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Digitalization and predictability in the BRICS countries: what can be learned from information about the dynamics of stock prices

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Abstract

The study aims to identify the impact of digitalization on predictability in the BRICS countries' stock markets. It is based on an analysis of the dynamics of stock markets volatility during the 1990-2023 period. The paper seeks to prove that the standard deviation of stock returns is determined by the volume of incoming new information, and higher volatility of returns indicates lower predictability. Digitalization may cause a reduction in uncertainty as it uses more data, improves their quality and develops data analysis methods. On the other hand, digitalization may lead to increased uncertainty due to the emergence and development of new industries, in which it is more difficult to predict cash flows in comparison with traditional industries because of increased complexity of supply chains and technologies. Based on quantitative analysis, it has been revealed that digitalization has led to a statistically significant decrease in the volatility of stock markets in the BRICS countries. In 2015-2023, relative to the period of the 1990s-2006, volatility in Russia decreased by 1 percentage point, in India by 0.4–0.5 percentage points, in China by 0.8 percentage points, in the UAE (Dubai) by 0.5-0.7 percentage points. Statistically insignificant decreases in volatility were observed in Brazil and South Africa. In the developed capital markets, the decrease in volatility between these two periods was also statistically insignificant, amounting to less than 0.1 percentage points. These findings may indicate that the processes of digitalization in the BRICS countries contributed to an accelerated increase in predictability thanks to an increase in the volume and quality of information and the

emergence of new methods of analysis. At the same time, part of the decrease in volatility may be explained by further development and improved efficiency of capital markets. The joint influence of these effects on the complexity of forecasting turned out to be more significant than the impact of innovative technologies and new industries.

Keywords
digitalization, forecasting, predictability, stock market, uncertainty, volatility, yield

Аннотация
Цель исследования заключается в выявлении влияния цифровизации на предсказуемость на рынках акций публичных компаний в странах БРИКС. Исследование основано на анализе динамики волатильности рынков акций на протяжении 1990-2023 гг. В статье обосновывается, что стандартное отклонение доходности акций определяется объемом поступающей новой информации, и более высокая волатильность доходности соответствует меньшей предсказуемости. При этом цифровизация может, с одной стороны, приводить к снижению неопределенности посредством большего количества данных, улучшения их качества и развития методов анализа данных. С другой стороны, цифровизация может приводить к росту неопределенности за счет появления и развития новых отраслей, в которых сложнее прогнозировать денежные потоки относительно традиционных отраслей, а также за счет усложнения цепочек поставок и технологий. На основе количественного анализа выявлено, что процессы цифровизации привели к статистически значимому снижению волатильности рынков акций в странах БРИКС. В 2015-2023 годах относительно периода 1990-х – 2006 годов волатильность снизилась в России на 1 процентный пункт (п.п.), в Индии на 0,4-0,5 п.п., в Китае на 0,8 п.п., в ОАЭ (Дубай) на 0,5-0,7 п.п. Снижение волатильности (статистически незначимое) также наблюдалось в Бразилии и ЮАР. В то же время на развитых рынках капитала снижение волатильности между двумя этими периодами не было статистически значимым и составило менее 0,1 п.п. Полученные результаты могут свидетельствовать о том, что процессы цифровизации в странах БРИКС способствовали ускоренному повышению предсказуемости вследствие роста объема и качества информации, появлению новых методов ее анализа. Вместе с тем, частично снижение волатильности может объясняться и повышением уровня развития и эффективности рынков капитала. В совокупности эти эффекты оказались более значимыми, чем влияние инновационных технологий и новых отраслей на усложнение прогнозирования.

Ключевые слова
волатильность, доходность, неопределенность, предсказуемость, прогнозирование, рынок акций, цифровизация

JEL: G12, G17.

Introduction

Digitalization affects all aspects of life in modern society; its impact on the financial sector is especially evident. New financial technologies have led to fundamental changes in the models of interaction between commercial banks and their clients.

