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Assessment of Homogeneity and Convergence of Environmental Performance of Enterprises into One Holding

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ABSTRACT

Taking into account the need for transition to sustainable development of the economy, it seems **relevant** to consider whether the holding is an effective structure to minimize the negative impact on the environment: is there a convergence of the environmental performance of the holding's enterprises with a general increase in its responsibility? **The purpose** of the research is to assess the degree of homogeneity and convergence of the environmental performance of Russian enterprises within the same holding, as well as to determine the relationship between the current level of homogeneity of the holding and the rate of its convergence and overall environmental responsibility. The environmental performance of 11 Russian holdings and 105 constituent enterprises for 2017–2021 was examined. **The methodology** involved the calculation of entropy and descriptive statistics; the evaluation of the homogeneity of holdings and its convergence, phase transition periods, and the relationship between homogeneity and other characteristics using analysis of variance and regression. **The results** of the study showed that Russian holdings correspond to the ascending line of the entropic criterion of social development, but at present the phase transition from a heterogeneous to a homogeneous state is incomplete, and homogeneous holdings are unstable. The influence of the type of corporate environmental policy on the homogeneity of the holding, the degree of its convergence and environmental responsibility was revealed. **The scientific novelty** of the work lies in the consideration of homogeneity and convergence of environmental characteristics of systematically unstudied objects — the enterprises of one holding; the inappropriateness of the perception of holdings as homogeneous objects is confirmed. Theoretical significance has shown the possibility of using the entropic criterion of the theory of social development and dialectical logic to study the homogeneity and convergence of the indicators of holdings, as well as the developed methodology of their assessment. **Recommendations** for the authorities and managers of companies, the implementation of which will increase the sustainability of the economy, are of practical value.

Keywords: environmental responsibility; sustainable development; Russian companies; homogeneity; convergence; entropy; phase transitions; corporate environmental policy; uniform environmental standard

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INTRODUCTION

Stakeholders of Russian companies (holdings, groups), which combine several subsidiaries and affiliated enterprises, branches, are interested in data on their activities. In particular, authorities, creditors, suppliers, and contractors on the indicators of the consolidated financial statements analyze the economic state of the holding as a whole. Recently, in connection with the understanding of the need to ensure sustainable development of the economy [1], interest in the environmental characteristics of companies has increased [2]. At the same time, the economic performance of holdings can be considered to a greater extent based on aggregated data of the enterprises in them (the inability of the state to receive taxes from one of them can partially offset the other; the presence of more profitable enterprises within the group increases the credit rating and less profitable, etc.). At the same time, the environmental characteristics cannot be summed up: instantaneous and spatially localized exceeding of the limit level of carbon dioxide emissions by one enterprise even at zero emissions of another requires cleaning activities. Accordingly, the

use of consolidated non-financial reporting by stakeholders is advisable only with a high level of homogeneity among enterprises in one holding, but data on the ecological homogeneity of Russian companies to date are not available.

At the same time, given the significance of the environmentalization problem, it is important to consider whether the holding is an effective structure for coordinating and reducing negative environmental impacts, and whether there is an integration (convergence) of the levels of environmental indicators of holding enterprises with the overall increase of its responsibility.

The purpose of this study is to assess the degree of homogeneity and convergence of environmental characteristics of Russian enterprises belonging to the same holding, as well as to determine the relationship between the holding's current level of homogeneity and its rates of convergence and overall environmental responsibility.

The study examined the environmental characteristics of 11 Russian holdings and 105 of their enterprises for 2017–2021. Indicators of descriptive statistics, entropy, homogeneity of holdings, and convergence of their enterprises were calculated, and periods of phase transitions (qualitative changes in state) were determined. The relationship between homogeneity and convergence, in addition to the overall environmental parameters of the holding, is analyzed using variance and regression analysis.

The scientific concept of the study is to consider the homogeneity and convergence of environmental indicators in relation to previously systematically unstudied objects — enterprises under the same holding.

