O‘ZBEKISTON RESPUBLIKASI
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IQTISODIYOT VA TARAQQIYOT
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RESEARCH AND GRANTS UPDATES

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74-91 xalqaro daraja
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Elektron nashr. 112 sahifa.
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08.00.12 Mintaqaviy iqtisodiyot
08.00.13 Menejment
08.00.14 Iqtisodiyotda axborot tizimlari va texnologiyalari
08.00.15 Tadbirkorlik va kichik biznes iqtisodiyoti
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Muassis: “Ma’rifat-print-media” MChJ
Hamkorlarimiz: Toshkent davlat iqtisodiyot universiteti, O‘zR Tabiat resurslari vazirligi, O‘zR Bosh prokuraturasi huzuridagi IJQK departamenti.

Jurnalning ilmiyligi:
““Yashil” iqtisodiyot va taraqqiyot” jurnali
O‘zbekiston Respublikasi Oliy ta’lim, fan va innovatsiyalar vazirligi huzuridagi Oliy attestatsiya komissiyasi rayosatining 2023-yil 1-apreldagi 336/3-sonli qarori bilan ro‘yxatdan o‘tkazilgan.

MUNDARIJA СОДЕРЖАНИЕ CONTENTS

MUNDARIJA

Dunyo sug‘urta bozorida yashil xizmatlarning taraqqiyot strategiyalari 7
Alimov Baxodir Batirovich

Yashil iqtisodiyot sharoitida amaliy va nazariy treninglar orqali xususiy tadbirkorlik faoliyatining samaradorligini oshirish 14
Marupov Kabil Komilovich

O‘zbekiston iqtisodiyotini yashillashtirishda raqamli texnologiyalardan foydalanishning joriy holati tahlili 20
Nurmetova Muyassar

Econometric assessment of the impact of investments on the economic system of Surkhandarya region 29
Nurbek Khatamov

Debt versus tax financing in infrastructure: impact on employment 37
Raxmatov Firdavs Feruz o‘g‘li, Kengesbaeva Gulfayruz Azamatovna

Digital infrastructure and green energy in export diversification: evidence from post-soviet countries 47
Sadriddinov Ulugbek Jaloliddin ugli

Jahon savdo tashkiloti doirasida O‘zbekistonning iqtisodiy rivojlanish istiqbollari: ko‘p tomonlama savdo kelishuvlari tahlili 55
Toshpulatova Malika Ulug‘bek qizi

Развитие финтеха в узбекистане: современное состояние и международный контекст 63
Адилова Сакинахон

Yashil iqtisodiyotni innovasion rivojlantirishning iqtisodiy samaradorligini baholash 68
Rasulova Dilfuza, Kaytarov Voxid

Gibrid avtomobillar importida to‘lovlar undirish amaliyotini takomillashtirish 80
Kaljanov Baxadir Dauletbaevich

Стратегии корпоративного управления и привлечения иностранных инвестиций в условиях устойчивой экономики 88
Фарход Каракулов

The impact of WTO accession on Uzbekistan’s trade policy: in the case of Kazakhstan 102
Azimjonov Muhammadsoli Muhammadolim o‘g‘li

DIGITAL INFRASTRUCTURE AND GREEN ENERGY IN EXPORT DIVERSIFICATION: EVIDENCE FROM POST-SOVIET COUNTRIES

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Abstract: Export diversification plays a crucial role in today's global world and world trade. This research is aimed at studying the impact of digital infrastructure and renewable energy consumption on export diversification in 15 post-Soviet countries. A fixed-effect regression model and standard errors robust against heteroskedasticity were used through panel data. The ICT index, renewable energy consumption as a % of total energy consumption, FDI inflows as a % of GDP, and European Union and Eurasian Economic Union memberships are used as independent variables for export diversification.