Investing in a wide range of financial assets has become possible for large numbers of organisations and individuals. Moreover, the development of new technologies, digitalisation included, has brought about changes in the whole structure of the economy, which is reflected in the composition of stock indices: in many countries the capitalization of IT corporations exceeds the capitalization of companies from traditional industries, such as mining, transport, and manufacturing. Digitalization also contributes to an exponential increase in the amounts of data, improvement of its quality, and development of data processing and analysis methods, which should lead to increased forecasting capabilities. At the same time, the digitalization processes are making the economy more complex, and, as a result, forecasting becomes more difficult and uncertainty increases. In the BRICS countries, including the new members of the association, these processes are going at an accelerated pace, owing, in some cases, to a "low base" effect.

Predictability-related problems in the context of digitalization have received much attention in the theorectical and practical literature (Fondeur & Karamé, 2015; D'Amuri & Marcucci, 2017; Lazaryan & German, 2018; Kurovskij, 2019; Vinogradova, 2021; Gurov et al., 2022; Kartaev & Besedovskaya, 2023). The issues of uncertainty and risk are now well explored (Sharpe et al., 1999; Bulinsky & Shiryaev, 2005; Tambovtsev, 2023; Trachenko et al., 2023) since financial instruments are sets of monetary flows, and future cash flows and their purchasing power are generally random variables. However, in academic literature there are few studies aimed at assessing the impact of digitalization on predictability and uncertainty in the economy. This paper attempts to identify the impact of digitalization on predictability in the stock markets in the BRICS countries with regard to public companies. It also describes the channels of influence of digitalization on predictability, formalizes a model for assessing changes in predictability based on an analysis of the dynamics of stock index returns, and obtains generalized conclusions for several countries of the BRICS association.

The impact of digitalization on predictability

Issues of growing complexity of economic relationships in contemporary economic systems have been raised in many studies (Galbraith, 1967; Apokin et al., 2015; Kutsenko, 2015; Chepurenko, 2015; Hesin, 2017). The increased complexity of the structure of the economy, technology and supply chains that results from digitalization may reduce the forecasting possibilities; at the same time, digitalization may have the opposite effect, increasing forecasting abilities and reducing uncertainty as it will raise the quality and volumes of statistical data, develop methods for their processing and analysis, and thus improve forecasting techniques.

In the literature on the relationship between finance and economic growth, the "too much finance" hypothesis is often explored; it suggests that there is a limiting level of development of the financial system, or part of it, for example, the consumer lending market, above which the development has a negative impact on the growth

rate. (Apergis et al., 2007; Law & Singh, 2014; Bangake & Eggoh, 2011; Arcand et al., 2015). A similar question about the maximum level of digitalization may be premature, but one should remember that digitalization processes have not only great benefits, but also high costs. The Solow Paradox that points to inability of researchers to establish a statistical relationship between the amount of investment in information technology and macroeconomic data on labor productivity (Platonov, 2007), may be explained, among other things, by the increase in costs of digital solutions that include the salaries of developers, investments into IT infrastructure, organizational costs associated with the implementation and operation of information systems, and forced reengineering of business processes as a result of the implementation of digital solutions. The rapid development of mobile banking in many countries was made possible by reducing the time for designing and implementing software products from several months to 2-3 weeks, but this also required a proportionately higher number of highly paid IT specialists. It thus becomes clear that a manifold reduction in the time necessary to develop and bring software solutions to market is a factor that promotes digitalization, but comes at a high price.

Regarding the processes of digitalization and predictability improvement, the experience of the Russian railway industry gives a telling example. About 10 years ago, many railcar companies and most railcar repair enterprises were at a low level of digitalization. Accounting for spare parts, including those with safekeeping legal status, was carried out either on electronic devices in an unsystematized format, or, in some cases, on paper only. Given the size of document flow and regular operations for receiving and returning spare parts, this approach to accounting led to constant errors. Today, most railcar companies and most railcar repair enterprises have switched to electronic document management with business transactions reflected in the ACS VRK program (automated control system for railcar repair complex). This transition made it possible not only to conduct electronic document management, but also to fundamentally improve the quality of accounting. Now, the data are actually verified by two independent parties; records are kept in a structured form, and all results are stored on remotely located servers; there is a gradual accumulation of large amounts of statistical data. Yet, as noted earlier, even the positive changes resulting from digitalization come at a cost. Apart from using the program itself, there is a need to maintain records in the automated process control system. As a rule, this requires additional workers, an so labor costs for accounting and maintaining regulated production logs are not reduced.