The theoretical significance is determined by the demonstrated possibility of using the entropic criterion of the theory of social development and dialectical logic to study the homogeneity and convergence of the characteristics of holdings, as well as, in the developed methodology of their evaluation on the example of environmental parameters. Recommendations for authorities, as well as managers of companies, the accounting and implementation of which will increase the resilience of the Russian economy, are of practical value.

REVIEW OF THE LITERATURE

Study of Homogeneity of Objects in Economics

The ideas of "homogeneity" and "nonhomogeneity" are general scientific concepts with an important role in social development theory. Economic development has resulted in social division of labor and thus increased heterogeneity in the economy [3], but in the next few periods there has been enlargement and consolidation of economic actors, with monopolies [4] and transnational corporations [5] playing a prominent role in recent decades. Similarly, territorial union and separation were formed primarily for economic reasons (see, for example, [6]).

However, despite the fact that the formation on the basis of independent territories of one spatial unit is based on their community, these territories, on a number of indicators, for example, economic and environmental, are heterogeneous [7]. And although enterprises in the holding are often perceived as similar, their targets depend on the availability and limitations of infrastructure, technologies, and equipment, and these parameters can be different even within the same holding. Companies with subsidiaries in other countries have demonstrated their ability to improve their overall level of environmental responsibility by implementing corporate environmental standards, ensuring enterprise uniformity in countries with strict and lenient legislation [8, 9]. Simultaneously, the practice of shifting productions with a higher environmental footprint to countries with lower regulations was formerly popular [8]. As a result, the level of enterprise homogeneity inside one company did not increase. Furthermore, the heterogeneity of a company's environmental

indicators may be related to the distance of control (holding management) [10].

In general, the homogeneity of indicators is often considered together with their convergence, as it can be both a cause and a consequence of homogeneity.

Economic Studies on Convergence of Indicators

The concept of convergence corresponds to dialectical logic, namely Heraclitus' idea of the unity and struggle of opposites and the triad of George Hegel, which became known in the simplified formulation of Heinrich Chalybäus as "thesis — antithesis — synthesis" [11].

Priority was given to indicators of countries and regions in economic theory when studying problems related to convergence of different systems: initially income ([12] and etc.), later many other economic parameters (human development index [13], labor productivity [14, 15], investment, unemployment [15], and etc.), and, for example, environmental factors were considered [16–18].

The number of papers studying the convergence of environmental indicators at the microlevel is significantly smaller, and companies from different countries are often compared. Thus, it is confirmed that in 1999–2002, there was a convergence in the environmental reporting of transnational corporations in Japan and Europe, with differences within European states [19]. There is a convergence of a number of environmental characteristics of firms in India and developed countries due to Indian companies borrowing innovation and targets. In general, however, the corporate models used in India are highly heterogeneous due to different responses to external pressure and differences in opportunities for environmentalization [20].

Differences in understanding of corporate responsibility and sustainability [21], as well as the holding's ability to promote its interests [22], could hinder the convergence of firms' environmental performance. In turn, the introduction of non-state standards [23] and a number of public initiatives can contribute to the convergence of ecological indicators [24].

For the purposes of the study, a comparison of the commitments to ensure sustainable development of the Australian university's campuses, which are separate business units of the same organization, is of particular interest. For the campuses studied, there is convergence in understanding the need for and use of elements of sustainable development, such as plans and reporting, but their application is non-standardized [25].

Based on the overall growth in corporate environmental responsibility [26], as well as the implementation of a common corporate policy within the holdings and the convergence of the development commitments of the structural units of the Australian university [25], it can be assumed that:

H_1: Convergence of monitoring levels of environmental responsibility for enterprises in the same holding.

Based on the high rates of improvement in the overall environmental performance of non-ecological Chinese macroregions [18] and the sustainability indicators of European states [17], as well as the entropy criterion of social development on the correspondence of the upward line to the reduction of entropy and heterogeneity and the downward one to their growth [3], we further propose the following hypotheses:

H_2: Increased homogeneity of holding enterprises leads to lower convergence rates, reduced homogeneity — to accelerated convergence.

