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SECTOR-SPECIFIC SOLUTIONS FOR QUALITY MANAGEMENT OF GREEN DIGITAL PRODUCTS TO SUPPORT SUSTAINABLE DEVELOPMENT IN AGRICULTURE, INDUSTRY, AND THE SERVICE SECTOR

Abstract: *The research aims to develop industry-specific solutions for managing the quality of green digital products to support sustainable development in agriculture, industry, and the service sector of developing economies. To this end, it examines the empirical experience of the 30 most sustainable developing economies, as measured by the SDG Index, in each geographic region of the world in 2026. The results quantitatively assess the relationship between the quality of green digital products and the sustainability of sectoral development in developing economies, revealing that this relationship is strongest in industry but weak in agriculture and the service sector. An industry-specific model of green digital product quality in developing economies was developed, demonstrating that AI-driven automation of production and distribution processes is the most effective product quality management measure in developing economies, whereas the complementary measure of green HRM is relatively ineffective. Based on this model, a new approach to such management was developed and supported by a roadmap extending to 2036. This approach enables flexible adaptation to the specific characteristics of each sector and thereby promotes the most sustainable progress by combining improvements in quality and productivity across all sectors while maintaining a balanced sectoral structure of national GDP.*

Keywords: *Industry-specific solutions, quality management, green digital products, sustainable development, agriculture, industry, service sector*

1. Introduction

Transition processes in the modern economy have fundamentally transformed the nature of competition in markets open to international participation. Although product quality remains at the core of the global competitiveness of producers and sellers, buyers' quality requirements have changed,

as have approaches to measuring quality. The relationship between quality and global competitiveness is most clearly reflected in product quality certification under the international ISO 9001 standard.

One of the large-scale transition processes that has substantially altered the conditions of global competition and perceptions of product quality in recent years is the

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worldwide transition toward a green model of economic activity in response to climate change. Circular use of natural resources, involving the reintegration of raw materials and materials into production and distribution processes, makes it possible to reduce the depletion of natural resources and decrease waste generated by economic activity.

A distinctive feature of environmentally friendly production is the creation of green jobs, in which professional activities require employees to pay greater attention to environmental protection. Green jobs represent a complex synthesis of, on the one hand, broad opportunities and favorable conditions for environmental protection provided by employers that foster an environmentally responsible organizational culture, make green investments, and encourage environmental initiative among their employees.

On the other hand, employees occupying green jobs possess a set of environmental competencies, both personal (e.g., a pronounced commitment to caring for the environment) and professional (e.g., in-depth knowledge of current environmental legislation and proficiency in advanced environmental protection technologies). The environmental characteristics of products, shaped by the extent to which green personnel are involved in their production and distribution, largely determine product quality and global competitiveness in the modern world.

Another transition process characteristic of the present period that significantly affects the interpretation of product quality and the ways in which it can be improved in the context of global competition is the digitalization of economic activity associated with the Fourth and Fifth Industrial Revolutions. Today, production and distribution operations are undergoing comprehensive automation based on artificial intelligence (AI) technologies.

AI-driven automation enables producers and distributors not only to manufacture

technically more sophisticated products but also to improve their quality characteristics, reduce defect rates, and achieve substantial productivity gains. Accordingly, the digital characteristics of products, which depend on the AI-driven automation of their production and distribution, largely determine product quality and global competitiveness.

The systemic response of producers to both transition processes in the contemporary economy has been the production of green digital products. Developed OECD economies were the first to establish such production. Through substantial investment, they succeeded in balancing AI-driven automation with green employment in production while simultaneously achieving high-quality green digital products, outstanding productivity, and strong global competitiveness.

The problem is that developing economies cannot simply replicate the successful experience of developed economies because they lack sufficient investment resources. AI-driven automation and green employment come into sharp conflict with one another, a contradiction that is particularly pronounced in developing economies and prevents them from achieving high product quality and strong global competitiveness.

The need to address this problem stems from the fact that the insufficient effectiveness of green digital product quality management in developing economies reduces their global competitiveness and limits their access to markets open to international participation. As a result, developing economies become less sustainable, widening the gap in the level and pace of sustainable development between developed and developing economies and intensifying global inequality at the country level.

As an original solution to this problem, this research proposes an innovative approach to managing the quality of green digital products that provides greater management flexibility through industry-specific adaptation. The implementation of the authors' approach in

developing economies will enable them to achieve significantly greater effectiveness in managing the quality of green digital products, attain strong global competitiveness, and secure a stable position in markets open to international participation. Accordingly, the research aims to develop industry-specific solutions for managing the quality of green digital products to support sustainable development in agriculture, industry, and the service sector of developing economies.

2. Literature Review

2.1. A Critical Perspective on the Established Universal Approach to Managing the Quality of Green Digital Products

The theoretical foundation of the conducted research is provided by the concept of product quality management reflected in the works of Mamurova et al. (2025) and Yulisetiari et al. (2024). Nowadays, an approach to managing the quality of green digital products has emerged that can be described as universal because it applies the same product quality management tools across all sectors of the economy.

The principal tools include HR management of green personnel through their selection, recruitment, corporate training, and work incentives (Bogoviz et al., 2018; Egnatosyan et al., 2023), as well as AI-driven automation of production and distribution processes through the acquisition of existing digital technologies and the development of proprietary ones, followed by their implementation and use in economic activity (Babakhanova et al., 2024; Kaliyeva et al., 2025; Ualtayev et al., 2024).

