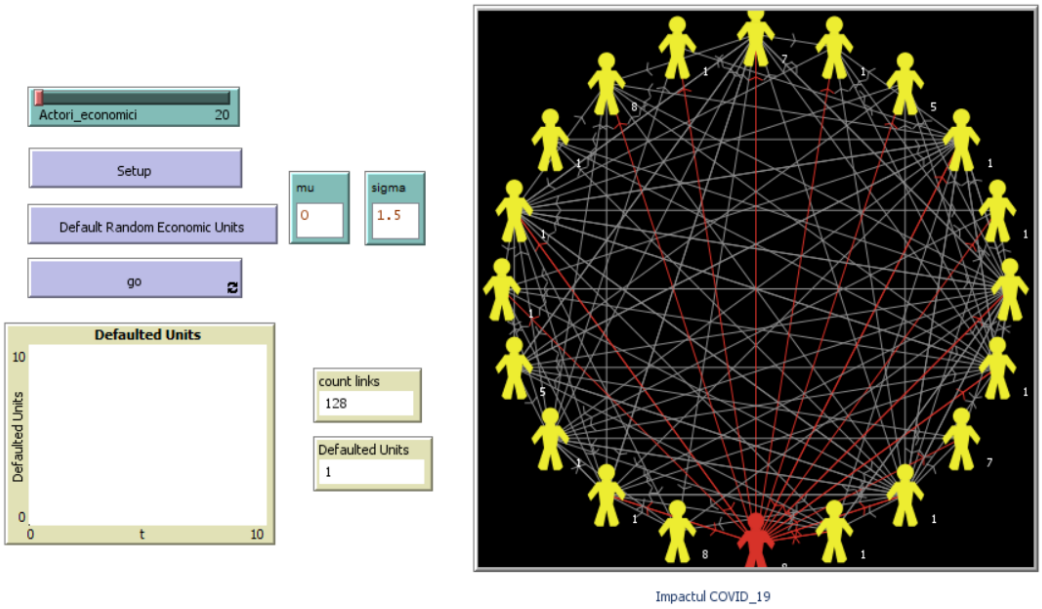
Another important player who could help increase citizens' optimism is the government itself, or even the president. For example, it should be appreciated that the President of Romania talks to citizens through press conferences and conveys that the level of mobilization remains high, but presents this information in a calm tone and the information is documented and correct. All citizens must understand that it is the responsibility of each individual, not just the institutions, to cooperate, to fully respect the indications and advice of the authorities, in order to have a successful strategy in preventing and combating

coronavirus infections. All the above aspects constitute the basic framework of risk management in such situations.

The financial impact of coronavirus goes beyond the worst old scenarios, building the ideal framework for a possible economic crisis. Economic changes and their effects have also affected the stock markets. FTSE, Dow Jones Industrial Average and Nikkei are just a few stock indices that have seen huge declines since the outbreak of the pandemic began on December 31, 2019. Investors fear that the spread of coronavirus will destroy economic growth and government action may not be enough to stop the decline. As a solution in the financial-banking market, central banks in several countries, including the United Kingdom, have reduced interest rates. In theory, this means reducing lending and encouraging spending to stimulate the economy. Global markets also recovered shortly after the US Senate passed a $ 2 trillion bill to help businesses and businesses survive the effects of the pandemic. However, the situation is quite volatile and, in the long run, this investment may not be enough.

The model developed by Gai and Kapadia can simulate in NetLogo a network formed by the economic units of a country.

Figure 1. *Simulation of COVID-19 impact*



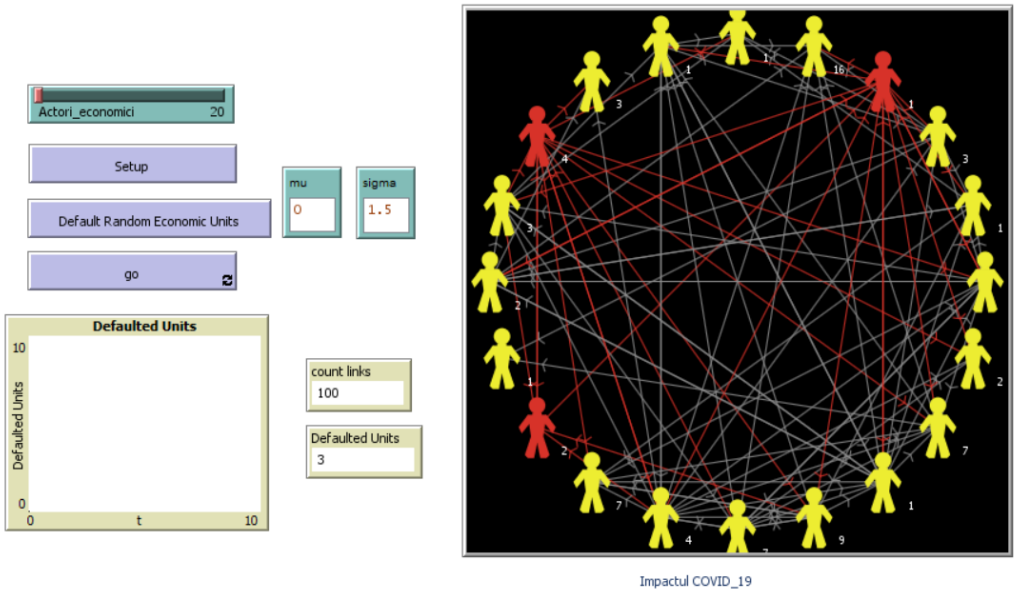
Source: Authors computation.

