

Green Finance Post-Pandemic Restructuring: Mini-Overview and Approaches to Modeling Links*

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Abstract

Green finance is an important area of tackling environmental threats, especially those associated with climate change. The Covid-19 outbreak has drawn additional attention to green finance as an economic mechanism for creating healthy living environments. The article examines the impact of COVID-19 on the financial industry, the involvement of green finance in the economic recovery after the pandemic, towards taking into account the Paris Agreement to reduce greenhouse gas emissions and improve sustainability. The authors put forward a provision on the presence of causal links between two concepts: "green" finance and "green" economy. The article substantiates the position that the global pandemic will have a long-term impact on the attitudes of investors, governments, and the public towards financing measures to protect the environment and prevent climate change.

The three-agent model proposed in the article makes it possible to analyze the behavior of green finance participants. By simulating their behavior, the mechanism of adaptation of both the system and agents to internal and external pressure is analyzed in order to preserve their functionality and increase the performance and efficiency of green financing.

Keywords: Green Finance, Green Bonds, Pandemic, Climate Change, Three-Agent Model.

Introduction

The outbreak of COVID-19 has demonstrated that society is not ready to respond quickly to global threats to both the environment in general and health in particular, and the economy (Guerriero et al, 2020). As uncertainties increase about protecting populations from disease and preventing climate change, it is important to make our society more resilient to both COVID-19 and long-term environmental challenges. This can be done by focusing on green finance - increasing its effectiveness and strengthening its position in post-pandemic economic recovery, which will bring significant benefits, both short-term and long-term, and increase societal resilience to shocks over time. The World Health Organization (WHO, 2019) ranks climate change as the biggest global health threat in the twenty-first century. Predicting future risks from climate change is not easy. An equally difficult task is to determine the response of the financial system to these risks, including insurance, as well as private and public financing of projects that contribute to their mitigation.

The suspension of habitual norms of life and activities during Covid-19 changed the way of life had a profound impact on the environment and attitudes towards health care. The pandemic has exacerbated many problems in the economy, increased risks, and increased uncertainties. Every week, the global economy loses \$ 200-250 billion from the pandemic (COVID-19, 2020). When all attention is focused on the fight against the virus, climate problems and the risks associated with climate change are formally somewhat relegated to the background (Wyns, 2020). Against this background, there is a need to rethink attitudes towards green finance in order to clarify its place in economic development and track the ongoing transformation in green finance. These days, the pandemic appears to be new opportunities for green finance and a green economy. Green growth, driven by green finance, could be a long-term megatrend winner rather than a niche zone.

A green focus in post-pandemic economic recovery will increase the resilience of society to pandemics and other emergencies, including climate change (OECD, 2020). Back in April 2020, at the initiative of the OECD General Secretariat, a document was prepared to discuss the post-pandemic economic recovery based on investments in improving the environment. The authors of the document propose "to increase resilience to pandemics with the help of environmental factors, which is a key component of measures to stimulate economic recovery, which are currently being developed by governments" (Cox and Piccolo, 2020). The transition to a green economy is necessary to achieve the goals set out in the Paris Agreement. During the transition, a system of regulation and measurement of investments is being created, the size of which is estimated at tens of trillions of dollars. All this requires a clear classification of green finance and the establishment of causal relationships, which will allow the transition to parameterization and assessment, comparisons, and targeted transformations of finance and the economy in a green direction.

Measuring the quality and depth of penetration of green finance into global markets, establishing causal relationships in this process, and determining the impact of investments on the preservation of the environment is a major challenge. The fact is that there are significant national and regional differences in their accounting and regulation. This problem can be fundamentally solved by standardizing green financial products and services, which makes it possible to move to their quantitative measurement, accumulation of statistical series, and their comparison between countries. In addition, in this way, you can move to the formation of proposals aimed at meeting the target demand of investors and preparing products for specialized markets (for example, green bond exchanges and markets where hydrocarbon emissions quotas are traded). This problem has attracted the attention of the UN and other international organizations. He has underpinned a number of initiatives, including the UNEP Positive Climate Change Initiative (UNEPFI, 2017), the UNEP Financial Centers Initiative for Sustainable Development (UNEP, 2017), the KIC climate finance initiatives, I4CE and PwC and UN PRI (2017-2018), as well as initiatives to create an environment for sustainable stock exchanges (UNPRI / UNCTAD 2009).