H_3: There is a direct relationship between the holding's homogeneity and their level of environmental responsibility.

MATERIALS AND METHODS

As the data was processed, four indicators of the environmental responsibility of ERA rating agency enterprises were presented:

1) energy-resource efficiency — the degree of useful use of energy and resources; geometric average from energy efficiency

Table 1

The Companies under Study and their Subsidiaries

Industry	Number of holdings	Number of enterprises
Oil and gas extraction and pumping	4	52
Engineering and Metal processing	2	8
Transportation	1	19
Chemical industry	1	4
Energy industry	3	22
TOTAL	11	105

Source: Author's calculation.

(the ratio of corporate revenue adjusted to the average sub-sector margin to the amount of energy spent) and resource effectiveness (excluding the division of revenue into normalized indicators of water spent, waste, emissions into the atmosphere and polluted water discharges);

2) technological efficiency — environmental efficiency of activities, ratio of energy spent to resources used and types of environmental impacts (the list is presented in the description of resource efficiency);

3) ecosystem efficiency — the ability of the territory where the company is located to assimilate harmful impacts; the ratio of the area of vegetation to the intensity of environmental impact (resource efficiency indicators are used);

4) transparency of environmental and energy reporting — share of disclosed parameters in the total number of analyzed parameters.

The rating was selected because, when it was developed, the firms were compared not by industries, but by enterprises with similar energy-resource ratios and, thus, under other equal conditions, having similar impacts on the environment. In this regard, for example, nuclear power plants and dam-hydroelectric power plants were considered separately. This approach has allowed us to correctly compare the level of environmental responsibility of enterprises belonging to the same holding and engaged in different activities.

During the study, 11 Russian holdings (companies, groups) and 105 enterprises (their branches, subsidiaries or subsidiary companies) were studied (for the only company from the UK, assets in the Russian Federation were analyzed) (*Table 1*). Holdings were selected for which the environmental indicators of two or more enterprises were openly available. Data from 2017 to 2021 were considered.

Initially, the entropy of environmental characteristics was calculated for each year to assess the orderliness of the various types of environmentalization of enterprises for each holding and on average for all holdings, see formula (1):

$$E_i = \sum_{j=1}^{n} \left[X_{ij} \ln\left(X_{ij} \right) \right], \qquad (1)$$

where E_i — entropy of i-holding; n — number of environmental indicators; X_{ij} — level j- environmental indicator of i- holding.

In order to facilitate interpretation, a minimum normalization of entropy (0 — is the minimum level of order, 1 — is the maximum level) was performed. Previously, the proposed approach to the calculation of entropy was tested in the assessment of differentiation of Russian regions [27].

Table 2

Normalized Entropy Value for Different Types of Environmental Responsibility

Holding number	Min	Max	Average	Standard deviation	Difference between 2021 and 2017 indicator
1	0.000	0.032	0.009	0.013	–0.003
2	0.055	0.271	0.110	0.093	0.215
3	0.562	1.000	0.773	0.202	0.423
4	0.007	0.065	0.028	0.026	0.021
5	0.035	0.107	0.070	0.030	–0.056
6	0.100	0.474	0.275	0.138	0.157
7	0.017	0.188	0.088	0.087	0.148
8	0.095	0.457	0.218	0.141	–0.362
9	0.021	0.091	0.052	0.032	0.058
10	0.058	0.113	0.085	0.024	0.055
11	0.166	0.580	0.376	0.148	–0.185
TOTAL	0.000	1.000	0.190	0.236	0.043

Source: Author's calculation.

