Decarbonization of National Economies as a Spillover Effect of Integration: The Case of the EAEU

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Abstract: One of the implicit positive effects of interregional integration is the process of decarbonization of the economies of the integrating countries. The positive spillover effect of integration, which manifests itself in the form of technology diffusion, leads to a decrease in CO_2 emissions by displacing traditional industries and increasing the overall level of production efficiency. The purpose of the study is to assess the relationship between technology development and a decrease in CO_2 emissions in the EAEU space. Using correlation analysis, the paper verifies the hypothesis that the positive spillover effect associated with technology diffusion contributes to the decarbonization of the EAEU economies. As a result of the analysis, it was found that there is a (multidirectional, asymmetric) statistically significant relationship between the studied variables - the level of technology development affects the level of CO_2 emissions. Moreover, the positive spillover effect of integration manifests itself with a time lag of 1 year, i.e. it does not act instantly (it is a dynamic effect of integration). The obtained results indicate that in more developed economies (in the case of the EAEU, this is Russia and Kazakhstan), the decarbonization effect from the introduction of new technologies is more pronounced than in less developed ones. The results of the study can be used to develop a strategy for the socio-economic development of the EAEU countries, taking into account the parameters of the technological development of the countries.

1 INTRODUCTION

One of the implicit positive effects of interregional integration is the process of decarbonization of the economies of the integrating countries.

The creation of a single economic space, the unification of norms, rules and procedures creates the preconditions for the intensification of trade turnover between countries and leads to a more efficient allocation of resources. This is not only about the direct flow of resources from the poorer economies of the integration association to the richer ones (Viner, 1950), but also about technological spillover (Duan, Sun, 2024) - due to the diffusion of technologies, there is a general increase in efficiency (Wu, Li, 2024) in the space of the integration association.

In particular, the acceleration of technology diffusion within the framework of an integration association (Perkins, Neumayer , 2005) creates the preconditions for reducing carbon dioxide (CO_2) emissions in several directions at once.

Firstly, automation of production processes is leading to a systemic transformation in traditionally labour-intensive industries such as coal mining, metallurgy and construction. Traditional manufacturing industries are often characterized by high CO_2 emissions, as their production processes rely on fossil fuels and require large amounts of energy. The introduction of new technologies and automation of production processes not only

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increases productivity, but also helps to reduce CO_2 emissions. Reducing the need for manual labor and optimizing production processes leads to a more rational use of resources and less waste, which has a positive effect on the environmental situation.

Secondly, in recent decades there has been a trend towards the rapid development of "digital industries" of the economy, which have a minimal impact on CO_2 emissions compared to traditional industry. For example, the use of cloud technologies and virtualization allow companies to reduce physical resources and, therefore, reduce their carbon footprint (for example, Apple introduced a carbon-neutral computer for the first time in October 2024). Thus, automation and technological development contribute to a shift away from environmentally harmful traditional industries in favor of cleaner and more resource-efficient ones.

An analysis of the literature confirms the existence of a link between technological development and the decarbonization of economies.

Yang et al. (2023) found an inverse relationship between innovations in alternative energy production and CO_2 emissions based on an analysis of 30 regions in China (with these innovations being inversely related to coal and crude oil production and directly related to gas production). Thus, innovation is the main driver of economic decarbonization (Yang, Li, Du, Huang, Li, 2023).

Dauda et al . (2021) show how innovation and new technologies reduce CO_2 emissions using African countries as an example. Moreover, the authors conclude that regional integration and technology diffusion are the basis of the green growth and decarbonization model (Dauda, Long, Mensah, Salman, Boamah, Ampon-Wireko, Kofi Dogbe, 2021).

Cheng et al . (2021) study 35 OECD economies in the period 1996-2015 and find evidence that technological innovation directly reduces CO_2 emissions. Although the decarbonization effect will be different for each specific OECD economy, it is asymmetric (Cheng, Ren, Dong, Dong, Wang, 2021).

Abbas , Gui , Chen & Ali (2022) confirm the existence of an asymmetric relationship between CO_2 emissions and the development of renewable energy sources, market regulation and innovation in the long term. Moreover, it is market regulation that acts as a key factor in the decarbonization process (Abbas, Gui, Chen, Ali, 2022).