The article puts forward and develops the following provisions: (i) there are the following links (a) between climate change, pandemic, and green finance; (b) between the concepts of "green" financial and "green" economy: "green" finance is a mechanism for the formation (reasons) of a "green" economy (consequence); (ii) a narrow focus on coping with a post-pandemic recession can have adverse environmental and health consequences, as long-term effects cannot always be considered in the pursuit of short-term results; (iii) the effect of green finance can be greatly enhanced by changes in lifestyles, the behavior of people and companies, legislative initiatives and government decisions aimed at protecting the health and the environment. The aforementioned provisions are viewed from the point of view of at least two competing discourses, according to which, during the post-pandemic economic recovery, the New Green Deal (Schroeder, 2019; Cobb, 2019), which gained international circulation in 2018-9, will undermine the economy (Walden, 2020) or increase its resilience. According to the first statement, investments in environmental projects will be reduced, and according to the second statement, "climate" investments will help restore and restructure the economy towards increasing its resilience. Also, in the article, to analyze the relationship between the main participants in financing environmental projects and analyze their behavior, simulations are carried out using a three-agent model.

Literature and Framework

Much of the economic literature on the optimal financial response to climate change focus on the trade-off between direct costs and the potential uncertainties of long-term benefits of carbon investments (Giglio et al, 2015). At the same time, the discount rate and its parameters play a central role in this discussion, since even small changes in discount rates can dramatically change the present value of investments in the long term. Thus, in the long term, make investments in carbon reduction attractive or unattractive. In this regard, financing was considered in terms of solving two problems: (i) climate change in the right direction (Mahsin et al, 2020; Campiglio, 2016), (ii) adaptation of economic systems (Birindelli et al, 2020; Kahn et al, 2019) and, above all, production and households to climate change (Pham and Huynh, 2020; Jones et al, 2020)

No less popular are futurological studies of a green future and the role of green finance in building it (Clapp, 2018). In this regard, there are various reviews and analysis of various aspects of green bonds: debt obligations associated with financing projects that claim environmental benefits (Anh, 2020; Jones et al, 2020; Banga, 2019). The role of finance in climate change mitigation is also widely explored (Painter, 2019; Kahn et al, 2019). There is a fairly large body of literature and research on the involvement of the green and environmental sectors in sustainable and socially responsible finance (Boubaker, et al, 2018; Alahbali and Nobanee, 2020; OECD, 2019). There are also studies on the link between green finance and the green economy (Klioutchnikov et al, 2018).

Policymakers, practitioners, and academics are just beginning to study the impact of COVID-19 on the financial industry, as well as its involvement in post-pandemic economic recovery (More, 2020). Overall, the link between climate change and the current pandemic (Sengupta, 2020) from a green finance perspective is a new topic.

Conceptual Approaches

Numerous organizations and institutions have developed their definitions of "green" finance. The G20 defines this concept as "financing investments that provide environmental benefits in the broader context of environmentally sustainable development" (G20, 2016). The OECD considers the term "stand-alone," derived from a broader investment theme, or closely related to other investment approaches such as socially responsible investing (SRI); environmental, social, and government (ESG) investment, sustainable, long-term investment or similar concepts" (Inderst et al, 2012). In general, the G20 and OECD represent "green" finance as a process aimed at achieving certain goals.