In the above simulation, we considered that a country's economy is built on the interactions between several economic agents, such as enterprises, banks, institutions and even the government of a country. All these agents are interconnected through the relations between them, but the central element of their connection is the bank. It is the only institution that interacts or can create connections with any economic agent of a country.

The actor colored in red is the economic unit affected by the pandemic. We can encounter the following effects of COVID-19: dismissal of employees, stopping interconnections with other economic units, stopping production, suspending banking and even lending, increasing unemployment, creating a speculative bubble in the prices of food or protective materials (surgical masks, disinfectant).

In the simulated model we considered the actor affected by the pandemic as a bank, therefore we connected this actor with most of the economic units in the built network. It is also taken into account that the size of these banks in terms of assets held is not very large, so the expected impact is not a major one as banks, unlike shadow banking, are regulated by the National Bank of Romania. The effect was the expected one, that of not influencing the whole network. But what would happen if the bank actor were one of the most important players on the Romanian banking market or if the effect would have been extended to two other banks?

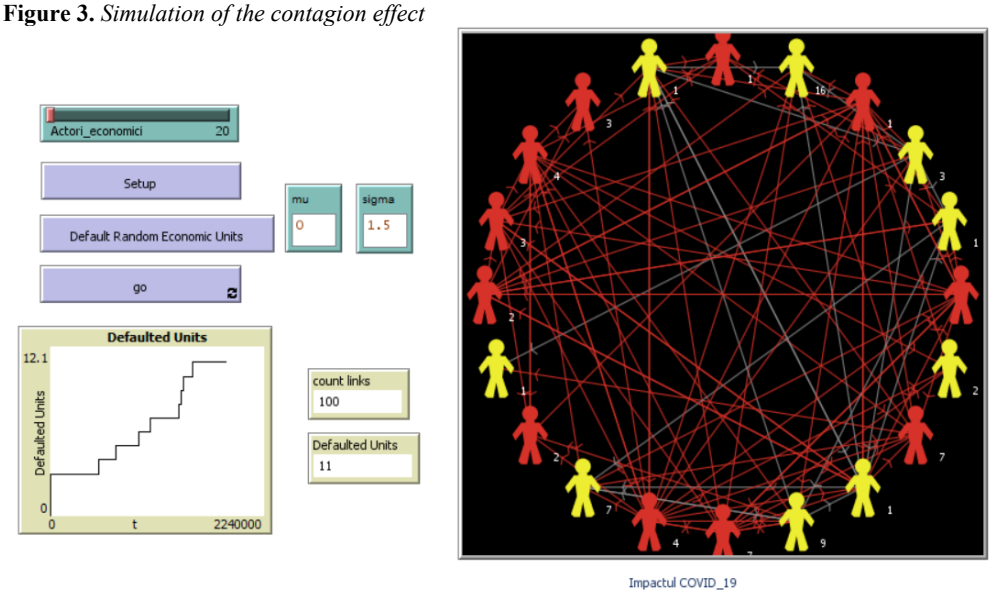
Figure 2. *Simulation of COVID-19 impact in banks sector*



Source: Authors computation.

In the figure above it can be seen that three actors (banks) are affected by the existing pandemic and are connected with different economic units.

Figure 3. *Simulation of the contagion effect*



Source: Authors computation.

In the image above, after a few simulations you can see how the contagion effect is transmitted in the network. Several economic agents have been affected and solutions need to be introduced to avoid an economic crisis. Due to the contagion in the network, several companies suspend their activities, this also having an impact on banking institutions because the employees of those companies may have loans from banks. By stopping the activities, the employees register a decrease of the income generated either by a technical unemployment, or by the suspension by the companies of the salary payments. Thus, the banks had to quickly adopt a solution in order not to reach the situation in the figure above.

Therefore, several discussions between the banks, the NBR and the Government of Romania decided as a temporary solution for customers to benefit from a debt moratorium. It was formalized by a Decision of the Romanian Government, published in the Official Gazette on April 6, 2020, called the Norm on Ordinance number 37.

However, this moratorium, although beneficial to customers, may have a negative effect on domestic credit risk estimation models.

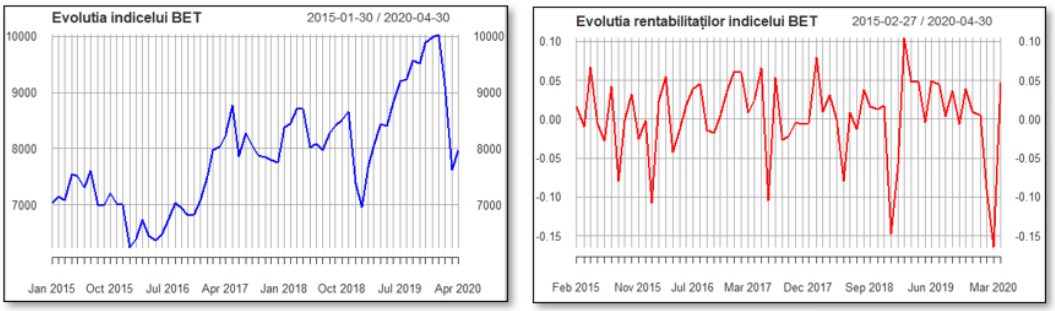
From the stock market point of view, in order to investigate the impact that the pandemic had, we carried out an analysis of the evolution of the capital markets. Thus, we analyzed the evolution of the following indices:

- BET: the reference index for the Romanian stock market;
- S&P 500: the representative index of the US stock market. It measures the capital performance of very large companies, 500 listed companies;
- FTSE China: representative index for the Chinese stock market measuring the performance of 50 listed companies;
- EuroStoxx50: the stock market index that characterizes the European stock market of a number of 50 representative companies;

- FTSE100: UK stock market index;
- DAX30: the performance of 30 companies in Germany is the evolution of this index.

