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The Prediction of Market Index Price

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Abstract

This study undertakes the theory of stimulus organism response (SOR theory) to explain and predict investor emotion and investor behavior during the Covid-19 pandemic in France and Germany financial markets. In this paper, we apply the non-parametric volatility model, the vector autoregressive model, and the nonlinear autoregressive exogenous neural network model. Empirical results show a high level of jumps in investor emotion and investor behavior during the first wave of Covid-19. Moreover, we find the existence of emotional response to Covid-19, lockdown, and government support stimuli. Indeed, we find that Covid-19 stimuli enhance investor fear, while government support stimuli minimize the level of fear. Then, the investor emotion stimulates investor behavior, generating a behavioral response that confirms the SOR theory. However, we find that during the Covid-19 pandemic, market and bank stimuli present a lower effect on investor emotion compared with stimuli related to the Covid-19 crisis. The Covid-19, lockdown, and government support stimuli efficiently predict investor emotion.

Keywords: neural network model, jump model, SOR theory, France and Germany financial markets, Covid-19.

I. INTRODUCTION

The Covid-19 pandemic has mainly disturbed investors' emotions and financial market dynamics. Indeed, an enhancement in stock price volatility and a decrease in index prices have been widely reported in financial markets. This crisis has seriously damaged the essential activities of companies all over the world.

This crisis could, therefore, affect the investor's emotions, which in turn affect their behavior in financial markets. Recent studies by Baig et al. (2021) and Hsu and Tang (2022) have found a significant effect of investor sentiment in financial markets during the Covid-19 pandemic. This pandemic has largely generated a combination of positive and negative emotions due to the increase and decrease in the number of deaths attributable to the Covid-19 pandemic. Thus, we found that is important to explain price dynamics in financial markets by emotional response theory. In this context, we rely on the stimulus-organism-response (SOR) theory, which focuses on the successive relationship between emotional response (stimulus-organism) and behavioral response (organism-emotion). Indeed, the Covid-19 pandemic generates environmental cues that may generate responses in an organism leading to a particular behavior. Thus, the decision-making process (buy, sell, or maintain stocks) may depend on the emotional reaction to environmental stimuli.

The stimulus-organism-response theory has been extensively used in the context of psychological studies and marketing studies (Li et al., 2021) to understand the emotional and then the behavioral response of an individual stimulated by an environmental or event stimulus. However, to our knowledge, this is the first research

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paper in financial markets that considers this theory and that distinctly the emotional response and the behavioral response.

During the Covid-19 pandemic, investors are exposed to traumatic events and a cascade of negative events such as sudden death, hospitalization, the rapid increase in the number of Covid-19 cases, and the absence of a vaccine. Indeed, using the SOR theory we focus on stimuli related to the event of the Covid-19 pandemic to assess the significant effect of these stimuli on investors' emotions. Then, we assess the behavior response due to the effect of the emotional response. Thus, we study the sequence of the stimulus-organism-response (SOR) theory on financial markets during the Covid-19 period. Indeed, the events related to the pandemic represent the stimuli (S) that may affect the emotions and may trigger an emotional reaction (O), which in turn may trigger a behavioral reaction (R), which can be reflected in the market index dynamics. Recent papers report a significant relationship between coronavirus events and the dynamic of financial markets. However, they did not highlight the emotional and behavioral responses. Dash and Maitra (2022) find that the increase in pandemic uncertainty is associated with an increase in investor pessimism, which enhances volatility and illiquidity. Anastasiou et al. (2022) report that an increase in the Covid-19 index carries a positive sign across the G20 index and is associated with a decrease in the Covid-19-related sentiment crisis. Focusing on investor behavior towards medical stocks, Sun et al. (2021) find that investor sentiment driven by Coronavirus-related news does not generate irrational investment behavior toward these stocks.

The identification of significant stimuli that trigger emotion could help researchers and practitioners to forecast investor emotions and behavior. Song and Yu (2022) found that the investor sentiment index based on the k-step algorithm mainly predicts stock market return. Ruan et al. (2020) find that the monthly investor sentiment index is positively correlated with future stock market returns. However, for a long period, the correlation becomes negative.

The objectives of this paper are to identify the significant stimuli that can generate investor emotional response during the Covid-19 pandemic period, confirming or infirming the theory of stimulus-organisme-response (SOR) in financial markets. Secondly, to predict investor behavior by predicting investor emotion based on the significant stimuli found.

In order to explain the significant effect of stimuli on investor emotions and the effect of these emotions on investor behavior, we studied firstly the dynamics of studied stimuli, measures of emotions, and market indexes during the pandemic crisis. Indeed, we have used five stimuli which are the Covid-19 stimulus, lockdown stimulus, government support stimulus, market stimulus, and bank stimulus. Secondly, using the non-parametric volatility model of Barndorff-Nielsen and Shephard (2006) we try to detect the presence of volatility jumps in the investor emotion measures and investor behavior measures to detect the potential effect of the stimuli on the investor's emotions and subsequently on his behavior. Thirdly, we estimate the vector autoregressive model to examine the causality effect between variables of the SOR framework Fourthly, we investigate the ability of these significant stimuli to predict the dynamics of investor emotions and investor behavior by using the nonlinear autoregressive exogenous neural network model.

Our paper has at least two contributions to make to the literature. First, to the best of our knowledge, we are the first to explain the emotional response and behavioral responses of investors jointly in financial stock markets by using the SOR theory. Indeed, the SOR theory can efficiently explain the market price dynamics subsequent to the

realized or anticipated environmental events through investor responses to these events. Second, we try to predict the emotional and behavioral responses by using the ANN. Indeed, the ANN mathematically depicts the biological neural system by considering human resonance in its operating logic which allows it to be the adequate method of predicting investor emotion and behavior. Accordingly, this new research approach to explaining and predicting investor sentiment emotion and investor behavior by the SOR framework and the ANN provided a deeper and richer description of the stimulus, organism, and response mechanisms in financial markets. Moreover, it provides novel results and more comprehension of the process of decision-making.

II. LITERATURE REVIEW

2.1. The SOR Theory

The beginning of the scientific study of emotion appeared in 1872 with the British naturalist Charles Darwin who published his book on the expression of the emotions in man and animal. There are physiological, neurological, and cognitive theories that may explain emotion and individual behavior. According to cognitive theories, thoughts, and other mental activities play an essential role in the formation of emotions. The stimulus-organism-response theory proposed by Woodworth (1929) is composed of three stages, namely stimulus, organism, and response. This theory explains how environmental stimuli elicit an emotional response (O) which in turn causes a variation in the behavioral response (R). The SOR theory has been considered efficient in explaining behavioral deviations resulting from various stimuli.

Stimuli refers to external forces affecting the individual psychological state. Skinner (1935) considers that sudden changes in the environment can influence the psychological and emotional stability of an individual, resulting in more behavioral changes. Eroglu et al. (2001) defined the stimulus as "the influence that arouses the individual". Li et al. (2021) considered that the negative consequences related to Covid-19 constitute an important environmental stimulus. An organism is recognized as an internal decision process that happens between a stimulus and a response (Loureiro & Ribeiro, 2011; Li et al., 2021). Organism elements include both cognitive and emotional states (Lin, 2004). Emotion is seen as a temporary affective reaction of more or less strong intensity, which occurs in response to a triggering event. The response is considered as the decision-making phase that presents a change in the individual behavior. Pandita et al. (2021) have examined the psychological and behavioral changes in students affected by the Covid-19 pandemic and lockdown using the stimulus-organism-response (SOR) model. They find that despite the negative effects of the Covid-19 crisis, it favors a positive effect on students like the family proximity and the use of technology solutions in their studies.