Chen & Lee (2020) also confirm the correlation between countries' R & D spending and reduced CO_2 emissions. Moreover, in countries with a high standard of living and advanced technologies, innovations significantly reduce CO_2 emissions in neighboring countries, while in poorer economies, increased R & D spending can lead to increased CO_2 emissions. Globalization has a significant impact on the decarbonization of economies: the more a country is drawn into global processes, the more technologies reduce CO_2 emissions (Chen, Lee, 2020).

Bilal , Li , Zhu , Sharma & Jahanger (2022) found a statistically significant inverse relationship between technological innovation and CO_2 emissions in their study. They also confirmed the relationship between globalization and decarbonization processes using the example of the Belt and Road countries (Bilal, Li, Zhu, Sharma, Jahanger, 2022).

Thus, we see that a consensus has emerged in the economic literature – technological developments contribute to the reduction of CO_2 emissions through a complex impact on various aspects of economic activity.

The aim of this study is to verify the relationship between technology development and the reduction of CO_2 emissions in the EAEU area.

In our study, we proceed from the assumption that the process of creating the EAEU has led to the emergence of a positive spillover effect – the diffusion of technologies has a positive effect on the decarbonization of integrating economies.

2 METHODS

The hypothesis of the study is that the spread of technologies in the EAEU space leads to: (1) the displacement of traditional industrial production; (2) and this, in turn, leads to a reduction in CO_2 emissions.

Methodological basis of the research:

1. The analyzed indicators are presented in tables 1 and 2:

- Global innovation inde x (GII) in the EAEU countries in the period 2011-24 (data provided according to a joint study by INSEAD and WIPO);
- Industry (including construction), value added (% of GDP); Carbon dioxide (CO_2) emissions from Industrial Processes; Carbon dioxide (CO_2) emissions from Power Industry (Energy); Carbon dioxide (CO_2) emissions from Transport (Energy); Carbon dioxide (CO_2) emissions from Industrial Combustion (Energy) in countries EAEU V interval 2011-23 (data provided by World Development Indicators , VB).

2. Research boundaries: EAEU countries, 2011-2024.

3. Research methods: correlation analysis is used to test the proposed hypothesis (p- value = 5% and 10%).

Table 1: Dynamics of Global innovation index in the EAEU member states, 2011-24.

Countries	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Belarus	-	32.90	34.62	37.10	38.23	30.39	29.98	29.35	32.07	31.27	32.60	27.50	26.80	24.20
Kazakhstan	30,32	31.90	32.73	32.75	31.25	31.51	31.50	31,42	31.03	28.56	28.60	24.70	26.70	25.70
Armenia	33,00	34.50	37.59	36.06	37.31	35.14	35.65	32.81	33.98	32.64	31.40	26.60	28.00	29,00
Kyrgyz Republic	29.79	26.40	26.98	27.75	27.96	26.62	28.01	27.56	28,38	24.51	24.50	21.10	20,20	20.40
Russian Federation	35.85	37.90	37.20	39.14	39.32	38.50	38.76	37.90	37.62	35.63	36.60	34.30	33.30	29.70

Source: compiled by the authors based on Global Innovation Index .

Table 2: Dynamics of indicators characterizing CO_2 emissions in the EAEU member states , 2011-24.

Country Name	Series Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Belarus	Industry (including construction), value added (% of GDP)	36.09	36.28	35.90	35,38	32.69	30.96	31.55	31.27	31.74	31.35	32.14	33.03	32.54
	Carbon dioxide (CO2) emissions from Industrial Processes	5.31	5.46	5.70	6.10	5.70	5.38	5.38	5.42	5.02	4.81	4.86	4.64	..
	Carbon dioxide (CO2) emissions from Power Industry (Energy)	30.27	29.75	29.24	29.33	27.59	27.52	27.99	30.15	28.95	27.79	29.30	28.39	..
	Carbon dioxide (CO2) emissions from Transport (Energy)	10.87	11.67	12.18	11.59	10.38	10.80	11.26	11.84	11.80	10.61	10.37	9.77	..
	Carbon dioxide (CO2) emissions from Industrial Combustion (Energy)	4.76	5.12	5.21	5.33	4.46	4.51	4.65	4.76	4.83	4.70	4.81	4.72	..
Armenia	Industry (including construction), value added (% of GDP)	..	27.83	26.71	25,27	25.71	25.58	25.81	24.76	24.97	26.82	26.36	25,28	23.93
	Carbon dioxide (CO2) emissions from Industrial Processes	0.22	0.21	0.22	0.21	0.21	0.14	0.18	0.26	0.28	0.33	0.37	0.37	..
	Carbon dioxide (CO2) emissions from Power	0.95	1.43	1.32	1.13	1.27	1.17	1.24	1.48	1.35	1.42	1.42	1.22	..