In quantitative terms, product quality, including the quality of green digital products, is currently commonly measured in terms of the value of officially registered international ISO 9001 quality certificates within an economy, as this enables

international comparisons.

A critical examination of the existing approach reveals a significant limitation: it disregards sector-specific differences in the relationship between green employment and AI-driven automation, on the one hand, and product quality across different sectors of the modern economy (industry, agriculture, and the service sector) on the other. Without accounting for these differences, the established quality management approach demonstrates limited effectiveness in each sector, preventing the full realization of the overall potential for improving the quality of green digital products in developing digital economies.

2.2. Sector-Specific Features of Managing the Quality of Green Digital Products from the Perspective of Sustainable Development

The sustainability of a sector's development is commonly measured in terms of the value added generated within that sector and its share in the country's GDP structure. An increase in the value added generated by a particular sector and an expansion of its share in the structure of an open national economy directly indicate growth in productivity, production capacity, and capacity utilization within that sector. They also indirectly signal improvements in the quality of the sector's products, because only high-quality products can achieve strong global competitiveness and high demand, thereby enabling an expansion in production volumes (Civelek et al., 2025).

Accordingly, when product quality is low, insufficient global competitiveness makes production economically unjustified because it hinders sales. At the level of the national economy, sustainable economic development implies maintaining a stable sectoral structure of GDP while increasing the value added generated in each sector (Drobot et al., 2024). The sector-specific features of managing the quality of green digital products are as follows.

In agriculture, HR management of green personnel involves soil conservation and the climate adaptation of natural resource use, while AI-driven automation of production and distribution processes is associated with the development of smart farms and online trade in finished agricultural products. The contradiction between quality and productivity lies in the fact that improving quality requires an individualized approach to each cultivated plant or animal, whereas increasing productivity requires the standardization of plant and animal care (Litvinova et al., 2017; Troyanskaya et al., 2017).

In industry, HR management of green personnel involves organizing recycling and improving the resource and energy efficiency of economic activity, while AI-driven automation of production and distribution processes is embodied in the creation of autonomous smart industrial production systems. The contradiction between quality and productivity is manifested in the fact that AI-automated industrial production achieves economies of scale but reduces the number of jobs (Paizov et al., 2011; Usenov et al., 2022). In the service sector, HR management of green personnel is associated with reducing the resource and energy intensity of service delivery processes and minimizing the waste they generate, while AI-driven automation of production and distribution processes involves shifting services to an electronic format. The contradiction between quality and productivity lies in the fact that AI-based automation tools, such as chatbots and online consultants, make it possible to increase productivity but lead to job losses and are also less functional and less attractive to customers than green personnel. (Omir et al., 2024; Tovmasyan, 2023).

2.3. Gaps in the Literature, RQs, and Hypotheses

The review of the available research literature revealed that only a limited number of published studies, such as those by Gyiazov et al. (2023a, 2023b), address certain aspects

of managing the quality of green digital products in developing economies (Tanasic et al., 2022). Nevertheless, the sector-specific characteristics of such management, as well as the relationship between the quality of green digital products and production productivity in developing economies, remain insufficiently studied, constituting a gap in the literature. This gap needs to be addressed and gives rise to the following two research questions (RQs):

RQ₁: How is the management of the quality of green digital products related to the sustainability of agricultural, industrial, and service-sector development in developing economies?

Based on the previously published studies by Galoyan et al. (2023a, 2023b), which highlight differences in the effects of digitalization and greening measures across sectors, this article proposes Hypothesis H₁: the degree of AI-driven automation of production and distribution processes and the extent to which green personnel are involved in these processes are differently associated with the shares of agriculture, industry, and the service sector in the GDP structure of developing economies.

RQ₂: How do the quality characteristics of green digital products and productivity in agriculture, industry, and the service sector affect the intensity of quality certification for these products in developing economies?

In accordance with the existing studies by Mkrtchyan and Navasardyan (2024) and Orlova et al. (2024), which draw attention to differences in the intensity of product quality certification across sectors, this article proposes Hypothesis H₂: the quality characteristics of green digital products (the degree of AI-driven automation of production and distribution processes and the extent to which green personnel are involved in these processes) and the shares of agriculture, industry, and the service sector in GDP affect the intensity of quality certification for these products in developing economies in different ways.

To address the identified gap in the literature, provide research-based answers to the stated RQs, and test the proposed hypotheses, this research examines the sector-specific features of managing the quality of green digital products in agriculture, industry, and the service sector from the perspective of the sustainability of these sectors, drawing on the empirical experience of developing economies.

3. Materials and Methods

3.1. Statistical Basis of the Study and Sample Structure

To reflect the most recent empirical experience of the modern economy, this article examines statistical data available at the beginning of 2026 and representing the results for 2025. To ensure a balanced representation of developing economies in the sample and maintain its representativeness, five countries from each geographic region of the world, as identified by UNSTATS (2026), were included.

To account for the sustainability of national economies, the sample includes five developing economies that are not OECD members and have the highest SDG Index

scores in each of the six world regions. From Eastern Europe and Central Asia, the sample includes Croatia (with an SDG Index score of 82.4 points), Malta (79.3 points), Moldova (78.8 points), Belarus (78.5 points), and Serbia (78.2 points).

From Eastern and South Asia, the sample includes Thailand (75.3 points), China (74.4 points), Maldives (74.0 points), Vietnam (73.4 points), and Singapore (71.5 points). From LAC, the sample includes Uruguay (77.4 points), Cuba (76.5 points), Argentina (74.8 points), Dominican Republic (74.1 points), and Brazil (73.8 points). From MENA, the sample includes Tunisia (72.0 points), Morocco (71.7 points), Jordan (71.0 points), Algeria (70.1 points), and the United Arab Emirates (69.8 points).