2.2. Investor Emotion and Financial Market Dynamic During the Covid-19 Pandemic Period

The SOR theory considers that emotion depends on different stimuli in the environment that trigger an emotional process. This emotional response results in behavioral and decisional responses. We will project this logic onto the behavior of investors in the financial markets. Indeed, investors are constantly called upon to make decisions. These decisions depend on the emotional process that is subject to different stimuli.

The Covid-19 pandemic has created an environment of psychological fear (Ahorsu et al., 2020). The Covid-19 epidemic is a pandemic that is associated with great pressure

and fear felt by people (Bavel et al., 2020) due to fear from both infection and economic recession. Jeronimus (2020) finds that age, culture, gender, socioeconomic status, and personality of individuals are factors that vary the effect of Covid-19. Brooks et al. (2020) noticed that lockdown measures have aggravated existing psychological problems, and this has been found to lead to anxiety, drug and alcohol abuse, and domestic violence in many cases. Moses (2020) reports that Covid-19 has provoked higher unemployment rates, which generated an increase in psychological problems.

In this context, Covid-19 is considered a shock, which can lead to a change in the expectations and behavior of stock market investors. Thus, the change in the behavior of financial actors during the pandemic can lead to stress in stock markets. Several studies have analyzed the investor sentiment and the cognitive biases that are involved in the decision-making process on the stability of financial markets. John and Li (2021) find that different categories of Covid-19 news influence price dynamics in equity and options markets. Similarly, Jiang et al. (2021) find that investor sentiment is generally affected by Covid-19 news, which has led to stock price fluctuations. Huynh et al. (2021) find that Covid-19 presents more negative effects on the financial market than H1N1 and Ebola. Moreover, they find that the sentimental shocks are spilled from the United Kingdom, China, the United States, and Germany to the other economies.

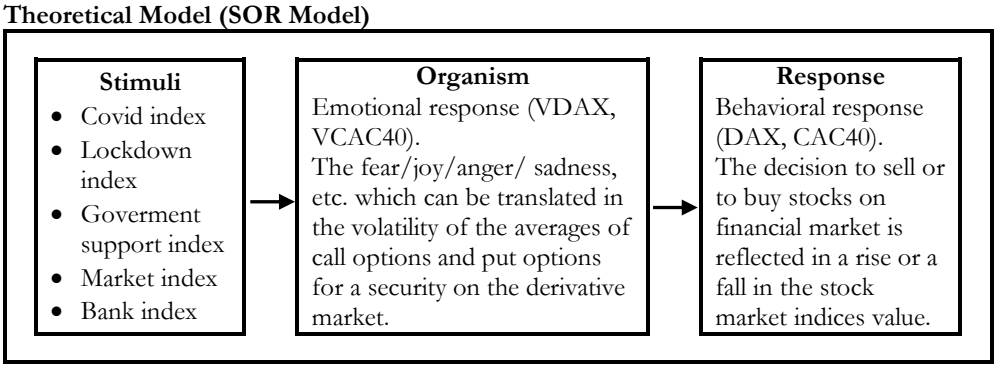
III. THE EMPIRICAL METHODOLOGY

3.1. Theoretical Model

Emotion constitutes spontaneous reactions to a situation accompanied by physiological reactions such as (fear, joy, sadness, etc.). To explain the role of these emotions in explaining and predicting the dynamics of stock market indices, we have considered the theory of (stimulus-organism-response). This methodology is an innovative idea in behavioral finance studies. Indeed, studies on the relationship between investors' emotions and price dynamics provide a significant relation between these two variables. However, they don't focus on the role of stimuli to explain such a relation. Thus, we considered the SOR theory, which deals with the existence of a relationship between stimuli, emotions, and behavior to explain and predict price dynamics during the period of Covid-19. In this paper, we have studied how environmental interventions are likely to affect the human emotional responses of investors and, consequently, their behavior in financial markets. Our work, therefore, focuses on the study of the emotional response of investors following the Covid-19 pandemic in German and French stock markets.

The intensity of emotions, beyond the magnitude and the direction of different news events, can be an important cause of price shifts and stock index volatility. To test the emotional process we need three groups of variables. The first group is related to emotional triggering events (stimuli), the second group is related to investor emotions, and the third group is related to investor behavior. Studied triggering events that can be able to affect emotions, and therefore, the price dynamics of market indexes are classified into 5 indexes. These indexes are the Covid index, lockdown index, government support index, market index, and bank index. To measure triggering events (stimuli), we use the frequency of searched terms related to Covid-19, lockdown, government support, market, and bank in the Google search engine. To measure emotions, we considered the indices of implied volatility in each country, which constitute a fear index on the stock markets. The behavior of the investor is analyzed by the variation of the stock market index.

Figure 1
Theoretical Model (SOR Model)



3.2. Data and Variables

3.2.1. Stimuli

To measure emotion-triggering events (stimuli) we used 5 indexes for Germany and France. These indexes are the Covid index, government support index, Lockdown index, bank index, and market index. We use the Google Trends database to extract the weekly search trends relating to the chosen terms for each index. To select the words related to each stimulus, we used the Loughran-McDonald dictionary. Firstly, we use the « Google Trend » to identify the frequency used words in the google search engine and which are related to the five indexes. Then, we keep only words that present volatile searching trends. Thus, each stimulus index is calculated by the average weekly frequency of used terms during the period from 01/03/2020 to 27/06/2021.

3.2.2. Investor emotion measure

Investors' emotions during the period from 01/03/2020 until 27/06/2021 is characterized mainly by fear because it corresponds to the Covid-19 pandemic. Thus, we have used the implied volatility index which measures the investors fear. For Germany, we used the VDAX index and for France we used the VCAC40 index.

3.2.3. Investor behavior measure

Following the fear emotion, the investor behavior changes from a buying behavior to a selling behavior of stocks. To measure this behaviour we used the retrun of market index. The negative return indicates a selling behavior. However, the positive retrun will be interpreted as a buying behavior. For Germany, we used the DAX index and for France we used the CAC40 index.

3.3. Empirical Models

3.3.1. Volatility jump process in investor emotion and investor behavior

Volatility jumps constitute an important tool for identifying crisis periods. Barndorff-Nielsen and Shepherd (2006) have identified volatility jumps as components of real variance (RV). Indeed, real variance is composed of a continuous variation component (CV) and a jump variation component (JV). The continuous variation component is estimated by the "bipower variation" component. The significant difference between the realized variance and the continuous variation constitutes the volatility jumps.

Following Andrew and Keith (2013) we estimate the realized variance as follows:

$$\mathbf{RV_t} = \sum_{\mathbf{j=1}}^{\mathbf{M}} \mathbf{r_j^2} \quad \text{.....} \quad \mathbf{1}$$

The realized bipower variation is calculated as follows:

$$\mathbf{BV_t} = \boldsymbol{\mu}_1^{-2} \sum_{\mathbf{j=2}}^{\mathbf{M}} |\mathbf{r_j}||\mathbf{r_{j-1}} \quad \text{.....} \quad \mathbf{2}$$

with, $\boldsymbol{\mu_1} = \mathbf{E}\,[|\mathbf{z}|] = \sqrt{\mathbf{2/\pi}}$ **3**

and z is a standard normal.