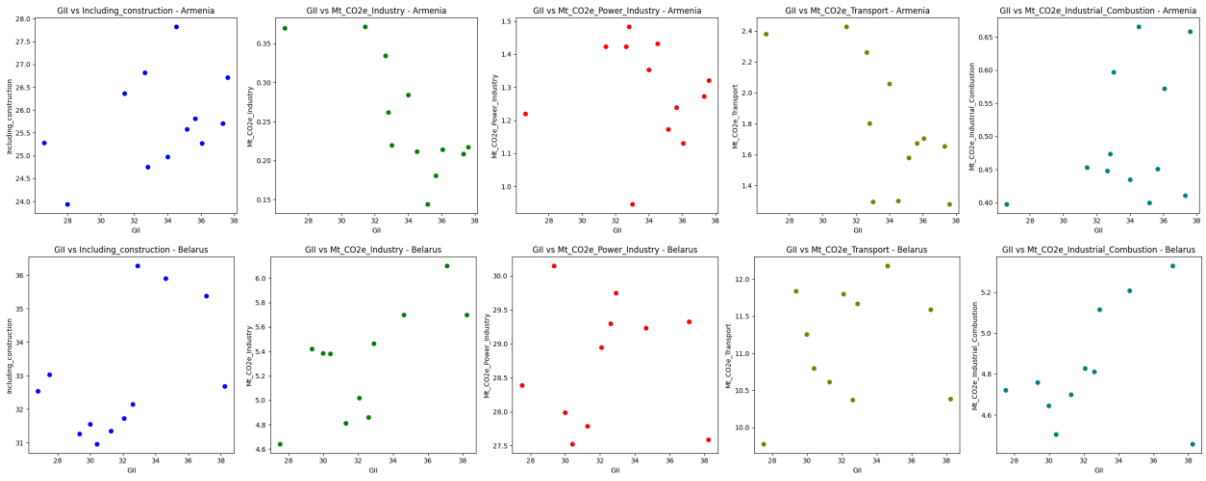
	Industry (Energy)													
	Carbon dioxide (CO2) emissions from Transport (Energy)	1.29	1.30	1.28	1.71	1.66	1.58	1.67	1.80	2.06	2.26	2.43	2.38	..
	Carbon dioxide (CO2) emissions from Industrial Combustion (Energy)	0.60	0.67	0.66	0.57	0.41	0.40	0.45	0.47	0.44	0.45	0.45	0.40	..
Kyrgyz Republic	Industry (including construction), value added (% of GDP)	27.45	22,26	24.84	23.89	25.08	26.55	27.31	27.48	26.58	26.90	23.75	24.19	22.64
	Carbon dioxide (CO2) emissions from Industrial Processes	0.50	0.56	0.78	0.75	0.64	0.62	0.71	0.90	0.91	0.86	0.96	0.96	..
	Carbon dioxide (CO2) emissions from Power Industry (Energy)	1.77	1.87	1.63	2.27	2.69	1.83	1.49	1.55	2.11	2.27	2.50	2.48	..
	Carbon dioxide (CO2) emissions from Transport (Energy)	2.77	3.94	3.94	3.15	2.67	3.27	1.84	1.49	1.13	1.38	1.55	1.64	..
	Carbon dioxide (CO2) emissions from Industrial Combustion (Energy)	0.57	1.52	0.74	1.40	1.77	0.82	0.80	1.13	0.84	0.46	0.50	0.50	..
Kazakhstan	Industry (including construction), value added (% of GDP)	37.27	36.30	33.70	33.21	30.85	31.98	32,33	33.50	33.03	33.10	35.27	34.98	32.05
	Carbon dioxide (CO2) emissions from Industrial Processes	8.74	9.51	11.97	11.63	13.39	12.27	12.74	12.33	13.36	14.49	14.37	14.45	..
	Carbon dioxide (CO2) emissions from Power Industry (Energy)	80.32	87.57	93.15	99.04	84.41	92.79	102.16	106.76	104.92	104.01	108.96	108.58	..
	Carbon dioxide (CO2) emissions from Transport (Energy)	13.47	14.59	13.73	14.41	15.35	15.95	15.37	17.47	16.34	20.69	22.40	27.14	..
	Carbon dioxide (CO2) emissions from	69.24	63.70	69.89	48,58	38.53	38,42	37.73	32.89	27.58	28.53	30.11	32.30	..