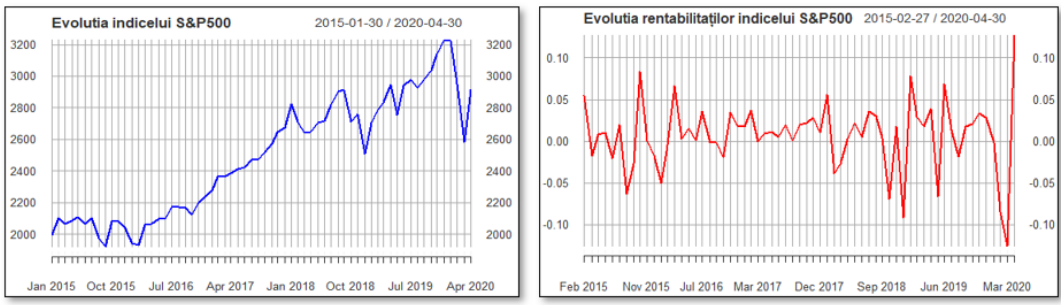
In the following we will graphically present the evolution of these stock market indices. In addition, as it is not enough to analyze only the evolution of stock market indices, we also represented the degree of changes in their returns.

Figure 4. *Evolution of the BET index*



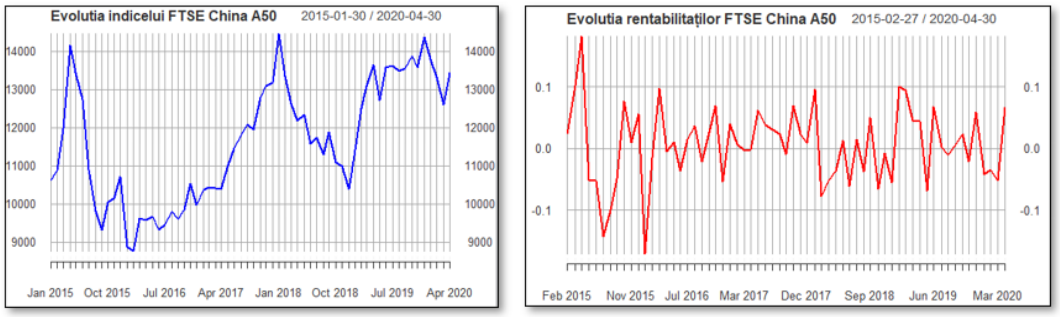
Source: Authors computation in R Studio.

Figure 5. *Evolution of the S&P500 index*



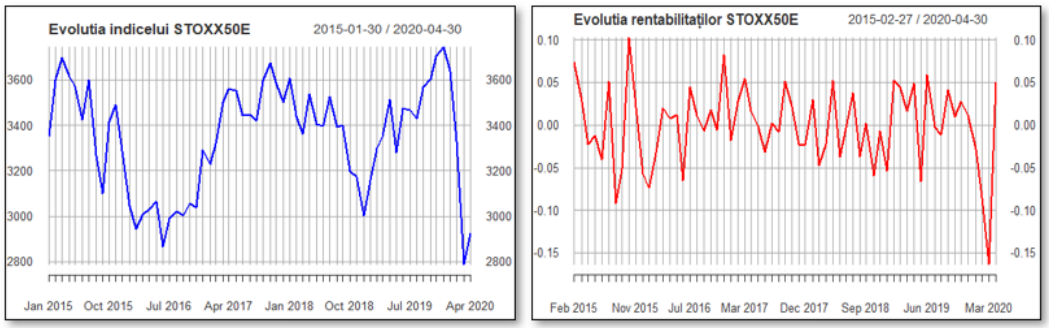
Source: Authors computation in R Studio.

Figure 6. *Evolution of the FTSE China A50 index*



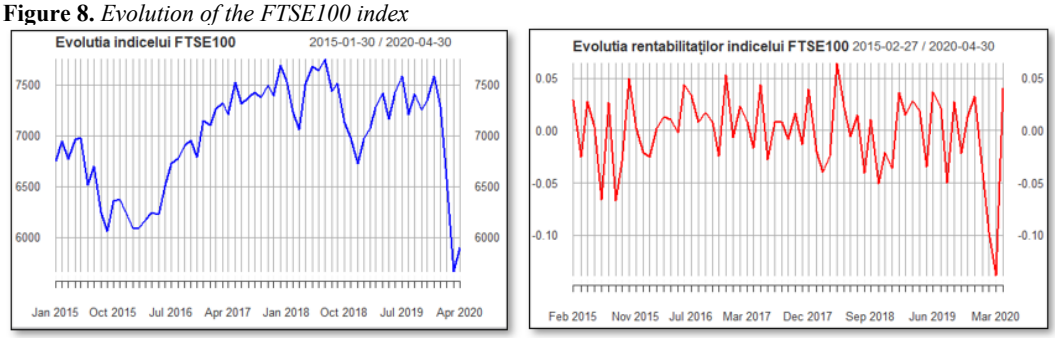
Source: Authors computation in R Studio.