The bipower variation is as follows:

$$\lim_{M\sim\infty} BV \xrightarrow{p} \int_0^1 \sigma^2(s)ds \quad \text{.....} \quad 4$$

Thus, the jumps can be estimated as the difference between Realized Variance and bipower variation.

$$\lim_{M\sim\infty} RV - BV \xrightarrow{p} \sum_{0\le s\le t} \Delta p_s \quad \text{.....} \quad 5$$

We have calculated volatility jump for investor emotion index and investor beahavior index to detect the significant changement in these indexes. The jumps in volatility (JV) are represented in bars, the realized variance (RV) is represented in a solid blue line and the continuous part of volatility "bipower variation" (BV) is represented in a broken orange line.

3.3.2. The study of SOR theory during Covid-period

To test the validity of the stimulus organism response theory on German and French financial markets, we estimate two autoregressive regression models. The first model tests the effect of stimuli on investors' emotion index, and the second model tests the effect of investor emotion on investor behavior.

The autoregressive regression model is as follows:

$$Y_t = \mu + \sum_{i=1}^{p} \phi_i Y_{t-1} + \varepsilon_t \quad \text{.....} \quad 6$$

with Y_t represents the vector of the investor's emotion or investor behavior, ϕ_t represents the matrix of autoregressive coefficients, and P is the optimal lag number (Akaike's information criteria (P= 2)).

The first model assesses the effect of stimuli and investor emotions lags on investor emotion. Then, the second model estimates the effect of investor emotions and lagged investor behavior on investor behavior.

3.3.3. Emotion and investor behavior prediction: artificial neural networks (ANN)

Most studies in behavioral finance try to predict the performance of market indexes without giving importance to the ability to predict emotions. Our research motivation is to predict firstly emotions. In this study, we have contributed to the literature on the one hand by predicting investors' emotions from stimuli during the Covid-19 pandemic and on the other hand by predicting investor behavior by emotions through the application of artificial neural networks. The ability of the artificial neural network to learn any nonlinear function is the best way to explain the relationship between stimuli, emotions, and behavior in financial markets. Moreover, artificial neural networks mathematically depict the biological neural system by considering human resonance in its operating logic. We have used the series-parallel architecture of the NARX model (Boussaada et al., 2018). Accordingly, the future value of the variable (Y) is predicted from the past values of the same variable and the present and past values of another variable X. The equation for the NARX model is:

$$\hat{y}(t+1) = F\begin{pmatrix} y(t), y(t-1), \dots, y(t-n_y), x(t+1), \\ x(t), x(t-1), \dots, x(t-n_x) \end{pmatrix} \quad \text{.....} \quad 7$$

with, $F(,)$ is the mapping function, $\hat{y}(t+1)$ is the predicted value of y for the time $t+1$, $y(t), y(t-1), \dots, y(t-n_y)$ are the past values of y , $x(t+1), x(t), \dots, x(t-n_y)$ are the inputs of the NARX. n_x is the number of input lag, n_y is the number of output lag.

In this study, we start in a first step by predicting investor emotion from the values of stimuli and the lagged observations of investor emotion. In a second step, we search to predict the values of investor behavior from its lagged observations and from the investor's emotions variable.

IV. RESULTS AND DISCUSSIONS

4.1. Descriptives Statistics

The descriptive statistics of studied variables for Germany and France stock markets are shown in Table 1. Panel 1 presents the descriptive statistics of the stimuli. Panel 2 presents the descriptive statistics of the investor emotion index. Panel 3 presents the investor behavior index.

Table 1
Descriptive Statistics

Coun-try							Panel 2: Investor Emotion	Panel 3: Investor Behavior
Germany		Covid-19	Lockdown	Government Support	Market	Bank	VDAX	DAX
	Mean	27.25	34.90	47.88	55.27	54.31	28.71	13112.46
	Max	57.07	59.40	71.60	70.25	68.00	74.29	15693.27
	Min	12.75	13.80	32.40	44.13	46.57	16.83	8928.95
	Std-dev	10.57	10.75	7.47	6.46	5.06	11.27	1710.19
France		Covid-19	Lockdown	Government Support	Market	Bank	VCAC40	CAC40
	Mean	30.51	35.94	52.64	58.77	64.75	29.21	5669.14
	Max	38.55	52.27	64.30	68.42	74.74	63.58	6622.87
	Min	22.31	20.91	33.30	34.95	43.21	18.96	4594.24
	Std-dev	10.74	10.83	5.55	6.53	6.02	10.28	594.95

Desciptive statistics show that the standard deviation of the Covid-19 and the lockdown stimuli in Germany and France are high compared to the other stimuli, which potentially indicates that these two events are very dynamic and have a stronger effect in stimulating investor emotion caompared to the other stimuli.

In addition, we notice that during this period, the investors emotion index shows very high values which reached the value of 74.29 for the VDAX index and 63.58 for the VCAC40 index. These values are considered high, however, they remain lower than the value reached during the subprime crisis.

Focsing on market indexes, we notice that they present a large difference between the highest and the lowest value. For CAC 40 index, the highest value is 6622.87 and the lowest value is 4594.24. For DAX index, the highest value is 15693.27 and the lowest value is 8928.95.

4.1.1. The dynamics of stimuli, investor emotion indexes and market indexes during the Covid-19 period

Before analyzing the relation between stimulus, emotion and investor behavior, it seems important to study the dynamic of these variables during the Covid-19 period of pandemic propagation (Figure 2 and 3). The Covid-19 pandemic in Germany has been spreading since January 27, 2020. On 19 March 2020 Germany report more than 15000 Caovid-19 cases (worldometer). The analysis of Figure 2 shows that the Covid-19 stimuli has two peaks in the first period of the emergence of Covid-19. The first peak happened in mid-March and the second had on 01/05/2021. These two peaks are triggered simultaneously with the increase in the number of new cases and the number of deaths. Moreover, we notice an increase of this index during the first six month of 2021. We also notice that the government support, market and banks stimuli follow the same trends as Covid-19 stimulus which indicates that the information concerning banks, financial