In 2016, the Committee on the Environment, together with the UN financial services, proposed to standardize the main definitions and concepts of "green finance" under the theme "Sustainable Financial System" (UNEP, 2016a). At the same time, the approaches to these concepts were analyzed, which operated in a number of intergovernmental organizations and countries. Approaches to this concept and its constituent parts of exchanges that trade in green bonds, banks that provide green loans, statistical bodies of a number of countries, investment companies, and others were also taken into account. As a result, schemes were developed for entering the green finance system of various clusters, as well as areas of its responsibility and actions - environment, social sphere, economy, and government. As a result, the following general approaches have been proposed for the following terms:

- "Climate finance" - within the framework of the UN Framework Convention on Climate Change, the concept is reduced to local, national, or transnational financing, which can be obtained from public, private and alternative sources. This concept serves both to denote solutions to the problems of reducing emissions, and to adapt countries to the adverse effects of climate change.
- "Green finance" is a broader concept than climate finance as it also includes other environmental goals and risks. It is used to characterize the greening processes of various investment projects

(UNEP, 2016a). At present, a kind of consensus has been reached on the inclusion of health issues and the fight against the COVID-19 pandemic in this topic.

- “Green Banking” - describes the process of banks' participation in “green finance” (UNEP, 2016b). As part of this process, the role of central banks in supporting green finance has been identified (UNEP, 2017a).

The refinement of these concepts resulted in a roadmap for the formation of a sustainable financial system, which began to determine the main parameters and processes of stabilization of the financial system towards its “greening” (UNEP, 2017b). In October 2017, at the annual meeting of the World Bank and the International Finance Corporation, together with Bloomberg, a mechanism for greening the financial system was considered and proposed, which included digital green finance (UNEP, 2018). Currently, a wide variety of information is generated, collected, transmitted, processed, stored, and used in digital form. Naturally, this process affected such areas as the environment and finance, which became the basis for the transition to digital “green” finance. The digital form of “green” finance has further contributed to the cross-border transformation of the “green” economy and is largely combined in the overall process of digitization of all assets of our time - from natural assets to knowledge and human capital, within which the digitalization of the environment among and the digitalization of management and recovery mechanisms it, including the digitization of green finance. Thus, green finance entered the digital sphere and gained significant development in it in a short period. It is associated with both digitized traditional financial services in green packaging and the use of blockchain technologies.

In 2018, the European Bank for Reconstruction and Development established that green finance covers the financing and risk management of projects in a clean economy, energy efficiency, energy conservation, rational use of water resources, waste recycling, green infrastructure, informatics, education, etc. social industries, as well as green building construction, green R&D (EBRD, 2018). Besides, it was suggested to define the level of zoning in ‘brown’ projects. Thus, the area of responsibility of green finance in society was expanded.

The International Finance Corporation has developed a methodology for defining green finance for bonds, loans, and investments (IFC, 2017). She approached the concept from the standpoint of project tasks (micro and macro data of the project, its result), location (borrower and investor, location of the project and its operator - legal registration and actual location), and supply and demand (including estimates and changes in economic indicators). This methodology allows you to cover the entire spectrum of financial activities and move from the bottom up. To this end, green is first determined at the project level, based on the intended use of the investment in the real economy, by applying estimates for the corresponding green share in the project. Then they move on to assessing the company as a whole, and then the numbers are aggregated at the industry and country level. These results can be compared with the need for green financing to identify problems and green points of action.

When calculating the Global Green Finance Index (GGFI, 2018), this concept refers to any financial instrument or activity in the financial services industry, including insurance, stocks, bonds, trading in commodities and derivatives, as well as analytical or risk management tools that lead to positive changes the environment and society in the long term, that is, create conditions for sustainability. This practice formed the basis for the development of the GGFI index (2018).

The most basic criterion for the “greenness” of a company, product, process, or project is the ability or contribution to reducing its greenhouse gas emissions. The past two decades have seen a surge in new financial instruments such as green bonds, and environmental markets such as carbon and forest markets or markets for water services and resources. In addition, there has been progressed in analytical methods and a shift to big data, which has fueled the development of green mechanisms in finance and economics and has drawn increased attention to these topics.

A differentiated approach to green finance in mature economies and emerging markets is often accepted. The latter is characterized by a concentration of green finance not only in areas such as clean energy, low-carbon transport, and energy-efficient buildings but also on financial support for industrial restructuring, including towards energy efficiency and environmental pollution control (Shultz, 2020). Probably, the post-pandemic economic recovery will also be associated with the widespread restructuring of industry in the above directions.