Results have shown that there is a positive and significant relationship between export diversification and digital infrastructure. Developing the ICT sphere and making investments in the sector bring new export markets and, of course, diversified exports of products. Also, the statistical significance of renewable energy consumption differs according to different econometric models, the renewable energy consumption supports declining export concentration of selected economies. These results show the importance of the integration of digital infrastructure and renewable energy in export diversification to the countries and business owners. And, of course, it provides practical and theoretical policies for innovations and economic integrations.

Key words: Export diversification, ICT, renewable energy, Post-Soviet countries.

Annotatsiya: Eksportni diversifikatsiya qilish bugungi global dunyo va jahon savdosida muhim o‘rin tutadi. Ushbu tadqiqotning maqsadi – raqamli infratuzilma va qayta tiklanuvchi energiya iste’molining 15 ta postsovet davlatida eksport diversifikatsiyasiga ta’sirini o‘rganishdir. Panel ma’lumotlar tahlili uchun fiksirlangan effektlar modeli va geteroskedastiklikka chidamli standart xatoliklar ishlatildi. Eksport diversifikatsiyasining mustaqil o‘zgaruvchilari sifatida IKT indeksi, umumiy energiya iste’molidagi qayta tiklanuvchi energiya ulushi, YaIMga nisbatan to‘g‘ridan-to‘g‘ri xorijiy investitsiyalar oqimi hamda Yevropa Ittifoqi va Yevroosiyo iqtisodiy ittifoqi a’zoligi qo‘llanildi.

Natijalar eksport diversifikatsiyasi va raqamli infratuzilma o‘rtasida ijobiy va sezilarli bog‘liqlik mavjudligini ko‘rsatdi. IKT sohasini rivojlantirish va ushbu sektorga investitsiyalar kiritish yangi eksport bozorlarini ochadi hamda, albatta, mahsulot eksportini diversifikatsiya qiladi. Shuningdek, qayta tiklanuvchi energiya iste’molining statistik ahamiyati iqtisodetrik modellarga qarab farq qiladi, ammo qayta tiklanuvchi energiya iste’moli ushbu davlatlarda eksportning bir yo‘nalishga qaratilish darajasini pasaytirishga yordam beradi. Bu natijalar eksport diversifikatsiyasida raqamli infratuzilma va qayta tiklanuvchi energiyani integratsiya qilishning mamlakatlar va tadbirkorlar uchun muhimligini ko‘rsatadi. Shuningdek, innovatsiyalar va iqtisodiy integratsiya uchun amaliy va nazariy siyosiy takliflar beradi.

Kalit so‘zlar: eksport diversifikatsiyasi, IKT, qayta tiklanuvchi energiya, postsovet davlatlari.

Аннотация: Диверсификация экспорта играет решающую роль в современном глобальном мире и мировой торговле. Цель данного исследования – изучить влияние цифровой инфраструктуры и потребления возобновляемой энергии на диверсификацию экспорта в 15 постсоветских странах. Для анализа панельных данных использовалась модель фиксированных эффектов и стандартные ошибки, устойчивые к гетероскедастичности. В качестве независимых переменных диверсификации экспорта использовались индекс ИКТ, потребление возобновляемой энергии в % от общего энергопотребления, приток ПИИ в % от ВВП, а также членство в Европейском союзе и Евразийском экономическом союзе.

Результаты показали положительную и значимую связь между диверсификацией экспорта и цифровой инфраструктурой. Развитие сферы ИКТ и инвестиции в данный сектор открывают новые экспортные рынки и, безусловно, способствуют диверсификации экспортируемой продукции. Кроме того, статистическая значимость потребления возобновляемой энергии варьируется в зависимости от выбранной эконометрической модели, однако потребление возобновляемой энергии способствует снижению экспортной концентрации исследуемых экономик. Эти результаты подчеркивают важность интеграции цифровой инфраструктуры и возобновляемой энергии для диверсификации экспорта, как для стран, так и для бизнес-сообщества. Кроме того, исследование предлагает практические и теоретические рекомендации для инноваций и экономической интеграции.