Still, however high or low might be costs and benefits for each individual company, the accumulation of large volumes of reliable information at the level of both individual company and the entire industry is important as it can increase predictability. In 2018, a sudden and severe demand shock occurred in the adjacent market of solid-rolled wheels that are used in both carriage building and the repair of railway cars. As a result, due to the existing shortage, the market price of solid-rolled wheels increased threefold in three months. Even the large market participants had not foreseen such a shortage in the market resulting in the increased risk of wagons being downtime for repairs,

a significant and unforeseen surge in the cost of repairing wheel sets, and, ultimately, in the higher cost of renting freight cars, which made logistics more expensive. If railway companies had access to a larger volume of statistical data about the condition of their rolling stock, then market participants could anticipate a demand shock in advance and stock up on solid-rolled wheels in time. It is thus obvious, that digitalization can indeed contribute to increased predictability and reduced uncertainty in individual markets.

If this industry example is extrapolated to the entire economy, then it can be assumed that the digitalization processes occurring in both developed and developing countries should help reduce uncertainty and increase predictability. However, digitalization also has reverse effects, including, in particular, an increase in exposure to cyber risks, a general complication of economic relationships, the development and introduction of innovative technologies to the market, and the formation of complex supply chains and value chains. Moreover, the very increase in the amount of various statistical data can lead to complications in the process of their analysis and to increases in the dispersion of forecasts obtained by different analysts. The emergence of new technologies in areas such as microbiology, medicine, and robotics complicates forecasting. The rise of digital technologies has brought benefits to consumers in many industries, notably retail, food delivery, kick-sharing and micromobility, but forecasting future developments in these industries and forecasting cash flows for companies doing business in their markets is extremely challenging.

Moreover, predictability becomes more complicated because, although contemporary society better and better mitigates exogenous risks and reduces uncertainty associated with them, the endogenous risks are now beginning to pose an increasing danger, the consequences of which are difficult to predict (Bernstein, 1998). Digitalization processes may lead to such endogenous risks becoming more frequent; if this happens the potential damage will be difficult to predict.

Clearly, the digital trends in today's world lead to more data and more opportunities to forecast and reduce uncertainty. On the other hand, the economy is becoming significantly more complex, making forecasting more difficult. In this regard, the main hypothesis tested in the study is that the positive impact of digitalization on predictability improvement through increasing the quality and volumes of data in the BRICS countries during the periods under consideration was stronger than the role of digitalization in reducing predictability owing to the emergence of new technologies and markets and the general complication of the economy. The research methods used in the study aim to determine which of these effects is prevalent in the BRICS countries at the present stage of development of the capital market.

Methods and data

This study attempts to answer the question of whether the future is becoming more predictable or less predictable for the BRICS countries. The study is carried out using

the daily data on the dynamics of stock indices that reflect the arrival of new information. The theoretical basis of the study is a set of provisions related to the market efficiency hypothesis, asset pricing models and the theory of random processes.