From Oceania, the sample includes Fiji (72.9 points) and Papua New Guinea (53.4 points), as well as Palau, the Solomon Islands, and Tonga, for which no SDG Index scores were assigned. From Sub-Saharan Africa, the sample includes Mauritius (70.3 points), Cabo Verde (67.3 points), Gabon (65.6 points), Namibia (65.5 points), and Botswana (64.5 points). The resulting sample and the values of the statistical indicators examined for each country are presented in Table 1.

Table 1. Statistical basis of the research

Country	AI technology diffusion, score 0–100	Green employment, score 0–100	ISO 9001 quality/bn PPP\$ GDP	Industry (including construction), value added (% of GDP)	Agriculture, forestry, and fishing, value added (% of GDP)	Services, value added (% of GDP)
Algeria	52.21	58.36	2.01	34.80	14.51	45.68
Argentina	49.15	43.40	17.24	22.87	5.53	56.15
Belarus	41.49	54.48	86.75	31.58	6.90	49.98
Botswana	38.15	32.98	1.42	27.88	1.78	64.63
Brazil	59.17	47.89	13.57	20.15	6.09	59.74
Cabo Verde	13.92	52.06	15.90	10.72	5.04	67.92
China	77.74	83.67	61.38	35.64	6.66	57.70
Croatia	50.46	27.69	55.49	18.95	2.83	60.93
Cuba	20.85	0.00	0.00	23.85	1.24	73.39

Dominican Republic	38.98	39.64	2.66	28.42	4.60	60.10
Fiji	32.48	49.90	0.00	13.88	14.05	56.96
Gabon	38.30	49.99	0.00	47.19	6.75	42.34
Jordan	60.63	45.10	22.94	27.37	5.56	56.77
Maldives	37.53	53.15	0.00	9.33	4.59	69.86
Malta	46.86	5.21	27.94	10.08	0.47	81.33
Mauritius	41.74	37.79	21.13	17.69	4.62	63.87
Moldova	27.19	45.27	7.31	16.92	7.38	61.46
Morocco	53.70	36.31	9.88	25.25	10.55	52.31
Namibia	26.30	42.75	4.71	28.95	6.99	54.98
Palau	34.33	0.00	0.00	13.02	2.73	73.08
Papua New Guinea	24.37	0.00	0.00	36.53	17.02	41.96
Serbia	46.62	41.70	66.43	22.31	3.29	59.73
Singapore	69.59	28.63	19.39	22.67	0.02	71.59
Solomon Islands	34.33	0.00	0.00	23.37	29.73	46.92
Thailand	58.94	50.91	26.10	31.07	8.75	60.18
Tonga	27.09	0.00	0.00	17.67	18.57	49.54
Tunisia	47.88	51.29	19.57	21.96	10.29	62.69
United Arab Emirates	67.95	58.90	27.14	44.33	0.77	54.90
Uruguay	46.84	38.92	35.16	16.89	6.38	65.17
Viet Nam	60.74	46.86	14.41	37.65	11.64	42.74

Source: Developed by the authors based on the materials from Global Green Growth Institute (GGGI, 2026), Oxford Insights (2026), WIPO (2026), and World Bank (2026a, 2026b, 2026c).

As shown in Table 1, the sample consists of 30 countries. The set of variables examined, whose values are presented in Table 1, includes the degree of AI-driven automation of production and distribution processes (Dg), as assessed by Oxford Insights (2026); the extent of green personnel involvement in these processes, as assessed by the Global Green Growth Institute (GGGI, 2026); the value of officially registered ISO 9001 quality certificates (QI), as assessed by WIPO (2026); and the shares of agriculture (Ag), as assessed by the World Bank (2026a), industry (Id), as assessed by the World Bank (2026b), and the service sector (Sv), as assessed by the World Bank (2026c), in GDP.

3.2. Research Design

At the first stage of the research, correlation analysis is used to answer RQ₁. This method is applied to calculate the correlation coefficients between the shares of agriculture (Ag), industry (Id), and the service sector (Sv) in GDP and the degree of AI-driven automation of production and distribution

processes (Dg), as well as the extent of green personnel involvement in these processes (Gr).

Hypothesis H₁ is considered supported if the variation in correlation coefficients across sectors is high, that is, exceeds 30% in absolute terms. Based on the results of the correlation analysis, general recommendations are formulated for improving the management of the quality of green digital products to support sustainable development in each sector of developing economies: agriculture, industry, and the service sector. A general multicollinearity test is also conducted to identify and exclude any mutually duplicative variables, if present.

At the second stage of the research, regression analysis is used to answer RQ₂. This method is applied to determine the regression relationship between the value of officially registered ISO 9001 quality certificates (QI), as the dependent variable, and a set of independent variables, including Dg, Gr, Ag, Id, and Sv. The research model is specified as follows:

$$QI = a + b_1 Dg + b_2 Gr + b_3 Ag + b_4 Id + b_5 Sv, e \quad (1)$$

In model (1), a is the constant, b represents the regression coefficients, and e is the standard error of the overall model. Hypothesis H_2 is considered supported if the variation in the regression coefficients b_3 , b_4 , and b_5 is high (i.e., exceeds 30% in absolute terms). The reliability of the regression analysis results is assessed using Fisher's F-test, Student's t-test, residual analysis as a test for heteroskedasticity, and standard errors for each independent variable.