Ключевые слова: диверсификация экспорта, ИКТ, возобновляемая энергия, постсоветские страны.

INTRODUCTION

The global economic environment is rapidly becoming digitalised, and export diversification is also becoming increasingly important in order to develop consistently and maintain economic growth. Nowadays countries and companies are trying to pay attention to their focus and economy in new and innovative areas because of technological revolution and environmental demands. Although most post-Soviet Union countries have relied upon natural resources, especially natural energy resources, these countries are making significant changes to implement new digital infrastructure and green technologies because it is also the need of today's era. These actions play an important role for export diversification and increasing economic stability.

The main goal of this research is to analyse and determine digital infrastructure (ICT) and renewable energy's role in export diversification. Research questions are formed as follows: How much will the introduction of ICT and renewable energy into the economy broaden the composition of export goods? Giving answers to the above questions about regional economic diversification, digital transformation and green economy significant strategies is intended to be studied in more depth.

The relevance of the research is that demand for digital technology and green products, specifically green energy, is increasing significantly day by day. Such these two factors are shown to have a great potential in stimulating export diversification in the context of the former Union of Soviet Socialist Republics (USSR). At the same time, reducing reliance options to traditional resources and such factors are expected to play key roles in order to increase economic sensitivity.

The main focus of this research is the impact of ICT and renewable energy on export diversification, but FDI, R&D, and economic union memberships will not be ignored at all. Through this research, results such as these factors' role in order to diversify the structure of export goods and provide economic stability are proven scientifically. Additional multidimensional analyses in this sphere and interactive effects perspectives can be considered in the future.

General context, research problem, objectives and research scope are briefly stated in the introduction part of this research. A detailed foundation for the methodology, results, and policy recommendation will be in the following sections. In the next parts, the detailed role and impact of ICT and renewable energy on export diversification and its economic significance will be analysed.

REVIEW OF LITERATURE ON THE SUBJECT

What is export diversification in the first place? Saying in one brief sentence, export diversification is diversifying export composition. It is recognised as relevant in the formation of economic stability and new industrial direction. Some empirical research shows that increasing export diversification has an important effect through digitalisation and improving the ICT industry in emerging markets and countries (Gavkhar Sultanova & Hanan Naseer, 2024). For example, Sultanova and Naseer investigated that the evolution of ICT infrastructure has a significant effect on export composition. Besides, (Hilal Atasoy, 2021) Atasoy found and reckoned that improving digitalisation plays an important role for increasing export sophistication. These theoretical foundations have shown that they open new chances for the export industry.

Besides that, there are some research investigations that learnt the impact of the digital economy on the green economy. Wang and others found a positive relationship between the digital economy and its positive effect on the environment, including analytical results of green energy investment impact on export diversification (Chenggang Wang, Tiansen Liu, Danli Du, Yue Zhu, Zuolong Zheng, & Hanchen Li, 2024). This work has shown that there is a synergy between technological innovation and environmental strategies to make sustainable exports.

Other researchers also studied the impact of ICT technologies on international trade in countries in the MENA region (Kamel Touati & Ahmed Aljazea, 2023). They analysed strategies to improve trade volume and product diversity through ICT impact in their work. Another study is that digitalisation's impact on high-tech export products using a panel data approach (Seren Özsoy & Oylum Şehvez Ergüzel & Ahmet Yağmur Ersoy & Metin Saygılı, 2021). This reflects the positive correlation between technological innovation and export earnings.