The GGFI classifies green finance as any financial instrument or activity in the financial services sector, including insurance, stocks, bonds, commodities and derivatives trading, analytical instruments, or risk management instruments, resulting in positive changes for the environment and society in the long term. The main criterion for the "greenness" of a company or project is that it helps to reduce greenhouse gas emissions. Over the past two decades, the rise of new financial instruments such as green bonds, and environmental markets such as carbon, forestry, or water services, along with advances in analytical methods, has drawn increased attention to green finance.

The term "green" finance is quite significant in international policy debates, such as recent meetings at the World Economic Forum. For example, green finance is no longer seen as a limited activity but is a profitable and promising sector of financial markets that serve society and raise the status of financial centers within which the main financial processes unfold. The transition to a green economy is taking place within the framework of the goals set out in the Paris Agreement. It is backed by a global investment strategy valued at tens of trillions of dollars.

There are many definitions of green finance and opinions on how to move towards green investment, but they can be summarized as an approach to financial systems that mobilize finance for clean and sustainable growth.

A group of specialists from the International Banking Institute (St. Petersburg, Russia) at the 2019 seminar on green finance (Klyuchnikov, 2019) identifies three main options or approaches to green finance - narrow, medium and broader senses. In a narrow sense, green finance is limited to financial solutions to climate and environmental problems, and in the medium one, to the creation of environmentally friendly technological processes, products, and energy. In a broader sense, the concept borders on sustainable financing, which is necessary to ensure sustainable economic growth. Each option has its own set of both market and non-market activities, which can be classified into two groups: (i) supporting and stimulating the use of finance in the green direction, (ii) controlling and limiting investments in dirty technologies and production.

In the course of the current pandemic, under the influence of digitization and cross-border activities, changes in both the content and the organizational structure and management of green finance have accelerated. In general, the process of their management can be defined as a set of formal and informal rules and norms, following which people interact in the financial sphere for the effective accumulation, direction, and use of financial resources to solve various nature management tasks and prevent climatic and other natural threats. Modern societies adhere to a basic set of rules and regulations defined by national interests. Nation-states have physical boundaries; while the problems of natural resources users often have trans boundary dimensions and are not limited to national borders. The modern pandemic, on the one hand, has blocked states in solving internal problems of fighting the virus, maintaining infrastructure and the environment, and on the other hand, it has drawn attention to the trans boundary nature of epidemiological and climate threats and the need for joint actions to address these problems.

To summarize, green finance is usually classified as loans and investments aimed at improving the environment and preventing climate threats through a wide range of actions to solve social problems. From this point of view, they have many macroeconomic effects, and different lending and investment procedures, directions, and forms of organization may have different macroeconomic goals and properties. First, green finance often has a huge impact not only on a specific industry or region but also on global processes. The localization of capital investment is often associated with extraterritorial consequences. Consequently, green finance, even when solving local problems, does

not have regional jurisdiction, since in most cases it has a broader and often global impact on the economy, that is, it has mega-economic and mega-social consequences and usually leads to the formation of a green economy worldwide. In this case, their purpose - utility, value, and result - go beyond certain cost characteristics of the immediate effect. Understanding how value is created and accumulated in a green economy through green finance requires a new approach to defining the categories of cost, value, price, and utility. A new approach can only be formulated as a result of an interdisciplinary search and solution to this problem by combining many disciplines - from computer science, finance, and behavioral economics to management, psychology, political science, and even epidemiology.

The concepts of 'sustainability' and 'green finance' have both concrete and amorphous features. Both concepts cover many different practices that relate to natural, social and political-economic phenomena. In everyday life, stability is quite understandable. This concept is widely used to define the state of physical phenomena or natural ecosystems. The latter is often considered in connection with the desire to prevent them from destruction and the need to preserve them for posterity. As for green finance, most economists continue to consider them in narrow terms as a financial subsystem, the dynamics of which unfolds in the environmental direction of financing, that is, corresponding to the solution of problems of preserving the environment, primarily the prevention of climate change, processes, tools, and goals. However, an alternative approach to green finance can be offered. In this case, green finance includes a variety of subsystems - from economic to non-economic. The central link of the economic system in green finance is the relevant elements of the financial system that are associated with solving environmental problems. As for non-economic subsystems, they include political, social, and cultural phenomena and institutions that are necessary for the future survival of a person. Moreover, green finance (i) becomes an integral part of capital accumulation and the creation of a sustainable system of capital accumulation, (ii) ensures the stability of financial markets and the stability of the entire economy, and also (iii) acts as a financial mechanism for the life support of humanity and the preservation of the Earth's ecosystem.