	Industrial Combustion (Energy)													
Russian Federation	Industry (including construction), value added (% of GDP)	29.41	29.10	28.19	27.93	29.79	29.17	30.67	32.55	32.15	29.72	31.40	32.10	30.65
	Carbon dioxide (CO2) emissions from Industrial Processes	98.62	99.86	101.89	101.22	100.27	98.67	103.93	110.25	112.49	111.44	116.89	114.79	..
	Carbon dioxide (CO2) emissions from Power Industry (Energy)	956.29	947.11	908.16	841.03	810,51	775.93	773.85	815,80	816,01	770.86	836.47	864,00	..
	Carbon dioxide (CO2) emissions from Transport (Energy)	249.69	237.32	238.70	241.39	240.61	240.20	246.06	258.86	256.10	234.02	251.06	246.47	..
	Carbon dioxide (CO2) emissions from Industrial Combustion (Energy)	184.01	226.31	223.86	247.03	249.98	259.78	262.09	250.55	280.46	273.55	293.98	274.09	..

Source: compiled by the authors based on World Development Indicators .

3 RESULTS

The results of the correlation analysis are presented in Figure 1-2 and in summary tables 3 and 4.



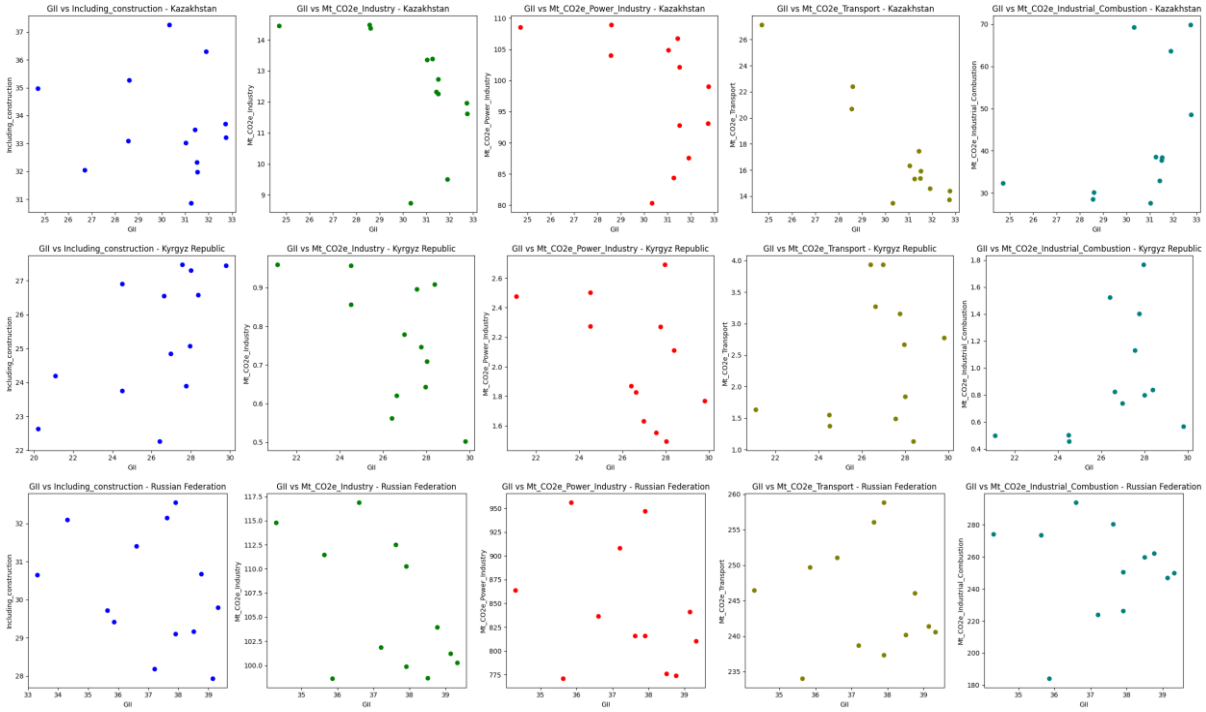


Figure 1: Scatterplot between Global innovation index and indicators characterizing CO_2 emissions in the EAEU member states. Source: built by the authors.

Table 3: Results of correlation analysis for the EAEU countries.

Country	Variable_X	Variable_Y	Correlation	P-Value	Significance	Direction	Interpretation
Belarus	GII	Industry (including construction), value added (% of GDP)	0.472209135	0.121126	It doesn't matter	Straight	Moderate
Kazakhstan	GII	Industry (including construction), value added (% of GDP)	-0.131433314	0.668647	It doesn't matter	Feedback	Very weak
Armenia	GII	Industry (including construction), value added (% of GDP)	0.39786469	0,200244	It doesn't matter	Straight	Moderate
Kyrgyz Republic	GII	Industry (including construction), value added (% of GDP)	0.562962555	0.045161	It is significant	Straight	Moderate to noticeable
Russian Federation	GII	Industry (including construction), value added (% of GDP)	-0.304979051	0.310952	It doesn't matter	Feedback	Moderate