The analysis of stock price dynamics from the perspective of the efficient markets hypothesis allows us to find out the effects of the arrival of new publicly available significant information. When studying financial markets, three forms of market efficiency are distinguished: weak, semi-strong (medium) and strong (Sharpe et al., 1999; Bulinsky & Shiryaev, 2005). Each subsequent form of efficiency contains more stringent requirements for the amount of information that is taken into account in current market

Table 1. Forms of market efficiency

Market Efficiency Form	Absent	Weak	Semistrong	Strong
Basic provisions	Asset prices do not take into account available information about those assets	All past price information is factored into the current price of the asset.	All past and current public information is taken into account in the current price of the asset	All past and current public and non-public information is taken into account in the current price of the asset
	Smaller markets may be inefficient	Confirmed in most studies	Confirmed in many studies. Not confirmed for small companies	Confirmed in some studies
			The work of investment analysts leads to the formation of market efficiency in a semi-strong formulation	Legislation and ethical principles: 1. prohibit the use of non-public information, 2. call for the protection of non-public information 3. regulate the processes of disclosure of non-public information

Source: compiled by the author

prices. Therefore, from the standpoint of the market efficiency hypothesis, the market can be in one of 4 states (Table 1).

The assumption is that, over the period under review, equity markets in the countries under study were semi-strong efficient. This assumption is justified by the fact that market efficiency in a semi-strong formulation is a consequence of the activities of analysts and auditors, and the presence of foreign investors has a positive impact on market efficiency. In conditions of semi-strong efficient markets, the price of an asset at time t-1 reflects all available information as of t-1. The price of an asset between time t-1 and time t changes based on both a predictable component and some random variable. For equity prices, the predictable component may be determined by expected changes in the discounted amount of the asset's cash flows.

Using the discounted dividend model, one can determine the intrinsic value of a share as:

$$P_t = \frac{D_{t+\alpha}}{(1+r)^{\alpha}} + \frac{D_{t+2\alpha}}{(1+r)^{2\alpha}} + \ldots + \frac{D_{t+n\alpha}}{(1+r)^{n\alpha}} + \ldots,$$

where P_t — stock price at time t, $D_{t+\alpha}$ — expected dividend at time $t+\alpha$, r — adequate discount rate (required return on the company's equity).

For a short period of time $\tau < \alpha$, the increase in the value of the asset is due to the fact that:

$$P_{t+\tau} = \frac{D_{t+\alpha}}{(1+r)^{\alpha-\tau}} + \frac{D_{t+2\alpha}}{(1+r)^{2\alpha-\tau}} + \ldots + \frac{D_{t+n\alpha}}{(1+r)^{n\alpha-\tau}} + \ldots > P_t,$$

since in the formula for the amount of discounted dividends the denominators are reduced.

Directly at the time of closing the register, taking into account the trading mode, a drop in the share price equal to the dividend value may be observed; however, if new information does not enter the market, then the total return (taking into account the dividend) for the investor will remain positive.

For long periods of time $T > \alpha$ c over time, an increase in the value of the asset will be observed if, for any $m > n$ is true that $CF_{t+m\alpha} > CF_{t+n\alpha}$, which, in general, is true due to the fact that cash flows increase in proportion to inflation, and provided that firms reinvest part of their profits, then cash flows grow due to an increase in business turnover.

It follows that, in the absence of new information, investments in shares (as well as in other financial assets) will provide the investor with the required return. For example, according to the CAPM model (Sharpe, 1964), the required return on stock A ($r_{A,t}$) is determined by the risk-free return ($r_{f,t}$), the market risk premium (ERP_t) and beta (β_A), which is a measure of the systematic risk of an asset:

$$r_{A,t} = r_{f,t} + \beta_A * ERP_t$$

Multifactor models (Fama & French, 2015; Chou & Chou, 2004) can more accurately describe the dynamics of stock returns, but over short periods of time, on daily data in particular, the required return values for any model are small. So, with 250 trading days and an expected return of 15%, the daily return in the absence of new information will, on average, equal 0.06%. This is approximately 20-30 times lower than the standard deviation of daily returns for the sample in question. In this regard, price dynamics are determined by information received for each trading day.

The main driver of price changes for daily data is, therefore, the arrival of new information. In an environment where the ability to predict future cash flows is high, there will be relatively less information available on any given trading day that will influence forecasts of future cash flows compared to a situation where the ability to predict future cash flows was initially limited. It should be expected that in such a situation, daily changes in stock prices will, on average, be lower than in conditions

where forecasting is difficult. That is why the study uses the standard deviation of stock market returns as a measure of predictability. The higher the predictability, the lower the standard deviation, and vice versa: with low predictability the standard deviation of stock returns is high.