Additional literature also provides in-depth theoretical and empirical analyses on this topic. For instance, Ouyang and Park (2024) studied the role of innovation in export diversification within global value chains. They have shown the positive relationship between ICT and industrial modernisation. Analysing digitalisation and innovation processes impact on international trade results, it proved that digital transformation positively affects export diversification. And another study investigated a positive and significant relationship between ICT development, export diversification, and income inequality through panel regression analysis (Gavkhar Sultanova, Rano Djuraeva & Aziza Usmanova, 2024). Chen and Zhao (2017) studied the relationship between renewable energy and industrial transformation; they revealed how ecological innovations motivate export

diversification. Last but not least, Martin and Lee (2016) empirically analysed the relationship between export diversification and economic stability. They demonstrated the essential nature of economic resilience in the global market environment. The result has shown that ICT impacts income inequality negatively. Lastly, another piece of research is about the empirical analysis of the relationship between the digital economy and renewable energy consumption through a panel data approach (Gavkhar Sultanova, Rano Djuraeva & Suriya Turaeva, 2022).

Overall, the existing literature has provided that both ICT and renewable energy investment play an important role in increasing export diversification. At the same time, FDI inflow, R&D and regional integration factors such as the EU and EAEU also have a partial impact. Through these theoretical and empirical researches, it is shown that the role of digital and green factors in expanding the export diversification is considered important in the process of economic transformation in post-USSR countries. Literature cited in this section serves to form the theoretical basis of research and identify gaps in the field. In the next section, empirical results and analyses will be covered more widely through these theoretical approaches.

RESEARCH METHODOLOGY

In this research, in order to identify impact factors on export diversification, a fixed effect (FE) regression model was applied to panel data. The main purpose of this research is to analyse the impact factors, such as digital infrastructure (ICT) and renewable energy consumption, on export diversification. The following approaches were used for this:

Data

Data in this research cover economic indicators of 15 former USSR countries between 2000 and 2022.

Dependent variable: Export Diversification Index – the diversity of export composition was taken from the UNCTAD database.

Independent variables:

ICT Index: Reflects the development of digital infrastructure was taken from the UNCTAD database.

Renewable Energy Consumption: Share of renewable energy in total energy consumption was taken from the World Bank database.

FDI Inflow: Foreign direct investment inflow also was taken from the World Bank database.

R&D: Expenditure allocated to research and innovation as % of GDP was also taken from the World Bank database.

Dummy variables: EU and EAEU membership are included as indicators were taken from open-source websites.

Model specification

Using panel data individual characteristics of each country (unobserved heterogeneity) are controlled over the time. Using panel data, the general linear-linear regression model can be expressed as:

$$Y_{it}=\beta_0+\beta_1 X_{1,i,t}+\beta_2 X_{2,i,t}+\cdots+\beta_k X_{k,i,t}+\alpha_i+\varepsilon_{i,t}$$

Equation (1)

In this study, the dependent variable is Export Diversification, and the explanatory variables are ICT, Renewable Energy, FDI inflow, R&D, and regional memberships (EU and EAEU). Therefore, the model is expressed through following mathematical equation:

$$\begin{aligned}\text{ExportDiversification}_{it} = {} & \beta_0+\beta_1\cdot\text{ICT}_{i,t}+\beta_2\cdot\text{RenewableEnergy}_{i,t}+\beta_3\cdot\text{FDI}_{i,t}+\beta_4\cdot\text{R\&D}_{i,t}\\ & +\beta_5\cdot\text{EU}_{i,t}+\beta_6\cdot\text{EAEU}_{i,t}+\alpha_i+\varepsilon_{i,t}\end{aligned}$$

Equation (2)

i — is the country index;

t — represents a time period;

α_i — individual (country) effect;

ε_{it} — error term.

Empirical methods and tests

Fixed effect model: The model was used in order to control for specific and constant factors in former USSR countries.

Hausman test: In the regression analysis, the Hausman test was checked to identify the difference between Fixed Effect and Random Effect models, and the Fixed Effect model was determined to be the correct choice.

Heteroskedasticity and multicollinearity: in order to identify if there is a heteroskedasticity problem, the White test was used. And to eliminate the determined heteroskedasticity problem, robust standard errors

(vce(robust)) were used to deal with the problem. The non-existence of multicollinearity was checked by the VIF test. It was found that multicollinearity did not exist.

