IQTISODIY TARAQQIYOT VA TAHLIL ILMIY ELEKTRON JURNAL

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DIRECT AND INDIRECT EFFECTS OF THE TEXTILE INDUSTRY ON AIR POLLUTION IN UZBEKISTAN – MACROECONOMIC ANALYSIS

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Abstract. *This article presents a macro-level econometric analysis of the direct and indirect effects of the textile industry on air pollution in Uzbekistan. The analysis incorporates key variables, including electricity supply across the entire industrial sector, textile production output, and the share of the textile industry in total industrial activity. The study examines observed deviations in pollution levels and identifies underlying economic and structural factors. Based on the findings, the article provides policy-oriented recommendations and strategic measures aimed at mitigating environmental impacts and reducing air pollution in Uzbekistan.*

Keywords: *air pollution, macroeconomic statistics, textile industry, industry output, SDG.*

O‘ZBEKISTONDA TO‘QIMACHILIK SANOATINING HAVO IFLOSLANISHIGA BEVOSITA VA BILVOSITA TA’SIRI – MAKROIQTISODIY TAHLIL

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Annotatsiya. *Ushbu maqolada O‘zbekiston to‘qimachilik sanoatining havo ifloslanishiga bevosita va bilvosita ta'siri makroiqtisodiy darajadagi ekonometrik tahlil taqdim etilgan. Tahlilda asosiy o‘zgaruvchilar tanlanib, jumladan, butun sanoat sohasida elektr ta'minoti, to'qimachilik ishlab chiqarish hajmi va to'qimachilik sanoatining umumiy sanoat faoliyatidagi ulushini o‘z ichiga olgan. Tadqiqot havo ifloslanish darajasidagi kuzatilgan og‘ishlarni tahlil etib, asosiy iqtisodiy hamda strukturaviy omillarni aniqlashtirib bergan. Tahlil natijalariga asoslanib, O‘zbekistonda atrof-muhitga salbiy ta‘sirlarni kamaytirish va havo ifloslanishini kamaytirishga qaratilgan iqtisodiy va siyosiy tavsiyalar taqdim etilgan.*

Kalit so‘zlar: *havo ifloslanishi, makroiqtisodiy statistika, to‘qimachilik sanoati, sanoat ishlab chiqarishi, BRM.*

ПРЯМОЕ И КОСВЕННОЕ ВЛИЯНИЕ ТЕКСТИЛЬНОЙ ПРОМЫШЛЕННОСТИ НА ЗАГРЯЗНЕНИЕ ВОЗДУХА В УЗБЕКИСТАНЕ – МАКРОЭКОНОМИЧЕСКИЙ АНАЛИЗ

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Аннотация. *В этой статье представлен макроуровневый эконометрический анализ прямого и косвенного влияния текстильной промышленности на загрязнение воздуха в Узбекистане. Анализ учитывает ключевые переменные, включая поставки электроэнергии во всём промышленном секторе, выпуск текстильного производства и долю текстильной промышленности в общей промышленной деятельности. В исследовании рассматриваются наблюдаемые отклонения уровней загрязнения и выявляются основные экономические и структурные факторы. Основываясь на результатах, статья содержит ориентированные на политику рекомендации и стратегические меры, направленные на смягчение воздействия на окружающую среду и снижение загрязнения воздуха в Узбекистане.*

Ключевые слова: *загрязнение воздуха, макроэкономическая статистика, текстильная промышленность, промышленное производство, ЦУР.*

Introduction.

Uzbekistan's ongoing economic transformation is strongly guided by the *Uzbekistan–2030 Strategy*, which prioritizes rapid industrial development, export diversification, and improved living standards while emphasizing environmental sustainability. Among industrial sectors, the textile industry plays a strategic role due to its high contribution to industrial output, employment, and foreign trade. However, accelerated industrial growth also raises concerns regarding environmental externalities, particularly air pollution, which may arise through both direct and indirect channels.