Furthermore, for all holdings individually and for their combination for all years, the four characteristics of the level of environmental responsibility are calculated as descriptive indicators: variance, variation coefficient, asymmetry and excess. An analysis of the convergence of the levels of environmental responsibility of enterprises of one holding was carried out. The main convergence measures are beta-convergence and sigma-convergence [28]. In this paper, we used the concept of sigma-convergence, describing a state in which the variation of characteristics at the end of a period is less than at the beginning.

According to all companies and the characteristics of the environmental responsibility of enterprises, the variation factors for different periods were compared. With the reduction of the coefficient of variation, i.e. increasing the homogeneity of enterprises, their convergence was confirmed, as was the approximation of environmental characteristics. With the increase of the variation — divergence, the reverse process.

Also, periods of phase transitions, i.e. qualitative changes in the state of the system, were defined for each holding in relation to homogeneity and convergence [27]. For homogeneity in phase transition, a heterogeneous holding with a coefficient of variation of more than 33% becomes homogenous, or, on the contrary, a homogenic holding is transformed into a heterogeneous holding. The phase transition by convergence, respectively, is recorded when the decrease of the indicators in the enterprises of one holding by their discrepancy or at the beginning of the decreasing of previously divergent characteristics.

Variance and regression analyses have been conducted to assess the relationship between the homogeneity of the holding and the level of its environmental responsibility, as well as the homogeneity and degree of convergence.