These arguments can be formalized as follows. At time l, market participants make a forecast of some indicator X (for example, a macroeconomic indicator or a company's cash flow) for s periods ahead. In this case, the forecast is built taking into account all information I available at the time the forecast l is built, that is, $E(X_{l+s}) \mid I_l$. At the next moment of time $l + 1$, say, a day later ($l + 1 < l + s$), the forecast is updated $E(X_{l+s}) \mid I_{l+1}$. On average, the absolute value of the forecast change $E(X_{l+s}) \mid I_{l+1} - E(X_{l+s}) \mid I_l$, and in the future the absolute value of the realized deviation $E(X_{l+s}) - E(X_{l+s}) \mid I_l$ will be determined by how much new information was received during the time interval between l and $l + 1$ (or l and $l + s$ respectively). The volume of this information depends, among other things, on the quality and quantity of information I_l available at time l. Thus, the change in the forecast is a function of the ratio of I_l and the amount of information available in the future. The change in the forecast will be less than most of the resulting complete information I_{l+s} (which completely determines the value of X_{l+s}) is contained in I_l. Since the standard deviation of $E(X_{l+s})$ over time is a measure of the change in the forecast, then it can be argued that the standard deviation of changes in the forecast value is a function of the ratio of the amount of information at the initial moment of constructing the forecast and complete information I_{l+s}:

$$\sqrt{\frac{\sum_{t=o}^{s}\left(E(X_{l+t}) \mid I_{l+t} - \frac{\sum_{t=0}^{s} E(X_{l+t}) \mid I_{l+t}}{s+1}\right)^2}{s+1}} = f\left(\frac{I_l}{I_{l+s}}\right).$$

Based on the dynamics of the standard deviation of stock returns, we can conclude that there is a change in predictability in stock markets.

To estimate changes in volatility, we used the logarithmic returns of stock indices based on daily data:

$$return_t = \ln\left(\frac{P_t}{P_{t-1}}\right),$$

$return_t$ — logarithmic return of the index; P_t — closing price of the index on the trading day t.

The standard deviation of daily returns for the period from l to k was determined based on the formula:

$$\mathrm{SD}_{\mathrm{dayly}} = \sqrt{\frac{\sum_{t=l}^{k}\left(return_t - \frac{\sum_{t=l}^{k} return_t}{k-l}\right)^2}{k-l}}.$$

For purposes of comparability between individual years and between countries with different numbers of trading days per year, the standard deviation (SD) for each given full year was normalized based on the calculated standard deviation for each trading day (SD_{dayly}) and the number of trading days (d) per year in corresponding country:

$$SD = SD_{dayly} * \sqrt{\frac{250}{d}}.$$

The following data were collected in the study (Table 2).

Table 2. Descriptive statistics of research data

Index	Shanghai Composite	South Africa Top 40	NIFTY 50	BOVESPA	DFM General	IMOEX
Stock market	China	South Africa	India	Brazil	UAE (Dubai)	Russia
Observation period (full years)	1991-2023	1995-2023	1996-2023	2001-2023	2004-2023	1988-2023
Minimum daily standard deviation for the year	0.55%	0.65%	0.57%	1,08%	0.66%	0.70%
Average daily standard deviation	2.18%	1.39%	2.26%	2.58%	1.41%	3.43%
Maximum daily standard deviation for the year	6.03%	2.49%	2.80%	3.30%	2.65%	6.08%

Source: compiled by the author based on calculations using the data from the site investing.com (URL: < https://ru.investing.com/indices/bm-fbovespa-unsponsored-bdrx >), calculations were made in MS Excel, date of the application: 18.01.2024.