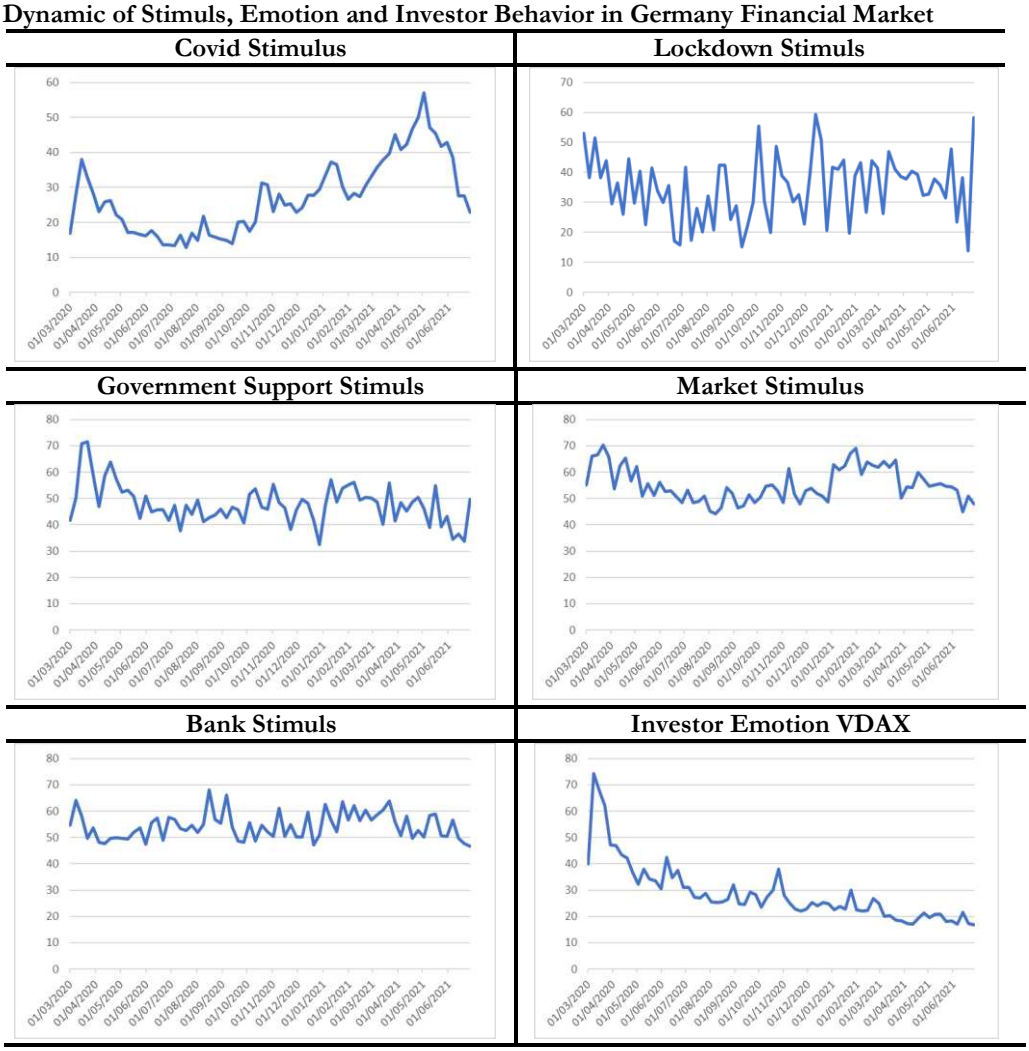
market, and the government support attract the attention of the investor during the same period.

Analysing the investor emotion dynamic, we notice the existence of a peak at March 2020 associated with the emergence of Covid-19. Indeed, the first developement of Covid has mainly distrub emotion compared with other periods. Similarly, the price dynamic of the DAX index shows a dramatic falls during the first studied period (March, April and May 2020). Then, it follows an upward trend over the time period.

Regarding France, we note a peak in Covid stimulus index from the beginning of March 2020. Morover, we notice the presence of two peaks in parallel in lockdown stimulus during the same period. At the beginning of March 2020, the market stimulus index shows an upward trend and peaks, this means that the investor attention is focused on financial market which can be explained by the very serious and disturbed situation of Paris stock exchange during this period. Indeed, during this period the Paris stock exchange collapses and experiences its worst sessions, surpassing the subprime crisis of 2008. During the months of February, March and April 2020 the CAC40 market index index has made a high decrease which can be considered as a stock market crash.

Figure 2

Dynamic of Stimuls, Emotion and Investor Behavior in Germany Financial Market



To be continued from Figure 2.

Investor Behavior DAX

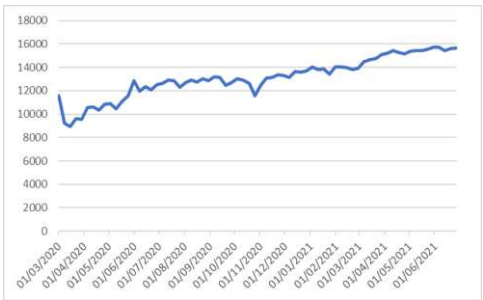
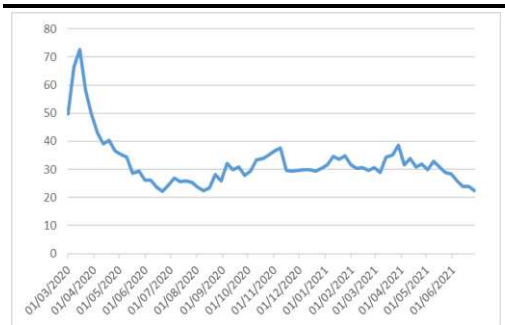
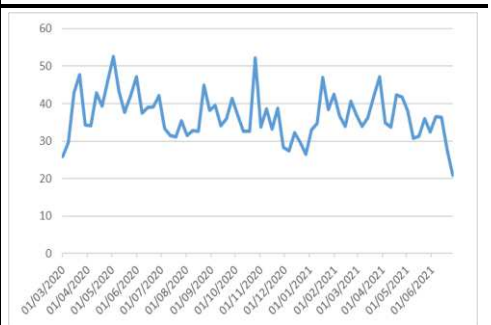


Figure 3
Dynamic of Stimuls, Emotion and Investor Behavior in France Financial Market

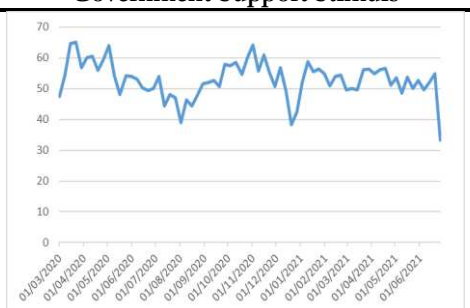
Covid Stimulus



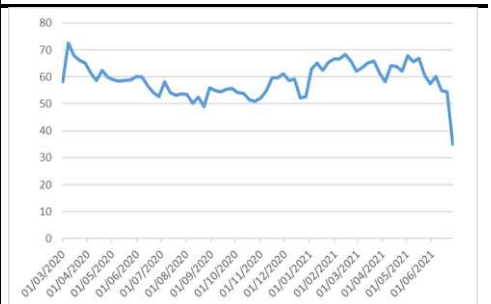
Lockdown Stimuls



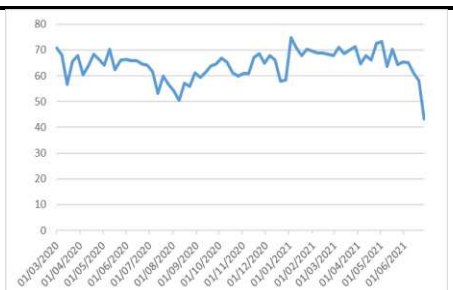
Government Support Stimuls



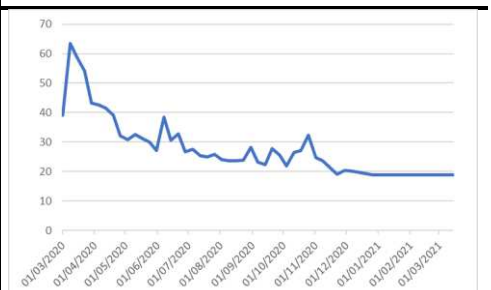
Market Stimulus



Bank Stimuls



Investor Emotion VDAX



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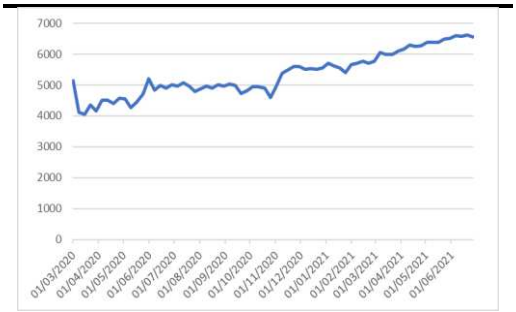
Investor Behavior DAX



4.1.2. Volatility jump of emotion and investor behavior

The detection of volatility Jump in investor emotion and investor behavior may indicate a significant change in these indexes, which can be due to the stimulus effect. Figure 4 presents volatility jumps in emotion and investor behavior indexes for Germany and France. The realized variance (RV) is decomposed into a continuous variation (CV) component and a jump component (JV). Volatility jumps are presented in the form of bars; the realized variance (RV) is schematized by a solid line, and the continuous variation is schematized by a broken line (CV).