Linking Climate Change to the Pandemic and Green Finance

The dominant schools viewed the environment (especially the climate) and finance as independent systems. As soon as the modern pandemic began to unfold, the shortcomings of this approach were immediately revealed. It turned out that the environment is directly related to finance. It's not just a shift towards social distancing during the COVID-19 pandemic that has impacted financial institutions' interactions with customers and fueled the rapid development of digital services. Important changes in financial liquidity were outlined and financial assistance programs were deployed, and the financial system began to prepare for post-pandemic economic recovery.

Traditionally, financial markets have been presented as an efficient system for allocating resources. They have been widely modeled and studied using general equilibrium models, game theories, in which agents behave rationally and maximize value. In this case, prices are determined using, for example, the Black-Scholes-Merton formula. In essence, it all boiled down to a linear approach. At the same time, optimization of the predictability of results was carried out under the strict control of two operators: the state and the market. However, first, during the 2008 crisis, the financial system showed its vulnerability. Internal misadventures turned out to be much stronger in their influence on the depth of shocks than external ones. Over the past twelve years, trends have emerged that may indicate new threats to the system, and this is not only a monstrous increase in debt and asymmetries but, above all, a gap in the balance between finance and the real sector. At the same time, the contradictions associated with the gap in the ratio between financial and natural capital are highlighted.

Another important circumstance is that the coronavirus pandemic could lead to a deeper understanding of the connections that bind people around the world. Well-equipped health systems are essential to protect people from health security threats, including climate change. Climate change has already paved the way for the spread of some infectious diseases. The current pandemic has shown that predicting future risks is not easy, but climate change is strongly affecting several areas

that play a prominent role in when, where, and how pathogens appear. In this regard, changes in temperature and precipitation are of key importance. To limit the risk of infectious diseases, it is necessary to significantly reduce greenhouse gas emissions and limit global warming to 1.5 degrees. That is, to implement the Paris Agreement by increasing green financing for economic development.

In the baseline scenario of post-pandemic development, proposed by the experts of the World Economic Forum, the key condition for normalization of activities is an investment in the long-term development of human health and the environment towards building a green economy (IMF, 2020). Green finance acts as a tool for creating measures to preserve the environment and increase the resilience of the economy. In the new conditions, green financing will provide epidemiological measures to protect people, which is extremely important for the effective reproduction of human capital. A green focus for economic recovery after a pandemic will increase the resilience of societies to pandemics and other emergencies, including climate change (Cox and Piccoli, 2020). In April 2020, at the initiative of the OECD General Secretariat, a document was prepared that discusses economic recovery after the pandemic based on investments in improving the environment (OECD, 2020).

Climate and environmental change, as well as the pandemic, have focused on leading players that can affect the future of society. Among them, finance, which determines future development, holds the palm. However, COVID-19 pandemic could be the biggest challenge for financial institutions. On the one hand, their involvement in economic recovery could potentially weaken the focus on climate bonds and environmental issues, but on the other hand, the pursuit of sustainable finance and investment in health and environmental improvements could also help raise awareness of green finance. These two tendencies will act simultaneously and in each case, the priority will be on the side of one or the other. As the economic impact spreads, green finance faces some big challenges. Their solution is associated with the choice of specific steps that are aimed at changing the position now, as well as associated with possible calibration for the future. In particular, the channels for raising capital are changing. There is growing interest in increasing their openness, despite the decrease in liquidity and the reduction in supply.

Post-pandemic financial institutions will contribute to unique solutions to finance environmental transformation. Already, various workarounds are being developed to eliminate bottlenecks, in particular, related to late payments, cancellation of fees, and the transfer of any investment decisions and changes in their directions.