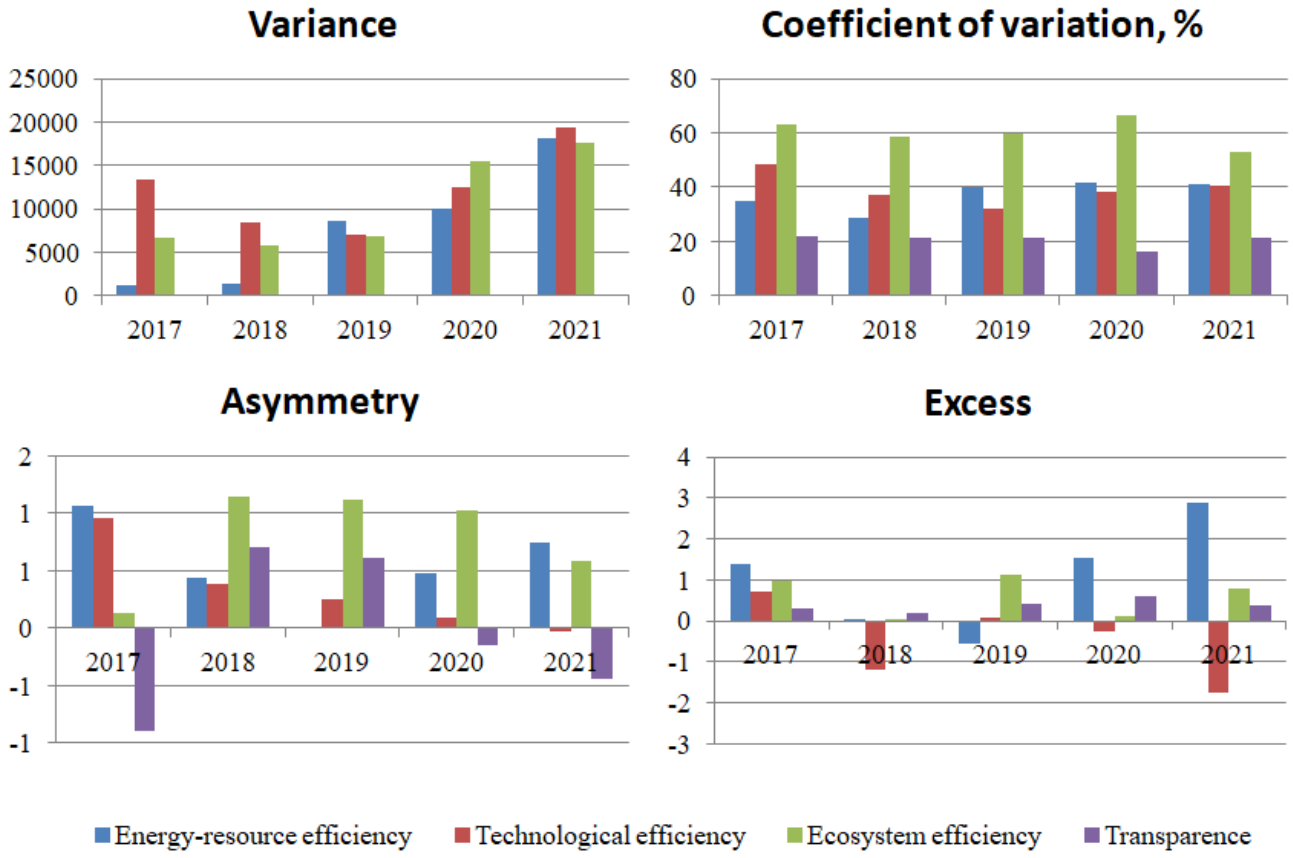

Fig. **Indicators of Descriptive Statistics of Environmental Enterprises into to the Same Holding**

Source: Author's calculation.

RESULTS

Today, the environmental performance of holdings is disorderly (*Table 2*). At the same time, in 2017–2021, the share of this disorder has increased by 4.3% on average. Entropy increased in most holdings (63.6%), with more than half of the increases exceeding 10%. As a result, the characteristics of environmental responsibility of firms must be examined independently by type.

For 2017–2021, for all environmental indicators of enterprises belonging to the same holding, the variance increased, the exception is only disclosure of information (see *Fig.*). And the variation factor predominantly decreased, growth occurred only according to the characteristics of energy and resource efficiency. In terms of energy-resource and ecosystem efficiency, holdings are dominated by under-average enterprises, in terms of transparency of reporting, above-average enterprises; with regard to technological efficiency, since 2017, the proportion of those whose performance was below average has gradually decreased, and by 2021, most enterprises had performance above average. The share of emissions in all environmental characteristics, except technological efficiency, can be recognized as high — above the normal distribution.

Homogeneous holdings prevail in energy-recurrence and technological efficiency indicators, as well as in the level of disclosure; from 2021 homogenous holdings have also become dominant in ecosystem efficiency (*Table 3*). In the whole, it can be noted that during the analyzed period, the homogeneity of holdings increased with simultaneous increase and stability of their state (decrease in the number of phase transitions — transformation of homogenous holdings into heterogeneous and vice versa).

Table 3

Homogeneity and Convergence of Environmental Characteristics of Enterprises of the Same Holding

Indicator	2017	2018	2019	2020	2021	Average	Average share of holdings with phase transitions
Energy and resource efficiency – share of holdings: with homogeneous enterprises	63.64	54.55	54.55	45.45	63.64	56.36	31.82
with enterprises convergence	No data	36.36	27.27	54.55	54.55	43.18	27.27
Technological efficiency – share of holdings: with homogeneous enterprises	45.45	54.55	72.73	54.55	45.45	54.55	31.82
with enterprises convergence	No data	54.55	54.55	54.55	45.45	52.27	31.82
Ecosystem efficiency – share of holdings: with homogeneous enterprises	9.09	18.18	18.18	18.18	36.36	20.00	29.55
with enterprises convergence	No data	45.45	63.64	72.73	63.64	61.36	27.27
Transparency – share of holdings: with homogeneous enterprises	63.64	81.82	72.73	81.82	81.82	76.36	25.00
with enterprises convergence	No data	45.45	54.55	63.64	27.27	47.73	22.73
Homogeneity: average	45.45	52.27	54.55	50.00	56.82	51.82	–
average share of holding with phase transitions	No data	25.00	15.91	13.64	20.45	18.75	–
Convergence: average	No data	45.45	50.00	61.36	47.73	51.14	–
average share of holding with phase transitions	No data	No data	61.36	59.09	50.00	56.82	–

Source: Author's calculation.