Air pollution generated by the textile industry can be classified as direct, originating from production processes such as dyeing, finishing, and on-site fuel combustion, and indirect, resulting from increased electricity consumption required to support expanding industrial activity. As electricity generation in Uzbekistan remains largely dependent on fossil fuels, rising energy demand from the textile sector contributes indirectly to higher emissions at the macroeconomic level. Therefore, understanding these linkages is essential for designing balanced industrial and environmental policies.

This article explores the relationship between textile industry output, total industrial production, electricity consumption, and air pollution in Uzbekistan using official data from the national statistical agencies. By applying a macroeconomic analytical framework, the study evaluates how industrial expansion affects environmental outcomes over time. The findings aim to support evidence-based policymaking aligned with the Uzbekistan–2030 Strategy and the Sustainable Development Goals, contributing to the development of a more resilient and environmentally responsible industrial sector.

Literature review.

In accordance with United Nations (UN) agencies, such as the UN Environment Programme (UNEP) and the World Health Organization (WHO), air pollutants are defined as contamination of the indoor or outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere. These are substances present in the air in concentrations high enough - and for durations long enough -to harm humans, animals, plants, ecosystems, reduce visibility, or corrode materials (World Health Organization, 2026).

Sources of air pollution in households and industries along with recent statistical and research-based data from academic journals and authoritative sources gives significant details on adverse contribution around the world.

Household Air Pollution - Sources & Key Facts. Household air pollution (HAP) refers to pollutants released inside or near homes, primarily from energy use and everyday activities:

a) Cooking and Heating with Solid Fuels. Use of biomass fuels (wood, dung, crop waste) and coal in traditional stoves releases fine particulate matter (PM2.5/PM10), carbon monoxide (CO), nitrogen oxides (NOx) and other harmful compounds (World Health Organization, n.d.). Globally, about 2.1 billion people still cook with polluting fuels and inefficient stoves - generating high levels of household air pollution.

b) Gas Appliances. Unvented gas stoves and heaters emit NO2 - indoors this pollution can be much higher than outdoor levels. Research shows NO2 levels indoors can be 3–12× higher during gas cooking. Indoor pollutant sources such as gas cookers are major predictors of NO2 and increase PM levels (Vardoulakis et al., 2020).

c) Smoking & Second-hand Smoke. Cigarette smoke is one of the most significant household sources of PM2.5 and carcinogenic substances (Morantes et al., 2023).

d) Household Products & Activities. VOCs (Volatile Organic Compounds) are released by: Building materials, furniture, paints, cleaning products, air fresheners, insect repellents, candles, incense, VOCs and PAHs (polycyclic aromatic hydrocarbons) contribute to harmful indoor air quality (Morantes et al., 2023).

Household air pollution is linked to ~2.9 million deaths per year globally (2021 estimates), especially in low-middle income regions. Household emissions contribute significantly to ambient PM2.5 exposure - estimated to account for ~20–30% of total PM2.5 exposure in some regions like South Asia (Ji et al., 2025). Indoor PM2.5 from cooking and biomass can exceed WHO limits by orders of magnitude in poorly ventilated homes (Kurmanbekova et al., 2025). Household activity (cooking, heating) is repeatedly identified as a leading indoor air pollutant source in Europe and elsewhere (Martins et al., 2025).