At the third stage of the research, a forecast is developed to determine the prospects for the sustainable development of agriculture, industry, and the service sector by projecting increases in the degree of AI-driven automation of production and distribution processes and the extent of green personnel involvement in these processes through 2036. For this purpose, the Monte Carlo method is used to generate 100 random values representing projected Dg and Gr values, considering their sample means and standard deviations in 2026.

The resulting projected values of the independent variables, Dg and Gr , are substituted into the regression equation (1). This makes it possible to identify the expected future values of the dependent variable QI , that is, the probable value of officially registered ISO 9001 quality certificates. Based on the identified projected values, a roadmap for improving the quality of green digital products in developing countries is developed.

4. Results

4.1. Relationship Between the Quality of Green Digital Products and the Sustainability of Sectoral Development in Developing Economies

At this first stage of the study, correlation analysis of the statistical data presented in Table 1 was conducted to answer RQ_1 . The resulting correlation coefficients between the management of the quality of green digital products and the sustainability of sectors in developing economies in 2026 are illustrated in Figure 1.

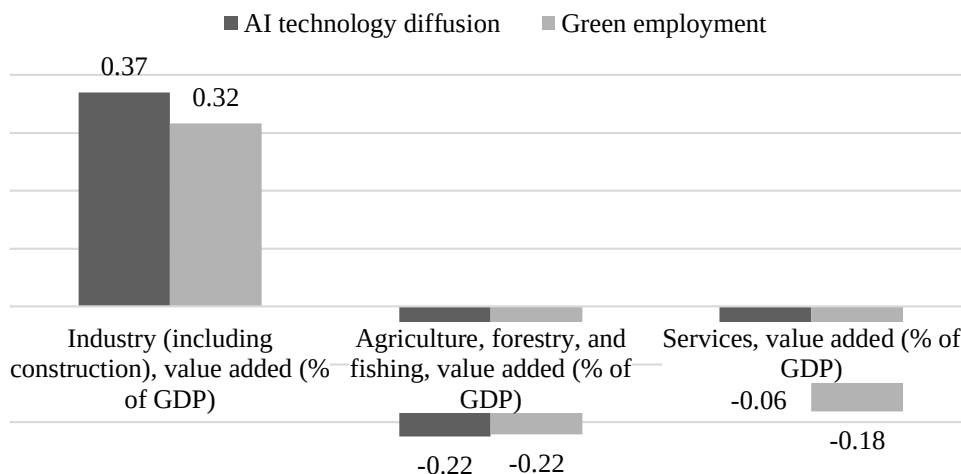


Figure 1. Correlation between green digital product quality management and sectoral sustainability in developing economies

Source: Developed by the authors

The results of the correlation analysis presented in Figure 1 indicate that, in developing economies, a higher degree of AI-driven automation of production and distribution processes is associated with greater sustainability in industry (the correlation between Dg and Id was 0.37), but with lower sustainability in agriculture (the correlation between Dg and Ag was -0.22) and the service sector (the correlation between Dg and Sv was -0.06).

Similarly, as the extent of green personnel involvement increases, the sustainability of industry rises (the correlation between Gr and Id was 0.32), whereas the sustainability of agriculture declines (the correlation between

Gr and Ag was -0.22), as does the sustainability of the service sector (the correlation between Gr and Sv was -0.18).

The variation in the obtained correlation coefficients between the shares of agriculture, industry, and the service sector in the GDP structure of developing economies and the degree of AI-driven automation of production and distribution processes amounted to 1055.11%, while the corresponding variation for the extent of green personnel involvement was -1047.64%. Thus, in both cases, the variation was very high, exceeding 30% in absolute terms. This supports Hypothesis H₁. The results of the multicollinearity test are presented in Table 2.

Table 2. Cross-correlation of variables

Cross-correlation	Dg	Gr	Ql	Id	Ag	Sv
Dg	1.00	-	-	-	-	-
Gr	0.48	1.00	-	-	-	-
Ql	0.43	0.37	1.00	-	-	-
Id	0.37	0.32	0.08	1.00	-	-
Ag	-0.22	-0.22	-0.30	0.11	1.00	-
Sv	-0.06	-0.18	0.05	-0.69	-0.66	1.00

Source: Developed by the authors

Since none of the correlation coefficients in Table 2 exceeded 0.90, there are no duplicative variables in this study, and the multicollinearity test was successfully passed.

4.2. Sectoral Model of Green Digital Product Quality and a Roadmap for Its Improvement in Relation to Productivity

At this second stage of the research, regression analysis of the statistical data presented in Table 1 was conducted to answer RQ₂. The results are presented in Table 3. The results presented in Table 3 indicate that the strength of the linear relationship between the dependent variable and the set of

independent variables is high, as the multiple R was 0.5394. Simultaneously, the management factors (the degree of AI-driven automation of production and distribution processes and the extent of green personnel involvement in these processes), together with the shares of agriculture, industry, and the service sector in GDP, determine 29.09% of the variation in the intensity of quality certification of green digital products in developing economies.