Belarus	GII	Mt_CO2e_ Industrial Processes	0.702875377	0.015846	It is significant	Straight	Tall or tight
Kazakhstan	GII	Mt_CO2e_ Industrial Processes	-0.532230517	0.074866	It is significant	Feedback	Moderate to noticeable
Armenia	GII	Mt_CO2e_ Industrial Processes	-0.775904077	0.003013	It is significant	Feedback	Tall or tight
Kyrgyz Republic	GII	Mt_CO2e_ Industrial Processes	-0.589095662	0.043852	It is significant	Feedback	Moderate to noticeable
Russian Federation	GII	Mt_CO2e_ Industrial Processes	-0.546928424	0.065733	It is significant	Feedback	Moderate to noticeable
Belarus	GII	Mt_CO2e_Power_Industry	0.014953759	0.965194	It doesn't matter	Straight	Very weak

Kazakhstan	GII	Mt_CO2e_Power_Industry	-0.460118549	0.132293	It doesn't matter	Feedback	Moderate
Armenia	GII	Mt_CO2e_Power_Industry	-0.065386125	0.840003	It doesn't matter	Feedback	Very weak
Kyrgyz Republic	GII	Mt_CO2e_Power_Industry	-0.469496217	0.123576	It doesn't matter	Feedback	Moderate
Russian Federation	GII	Mt_CO2e_Power_Industry	-0.295437115	0.351185	It doesn't matter	Feedback	Weak
Belarus	GII	Mt_CO2e_Transport	0.218439021	0.518744	It doesn't matter	Straight	Weak
Kazakhstan	GII	Mt_CO2e_Transport	-0.930085715	1,17E-05	It is significant	Feedback	Very high
Armenia	GII	Mt_CO2e_Transport	-0.687888506	0,013412	It is significant	Feedback	Moderate to noticeable
Kyrgyz Republic	GII	Mt_CO2e_Transport	0.267303861	0.400956	It doesn't matter	Straight	Weak
Russian Federation	GII	Mt_CO2e_Transport	-0.068851225	0.831628	It doesn't matter	Feedback	Very weak
Belarus	GII	Mt_CO2e_Industrial_Combustion	0.344259168	0.299876	It doesn't matter	Straight	Moderate
Kazakhstan	GII	Mt_CO2e_Industrial_Combustion	0.455606279	0,136626	It doesn't matter	Straight	Moderate
Armenia	GII	Mt_CO2e_Industrial_Combustion	0.367420415	0.240018	It doesn't matter	Straight	Moderate
Kyrgyz Republic	GII	Mt_CO2e_Industrial_Combustion	0.39853635	0,199416	It doesn't matter	Straight	Moderate
Russian Federation	GII	Mt_CO2e_Industrial_Combustion	-0.052786658	0.870577	It doesn't matter	Feedback	Very weak