Convergence indicators, compared to homogeneity, differ more in terms of different environmental characteristics: periods of convergence of some indicators are accompanied by differences in others. In 2021, convergence was observed for half of the characteristics of the level of environmental responsibility and divergence for the remaining half. This resulted in a slight increase in convergence over the five years under review; the number of phase transitions decreased. At the same time, in 2021, half of holdings with converging holders began to divide, diverge, or converge (holdings with

Table 4

Interrelation of Homogeneity and Convergence Levels of Holding Companies*

Model type	R^2	F-criterion	Significance of the F-criterion
Energy and resource efficiency: linear	0.019	0.823	0.369
logarithmic	0.021	0.892	0.350
inverse	0.020	0.860	0.359
quadratic	0.020	0.413	0.665
cubic	0.020	0.268	0.848
exponential	0.139	6.759	0.013
Ecosystem efficiency: linear	0.081	3.705	0.061
logarithmic	0.066	2.966	0.092
inverse	0.042	1.837	0.183
quadratic	0.084	1.889	0.164
cubic	0.087	1.268	0.298
exponential	0.283	16.556	<0.001

Source: Author's calculation.

Note: * Data are given only for those environmental characteristics for which there is a statistically significant relationship.

phase transitions in homogeneity were only 20.5%).

Given that in 2017–2021, the average share of holdings characterized by convergence was 51.1%, and in 2021 this value did not even reach 50%, we cannot consider convergence to be the dominant trend in holdings, so the H_1 hypothesis is refuted.

Only in terms of energy-resource efficiency and ecosystem was it established that there was a statistically significant dependence of the convergence level of the holding indicators on their current homogeneity, and in both cases the relationship can be described most accurately using an exponential curve: in more heterogeneous holdings, the rate of convergence growth is higher than in homogeneous holdings (hypothesis H_2 for a number of indicators is confirmed; *Table 4*). At the same time, we note that both models have a very low determination coefficient, less than 30%. Accordingly, the level of convergence of enterprises is predominantly determined by the non-current homogeneity of the holdings.

It's also important to remember that the current similarity in companies is based only on the technology component of environmental responsibility, and it's best defined by the cubic curve (*Table 5*). Newton's method determines that the minimum function, namely 48.0, is achieved with a variation factor of 32.1%, which practically corresponds to the threshold value indicating the transition of a homogeneous object into a heterogeneous object. Consequently, it can be concluded that with the decrease in homogeneity of the holding, its level of environmental responsibility first decreases,

Table 5

Relationship between the levels of homogeneity and technological efficiency of holdings*

Model type	R^2	F-criterion	Significance of the F-criterion
Linear	0.019	0.823	0.369
Logarithmic	0.021	0.892	0.350
Inverse	0.020	0.860	0.359
Quadratic	0.020	0.413	0.665
Cubic	0.020	0.268	0.848
Exponential	0.139	6.759	0.013

Source: Author's calculation.

Note: * There is no statistically significant correlation for other studied environmental characteristics.

and then, after the phase transition of holding to heterogeneity, the degree of responsibility begins to increase. On this basis, the H_3 hypothesis is refuted.

DISCUSSION

The possibility of describing the relationship between the homogeneity and the overall technological efficiency of the holding using the U-shaped curve suggests that Russian companies are using two main strategies of environmentalization: the first is the adoption of uniform corporate standards and increased responsibility of each enterprise that is part of the holding; the second is the formation of "model" enterprises, with minimal environmental footprint, due to which the public pressure on the company is reduced, while retaining other economically profitable enterprises that have a significant negative impact on the environment. The choice of the second strategy may be due to the fact that it is easier to implement, given the limited possibility of greening or the extremely low return on environmental investment in a number of sub-sectors. This can be related to, among other things, statements from a number of holdings, such as the joint company "RUSAL" and Evraz Group, about the planned allocation of the "dirtiest" assets to the new structures (both allocations were not officially held due to changes in taxation rules and the introduction of foreign economic sanctions).