ANALYSIS AND RESULTS

According to received results from 345 observations in table 1, the average export diversification result is 0.671 (min: 0.411, max: 0.871). This shows that the export portfolio in some countries is narrow or broad. The ICT index average is 41.275 (min: 6.03, max: 85.75); it means that there is a significant difference in digital infrastructure too. Environmental policy and energy strategies indicate totally different ideas that average energy consumption is 16.2% (min: 0, max: 64.6) (Table1).

Table 1. Descriptive Statistics of data[1]

Variable	Obs	Mean	Std. Dev.	Min	Max
diver	345	.671	.121	.411	.871
ICT	345	41.275	19.518	6.03	85.75
renew_ energy	330	16.441	16.872	0	64.6
eu	345	.165	.372	0	1
eaeu	345	.116	.321	0	1
fdi inflow	345	5.245	5.935	-5.678	55.073
rd	306	.495	.405	.067	2.305

The ideas which were given above can be redirected to the R&D variable too. In general, economic development, digital infrastructure, renewable energy, FDI inflow, and R&D reflect significant differences (Table 2).

Table 2. Matrix correlations of data[2]

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) diver	1.000						
(2) ICT	-0.571	1.000					
(3) renew_energy	-0.140	0.002	1.000				
(4) eu	-0.771	0.518	0.361	1.000	—		
(5) eaeu	0.093	0.299	-0.160	-0.173	1.000	—	
(6) fdi_inflow	0.091	-0.119	-0.028	0.036	-0.145	1.000	—
(7) rd	-0.755	0.447	-0.068	0.562	-0.085	-0.032	1.000

1 Source: Author's calculation through Stata
2 Source: Author's calculation through Stata

In Table 2, the correlation of variables is shown. Based on results, some variables are negatively correlated with the export diversification index, which is considered a good result. The reason is that the closer the export diversification index is to zero, the more diversified the country's exports can be; otherwise, we can consider exports concentrated. Especially, ICT (-0.571) and renewable energy (-0.140) variables are negatively correlated with the diversification index, their increase effect decreasing the index of diversification. FDI inflow (0.091) and EAEU (0.093) variables have a positive correlation with the diversification index, which was expected to be minus, but they have a very low correlation. The last one is the R&D (-0.755) index, which has a negatively significant correlation, which is considered a positive result. Overall, there is no strong multicollinearity among the independent variables, which are indicated by the results (Figure 1).