Source: built by the authors

Data analysis showed:

- Armenia: High feedback between technology development and CO_2 emissions from Industrial Processes ; a significant feedback between the level of technological development and CO_2 emissions from Transport (Energy);
- Belarus: High Direct Correlation Between Technological Development and CO_2 emissions from Industrial Processes ;
- Kazakhstan: Significant feedback between technology development and CO_2 emissions from Industrial Processes ; very high feedback between the level of technology development and CO_2 emissions from Transport (Energy);
- Kyrgyzstan: A noticeable direct link between the level of technology development and Industry (including construction), value added (% of GDP) ; significant inverse relationship between technology development and CO_2 emissions from Industrial Processes ;
- Russia: Significant feedback between technology development and CO_2 emissions from Industrial Processes .

Next, we verify our hypothesis taking into account a time lag of 1 year (the spread of the positive spillover effect of integration may not be immediate).

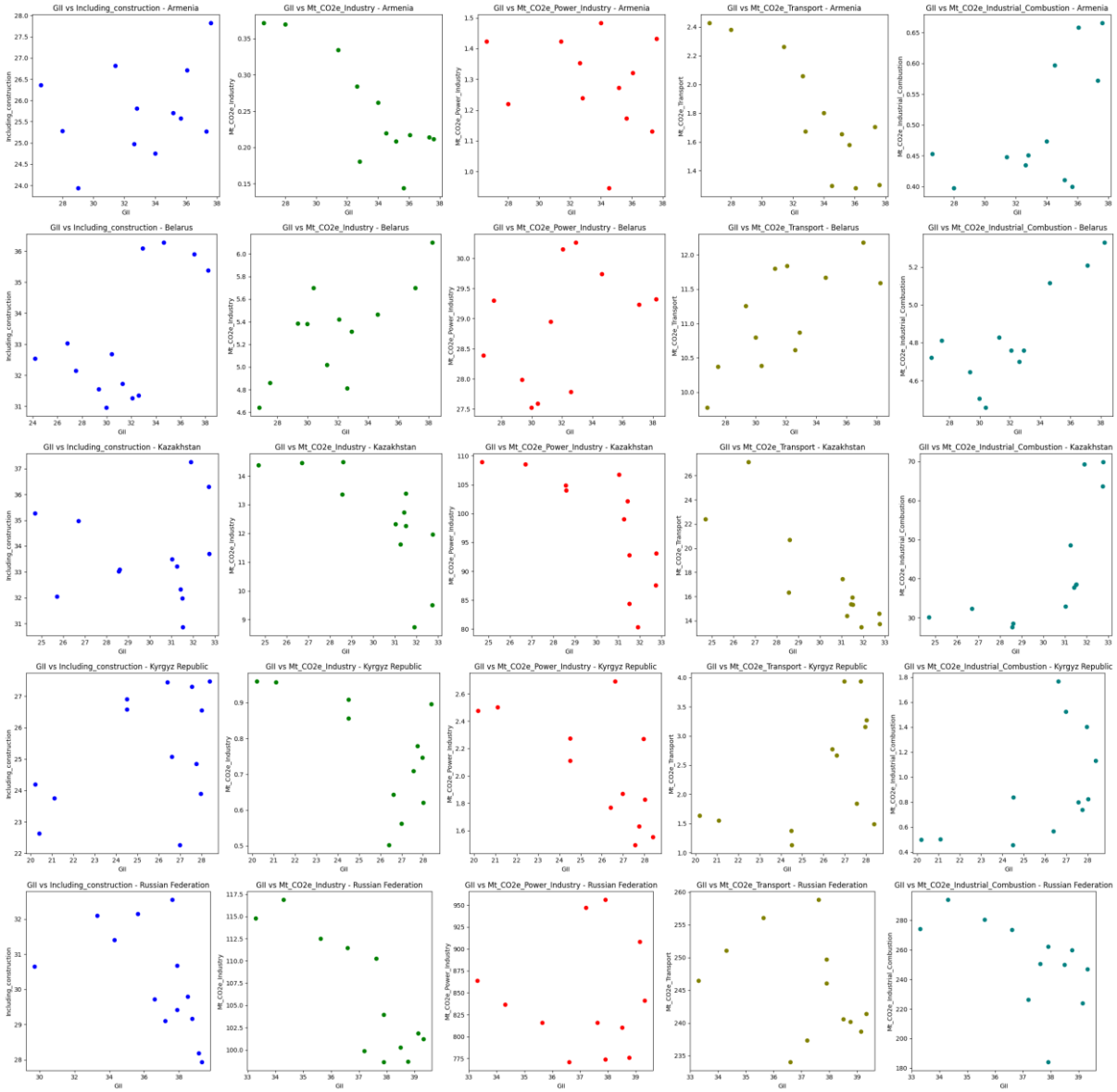


Figure 2: Scatterplot between Global innovation index and indicators characterizing CO_2 emissions in the EAEU member states with a lag of 1 year. Source: built by the authors.

Table 4: Results of correlation analysis for the EAEU countries with a lag of 1 year.

Country	Variable_ X	Variable_Y	Correlation	P-Value	Significance	Direction	Interpretation
Belarus	GII	Industry (including construction), value added (% of GDP)	0.603189	0.029078	It is significant	Straight	Moderate to noticeable
Kazakhstan	GII	Industry (including construction), value added (% of GDP)	0,009041	0.976614	It doesn't matter	Straight	Very weak
Armenia	GII	Industry (including construction), value added (% of GDP)	0.311503	0.324322	It doesn't matter	Straight	Moderate
Kyrgyz Republic	GII	Industry (including construction), value added (% of GDP)	0.439936	0.132491	It doesn't matter	Straight	Moderate