Accordingly, a sectoral model of green digital product quality in developing economies was developed in the form of the following multiple linear regression equation:

$$Ql=70.30+0.56Dg+0.13Gr-1.53Ag-0.79Id-0.97Sv, e=20.8265 \quad (2)$$

Table 3. Results of the regression analysis

Regression statistics		Fisher's F-test		
Multiple R	0.5394	Significance F	0.1199	
R ²	0.2909	Significance level	0.15	
Normalized R ²	0.1432	k ₁ =m	5	
Standard error	20.8265	k ₂ =n-m-1=30-5-1	24	
Observations (n)	30	Table F	1.8047	
Factor variables (m)	5	Observed F	1.9695	
Variance analysis				
-	df	SS	MS	
Regression	5	4271.3058	854.2612	
Residual	24	10409.8443	433.7435	
Total	29	14681.1501	-	
Coefficients, standard errors, and Student's t-test				
-	Coefficients	Standard error	t-statistic	P-value
Y-intercept	77.3050	81,9538	0.9433	0.3549
Dg	0.5573	0,3132	1.7792	0.0879
Gr	0.1320	0,2291	0.5760	0.5700
Id	-0.7880	0,7584	-1.0391	0.3091
Ag	-1.5275	1.1421	-1.3374	0.1936
Sv	-0.9753	0.9980	-0.9773	0.3382

Source: Developed by the authors

Model (2) indicates that a one-point increase in the degree of AI-driven automation of production and distribution processes in developing economies contributes to an increase in the value of officially registered ISO 9001 quality certificates by 0.56 bn PPP\$ GDP. For the independent variable Dg, Student's t-test was passed at the 0.10 significance level, as the t-statistic was 1.7792 and the p-value was 0.0879. The standard error for the independent variable Dg was 0.3132 and was therefore relatively low.

In turn, a one-point increase in the extent of green personnel involvement in the economic activities of developing economies leads to an increase in the value of officially registered ISO 9001 quality certificates by 0.13 bn PPP\$ GDP. For the independent variable Gr, Student's t-test was passed at the 0.60 significance level, as the t-statistic was 0.5760 and the p-value was 0.5700. Consequently, the relationship between green employment and the prevalence of international ISO 9001 quality certificates in developing economies is relatively weak. The standard error for the independent variable Gr

was 0.2291 and was therefore relatively low.

At the same time, a 1% increase in the share of industry in the GDP structure of developing economies results in a decrease in the value of officially registered ISO 9001 quality certificates by 0.79 bn PPP\$ GDP. For the independent variable Id, Student's t-test was passed at the 0.35 significance level, as the t-statistic was -1.0391 and the p-value was 0.3091. The standard error for the independent variable Id was 0.7584 and was therefore relatively low.

A 1% increase in the share of agriculture in the GDP structure of developing economies leads to a decrease in the value of officially registered ISO 9001 quality certificates by 0.53 bn PPP\$ GDP. For the independent variable Ag, Student's t-test was passed at the 0.20 significance level, as the t-statistic was -1.3374 and the p-value was 0.1936. The standard error for the independent variable, Ag, was 1.1421, which was relatively low.

Additionally, a 1% increase in the share of the service sector in the GDP structure of developing economies is accompanied by a decrease in the value of officially registered ISO 9001 quality certificates by 0.97 bn

PPP\$ GDP. For the independent variable Sv, Student's t-test was passed at the 0.35 significance level, as the t-statistic was -0.9773 and the p-value was 0.3382 . The standard error for the independent variable Sv was 0.9980 and was therefore relatively low. The variation in the obtained regression coefficients for the independent variables Id, Ad, and Sv (b_3 , b_4 , and b_5 in research model (1)) in model (2) amounted to -35.05% and was therefore very high, exceeding 30% in

absolute terms. This supports Hypothesis H₂. The standard error of model (2) was relatively low at 20.8265 , indicating the overall high quality of the model. Fisher's F-test was passed for model (2) at the 0.15 significance level, since the significance F was 0.1199 and, with $k_1=5$ and $k_2=24$, the table F-value was 1.8047 , which was exceeded by the observed F-value of 1.9695 . The residuals of the regression model are presented in Table 4.

Table 4. Analysis of regression model residuals

Observation	Predicted Ql	Residue	Observation	Predicted Ql	Residue
1	19.9621	-17.9521	16	22.2716	-1.1416
2	29.1823	-11.9423	17	13.8944	-6.5844
3	23.4437	63.3063	18	25.0059	-15.1259
4	15.1951	-13.7751	19	10.4898	-5.7798
5	33.1631	-19.5931	20	10.7270	-10.7270
6	9.5458	6.3542	21	-4.8299	4.8299
7	37.1415	24.2385	22	27.9314	38.4986
8	30.4001	25.0899	23	32.1413	-12.7513
9	-3.3415	3.3415	24	-13.1495	13.1495
10	16.2219	-13.5619	25	20.3312	5.7688
11	14.0496	-14.0496	26	1.8028	-1.8028
12	16.4522	-16.4522	27	16.5881	2.9819
13	31.6178	-8.6778	28	33.2952	-6.1552
14	22.7372	-22.7372	29	21.9338	13.2262
15	16.1274	11.8126	30	28.1983	-13.7883

Source: Developed by the authors.

To perform the heteroskedasticity test, Figure 2 was constructed based on the residual analysis results presented in Table 4, with the residuals shown on the y-axis and the independent variables in model (2) shown on the x-axis.

The residual plots in Figure 2 show a random dispersion of points around the horizontal axis. Therefore, heteroskedasticity is absent, confirming the reliability of model (2). Thus, all diagnostic tests were successfully passed and confirmed the suitability of model (2) for further use in the subsequent stages of the presented research.