Industrial Air Pollution - Sources. Industrial air pollution originates from manufacturing processes, energy production, and combustion of fuels in factories and industrial facilities. Major industrial sources:

a) Combustion of fossil fuels. Power plants, refineries, and factories burn coal, oil or natural gas, releasing: Particulate matter (PM2.5, PM10), Sulfur dioxide (SO2), Nitrogen oxides (NOx), Carbon monoxide (CO), these are primary contributors to smog, acid rain and respiratory diseases (Arshad et al., 2024).

b) Chemical & Process Emissions. VOCs and other pollutants from paints, solvents, chemical plants, coatings, and manufacturing processes. Industries also emit secondary pollutants from chemical reactions in the atmosphere (Nakhjiri and Kakroodi, 2024).

c) Heavy Industry & Metallurgy. Smelting (e.g., metal production) and large-scale industrial processes are responsible for large fractions of SO2 and heavy particulate emissions (Adnan et al., 2022).

d) Brick Kilns & Small-Scale Heat-Intensive Industries. Small-scale manufacturing like brick kilns disproportionately contributes to local air pollution in South Asia and other regions (Nazir et al., 2023).

In the European Union Industry contributed about 30% of total PM2.5 emissions. 55% of greenhouse gas emissions were from industry sectors. 29% of ozone precursors also came from industrial activities (European Commission, n.d.). A recent city-scale analysis (Hyderabad) showed industries accounted for 66% of VOC emissions, 91% of sulfur dioxide emissions (SO2), 33% of PM10 contributions in industrial or peri-urban zones (Yadav et al., 2021).

Health Effects. Particulate matter (especially PM2.5) can penetrate deep into lungs, causing: Asthma, Cardiovascular disease, Lung cancer, Premature death. NO2 and SO2 irritate airways and can worsen respiratory conditions (Morantes et al., 2023).

Environmental Impacts. Industrial SO2 and NOx lead to acid rain and gas emissions contribute to energy sector greenhouse gases and climate forcing (Arshad et al., 2024).

Air pollution is a significant environmental and public health challenge in Uzbekistan. Official monitoring by the Uzbekistan Hydrometeorological Center (O'zgidromet) shows that air quality in many urban areas is shaped by both natural and human factors, including industrial emissions, vehicle exhaust, construction dust, and dust storms originating from arid regions. O'zgidromet operates monitoring networks in 26 cities with over 70 stations that regularly track pollutants such as particulate matter and nitrogen oxides (Hydrometeorology Service of Uzbekistan, n.d.).

Particulate matter (PM2.5) is the main concern. In the capital Tashkent, the annual average PM2.5 concentration is over six times higher than the World Health Organization's recommended guideline of 5 μg/m^3, largely due to emissions from heating, transport, industry, and wind-blown dust. A joint report by the World Bank and the Ministry of Ecology indicates that 83 % of Tashkent residents live in high pollution zones, where PM2.5 routinely exceeds safe levels, contributing to respiratory and cardiovascular illnesses and an estimated 3,000 premature deaths annually in the city (Akramkhanov et al., 2024).

National data also highlights seasonal spikes in pollution due to coal and fuel oil used for heating, especially in winter, along with emissions from millions of vehicles that together release large amounts of pollutants. Natural phenomena such as dust storms from desert regions further raise particulate levels, particularly in cities like Bukhara, Samarkand, and Fergana (State of the Environment of the Republic of Uzbekistan, n.d.). In response, Uzbekistan has strengthened air quality standards and expanded monitoring networks, aligning PM2.5 limits closer to international benchmarks and planning further enhancements to emissions tracking and regulation (O'zbekiston Respublikasi Prezidenti, 2023).

The textile industry is one of the most vital sectors of Uzbekistan's economy, significantly contributing to industrial output, exports, and employment. In 2025, the total production value of textile goods in Uzbekistan reached 134 trillion Uzbek soums, reflecting sustained growth in manufacturing capacity and modernization of production facilities. The sector also attracted about $2.1 billion in foreign investment during the same year, underscoring international confidence in its development potential. Employment in the textile industry rose to approximately 623,000 people, with plans to expand to around 650,000, highlighting its role as a major employer across the country (ugli Sapaev and Bakoeva, 2025).