Due to the pandemic, there have been several changes in cleantech funding:

- 1) The importance of the processes of monitoring financial flows has increased. The changes were associated with an increase in the impact on profit of changes in financing terms and balances on bank accounts, which was influenced by both lower interest rates and increased delays in debt and interest payments, changes in the conditions for raising capital, methods and priorities of working with clients as during pandemic and with subsequent recovery.
- 2) Investors' interest in financial products that have ESG criteria is growing.
- 3) There has been a change in the yield and liquidity of green bonds, as well as the demand for them. In the course of significant price fluctuations, demand was redistributed, attention to some green bonds declined, while others increased.
- 4) With a general increase in risk and uncertainty in the financial sector, green bonds and green loans tend to become more stable and therefore more attractive financial products.
- 5) The disruption of supply chains in all spheres of the economy caused a reorientation of attention and financial investments in this area. In particular, there have been changes in the financing chains for climate investments.

6) Information asymmetries have increased and information priorities have changed, leading to a change in the way financial institutions deal with climate information.

7) With the overall increase in business value, the flexibility of producers of environmental goods and services, as well as mechanisms for lending and investing in production chains, increases.

8) Under the influence of changes in the production and supply chains, an increase in inventories was required, which affected the structural changes in the cost of environmental products. There has been a revision of investment strategies and pricing of environmental investment projects, also related to a change in attitudes towards health and the environment as a result of cheaper money.

The coronavirus pandemic is contributing to a deeper understanding of the links that link society, the economy, and the environment. Well-equipped health systems are essential to protect people from threats to health security, including climate change. A stable financial system can financially withstand threats to the environment and human health.

Social interaction, as well as interaction with nature, can be considered as part of the human ecological environment. The growing popularity of investment strategies that incorporate ESG (Environmental, Social, and Governance) criteria is one of the main investment trends. More and more investors want their money to be invested sustainably or with positive effects, both socially and environmentally, and not harm the environment. Actions that can generate economic growth and prevent a new pandemic outbreak: (i) investing in public health, an early response to outbreaks and testing materials, and (ii) combating illegal wildlife trade. Financial support for their implementation fits well with green financing". Besides, mitigation measures are intended to work in the same direction. For example, preventing deforestation (a major cause of climate change) can help (i) halt biodiversity loss and (ii) slow down animal migration, which also carries the risk of spreading infectious diseases.

Three-agent model of behavior in the green bond market

Green finance is complex systems exhibiting a wide range of non-trivial emerging phenomena, including extreme shocks, short and long-term memory, dynamics, and multifractality. Collective behavior in systems can be modeled using a variety of approaches, including complex dynamic models, agent-based models, or graph theory. One of the most important and complex tasks is to describe the collective behavior of interacting edges, the corresponding information flows between them, and also to determine the role of nodes in these interactions. This study proposes a three-agent model in which the nodes are (i) the issuer of the green investment project, (ii) the investor or underwriter, and (iii) the regulator. The model of behavior is considered on the example of issuing, placing, and regulating green bonds - innovative financial instruments (Bange, 2019).

Green bonds represent one of the most visible innovations in sustainable finance over the past decade. Their growing market reflects the growing interest of the financial sector in climate risks. There is no universal definition of green bonds, although there is growing consensus as to what they are for. The Green Bond is defined as a fixed-income financial instrument to raise capital to finance or refinance related green projects (OECD 2017; ICMA 2017). Green bond issuance surged from \$ 1 billion in 2007 to \$ 259 billion. In 2019, with cumulative output for all years (since inception in 2007) \$ 754 billion (Almeida, 2020).

In the Russian Federation, the green bond market is in its infancy. The first bonds were issued in 2018, and as of July 2020, there were only five issues. In 2016-18, a number of steps were taken at the government level to create a market for green debt instruments: the creation of a regulatory framework; determination of the principles of information disclosure by issuers; development of a procedure for opening and approving green bonds; compiling a list of areas in which green bonds can operate; creation of a commission that marks bonds and controls the sending by the issuer of funds received for the implementation of the declared project.