At this third stage of the research, to determine the prospects for the sustainable development of agriculture, industry, and the

service sector, a forecast was developed for increases in the degree of AI-driven automation of production and distribution processes and the extent of green personnel involvement in these processes through 2036. Accordingly, projected changes in the values of the independent variables Dg and Gr were estimated for this period.

To generate the forecast, the Monte Carlo method was used to produce 100 random values for each of Dg and Gr, representing their projected values while accounting for their sample means in 2026 (44.18 and 37.43 , respectively) and standard deviations (15.33 and 21.27 , respectively), as presented in Table 5.

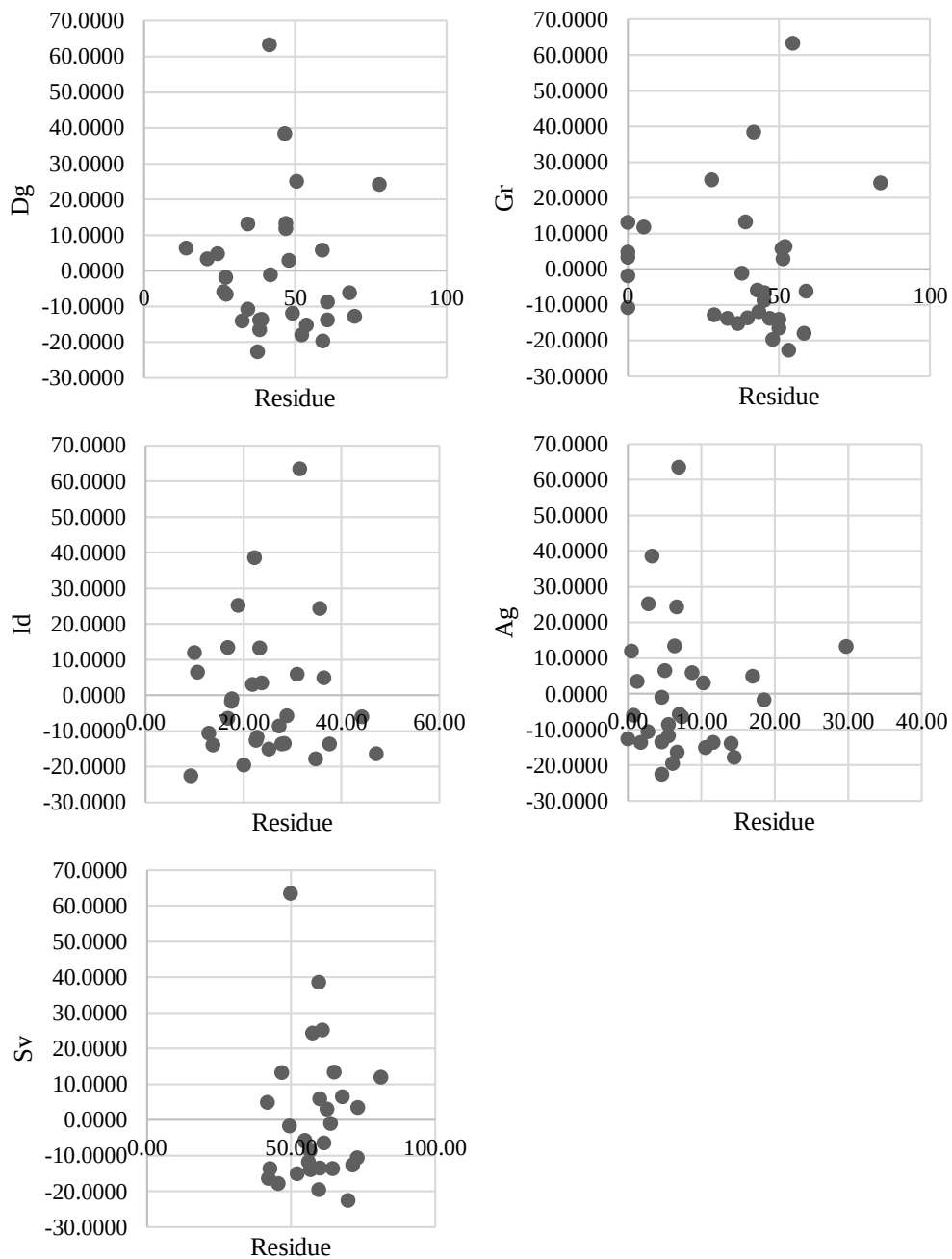


Figure 2. Graphs of residues
Source: Developed by the authors

Table 5. Projected values of Dg and Gr through 2036 (Developed by the authors)