Textile exports are a cornerstone of Uzbekistan's foreign trade. According to the State Statistics Agency, the country exported nearly $2.9 billion worth of textile products in 2024, which accounted for about 10.6 % of total national exports. Key export products include cotton yarn ($1.237 billion), finished textile products ($1.124 billion), knitwear ($292 million), fabrics, and hosiery. Uzbekistan's textile goods reach markets around the world, strengthening the country's global trade presence (State Statistics Agency, n.d.). Despite a slight export decline noted in some reporting periods, the government continues to pursue strategic goals to expand capacity and increase value-added production, aiming to raise output to 147 trillion soums and boost exports to $3.3 billion in 2026. Continued investments in technology, quality standards, and international certifications are expected to enhance competitiveness and support sustainable growth.

Research methodology.

1) *The method of analysis and synthesis* is applied to evaluate investment and pollution outcomes and their correlation with output in the context of developing Uzbekistan's textile industry.

2) *Scientific abstraction,* along with the methods *of induction and deduction*, is employed in research to compare similarities and evaluate findings from various scientists and statistical data.

3) The abstract-logical method is applied to theoretically synthesize the research findings and derive conclusions of research.

4) The mathematical, econometric and statistical, analysis of research results entails examining the collected data on pollution and textile output, using various methods, including ranking, scaling, classification, systematization, differentiation, grouping, and graphical representation.

Analysis and discussion of results.

National assessments of air quality in Uzbekistan show that industrial emissions are a persistent contributor to poor air quality. According to the National State of the Environment Report, atmospheric pollution arises from stationary sources such as industrial and manufacturing facilities, alongside mobile sources like transport. Textile production processes—particularly energy-intensive stages like spinning, weaving, dyeing, and finishing—rely on fossil-fuel-based energy and chemical inputs, which can generate particulate matter (PM2.5/PM10) and volatile organic compounds (VOCs) that degrade air quality. While specific official emission inventories for the textile sector are limited, such industrial activities fall within broader stationary source pollution that regularly drives air quality exceedances in urban and industrial regions (iisd.org, 2024).

Scientific analyses of Uzbekistan's air quality further underline that industrial emissions are among the key contributors to hazardous air pollutant levels such as PM2.5 and NO_2, particularly in urban centers like Tashkent where industrial, transport, and energy sources overlap. These pollutants are known to have adverse health impacts and contribute to environmental degradation (unece.org, 2025).

The correlation between the textile industry's growth and air pollution reflects a broader pattern in which rapid industrialization and energy use intensification are linked to poorer air quality. Policymakers and industrial stakeholders are increasingly focusing on cleaner technologies and environmental management strategies to mitigate these impacts while maintaining economic development.

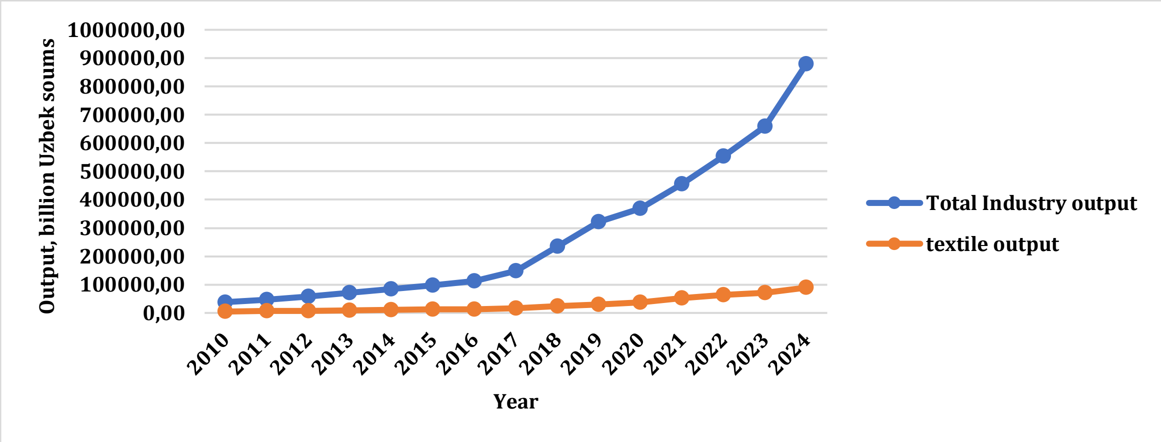
Table 1.