The Moscow Exchange has become the center for the issuance and placement of Russian green bonds (except the Russian Railways issued green bonds on the Irish Exchange) (Annual Report, 2020). It supports the development of the concept of sustainable development in Russia and in April 2019 joined the global initiative Sustainable Stock Exchanges (SSE). In 2019, the Sustainable Development Sector was created at the Moscow Exchange to finance projects in the field of ecology, environmental protection, and socially significant initiatives (Tuteeva, 2020). Within the sector, there are five issues of green bonds with a total issue volume of 7.55 billion rubles and 500 million euros (Table 1). In 2020, the exchange plans to expand the range of structural and green bonds, including the appearance of social bonds in the Sustainable Development Sector.

Table 1: Green bonds of Russian issuers (issues March 2017 - July 2020)

Issuer	Industry	Volume of issue	Placement year	Placement
JSC "Commercial real estate FPK" Garant-Invest	Commercial real estate, green technologies	RUB 500 million	2017	Moscow Exchange
LLC "Resource-saving" KhMAO	Housing and communal services, waste management	RUB 1.1 billion	2018	Moscow Exchange
PJSC CB "Center-Invest"	Renewable energy sources, environmentally friendly transport	RUB 250 million	2019	Moscow Exchange
JSC "Russian Railways"	Railway transport infrastructure	EUR 500 million	2019	Irish Exchange
JSC "OFO Rusol 1" (organizer of the placement Sovcombank)	Green energy, solar power plants	RUB 4.7 billion, RUB 900 million, RUB 100 million	2019	Moscow Exchange

The main purpose of the modeling is: (i) to show the main interactions of the three main participants; (ii) trace the flow of information between the three main participants in the issuance and placement of green bonds; (iii) consider the behavior of the participants. Entropy transfer can measure the movement of information; a model-free measure that determines the amount of information transferred from the source time series to the target time series. It can successfully describe complex systems with nonlinear interactions. The strongest flows are in the sectors associated with climate bonds (for example, the stock markets). On the other hand, outside the exchanges, much weaker information flows are demonstrated. This is because exchanges generate a significant transmission of information about marginal events, which becomes much more important in the transferred entropy picture (Korbel et al, 2019).

There are at least three major market participants involved in the issuance of green bonds (Figure 1), including:

- 1) The issuer or developer of the project who creates a "green" project. In the project document, the issuer describes the expected positive impact of its project on the environment. To avoid overestimating or underestimating such impacts, the project is audited in terms of its impact on the environment and compliance with the greenness criteria,
- 2) A regulator. The role of the regulator is to conduct a quantitative and qualitative assessment of the project:
 - a. Use of proceeds: Before issuance, the legal document must state how the proceeds of the bond will be used.
 - b. A technical assessment of the specific risks and opportunities associated with the project, as well as the creditworthiness of the green bond issuer.
 - c. Monitoring, Reporting and Transparency Requirements: Several reports are regularly published to monitor both the project and the use of proceeds to ensure that proceeds from green bonds are distributed in accordance with the Green Bond Principles, and
- 3) Underwriter. Green bond underwriter provides capital to the issuer for a specified period at a fixed or variable interest rate.

The tripartite process of issuing green bonds can entail significant transaction costs - which is one of the barriers to the development of green bonds.

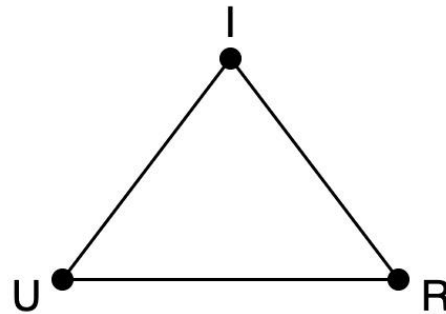


Figure 1: Three-agent-based model

The logic behind the three-agent model is as follows:

- The issuer (I) prepares an issue prospectus that meets certain criteria for "greenness", which is controlled by R.
- A project that meets these criteria goes to the Investor (U).
- The investor, by placing bonds on the stock exchange, mobilizes the necessary capital, and transfers it to the issuer.
- In turn, the issuer makes coupon payments and pays the capital base to the underwriter.

The regulator moderates the process - it affects both the issuer and the underwriter.