No.	Dg	Gr	No.	Dg	Gr
1	56.1553	84.0351	51	29.5686	49.38
2	29.2062	40.4807	52	37.6498	14.6969
3	61.6362	64.0774	53	50.4008	5.85169
4	62.0925	9.06716	54	53.9941	7.96459
5	63.4191	24.9311	55	38.2485	59.0071
6	70.887	46.8356	56	42.2298	9.82872
7	34.8504	25.2392	57	39.0434	30.6189
8	56.3729	43.9949	58	40.8138	93.3648
9	43.8698	72.0765	59	80.579	43.0792
10	36.2255	58.9528	60	34.6919	30.0513
11	46.4143	27.7996	61	43.1126	56.064
12	59.7137	36.0696	62	19.2267	29.2527
13	76.5382	34.8438	63	38.151	34.9585
14	47.6761	14.3423	64	14.6587	32.0904
15	28.7245	1.42692	65	56.3922	82.0874
16	41.2952	34.7733	66	25.6861	63.0595
17	57.4133	24.776	67	56.6092	84.107
18	37.4515	69.8249	68	60.2422	36.9914
19	47.2836	24.1708	69	51.7837	28.4852
20	40.1558	47.1452	70	52.4991	61.3783
21	49.9337	51.4022	71	56.6451	9.20117
22	25.6399	45.6336	72	43.0749	31.0475
23	49.1433	9.75298	73	25.0996	62.8191
24	28.2994	24.9813	74	33.0675	0.33015
25	42.7831	44.2496	75	23.405	52.4553
26	28.0547	-5.545	76	36.426	-16.956
27	64.6506	46.8535	77	38.2459	44.8451
28	49.8784	24.9717	78	44.6791	32.591
29	44.0375	7.98582	79	43.2289	25.4972
30	61.7692	31.9324	80	54.0503	75.5634
31	25.9456	70.3538	81	42.5109	55.2581
32	33.2482	29.5846	82	39.2822	58.1639
33	62.8623	88.0704	83	25.7563	19.2034
34	53.0203	65.3401	84	58.3092	66.6971
35	66.4096	53.2018	85	30.7705	21.4173
36	47.6207	45.8954	86	36.1597	52.6291
37	24.7669	15.812	87	54.9491	43.9573
38	42.7972	67.2869	88	31.5806	39.0302
39	69.8815	16.982	89	38.2864	18.5222
40	41.0142	24.6613	90	25.2715	3.09252
41	55.5395	35.1239	91	57.7414	35.3807
42	37.7473	51.4224	92	48.0345	16.126
43	50.7038	60.5441	93	46.1893	78.8895
44	40.3037	43.2091	94	32.9512	25.8931
45	27.6305	35.9734	95	49.084	6.80878
46	35.4337	64.3688	96	44.2122	63.0125
47	50.1862	6.05104	97	27.7497	30.6121
48	73.2498	17.8161	98	48.5463	37.4357
49	55.7193	41.4856	99	67.6183	54.3183
50	44.2228	66.5926	100	44.5735	11.7364

The projected values of the independent variables Dg and Gr presented in Table 5 are organized by constructing histograms of their normal distribution, as shown in Figure 3.

In the histograms, values below the 2026 baseline levels (Dg below 44.18, that is, from 14.66 to 41.03, and Gr below 37.43, that is,

from 5.11 to 27.17) are considered unlikely because they contradict the general trends of technological progress, the development of environmental communities, and efforts to combat climate change. Therefore, these values are excluded from further analysis in this research.

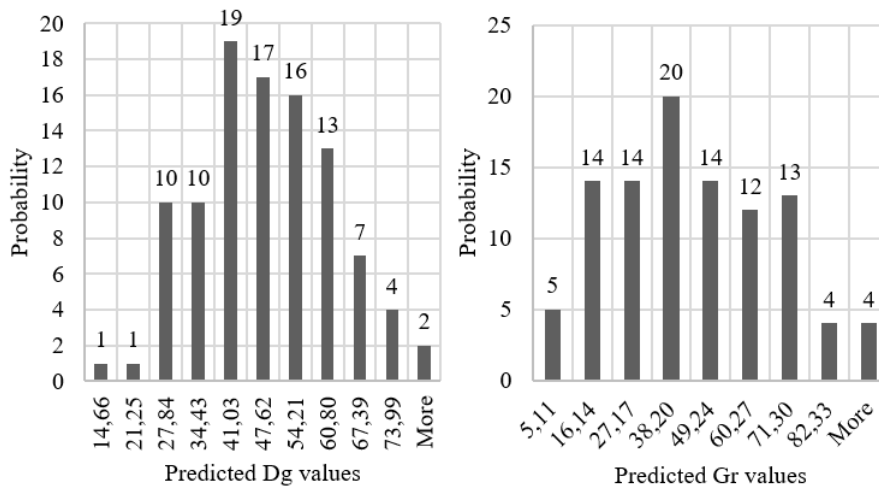


Figure 3. Histograms of the normal distribution of forecast values

Source: Developed by the authors

The remaining, highly probable values are substituted into the regression model (2). This makes it possible to determine the expected future values of the dependent variable QI, that is, the probable value of officially registered ISO 9001 quality certificates. Based on the identified projected values, a roadmap for improving the quality of green digital products in developing countries was developed, as presented in Table 6.

To improve the management of the quality of green digital products in support of the sustainable development of agriculture, industry, and the service sector in developing economies, it is recommended to increase the degree of AI-driven automation of production and distribution processes to 73.99 points by 2036 (+61.45% compared with 2026), as well as to increase the extent of green personnel involvement in the economic activities of developing economies to 82.33 points by

2036 (+119.97% compared with 2026).

The authors' recommendations form the scientific core of the proposed new sector-specific approach to managing the quality of green digital products, which differentiates this management across sectors of developing economies. The roadmap presented in Table 6 demonstrates that implementation of the authors' recommendations will increase the value of officially registered ISO 9001 quality certificates to 41.15 bn PPP\$ GDP by 2036 (+121.03% compared with 2026).

Improving the management of the quality of green digital products in developing economies will support the sustainable development of agriculture, industry, and the service sector by increasing the value added generated in each of these sectors while preserving the sectoral structure of GDP through 2036.