Figure 7. *Evolution of the STOXX50E index*



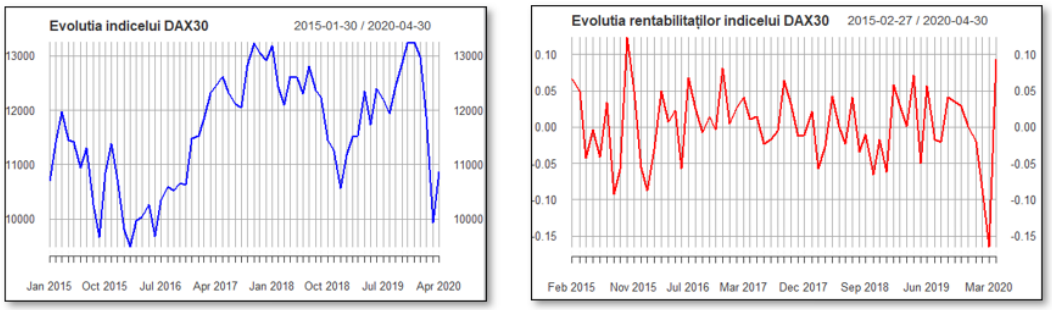
Source: Authors computation in R Studio.

Figure 8. *Evolution of the FTSE100 index*



Source: Authors computation in R Studio.

Figure 9. *Evolution of the DAX30 index*



Source: Authors computation in R Studio.

The current economic context, similar to one in recession, underlines the importance of analyzing the evolution of the returns of stock indices and identifying spikes over the analyzed period.

The events of this period, the first half of 2020, have completely reshaped the economic context, and banks are making efforts to further support the economy, manage financial resources sustainably and maintain a degree of stability.

The above graphs show stronger negative economic effects when there is a sharp decrease in the average values of the analyzed indices, than decreases recorded over a longer period of time. The stock market can be seen as a complex adaptive system and due to its

properties, it adapts to the environment and macro and micro economic conditions. Thus, a sudden shock may outline a systemic event whose effect may not be immediately controlled. This explains the fact that when decreases are recorded over a longer period of time, the system has time to adapt and identify solutions to maintain stability.

As is already known, many countries have been severely affected by the COVID crisis19 and the identification of measures to combat it is still under analysis. Large sectors of the economies of several countries have been suspended, outlining a systemic event with a visible impact on the capital market.

The BET index, like an economy, follows a cycle as can be seen in Figure 10.4.4 and since 2018 has recorded an impressive increase, reaching in 2019 the maximum value of the analyzed period. The impact of the pandemic is felt on the Romanian capital market. Thus, in March 2020 there was a sudden decrease in the stock market index in Romania. However, its value does not exceed the lowest stock market value recorded in the analyzed period, 2015-2020.

Also, in March 2020, the S & P500 index registered a strong shock on the American stock market. According to graph 10.4.5, we can observe that the amplitude of the decrease of the index in March 2020 is the largest in the analyzed period, this being confirmed by the existence of oscillations of the returns of this index.

An interesting aspect that we can observe in the analysis of the FTSE China index, related to figure 6 is the fact that although the origin of the pandemic is in China, its impact on the stock market was not devastating. Moreover, in December 2018, there were more virulent events that affected China's economy than the coronavirus. This shows that the severe measures taken easily, perhaps also due to the communist regime, helped more to maintain stability. On the other hand, it is known that China's economic power is very high and the country is very well developed technologically and digitally.

Considered an engine of the European economy, Spain, Germany, Italy and France were severely affected. Their effects were propagated as a contagion effect at the level of the European Union, a fact observed in the evolution of the STOXX50 index. It can be seen that in the analyzed period, the lowest market value and the highest negative profitability is observed in March 2020. The contagion effect is observed not only among the population but also among the economies. Capital markets around the world have been affected.

The British economy has also been hit by the coronavirus crisis. At the end of March 2020 and April, there were strong shocks on the British stock market.

4. Adaptive market behavior modeled in other adaptive modeler

A didactic means and not only to model the forecast of some stocks, assets, markets is represented by the computer system Altreva Adaptive Modeler, being based on an innovative and unique technology, it creates market simulation models in which thousands of virtual traders apply their strategies, trading using real world market data to trade. Based on the agent-based modeling methodology, with the help of the software application one

can observe the behavior of the agents with the help of which certain prices and certain trading signals can be predicted. Agencies compete and adapt in this virtual environment.

Agent-based modeling has been shown to be able to explain the behavior of financial markets better than traditional financial models.

Next, I will build a speculative trading model based on the adaptive behavior of economic agents. This behavior is expressed through a feedback mechanism on changing the stock-bond ratios of agents, depending on the previous performance of their portfolios. The share price is set according to the supply demand for the asset derived from the agents' risk levels. Using the agent-based modeling methodology, I will show that agents, which act endogenously and adaptively, create a persistent price bubble. The price dynamics generated by the trading process do not reveal any singularity, however, the process is accompanied by an increase in aggregate risk which indicates an increase in the probability of an accident.