In the model, each agent has a certain set of properties. By simulating real-world phenomena, the behavior of each agent can be studied.

The three-agent model that studies the behavior of decentralized agents is based on three main ideas:

- The objective orientation of information objects from the point of view of their controllability;
- The emergence and learning ability of agents;
- Classification of solvable problems according to their complexity by reducing them to a set of simpler problems with efficient algorithms for solving.

It is assumed that the regulator mediates the interaction between the issuer and the investor. The search for a mechanism for the regulator's influence on the issuer and the investor can be reduced to discovering cause-and-effect relationships in a complex context (Anderson and Scott, 2012) or by opening a "black box" (Bathae, 2018). By simulating the actions of agents, the effectiveness of the interactions is tested. For this, a number of hypotheses are put forward.

A hypothesis can be defined as a logically implied relationship between two or more variables, expressed in the form of a testable statement. Communication is offered using rigorous logical reasoning. These logical relationships can be part of the theoretical framework for research. Let's consider some of the hypotheses: 1) the issuer of the network is interested in the investment (variable); 2) the level of interest in investments is related to the level of their solution to environmental problems; 3) the level of solving environmental problems is related to the level of the investment effect; 4) if the effect decreases, then the demand for investment falls; 5) if the effect grows, then the demand for investment increases. These are verifiable proposals. Moreover, the first hypothesis contains only one variable. And this hypothesis is rather abstract. The second and third hypotheses have two variables that are related to each other, but the nature of their relationships is not determined (there is no directional relationship). In the fourth and fifth hypotheses, in addition to the relationship between the two variables, directions are set (in the fourth - negative, and the fifth - positive). Regulators can test these hypotheses: market (exchanges) and government (special commissions, as well as by checking compliance with ESG criteria).

The evaluation of the participation of the parties in a triangle can be carried out from the graph theory. Directional graphs can be used to model information flows of financial intermediaries with clients. For this, the links between the nodes are given the necessary orientation. In graph theory, the Tutte-Berge formula (Berge, 1962) characterizes the size of the maximum match in a graph. It can be used to determine the smallest distance between the vertices. Usually, the formula is used when organizing traffic - finding the best routes (Bondy and Merty, 2010). However, it is quite suitable for understanding the processes that determine (i) the issuer's interest in investments, with appropriate environmental regulation, and (ii) the investors' interest in financing projects with their corresponding efficiency. Thus, issuers strive to maximize the effect. This principle follows from the laws of entropy of information. Like gas molecules, agents interact with each other. Collective interactions can influence individual behavior.

The three-agent model makes it possible to establish certain rules for the behavior of agents located in time and space and located in networks. Moreover, the behavior of agents can be "tied" to a certain time and place. This approach allows you to focus not on the stable state of the system, but on how the system and agents adapt to internal and external pressure to maintain their functionality, which is extremely important in the face of changing requirements for protecting the environment and people from climatic and pandemic threats.

Conclusions

There is a strong likelihood that changes in the behavior of people, companies, governments, and investors as a result of the pandemic will have a significant impact on the state of green finance. The article substantiates the position that the way out of the economic crisis caused by the pandemic will be based on ESG criteria, the main link of which will be green financing.

There is a fairly wide range of assessments of financial mechanisms for overcoming the crisis caused by the pandemic and directions for financing economic recovery (Rathi, 2020). However, the prevailing opinion is that the way out of the economic crisis caused by the pandemic will be based on a further increase in the importance of sustainable financing with the transition to new norms that take into account the real threat to humanity, in particular, from natural disasters, primarily related to climate change (Krurowska, 2020), possible pandemics and other natural disasters.

Green finance is designed to address the challenges of economic recovery in ways that help not only reduce the risks and vulnerabilities of the economy and society to unwanted external influences, but also reduce emissions that cause climate change and increase uncertainties, and mitigate the negative impact of future pandemics.

The three-agent-based model proposed by the authors makes it possible to analyze the behavior of agents in the process of green financing. By simulating the various participants in the green finance system, a mechanism is considered for adapting both the system and the agents to internal and external pressures to maintain their functionality and increase the productivity and efficiency of green finance.

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