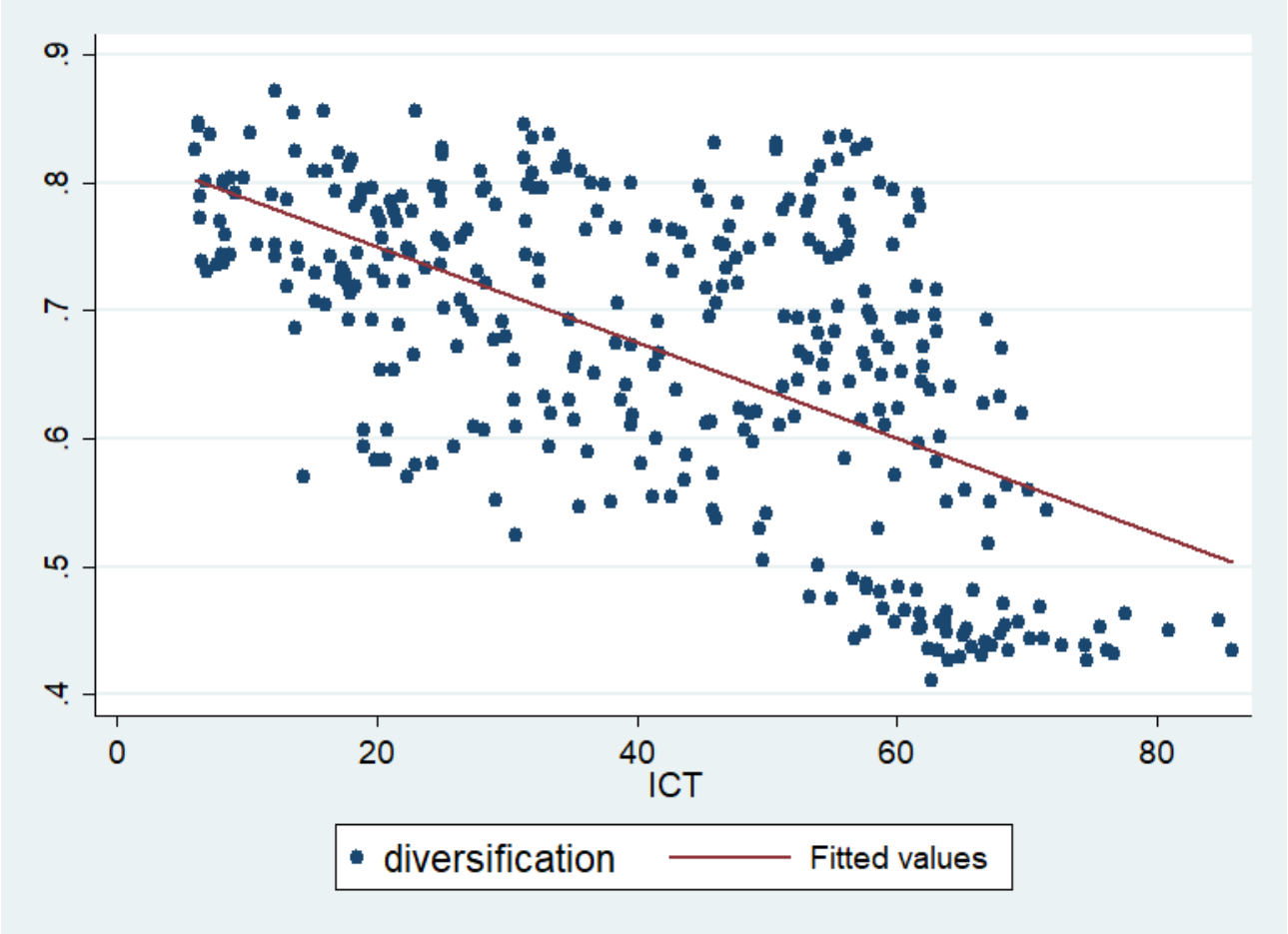

Figure 1. Scatterplot of export diversification and ICT index[3]

Figure 1 shows a negative correlation between export diversification and ICT index by scatterplot. Export diversification indicates improvement, since as the ICT index increases, the value of the diversification index decreases in the diagram. Because, as mentioned above, if the diversification index approaches zero, it means that countries exports grow and narrow concentration declines. This situation shows that the development of digital infrastructure plays a vital role in diversifying exports. In conclusion, investment in the ICT sphere creates opportunities for the empowerment of export diversification. These results support the main hypothesis of this study.

In Figure 2, it is shown that there is a negative correlation between export diversification and renewable energy consumption by scatterplot. Export diversification indicates improvement here too. Since as renewable energy consumption expands, the value of the diversification index declines in the diagram. As stated in figure 1, if the diversification index approaches zero, it means that countries exports increase and narrow concentration decreases. Although the relationship was not well expressed in some periods, the fitted line generally showed a positive trend. Therefore, a transition to environmentally friendly energy sources may have a positive impact on expanding the exported goods and countries (Figure 2).