Annual pollution, industrial output and output in textile industry.

year	Pollutants released into the atmosphere (annual, thousand tons)	Volume of electricity supply in the industrial sector (Million kWt hour)	Industrial production (annual, Billion soums)	Manufacture of textiles (annual, Billion soums)	Textiles in total industry (%)
A	B	C	D	E	F
2010	729.00	18117.70	38119.00	4845.50	12.71
2011	788.20	18988.00	47587.10	6736.90	14.16
2012	817.60	19099.20	57552.50	7672.90	13.33
2013	855.20	19469.00	70634.80	8898.30	12.60
2014	1162.10	20232.30	84011.60	10839.50	12.90
2015	975.10	20811.40	97598.20	13241.70	13.57
2016	1008.20	21035.80	111869.40	13335.30	11.92
2017	853.50	22298.40	148816.00	16763.30	11.26
2018	883.70	15007.10	235340.70	24835.20	10.55
2019	952.80	16967.30	322535.80	29946.60	9.28
2020	924.40	18284.30	368740.20	36713.90	9.96
2021	908.70	18683.30	456056.10	52372.30	11.48
2022	873.60	21324.10	553265.00	62850.70	11.36
2023	763.20	24408.30	658991.70	71509.80	10.85
2024	866.70	26151.60	880198.50	89489.00	10.17

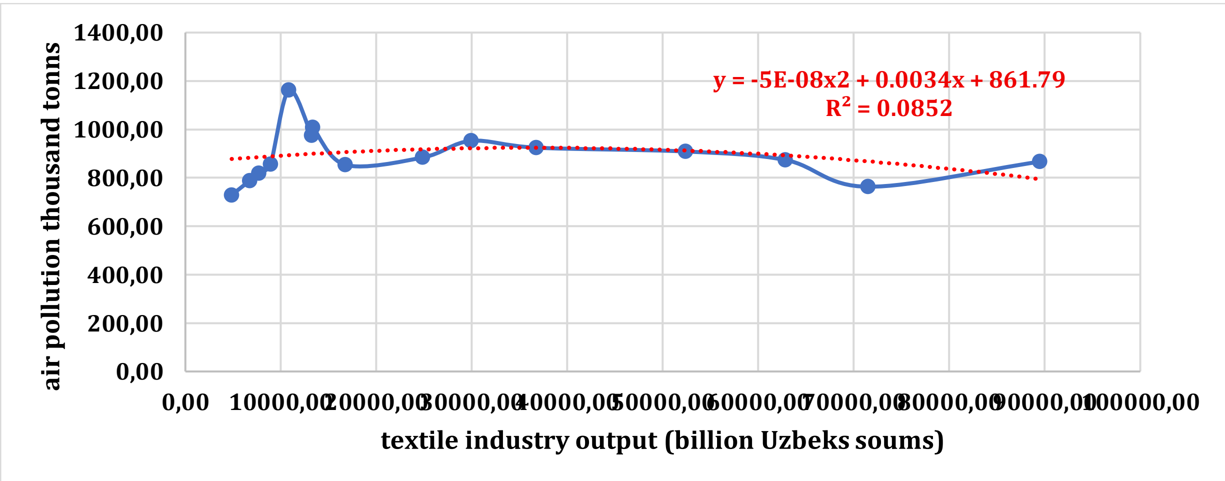
Table 1 presents a comparative overview of general air pollutant emissions alongside electricity generation, total industrial output, and textile industry output in Uzbekistan from 2010 to 2025. The data indicate a steady increase in electricity production and industrial output over the observed period, reflecting rapid economic growth, industrial expansion, and rising energy demand. Electricity generation shows particularly strong growth after 2016, driven by industrial modernization and increased household and industrial consumption.