We will consider a model of economic behavior based on agents. It is characterized by behavioral traits typical of exchange patterns, described by either a group behavior or an individual. The ownership of group behavior describes the fact that agents have a common belief that it is advantageous to participate in market activity. On the other hand, individual behavior is characterized by the following properties:

- each agent shall act in his own interest;
- agents have heterogeneous preferences;
- agents interact and interactions lead to an optimal, reciprocal outcome;
- the behavior of the agents is adaptive.

The importance of the behavioral aspects of speculative markets has always been recognized, under different interpretations. It is hard to deny that the irrationality of market participants is a pervasive feature that causes price instability and critical events. Attempts to understand price changes in the stock markets lead to the introduction of agent-based models that mimic the behavioral patterns of different groups of traders. Kim and Markowitz showed the destabilizing effect of constant portfolio insurers on price dynamics and proposed it as an explanation for the 1987 market crash. Levy and Solomon demonstrated in their research that there are rational and irrational traders in the analysis of multi-agent models, and the group of these agents will cause the price dynamics to go through a series of booms and imbalances.

A number of models of nonlinear differential equations have been proposed to describe the evolution of the population of different types of traders, their interactions, price dynamics and changes in the wealth of agents. The proposed model generates complex chaotic dynamics, with the agglomeration of yield volatility, queues in the distribution of returns and wealth, as well as long-term memory. Even if traders are restricted to rational utility maximizers, the price that will persistently grow will create so-called rational bubbles. Thus, the significant deviation from the fundamental value is the generic property of speculative prices.

The statistical properties of market portfolios are different from those of a single stock. Analyzing the charts of stock indices, after the Great Depression and before, it is not

unusual to observe over certain medium and long periods fluctuations of returns around the average, when market indices increase at almost constant rates, with a slight volatility.

Positive returns are certainly influenced by macroeconomic parameters, but the quantitative expression for dependence or deviations is unclear. Thus, for the next analysis, modeling based on agents that mimic real trading processes will be used. The model is based on the following assumptions, described below. (Dezsi et al., 2014)

In a changing market environment, traders need to constantly review their investment portfolios, shifting funds between 'safer' and 'riskier' assets, changing their level of risk. I will assume that this rebalancing and updating of portfolios completely determines the dynamics of the market as a whole. To be more specific, I describe the following conditions:

a) the market portfolio price is set by the agencies willing to rebalance the funds between their stock and a secure asset, in cash or bond;
b) on rebalancing, agents act only on the basis of the relationship between stock and bonds;
c) the agents change the proportions of their investments in an adaptive way to the changes of their portfolios.

To introduce the model, it is necessary to establish the number of agents that will enter the market that will trade shares of a single asset. Agents do not know the fundamental value of the asset, but expect the price to rise at moderate rates over long periods of time, and always prefer the value to rise rather than fall. The decision to buy or sell the asset will determine the position in the market: short or long. In the Altreva simulation, I will assume that agents meet at intervals that I will note with $t = 0,1,2, \dots, n$. In period t, an agent has a portfolio described by the stock-bond relationship denoted by (a_i^t, o_i^t), i representing an agent who trades at a time t. I will mark the price of a share at time t with p^t. The next moment, the player is described by a portfolio (a_i^{t+1}, o_i^{t+1}) and the price per share in the portfolio p^{t+1}. Assessing the latest changes in the agents' portfolios, it will be noticed that they set targets on the stock-bond ratios for the next period, which I will note with x_i^{t+1}. To better understand the relationship between agents, I will assume that there will be another agent (a_j^t, o_j^t), player on the same portfolio, according to the approach proposed by Misha Prepelitza. According to this approach, it is assumed that the new price p^{t+1} is set so that the dollar amount of the agent's funds wants it to move from shares to bonds, and the target ratio x_i^{t+1} is equal with the dollar amount that agent j wants to pass from bonds to shares, and the target ratio of agent j to be x_j^{t+1}. This balance can be expressed by the following relation:

$$\frac{p^{t+1}}{p^t} * a_i^t - x_i^{t+1} * o_i^t = x_j^{t+1} * o_j^t - \frac{p^{t+1}}{p^t} * a_j^t$$

The two players, agent i and j, have different opinions and behaviors on market performance. They shall update the target portfolio reports in accordance with the following rule:

$$x_k^{t+2} = \begin{cases} \alpha * x_k^{t+1} * \dfrac{p^{t+1} * a_k^t}{p^t * o_k^t} > x_k^{t+1} \\ x_k^{t+1} * \dfrac{p^{t+1} * a_k^t}{p^t * o_k^t} = x_k^{t+1} \\ \gamma * x_k^{t+1} * \dfrac{p^{t+1} * a_k^t}{p^t * o_k^t} < x_k^{t+1} \end{cases}$$

Where $\alpha > 1$ and $\gamma \in (0,1)$ are the parameters that define a feedback mechanism of a complex adaptive system. If the agent identifies a growing market, it increases its ratio of shares to bonds by a fixed amount, while the other agent reduces its ratio. The feedback reflects that when faced with a series of weak investments, the agent will reduce the share of capital in the portfolio, while if the investment grows better than expected, he will take a riskier position.