3 Source: Author's calculation through Stata

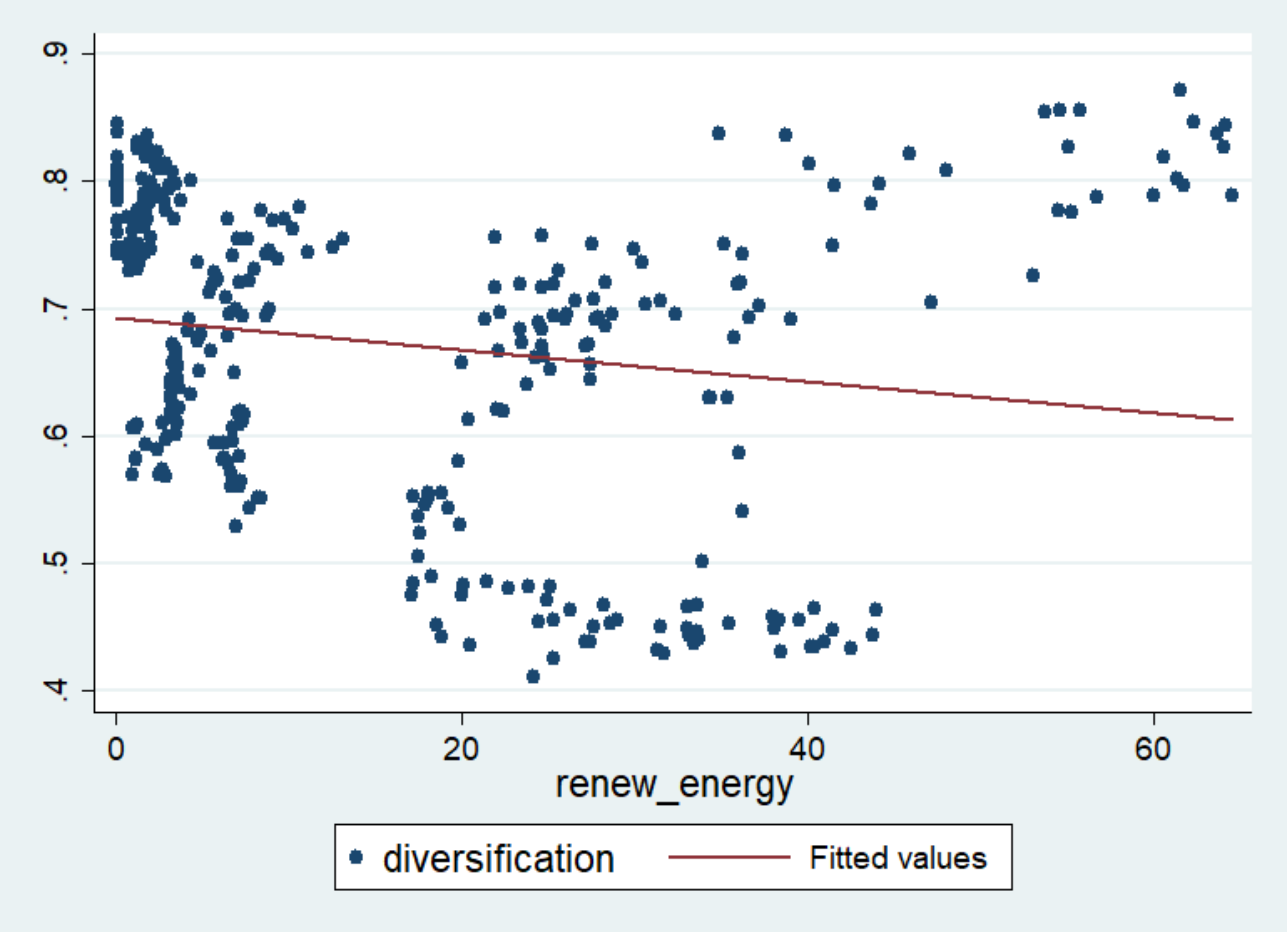

Figure 2. Scatterplot of export diversification and renewable energy consumption[4]

According to Table 3, it can be concluded that the model is statistically significant (Prob > F = 0.0000). Given independent variables, they explain approximately 76.9% of the variation in the diversification index. The research's main independent variable, which is the ICT index, is statistically significant at the 5% level, and it has a negative coefficient that explains the smaller the diversification index, the better the diversification. If the ICT index expands by one unit, the diversification index declines by 0.0004 units. Another main variable is renewable energy consumption, which is also statistically significant at the 1% level, but it has a positive coefficient, which results in one unit of increase in energy consumption and a 0.001 unit increase in diversification, which leads to export concentration.