At the same time, the table demonstrates that air pollutant emissions have followed an upward trend, especially during periods of accelerated industrial and textile sector growth. This suggests a positive correlation between increased energy production, industrial activity, and air pollution levels. The textile industry, as an energy-intensive manufacturing sector, shows consistent output growth, which coincides with higher emissions from stationary sources such as boilers, power plants, and production facilities.



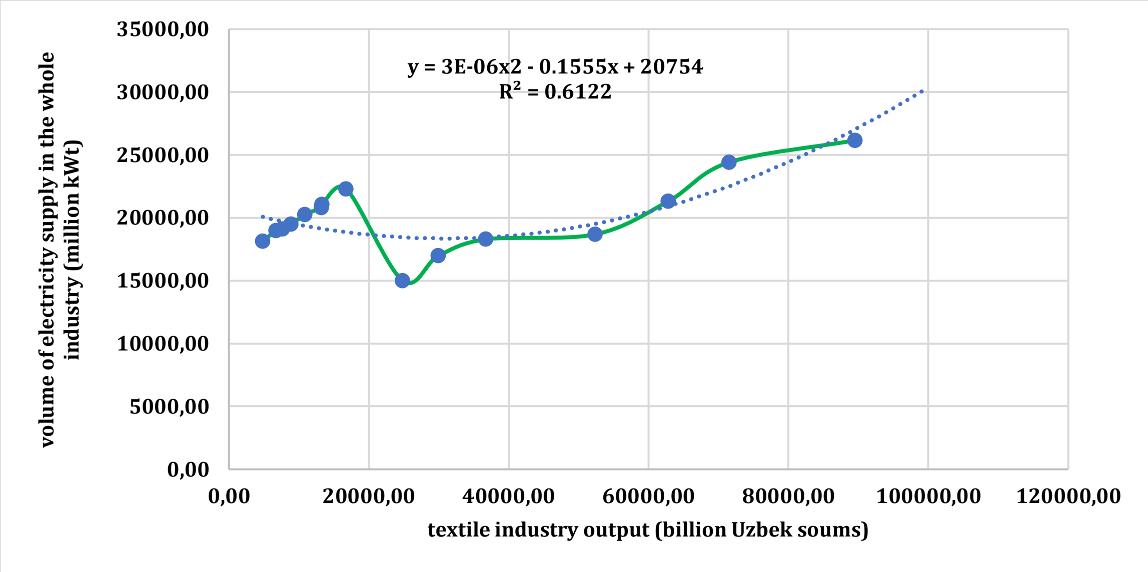
Picture 1. Total Industry and textile output growth

Although technological upgrades and environmental regulations introduced in recent years appear to have slowed the rate of emission growth, pollution levels remain elevated compared to earlier years. Overall, the data in Table 1 highlight the environmental pressure associated with industrialization and underline the importance of cleaner energy sources, improved energy efficiency, and emission-control technologies to decouple economic growth from air pollution in Uzbekistan (Muminova et al., 2024). From the graph (Figure 1), it is possible to observe the growth trend of overall industrial output as well as that of the textile industry. However, the gap between them is significant, as shown in Table 1, and the textile industry contributed 10.17% of total industrial output in monetary terms.