According to Figure 4, it can be seen that (RV) and (CV) components for the studied indexes are superposed. However, they present an extreme peak in mid-March 2020 corresponding with the peak of Covid-19 crisis. This result proves the disruption of investor emotion by fear during this crisis.

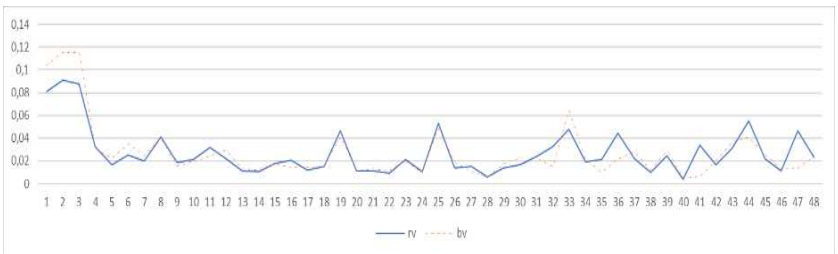
For the component of volatility jumps (VJ) presented in bars, there are positive and negative bars for all indexes. Analyzing the volatility Jump component of investor behavior in the German financial market, we notice that the first bar is negative with a large magnitude. We can explain the first negative jump by a succession of lockdowns during this period. However, at the end of May, we notice the existence of a positive peak which can be explained by the deconfinement. In November 2020, we noticed a negative peak, which is associated with an increase in Covid-19 cases. In fact, on November 8, 2020, Germany had 672507 cases and 11536 deaths (Worldometer), with the contagion rate starting to rise again. Then, we notice the presence of two positive peaks in the mid-studied period. These two positive peaks are associated with the period of vaccination. The volatility jump of German investor emotion presents two large negative bars in November 2020 and in May 2021. These jumps may indicate the presence of disturbance in investor emotion associated with an increase in Covid cases and the number of deaths. Li et al. (2021) find that investor sentiment aware significantly affect variances indicating a bounded rationality of investors. Gao et al. (2022) report a significant impact of investor sentiment on jump volatilities in chinese financial market.

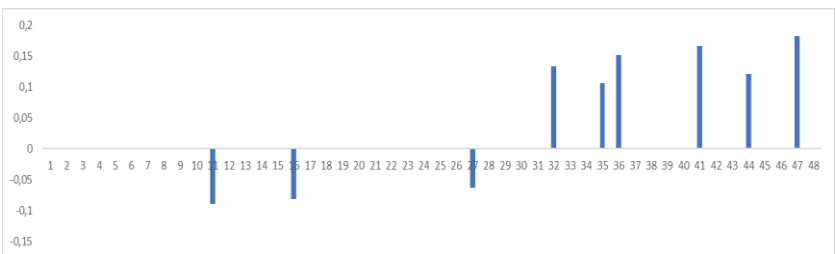
Focusing on volatility jump of investor emotion in France financial market, we find that it presents three negative peaks with high magnitude. The first peak is associated with the first Covid-19 wave. This proves that the market is hyper stressed during this period.

Figure 4
Volatility Jump

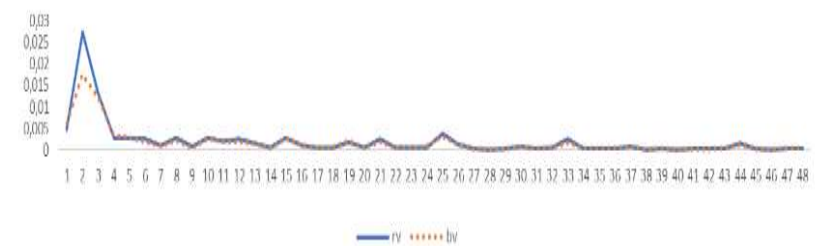
Germany

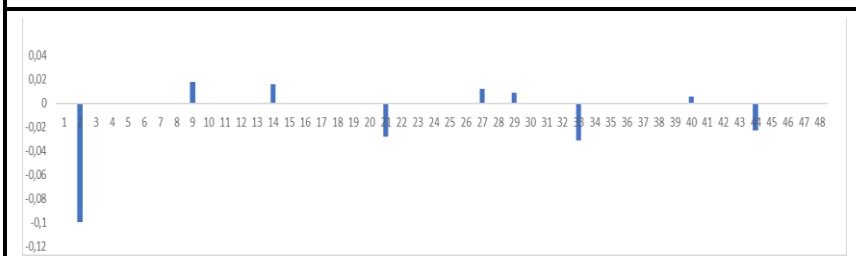
Investor Emotion





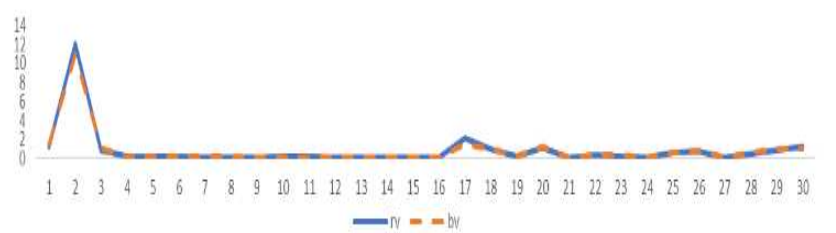
Investor Behavior





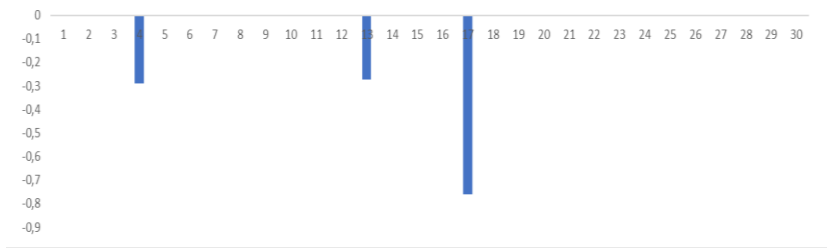
France

Investor Emotion

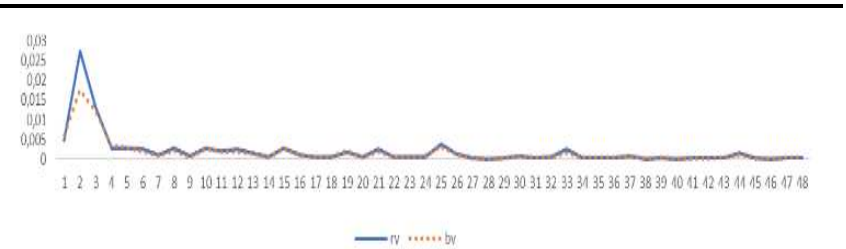


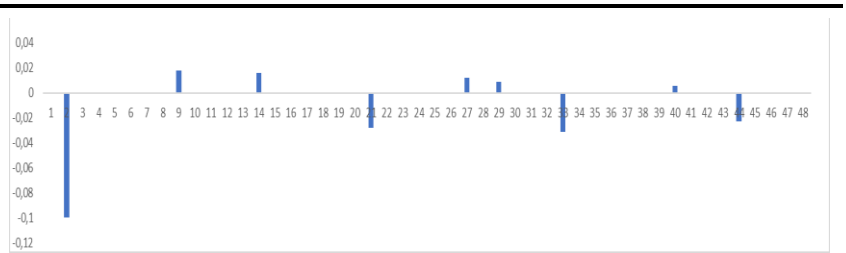
To be continued Figure 4 (France)