Why might the results be like this? It is because the countries might be at the initial stage of generating environmental energies. Or even though countries invest in the green energy sector, export reliance on one or two sectors might rise concentration. In short, the result is the opposite of what we expected. However, it should also be taken into account that in practice, investments in the green economy do not always pay off immediately. The control variable, which is FDI inflow, has a positive effect on decreasing the index of export diversification, but it shows statistical insignificance. The other two variables, membership in the EU and investment in research and development, play an important role for export diversification since they are both statistically significant and have a positive effect on decreasing the diversification index. And so, results showed that different factors impact each other differently in terms of the export diversification index. In any case, the ICT index indicated a positive result, as expected (Table 3).

Table 3. Fixed effect estimation result of the impact of ICT index and renewable energy on export diversification.

	(1)
VARIABLES	diver
ICT	-0.000375**

4 Source: Author's calculation through Stata

	(0.000163)
renew_energy	0.000961**
	(0.000377)
eu	-0.0932***
	(0.0132)
eaeu	0.00942
	(0.00777)
fdi_inflow	-0.000592
	(0.000378)
rd	-0.0441***
	(0.0142)
Constant	0.701***
	(0.0118)
Observations	296
Number of country_id	14
R-squared	0.347

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Author's calculation through Stata

CONCLUSIONS AND SUGGESTIONS

The impact of digital infrastructure and renewable energy on export diversification was investigated in this research. The results showed that the development of ICT infrastructure has a significantly positive effect on expanding the export portfolio. Through digital technology, new innovative products and services will be implemented by export and provide an exit from the trading model based on traditional resources. Also, increasing renewable energy consumption increases the ecological sustainability of a country and gives impetus to develop new industrial sectors. The result means that export diversification can be strengthened not only through digital transformation but also through the implementation of green economy strategies. Besides, FDI inflows, R&D expenditures and regional integrations may also play a crucial role in shaping the export composition.

In this context, it would be appropriate if government policymakers, businessmen, and leaders in the field follow the following recommendations:

Firstly, it would be appropriate to increase investment in ICT sectors. The growth of digital technology and information technology infrastructure are the main factors of export diversification. It is possible to expand export composition and create new goods and services by encouraging ICT investment in government and the private sector.

Secondly, expanding green energy strategies. Investing in renewable energy technologies increases not only environmental sustainability but also supports industrial innovations too. Export diversification will be strengthened through this.

Thirdly, increase attention to FDI and R&D sectors. The possibility of introducing new technology and industrial modernisation increases export efficiency through enlargement of foreign investment and research & development expenditure.

Lastly, gaining regional integration membership or integration with regional countries will improve trading conditions.

In general, research results showed the importance of ICT development and renewable energy consumption to increase export diversification. Overall, these recommendations could help selected countries to improve their ICT infrastructure and increase renewable energy consumption for the growth of export diversification and contribute to sustainable economic development.

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IQTISODIYOT&TARAQQIYOT

Ijtimoiy, iqtisodiy, texnologik, ilmiy, ommabop jurnal

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2025-yil. navbatdan tashqari son

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““Yashil” iqtisodiyot va taraqqiyot” jurnali 03.11.2022-yildan
O‘zbekiston Respublikasi Prezidenti Adminstratsiyasi huzuridagi
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№566955 reyestr raqami tartibi bo‘yicha ro‘yxatdan o‘tkazilgan.
Litsenziya raqami: №046523. PNFL: 30407832680027

Manzilimiz: Toshkent shahar, Mirzo Ulug‘bek tumani
Kumushkon ko‘chasi, 26-uy.

Jurnal sayti: https://yashil-iqtisodiyot-taraqqiyot.uz