Note that the use of the strategy of "model" enterprises can also be explained by the current low level of homogeneity and convergence of enterprises of one holding. Other possible factors include the holdings' attraction to investment firms that do not have direct control over assets, invest in securities, and try to maximize profits. Furthermore, because firms within the same holding may be in different sub-industries, they could face varying external pressure from stakeholders.

Furthermore, the practice of developing "model" enterprises inside the holding results in a lack of correlation between the amount of homogeneity and convergence on this indicator. In terms of transparency in company reporting, the statistical insignificance of the correlation can be explained by firms' propensity to reveal the characteristics for which they specialize.

Unlike technological efficiency (using greener technologies), increased energy-resource efficiency (resource savings) and ecosystem efficiency (greenery) in most

cases do not require such significant capital investments. As a result, it appears that the holdings mostly utilize a unified corporate approach in regard to these areas, leading to the improvement of the most environmentally enterprises. At the same time, compared with emerging competitors, there is a decrease in the relative characteristics of previously greener enterprises, because they are given less attention and their internal motivation is insufficient to accelerate greening. Thus, in relation to resource savings and greenery, there is a convergence of indicators (growth of non-ecological characteristics and decrease of more environmental characteristics) without a general change in the performance of holdings.

The large number of phase transitions confirms the weakness of the internal motivation of enterprises, the unequal attention of managing bodies to them over different years, as well as the prevalence of border states of homogeneity and heterogeneity of holdings.

CONCLUSION

According to the study, the transformation of Russian holdings corresponds to the ascending line of the entropic criterion of social development, but the phase transition from heterogeneous to homogeneous state has not been completed, and homogenic holdings are stable. Thus, in 2021, the number of holdings with homogeneous enterprises only slightly, by 6.8 p.p., exceeded the numbers of heterogeneous enterprises, but in the last five years this figure has increased by 25%. At the same time, the convergence of the environmental performance of enterprises in 2017–2021 was observed on average for only half of them, respectively; this trend cannot be recognized as dominant.

Therefore, the availability and speed of phase transitions are largely determined by the corporate policy: the introduction of uniform environmental standards or the practice of "model" enterprises. The first type of policy is mainly implemented for areas that do not require significant investments (resource savings and greenery), increases enterprise homogeneity and the rate of their convergence, but often with the goal of reducing the negative impact of previously least environmentally friendly enterprises; attention is weakened to those that have already had a lower environmental footprint, and because of their insufficient internal motivation for environmentally sound conduct. Based on the above, uniform environmental standards do not significantly improve the overall performance of the holding.

The transition to ecological technologies often requires significant capital investments. And Russian holdings, apparently, sometimes decide not to conduct general environmentalization but to create enterprises with a minimal environmental footprint while preserving non-environmental, but profitable. With this in mind, there is currently no increase in uniformity and convergence in the level of environmental impact of the technologies used. At the same time, there is a U-shaped relationship between the homogeneity of enterprises in terms of technological efficiency and its overall size for the holding: the decrease in homogeneity of a holding at first reduces its level of environmental responsibility, and then, after the phase transition of the holding to heterogeneous (introduction of the practice of "model" enterprises), the level of responsibility begins to increase. Companies prefer to reveal the characteristics in which they perform best.

In view of the above, due to the impossibility of selecting the incentive and disincentive instruments of environmental responsibility of individual enterprises to rely on the indicators of the consolidated non-financial reporting of the holding, it is worth recommending to the state and regional authorities to use the reports and to request the environmental performance of each of the enterprises. In their goals, managers should consider the demonstrated consequences of

implementing all types of corporate policy and improve its effectiveness by preventing typical errors (in particular, non-systematic monitoring and insufficient attention to enterprises with the current minimum environmental footprint in the holding). Implementation of these recommendations in practice will contribute to the overall improvement of the resilience of the Russian economy.

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