Investor Emotion



Investor Behavior





4.1.3. The study of SOR theory during the Covid-19

In order to detect which are the more significant stimuli in disturbing investor's emotion and which in turn affect the investor's behavior during the Covid-19 period, we tested the causal effect between the three variables of interest by VAR autoregressive models. The estimations results are reported in Table 2. Panel A reports the effect of stimuli on investor emotion and Panel B represents the effect of investor emotion on investor behavior.

Analysis of Table 2 shows that in Germany and France financial markets Covid-19 stimuls positively affects the investor emotion. Thus, the increase in the level of Covid cases or any information or events related to this pandemic significantly stimulated investor fear, whether in Germany and France. The government support stimulus presents negatively significant effect on investor emotion only on France financial market. Thus, the increase of government support reduces the fear during this crisis. Indeed, government actions have reassured investors by showing that the state is able to overcome this crisis, giving hope and minimizing fear. Focusing on market and bank stimuli, we found that the market stimlus is also significant only on France financial market. However, the bank variable does not have a significant effect. These results indicate that during the Covid-19 crisis period, terms that are directly related to the pandemic, goverment suppport and lockdown significantly affect and stimulate investor emotion.

Additionally, we found that the investor emotion that was stimulated by the Covid-19 related term triggers significantly investor behavior in both countries. Indeed, the increase in the level of fear forces the investor to sell their shares which generated a decline in market index and therefore the generation of negative returns. This result

confirms those found by Smales (2021) that investor attention towards Covid-19 significantly affects US stock retruns.

These results found confirm the SOR theory and show that during the crisis period the stimuli in direct relation to the Covid-19 significantly disturbs the emotion which in turn significantly affects the behavior. This, relation explain the dramatic decline observed during this period.

Table 2
VAR Test of SOR Theory

Panel A			Panel B		
	Germany	**France**		**Germany**	**France**
	Emotion (VDAX)	**Emotion (VCAC40)**		**Behavior (DAX)**	**Behavior (CAC40)**
Emotion (VDAX) (-1)	0.659***	0,576***	**Behavior (-1)**	0,571***	0,055
	(4,123)	(2,77)		(3,91)	(1,08)
Emotion (VDAX) (-2)	0,131	0,246	**Behavior (-1)**	0,158	-0,022
	(0,704)	(1,028)		(1,16)	(-0,59)
C	8,327	25,828	**C**	4612,472**	-2982**
	(0,82)	(2,087)		(4,42)	(-1,98)
Stimulus Covid	0,178**	0,257**	**Emotion**	-39,556***	-0,11***
	(2,051)	(1,67)		(-4,280)	(-24,78)
Stimulus GOV	-0,186	-0,439**			
	(-1,337)	(-2,16)			
Stimulus LOCK	-0,149**	-0,078			
	(-2,10)	(-0,472)			
Stimulus MAR	0,083	-0,493**			
	(0,491)	(-1,65)			
Stimulus BANK	0,051	0,419			
	(0,360)	(1,51)			
R^2	**0,790**	**0,79**		**0,921**	**0,99**

Notes: *, **, and *** indicate signifcance at the 10%, 5%, and 1% levels, respectively.

4.1.4. The prediction of investor emotion and investor behavioral response: The artificial neural network (ANN)

The SOR theory provides a comprehensive view of the relation between environmental stimuli and investor emotion. Moreover, it explains the relation between investor emotion and investor behavioral response. To investigate the ability of stimuli to predict investor emotion and the ability of investor emotion to predict investor behavior, we estimate the artificial neural network (ANN) model based on the nonlinear autoregressive exogenous (NARX) model.

Figures 5 presents the response curves of the predicted series by the ANN model (output) and the performance of the artificial neural network model.

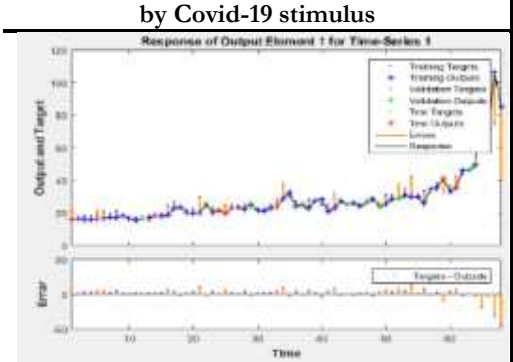
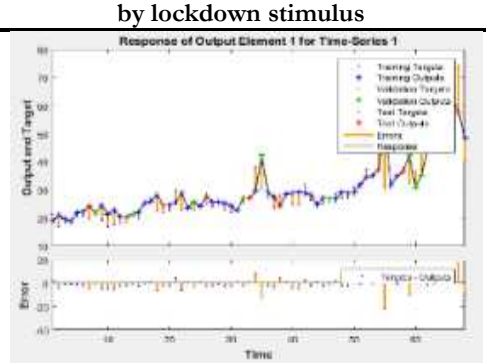
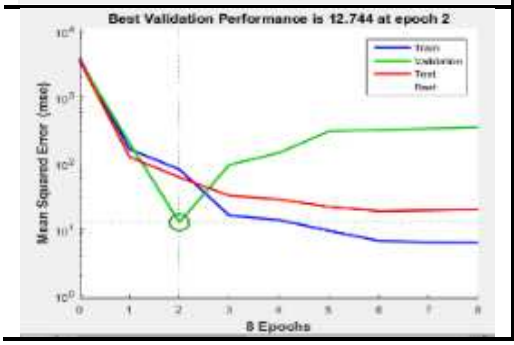
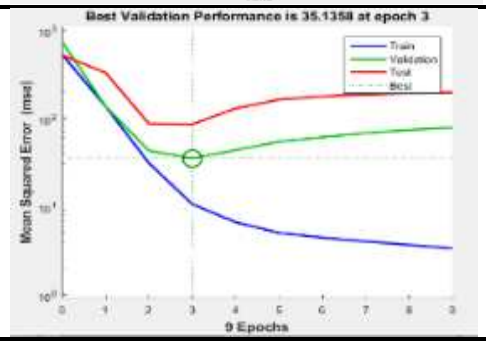
Focusing on Germany financial market, we find that MSE decreases quickly and take low values. This indicates that the model of ANN predicts in an efficient way the series to be predicted. Moreover, this result indicates the ability of stimulus indexes to predict emotion. This result confirms that after the exposure to stimuli related to Covid-19, lockdown, government support investor develops inner organism. Thus, events related to Covid-19 such as the number of cases, vaccine, death etc., government support and lockdown are very useful and very important tool in the prediction of emotion detection. Furthermore, these results show the importance of event detection in predicting investor emotion. After emotion response, investor develops a behavioral

response which generate positive or negative returns in financial markets. In fact, the bavioural response can be predicted by investor emotion as a response to exposure to environmental stimuli. This result corroborates results found by De Long et al. (1990) who demonstrated the existence of a correlation between market sentiment and equity market returns. John and Li (2021) studied the effect of sentiment indices (Google trend sentiment indices) on the implied volatility of S&P 500 and FTSE. They find that Covid index and Market index increase the volatility jump component of S&P 500 index. Jabeen et al. (2021) explored the positive and negative effects of coronavirus-related events on major financial market sectors like airline, pharmaceuticals, e-commerce, technology, and hospitality. They found that these events have a significant effect on major stock market sectors and improve prediction.