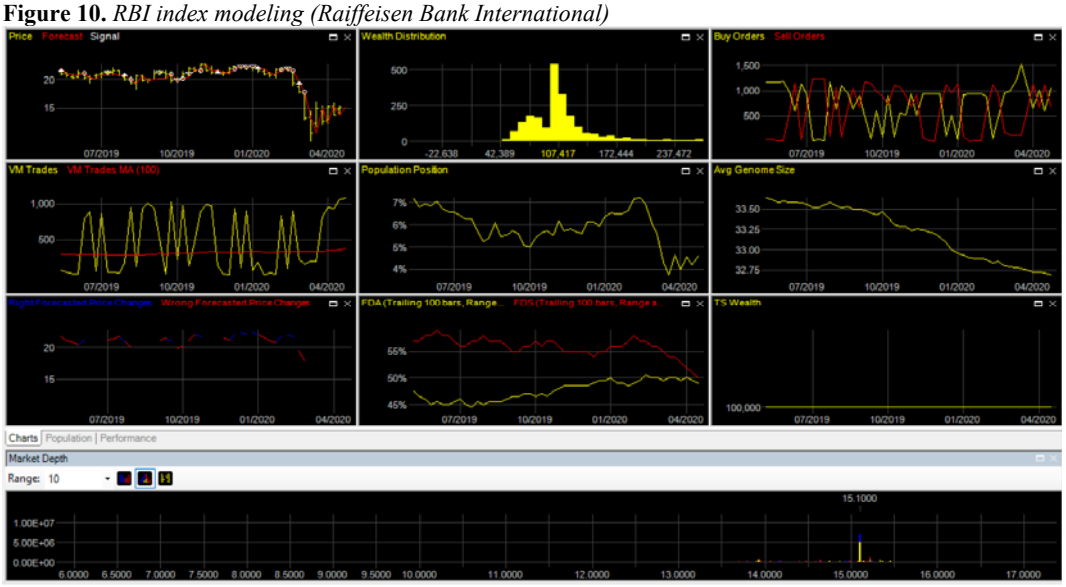
In addition to price charts, agent-based models provide detailed information on the distribution of wealth between agents. This information allows the study of the effects of market activity on the agent population.

Thus, in the analysis we collected data on the following stock market indices: S & P500, Dow Jones Industrial Average, FTSE but also indices related to the banking groups that include both Raiffeisen Bank Romania and Romanian Commercial Bank. The two are some of the most important banking actors in the Romanian system, both in terms of assets and trading, lending or relations with other economic systems. In my opinion, cryptocurrencies are also an interesting topic to analyze and I think that in the future they will have a significant impact on the banking network. An agent-based model is a computational model for simulating the actions and interactions of multiple agents to analyze the effects on a complex system as a whole and is a powerful tool in understanding markets and trading behavior. An agent-based financial market model consists of a population of agents (investor representatives) and a price discovery and clearing mechanism (representing a virtual market).

In terms of financial markets, agent-based models can successfully replicate time series features, such as fat-tailed distributions (leptocurtures) and the volatility cluster, for which standard financial models offer little explanation. Conventionally, financial markets have been studied using analytical mathematics based on a generalization of market participants and other simplifications.

In the figure below we have represented the evolution of the RBI portfolio for the period May 2010 - April 27, 2020, simulating the model starting from March 2012. We assumed a population size of 2000 agents, with an equal initial distribution of wealth and a capital of start worth 100,000 units. The result of agent-based modeling is shown in the figure below.

Figure 10. *RBI index modeling (Raiffeisen Bank International)*



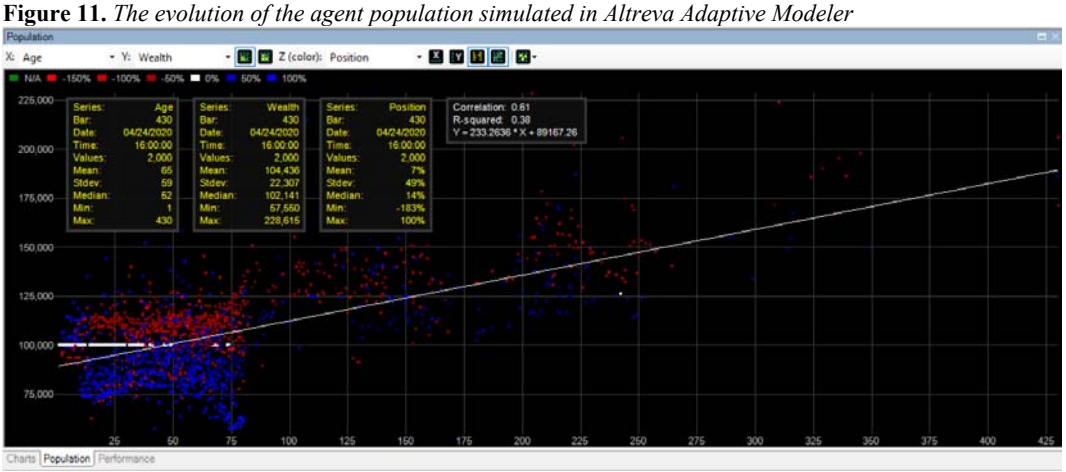
Source: Authors computation in Altreva Adaptive Modeler.

The following figure shows how the population of agents evolves according to their age and wealth. The correlation coefficient is 0.61, the square deviation R = 0.38 and the regression line is constructed according to the function:

$$f = 233{,}2636 * X + 89167{,}26$$

The slope of the curve has the value of 233.2366 (slope).