Table 6. Road map

Period		Value			Ratio of values to base values, %		
		AI technology diffusion, score 0–100	Green employment, score 0–100	ISO 9001 quality/bn PPP\$ GDP	AI technology diffusion, score 0–100	Green employment, score 0–100	ISO 9001 quality/bn PPP\$ GDP
Base values in 2026		44.18	37.43	18.62	-	-	-
Forecast values	2028	47.62	38.20	20.63	7.77	2.07	10.81
	2030	54.21	49.24	25.76	22.69	31.55	38.36
	2032	60.80	60.27	30.89	37.61	61.02	65.92
	2034	67.39	71.30	36.02	52.53	90.50	93.47
	2036	73.99	82.33	41.15	67.45	119.97	121.03

Source: Developed by the authors

5. Discussion

The obtained results extend the literature of Mamurova et al. (2025) and Yulisetiari et al. (2024), as well as the concept of product quality management, by revealing previously unknown sector-specific characteristics of such management and clarifying the relationship between the quality of green digital products and production productivity in developing economies.

In support of Galoyan et al. (2023a, 2023b), Hypothesis H₁ was confirmed, demonstrating that the degree of AI-driven automation of production and distribution processes and the extent of green personnel involvement in these processes are indeed differently associated with the shares of agriculture, industry, and the service sector in the GDP structure of developing economies.

The answer to RQ₁ is that the opportunities for managing the quality of green digital products are greatest in the industry (confirming the findings of Paizov et al. (2011) and Usenov et al. (2022)) and support its sustainable development. However, these opportunities are limited in agriculture (in contrast to the findings of Litvinova et al. (2017) and Troyanskaya et al. (2017)) and the service sector (in contrast to the findings of

Omire et al. (2024) and Tovmasyan (2023)), where AI-driven automation of production and distribution processes and the involvement of green personnel hinder sustainable development.

In support of Mkrtchyan and Navasardyan (2024) and Orlova et al. (2024), Hypothesis H₂ was confirmed, demonstrating that the quality characteristics of green digital products and the shares of agriculture, industry, and the service sector in GDP indeed affect the intensity of quality certification for these products in developing economies in different ways.

The answer to RQ₂ is that, among the quality characteristics of green digital products, the degree of AI-driven automation of production and distribution processes is the most significant, whereas the extent of green personnel involvement in these processes is secondary and relatively insignificant. Among the sectors of developing economies, the contradiction between quality and productivity is most pronounced in agriculture, less pronounced in the service sector, and least evident in industry.

Taken together, the findings provide an evidence-based foundation demonstrating the inapplicability of the existing universal approach to managing the quality of green

digital products, in contrast to the findings of Babakhanova et al. (2024), Bogoviz et al. (2018), Egnatosyan et al. (2023), Kaliyeva et al. (2025), and Ualtayev et al. (2024). Instead, a sector-specific approach to managing the quality of green digital products is recommended. Under this new approach, quality management should be adapted to the specific characteristics of each sector in developing economies.

To this end, the authors' approach recommends increasing the degree of AI-driven automation of production and distribution processes and the extent of green personnel involvement in industry to ensure systematic growth in both quality and productivity. In agriculture and the service sector, by contrast, quality and productivity should be managed separately, with moderate AI-driven automation and limits on the number of green jobs.

6. Conclusion and Limitations

The principal findings obtained from the research conducted in this article can be summarized as follows. The relationship between the quality of green digital products and the sustainability of sectoral development in developing economies was clarified and found to be strongest in the industry but weak in agriculture and the service sector.

A sectoral model of green digital product quality in developing economies was developed, mathematically expressing the effects of management factors and sectoral productivity on the intensity of quality certification under the international ISO 9001 standard. Based on this model, the authors concluded that the most effective product quality management measure in developing economies is AI-driven automation of production and distribution processes, whereas the complementary measure of green HRM is relatively ineffective. It was also concluded that the contradiction between quality and productivity is most pronounced in agriculture, while it is less significant in

industry and the service sector.

Given the identified sector-specific features of green digital product quality management, a new approach to such management was developed that enables flexible adaptation to the specific characteristics of each individual sector and thereby ensures the most sustainable progress, combining improvements in quality and productivity in each sector while maintaining a balanced sectoral structure of national GDP.

First, the new approach includes scientific and practical recommendations for improving the management of the quality of green digital products. The authors' applied sector-specific solutions for managing the quality of green digital products to support the sustainable development of sectors in developing economies involve increasing the degree of AI-driven automation of production and distribution processes and the extent of green personnel involvement in these processes in industry to ensure systematic growth in both quality and productivity. In agriculture and the service sector, by contrast, quality and productivity should be managed separately, with moderate AI-driven automation and limits on the number of green jobs.

Second, the authors' approach is supplemented by a roadmap for improving the quality of green digital products in developing countries in relation to productivity. The developed roadmap proposes target values for the degree of AI-driven automation of production and distribution processes and the extent of green personnel involvement in these processes in developing economies through 2036, as well as the associated projected increase in the value of officially registered ISO 9001 quality certificates, which is expected to reach 41.15 bn PPP\$ GDP by 2036 (+121.03% compared with 2026).

In conclusion, the limitations of the research should be noted. These limitations are associated with the sample size of 30 observations and five independent variables, the generalized nature of the study based on

countries from different regions of the world, and the fact that sectoral experience was examined using officially available international statistics on the shares of economic sectors in GDP.

These limitations should be addressed in future research by examining larger country samples, conducting in-depth case studies of individual countries and regions to account for the geographic dimension of green digital product quality management, and extending the developed model by incorporating variables that provide a more detailed

representation of economic activity across sectors, including employment, labor productivity, and value added generated.

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