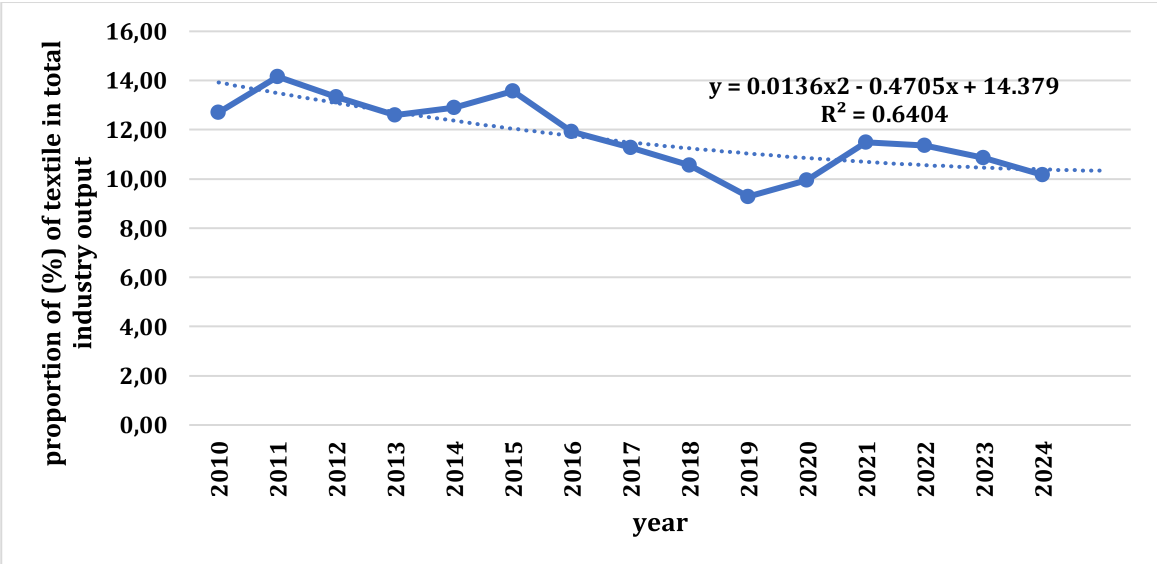
Picture 2. Air pollution per textile output (tonn per billion Uzbek soums)

Conducting a correlation and regression analysis between textile output and overall air pollution is not meaningful [23] because the R^2 value is only 0.0852 as it is shown in the graph (Picture 2). However, despite this weak correlation, it is possible to suggest that air pollution per unit of monetary textile output is likely to decrease in the future.



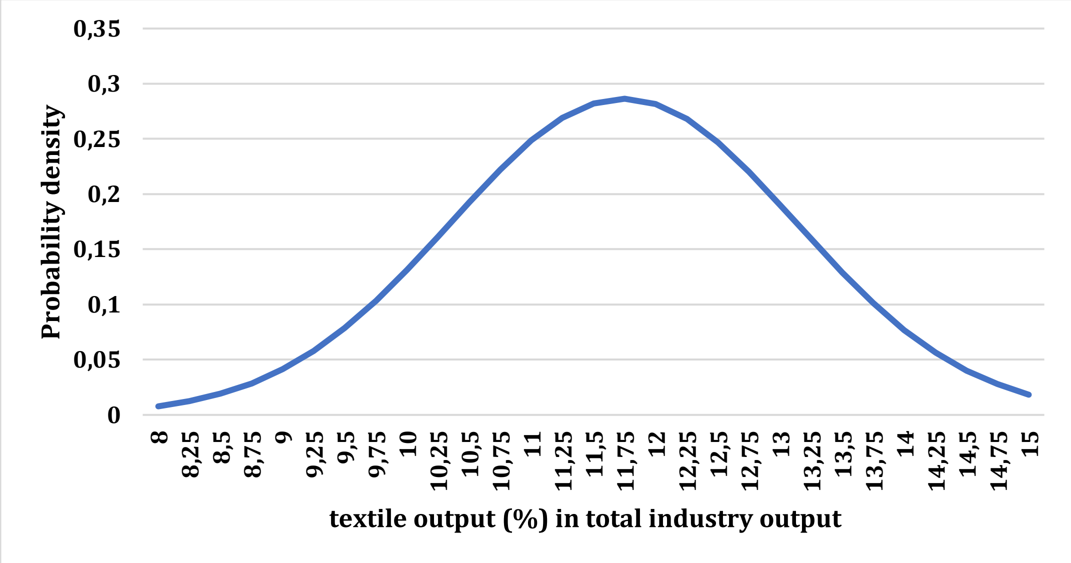
Picture 3. Volume of electricity supply in the industry sector per textile output (million kWt per billion Uzbek soums)