Figure 11. *The evolution of the agent population simulated in Altreva Adaptive Modeler*



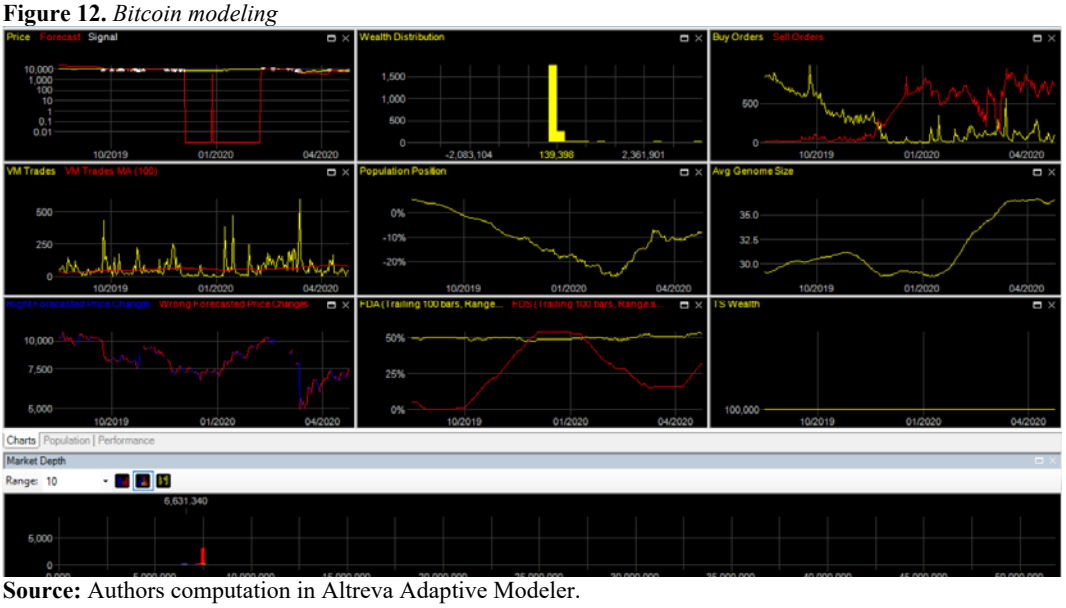
Source: Authors computation in Altreva Adaptive Modeler.

The behavior of financial markets, as observed in reality, cannot be fully described by such mathematical models. In reality, market prices are set by a wide variety of investors with different decision-making methods and different investment objectives. The complex dynamics of these heterogeneous investors and the resulting price formation process

require a multi-heterogeneous simulation model and a virtual market. The model works as follows: The agent-based smart model cycle begins with receiving a new portfolio of offerings, so that agents can place a new order or remain inactive according to the trading strategy. After all the agents have evaluated their trading strategy, the Virtual Market determines the clearing price, executes all executable orders and releases the price forecast for the next bar. After that, new agents can reproduce and be replaced by evolutionary operations, such as crossover and mutation, a process that is repeated for each interval (bars).

The model's trading rules use historical price data as input, either from the virtual market or the real market, and return an output consisting of a desired position, as a percentage of wealth, and a limit price for buying or selling. Trading procedures are implemented by genetic programming technology. During the reproduction process, which is specific only to the smart agent-based model, new offspring agents are created from some of the best performing agents to replace some of the weakest agents. To achieve this, at each bar, the highest yielding fitness reproduction agents are selected as parents, and the genomes (trading rules) of these parents' pairs are then recombined by genetic crossover to create new genomes that are given the new successor agents. These new agents replace the agents with the lowest replacement efficiency. Fitness functions are a measure of the return on investment of agents over a period of time, so the reproduction yield of reproductive capacity is calculated as a measure of short-term return of wealth and is the selection criterion for reproduction (best agents), while fitness replacement efficiency is calculated as the average performance per bar and is the selection criterion for replacement (worst agents).

Figure 12. *Bitcoin modeling*



Source: Authors computation in Altreva Adaptive Modeler.

In the figure above you can see a model based on agents related to the evolution and prediction of the cryptocurrency Bitcoin. In all cases, the shock of the first part of 2020

regarding the COVID-19, which had an impact on financial markets around the world, can be seen. The outputs resulting from the processing and simulation of the other indices mentioned above can be found in Appendix A.

Taking into account the literature on the impact of high frequency trading on financial markets, the results showed that this algorithmic transaction led to increased liquidity, improved market efficiency, without affecting market integrity and lower incidence of market manipulation. The results of this case study show that, in almost all cases, the smart agent-based model performed better, which could be interpreted as lower market efficiency, allowing stock market price predictions to manipulate the market. All these events can represent shocks that can affect both the banking network and the global economy. Complex Adaptive Systems have properties necessary to be understood in order to quantify and propose methods of regulation and self-regulation at the level of financial markets that have an impact on banking networks. It is also interesting how the emergence and evolution of cryptocurrencies impact the evolution of the financial market.

5. Conclusions

The context of the COVID-19 pandemic represents a new challenge for the whole world. The event caused huge losses, both human and material and financial. The economies of many countries have been troubled, with the pandemic of this virus being an extremely strong shock in the global economic network. Therefore, another analysis is presented in the next research study, number four.

We adapted the model proposed by Gai and Kapadia and performed an analysis in NetLogo to observe how the transmission of the contagion effects that appeared after the pandemic. Banks are the binder of the national economy, from my point of view, and maintaining financial stability at this time is very important.

The second part of this case study is the behavior of the capital market in several countries in the context of coronavirus. The results showed that this pandemic created significant shocks on the stock market in several countries, some registering the highest negative returns in the analyzed period.