Russian Federation	GII	Industry (including construction), value added (% of GDP)	-0.53873	0.057484	It is significant	Feedback	Moderate to noticeable
Belarus	GII	Mt_CO2e_ Industrial Processes	0.727811	0,00729	It is significant	Straight	Tall or tight
Kazakhstan	GII	Mt_CO2e_ Industrial Processes	-0.72392	0,00777	It is significant	Feedback	Tall or tight

Armenia	GII	Mt_CO2e_ Industrial Processes	-0.84293	0.000575	It is significant	Feedback	Tall or tight
Kyrgyz Republic	GII	Mt_CO2e_ Industrial Processes	-0.61153	0.034605	It is significant	Feedback	Moderate to noticeable
Russian Federation	GII	Mt_CO2e_ Industrial Processes	-0.85014	0,00046	It is significant	Feedback	Tall or tight
Belarus	GII	Mt_CO2e_Power_Industry	0.406995	0,189161	It doesn't matter	Straight	Moderate
Kazakhstan	GII	Mt_CO2e_Power_Industry	-0.72389	0,007774	It is significant	Feedback	Tall or tight
Armenia	GII	Mt_CO2e_Power_Industry	-0.22621	0.47958	It doesn't matter	Feedback	Weak
Kyrgyz Republic	GII	Mt_CO2e_Power_Industry	-0.64406	0.0238	It is significant	Feedback	Moderate to noticeable
Russian Federation	GII	Mt_CO2e_Power_Industry	0,01302	0.967965	It doesn't matter	Straight	Very weak
Belarus	GII	Mt_CO2e_Transport	0.727708	0,007302	It is significant	Straight	Tall or tight
Kazakhstan	GII	Mt_CO2e_Transport	-0.8566	0,000373	It is significant	Feedback	Tall or tight
Armenia	GII	Mt_CO2e_Transport	-0.87006	0.000234	It is significant	Feedback	Tall or tight
Kyrgyz Republic	GII	Mt_CO2e_Transport	0.545903	0.066344	It is significant	Straight	Moderate to noticeable
Russian Federation	GII	Mt_CO2e_Transport	-0.35529	0.257073	It doesn't matter	Feedback	Moderate
Belarus	GII	Mt_CO2e_Industrial_Combustion	0.778605	0.002849	It is significant	Straight	Tall or tight
Kazakhstan	GII	Mt_CO2e_Industrial_Combustion	0.683651	0.014233	It is significant	Straight	Moderate to noticeable
Armenia	GII	Mt_CO2e_Industrial_Combustion	0.579982	0.048065	It is significant	Straight	Moderate to noticeable
Kyrgyz Republic	GII	Mt_CO2e_Industrial_Combustion	0.532312	0.074813	It is significant	Straight	Moderate to noticeable
Russian Federation	GII	Mt_CO2e_Industrial_Combustion	-0.57889	0.048588	It is significant	Feedback	Moderate to noticeable