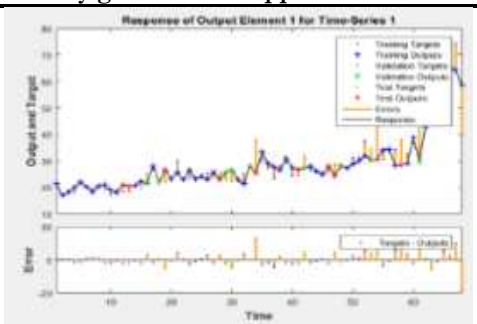
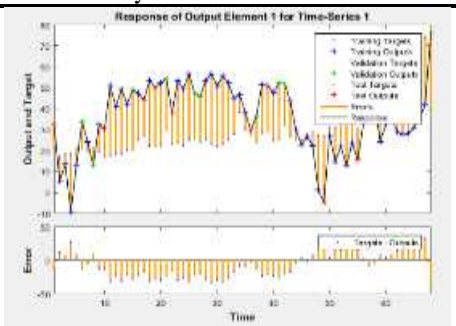
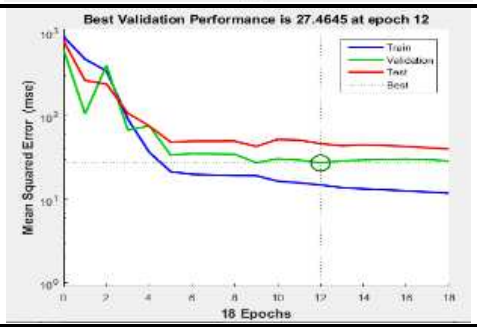
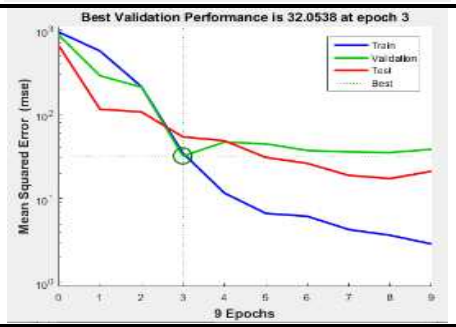
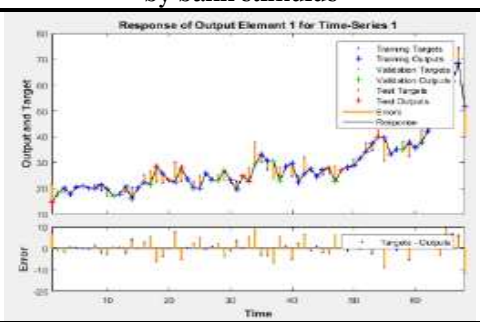
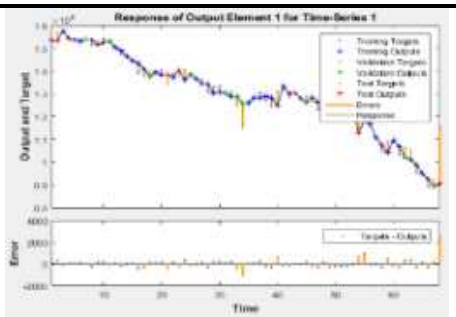
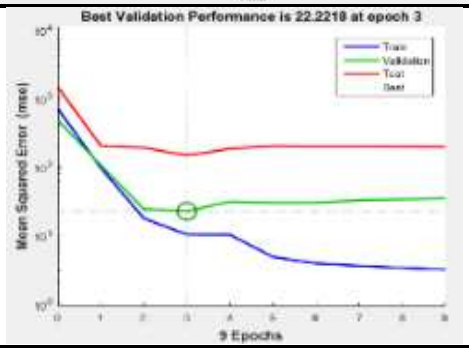
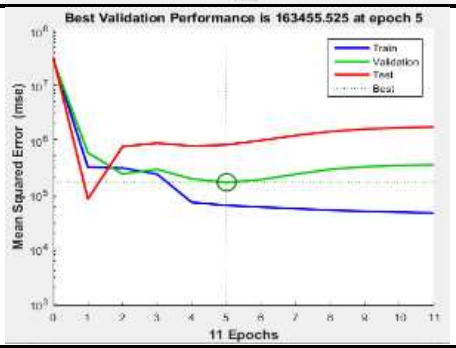
Analysing the prediction results in France financial market, we find that the stimulus indices predict investor emotion since the errors are small between the tested series and the predicted series. This result is confirmed for the five stimulus indices (Covid, lockdown, government support, market and bank stimulus). Morover, we find that the investor emotion predict the investor behavior. As a conclusion, the stimulus indices detect the presence of an emotional reaction which is the origin of investor behavior during crisis period.