Romanian banks support the country's economy by applying extensive protection and support programs for companies and individuals affected by the COVID-19. The measures aim to support the economy and jobs, as well as support for credit adjustment, along with a range of solutions to ensure fast and efficient remote banking assistance.

The outbreak of the COVID-19 (Coronavirus) epidemic and its global spread since February 2020 have created immediate significant challenges for society and risks to the economic outlook. Although the long-term magnitude of the economic shock cannot yet be quantified, economic activity is likely to shrink.

In the following researches we want to investigate the potential effects that the COVID-19 pandemic can generate if a wave 2 of pandemic aggression is generated in Romania.

Note

(1) Altreva Adaptive Modeler can be downloaded, for education purpose, from the following available address: https://www.altreva.com/

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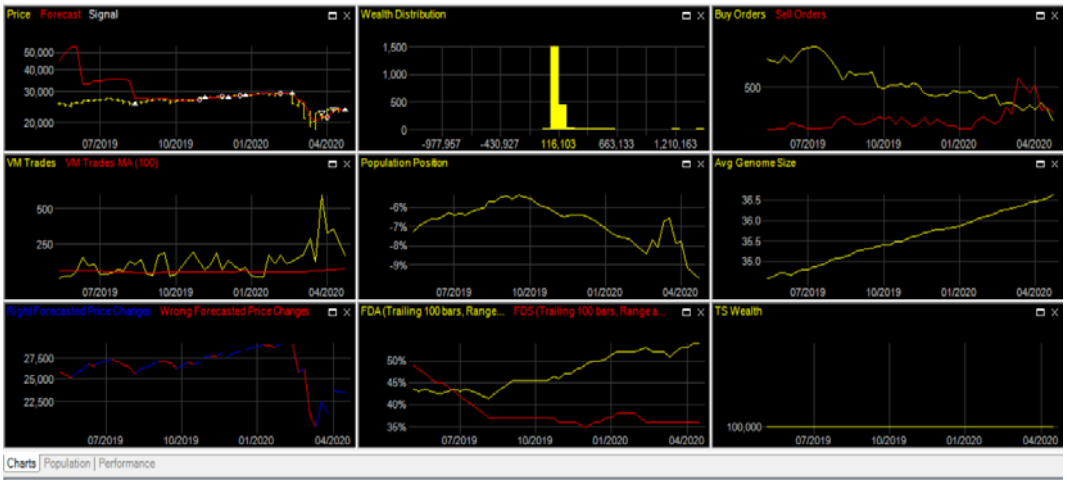
Appendix A

Figure A.1. *The evolution of the Dow Jones index*

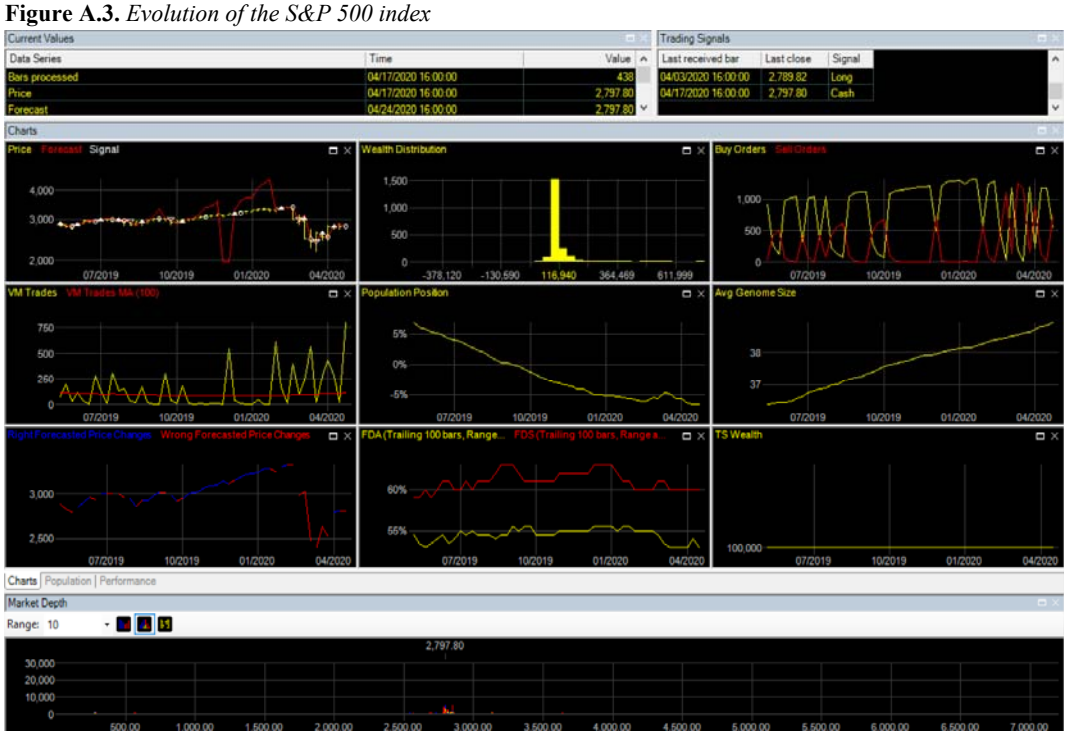


Source: Authors computation in Altreva Adaptive Modeler.

Figure A.2. *Evolution of the Erste Bank Group index*

Source: Authors computation in Altreva Adaptive Modeler.

Figure A.3. *Evolution of the S&P 500 index*



Source: Authors computation in Altreva Adaptive Modeler.