Table 3 presents the correlation matrix of standard deviations of profitability (values were calculated for the maximum available time periods):

Table 3. Correlation matrix of daily standard deviations of stock indices returns

	Shanghai Composite	South Africa Top 40	NIFTY 50	BOVESPA	DFM General	MOEX
Shanghai Composite	1	0.24	0.60	0.58	0.59	0.37
South Africa Top 40	0.24	1	0.80	0.86	0.59	0.72
NIFTY 50	0.60	0.80	1	0.85	0.66	0.71
BOVESPA	0.58	0.86	0.85	1	0.65	0.65
DFM General	0.59	0.59	0.66	0.65	1	0.59
MOEX	0.37	0.72	0.71	0.65	0.59	1

Source: authors' calculations made in MS Excel.

We also note that the most accurate estimates of the volatility of stock indices can be obtained based on the data on the dynamics of total return indices, which take into account not only the dynamics of stock prices, but also dividend payments. However, owing to the need to use data over a relatively long period and to the limited availability of data on the values of total stock return indices for a number of countries, this study used data on the volatility of stock indices excluding dividend payments. It should also be noted that in practice this does not lead to a decrease in the validity of the results, since, according to the author's estimates based on data for individual countries, the correlation of data series of standard deviations of total return indices and indices that do not take into account dividend payments is more than 0.99, and the module of the average deviations does not exceed 2%.

Since each of the indices under consideration summarizes information on the returns of at least 40 shares of various companies, such indices are well diversified, and therefore the dynamics of their returns reflect the general market risk and are not subject to the idiosyncratic risks of individual assets. However, the industry composition of the index can have an impact because, if the index is dominated by industries whose cash flows are more difficult to predict than traditional industries (for example, the cash flows of technology, media and telecommunications (TMT), companies depend on much more significant factors than the cash flows of companies in the metals and mining sector.

The volume of data in the economy has been growing particularly fast for over half a century, thanks to the emergence of computer technology and the development of means of storing and transmitting data. The task of choosing a date or period, after which the digitalization trend could have a special impact on predictability in the economy, is not a trivial one and it has multiple solutions. Within the framework of this study, the choice of the limited period, for which information on the dynamics of stock indices is available, is also significant (Table 2). Given that digitalization processes occur virtually continuously, it is reasonable to assume that in later years the impact of digitalization has a higher impact on predictability than in comparatively earlier years. Here, the late period is the period from 2015 to 2023 inclusive, and the early period from 1990 (or the earliest year for which information is available on the stock index of the country in question) to 2006 inclusive. Other time periods are also used to test the robustness of the research results.

The rest of the paper presents estimates of changes in predictability during the indicated periods for the chosen countries.

Results

The results obtained in this study, reveal that in 2015-2023, in the stock markets of the countries examined, the standard deviation of the returns of stock indices was, on average, lower than in earlier periods (Table 4). For the stock indices of China

(Shanghai Composite), India (NIFTY 50), UAE (Dubai, DFM General) and Russia (IMOEX), the results were generally significant. For the indices of South Africa (South Africa Top 40) and Brazil (BOVESPA), the pattern of dependence remained, but the estimates were statistically insignificant.

Table 4. Results of quantitative research

Index	Shanghai Composite	South Africa Top 40	NIFTY 50	BOVESPA	DFM General	IMOEX
for the period 2015-2023 relative to all available data	Lower by 0.8* p.p.	Lower by 0.1 p.p.	Lower by 0.6*** p.p.	Lower by 0.3 p.p.	Lower by 0.7** p.p.	Lower by 1** p.p.
for the period 2015-2023 relative to all available data without 2008-2009	Lower by 0.8* p.p.	invariably	Lower by 0.4*** p.p.	Lower by 0.1 p.p..	Lower by 0.5* p.p.	Lower by 0.9* p.p.
for the period up to 2006 inclusive relative to all available data	Higher by 0.8** p.p.	invariably	Higher by 0.4* p.p.	Higher by 0.2 p.p.	Higher by 0.4 p.p.	Higher by 1.1** p.p.
SD for the period up to and including 2006 relative to all available data without 2008-2009	Higher by 0.9** p.p.	Higher by 0.1 p.p.	Higher by 0.5* p.p.	Higher by 0.3 p.p.	Higher by 0.6* p.p.	Higher by 1.4*** p.p.