Figure 5

The Prediction of Investor Emotion and Investor Behavior

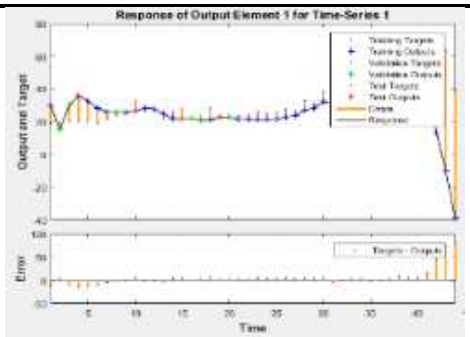
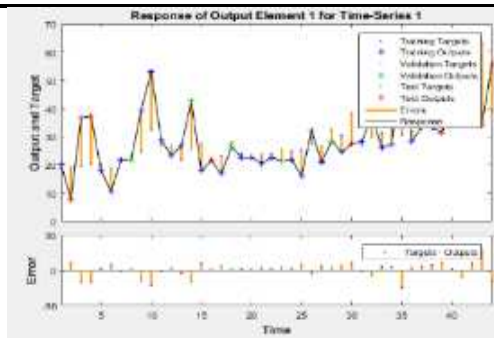
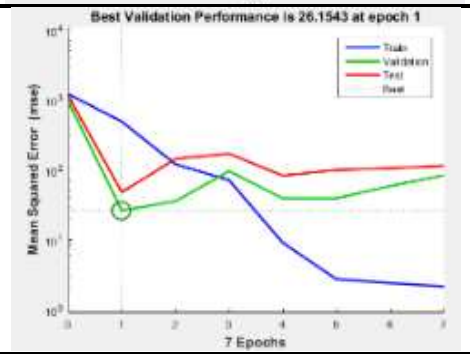
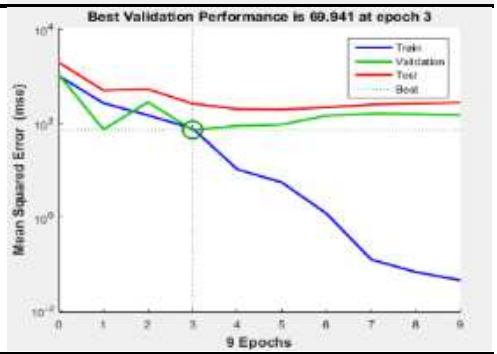
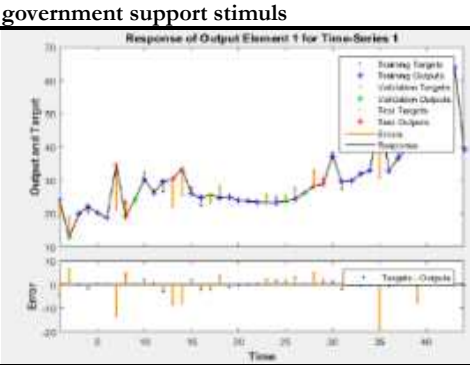
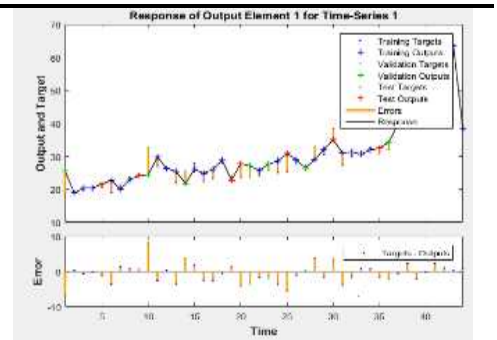
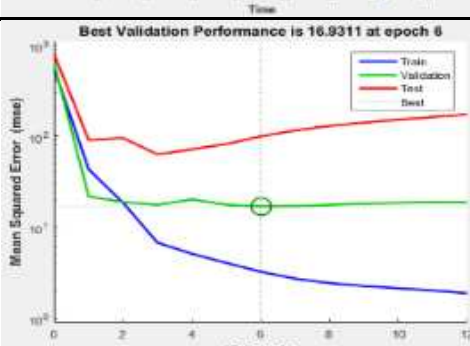
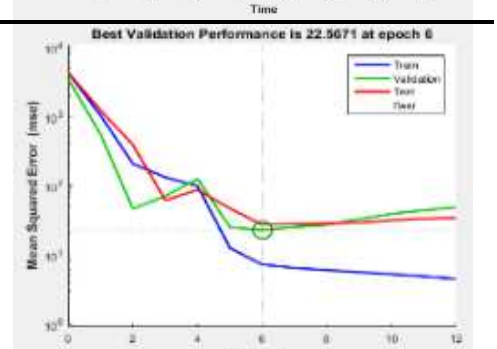
Germany	
The prediction of investor emotion by Covid-19 stimulus	**The prediction of investor emotion by lockdown stimulus**
	
	

To be continued Figure 5 (Germany)

Germany	
The prediction of investor emotion by government support stimuls	**The prediction of investor emotion by market stimulus**
	
	
The prediction of investor emotion by bank stimulus	**The prediction of investor behavior by investor emotion**
	
	

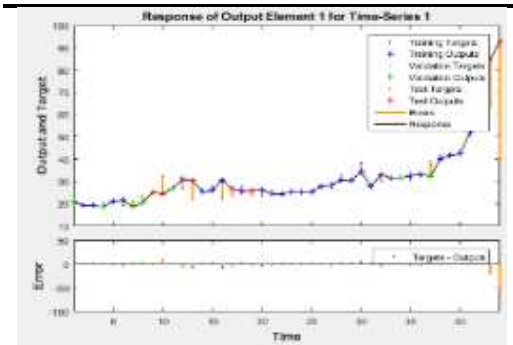
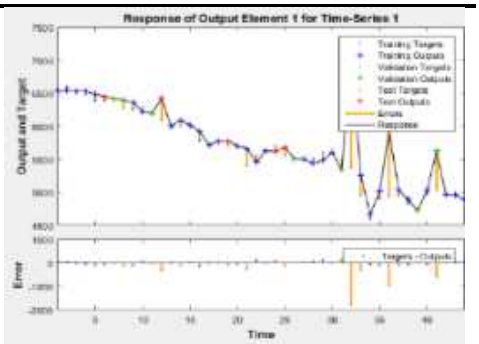
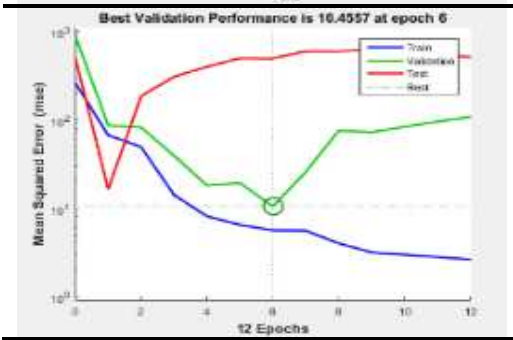
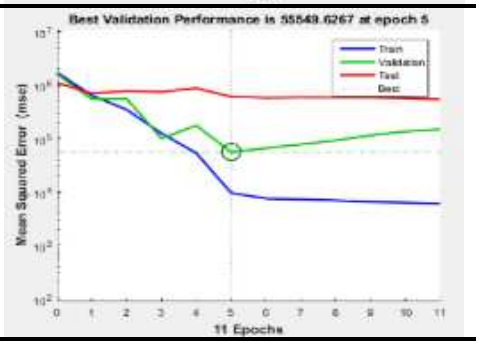
To be continued Figure 5 (France)

France

The prediction of investor emotion by Covid-19 stimulus	**The prediction of investor emotion by lockdown stimulus**
	
	
The prediction of investor emotion by government support stimuls	**The prediction of investor emotion by market stimulus**
	
	

To be continued Figure 5 (France)

France

The prediction of investor emotion by bank stimulus	**The prediction of investor behavior by investor emotion**
	
	

V. CONCLUSION

The majority of financial markets has been disturbed during the Covid-19 pandemic period. This study focuses on the SOR theory to explain the relation between stimuli, investor emotion and investor behavior in Germany and France financial markets during this pandemic.

Studing the Jump component of Germany and France investor behavior during the Covid-19 pandemic reports the existence of negative jump during the succession of lockdown. However, during period of deconfinement there exist a positive peak.

Investigating the ability of SOR theory to explain price dynamic in stock markets during Covid-19 pandemic, we find that investor emotion is significantly stimulated by the confinement, the increase of the number of covid cases, the vaccination and the government relief which in turn affect investor behavior.

Based on artificial neural network (ANN) we find that that bavioural response can be predicted by investor emotion which in turn can be predicted by environmental stimuli during pandemic period as covid, vaccination, confinement and financial market information.

Our findings have several important implications for academics, investors and policy makers. Indeed, academics can use the SOR theory to explain stock price dynamics in financial markets especially during crises period which are carecterized by the development of new environmental stimuli that trigger emotion. Policy makers should supervise financial markets in order to identify environmental stimuli and take decision that help to stabilize emotion to evoid financial crises. Moreover, investor can use stimuli to predict investor behavior and stock price dynamic.

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