Source: built by the authors

Data analysis showed:

• Armenia: High feedback between technology development and CO_2 emissions from Industrial Processes ; high feedback between technology development and CO_2 emissions from Transport (Energy); a noticeable direct relationship between the level of technological development and CO_2 emissions from Industrial Combustion (Energy);

• Belarus: a noticeable direct link between the level of technology development and Industry (including construction), value added (% of GDP); high positive correlation between technology development and CO_2 emissions from Industrial Processes ; high direct correlation between the level of technology development and CO_2 emissions from Transport (Energy); high direct correlation between the level of technological development and CO_2 emissions from Industrial Combustion (Energy);

• Kazakhstan: High feedback between technology development and CO_2 emissions from Industrial Processes ; high feedback between technology development level and CO_2 emissions from Power Industry (Energy); high feedback between the level of technology development and CO_2 emissions from Transport (Energy); a noticeable direct relationship between the level of technological development and CO_2 emissions from Industrial Combustion (Energy);

• Kyrgyzstan: Significant feedback between technology development and CO_2 emissions from Industrial Processes ; significant feedback between technology development and CO_2 emissions from Power Industry (Energy); a significant direct relationship between the level of technology development and CO_2 emissions from Transport (Energy); a significant direct relationship between the level of technological development and CO_2 emissions from Industrial Combustion (Energy);

• Russia: a noticeable inverse relationship between the level of technology development and Industry (including construction), value added (% of GDP); high feedback between technology development and CO_2 emissions from Industrial Processes ; a significant feedback between the level of technological development and CO_2 emissions from Industrial Combustion (Energy).

4 CONCLUSION

• As a result of the analysis carried out in the work, it can be concluded that there is a (multidirectional, asymmetric) statistically

significant relationship between the studied variables - the level of technological development affects the level of CO_2 emissions . This is consistent with the previously obtained research results of a number of authors: Dauda et al . (2021) ; Cheng et al. (2021); Chen & Lee (2020); Bilal, Li, Zhu, Sharma & Jahanger (2022) and etc.

- Moreover, the positive spillover effect of integration, which manifests itself in the form of diffusion of technologies, which in turn leads to decarbonization of integrating economies , manifests itself with a time lag of 1 year, i.e. it does not act instantly (it is a dynamic effect of integration).
- Moreover, the obtained results are generally consistent with the hypothesis of Chen & Lee (2020) that in more developed economies (in the case of the EAEU, this is Russia and Kazakhstan), the decarbonization effect from the introduction of new technologies is more pronounced than in less developed ones.
- Limitations of the study:
- - data outliers distorting the overall picture due to the coronavirus pandemic and subsequent lockdowns in 2020 and 2021;
- - external shocks that have a significant impact on the dynamics of socio-economic development of the EAEU countries;
- - incorrectly selected indicators (Global Innovation Index) characterizing the level of technological development of the EAEU countries;
- - perhaps the use of correlation analysis to solve the research problem was not optimal (testing and searching for a research methodology adequate to the research problems is underway).
- We hope that the data obtained as a result of the study and the tasks solved will stimulate a new wave of applied research on interregional integration in the EAEU space.

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