Designations:

p.p. means percentage points

SD means the average daily standard deviation of the returns of stock indices,

**** means statistical significance at the 1% level,*

*** means statistical significance at the 5% level,*

** means statistical significance at the 10% level,*

- means no statistical significance (p-value>10%).

Source: calculated by the author in Gretl.

The exclusion of data for the period of 2008-2009, when the stock market volatility increased in all countries in the sample because of the global financial crisis, does not lead to significant changes in the results. The robustness of the results obtained was additionally checked by excluding other periods, in particular, 2020, in which there was high uncertainty caused by the COVID-19 pandemic. Such exclusions from the sample also did not have a significant impact on the results obtained. When changing the boundaries of time intervals, the main results also remained unchanged.

Discussion

This study shows that in recent years the volatility of stock indices in the BRICS countries under consideration has decreased. This may mean that predictability has increased in these countries thanks to accelerated digitalization. The standard deviation of an index can be influenced by its structure, investor sentiment, and their sensitivity to various risks. However, the results show that in the BRICS countries there is no pronounced trend towards a decrease in volatility and an increase in predictability, which suggests that the effect of an increase in the quantity and quality of information due to digitalization is more significant than the complication of the economic structure (which also occurs due to the emergence of innovative technologies, the development of new markets, and the complexity of supply chains).

Note that measures aimed at reducing volatility do not guarantee high returns. Moreover, investors prefer the stock market to be highly volatile and rising rather than low volatile and falling. However, a decrease in stock volatility, other things being equal, is positive for owners of such financial assets because investors are risk averse.

This study has also calculated the dynamics of the standard deviation of the S&P 500 index. The results obtained are useful for the comparison with the dynamics of the volatility of the BRICS countries' stock indices. The standard deviation of the S&P 500 index also decreased in 2015-2023 relative to the period 1990-2006, but this decrease was less than 0.1 percentage points and not statistically significant. It is possible that such result was obtained because in the BRICS countries during the periods under review, digitalization proceeded at an accelerated pace. A more general reason for both periods is that it was time when the countries built their capital markets, worked at improving their auditing practices, formed the practices of assessing the value of business and quality and volumes of statistical data. All these certainly contributed to increased predictability.

At the same time, we note that the volatility of stock index returns may be influenced by the average level of debt burden of companies included in the index, since an increase in debt leads to an increase in systematic risk (Hamada, 1972). Moreover, in some cases the market efficiency hypothesis may not be satisfied (Vaga, 1991), and stock market volatility may be influenced by the psychological state of market participants. Taking account of these volatility factors is a promising subject for future research.

Conclusion

This study confirms the hypothesis that during the periods under review in the BRICS countries, digitalization contributed to increased predictability, probably because the increase in the volume and quality of data and the development of methods for analyzing them had a greater effect than the increase in uncertainty caused by the advent of new technologies and the general complication of the economy. Uncertainty

and the fundamental impossibility of making accurate forecasts are an integral part of the financial system; moreover, existing financial instruments can effectively quantify and redistribute risks. However, since rational economic agents are risk averse, a decrease in uncertainty is a positive event for them as it can lead to a decrease in risk premiums in the structure of interest rates and an increase in the amounts invested. At the same time, further development of technology and the emergence of new industries will certainly contribute to a decrease in predictability and an increase in uncertainty. In order to increase or at least maintain the current level of predictability, it is necessary to further improve the transparency of the economy and the quality of accounting both at individual enterprises and in the national economy as a whole. It should also be noted that some of the tasks in the field of forecasting, e.g. the qualitative analysis of companies in order to assess the value of a business, cannot be solved solely on the basis of artificial intelligence. This points to the crucial importance of critical and analytical thinking skills and hence the necessity of improving fundamental education.

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