Electricity consumption per unit of textile industry output, measured in monetary terms, is increasing, as shown in Figure 3. The projection indicates that electricity consumption will reach 30,000 kWt if textile output reaches 100 trillion Uzbek soums, with an R^2 value of 0.61122. Though, correlation is weak.



Picture 4. Annual proportion of textile (%) in total industry output.

The highest correlation is obtained using a polynomial model, with an R^2 value of 0.6404. This suggests that there may be fluctuations in the slope over time, and that the share of textile output in total industrial output, measured in monetary terms, may increase in the future (Picture 4).



Picture 5. Distribution of textile output (%) in total industry output.

If normal distribution is used as it is given in the graph (Picture 5) - ($f(x,\mu,\sigma)=\frac{1}{\sigma\sqrt{2\pi}} \cdot e^{\frac{-(x-\nu)^2}{2\sigma^2}}$), μ- mean value (%) of tha last years (fomr 2010-2024) is 11.74061%, with σ - standard deviation 1.39279, it is possible to assume that for the forhtcoming years the probability of textile industry output in total output % ($\mu \pm \sigma$) between 10.34782% and 13.1334 is 67%. It means, that textile indstry monetary vallue will have in average 12.7% of total industrial output.

Conclusion and suggestions.

Based on the research data and analysis, it is evident that industrial output in Uzbekistan will continue to expand, with the textile industry remaining a major contributor to this growth. Empirical trends confirm a strong correlation between industrial production, textile output, electricity generation, and air pollution levels. As textile manufacturing scales up, demand for electricity will increase, which, under current energy structures, is likely to intensify environmental pressures through higher emissions.

However, the long-term sustainability of industrial growth depends not only on regulatory enforcement and technological modernization, but also on the availability of skilled human capital. The analysis highlights the critical role of education and specialist training in supporting cleaner and more efficient production processes. Expanding both the quantity and quality of education, particularly in engineering, environmental sciences, data analytics, and industrial management, is essential for improving productivity while reducing environmental impacts. A well-trained workforce enables firms to adopt energy-efficient technologies, optimize resource use, and comply with environmental standards.

From a policy perspective, effective supply-side measures are necessary to balance industrial growth with sustainability objectives. These include targeted investments in vocational education (Akhunova et al., 2024), university–industry partnerships, incentives for research and development (Askarov va Numanov, 2023), and support for innovation in clean technologies. Such policies can increase production capacity (Aropitdinovich va boshq., 2025) without proportionally increasing pollution, thereby decoupling economic growth from environmental degradation.

In conclusion, sustainable development of the textile and industrial sectors requires an integrated approach that combines strict environmental regulations, investment in human capital, and forward-looking supply-side policies. Aligning these measures with the Sustainable Development Goals (SDGs) will allow Uzbekistan to achieve resilient economic growth (Valiyev, 2025) while safeguarding environmental and social well-being.

References:

Adnan, M., et al. (2022) 'Research progress on heavy metals pollution in the soil of smelting sites in China.' Toxics, 10(5), 231.

Ahmadjonovich, U.A. and Rakhmatovich, A.F. (2023) 'Utilizing dynamic models in analyzing investment activities in regions.' The American Journal of Management and Economics Innovations, 5(12), pp. 29–35.

Akhunova, S.N., et al. (2024) 'The qualitative and quantitative development of education is a crucial factor in improving the innovation ranking of Uzbekistan.' International Journal of Management and Economics Fundamental, 4(04), pp. 07–19.

Akramkhanov, A., et al. (2024) Sand and Dust Storms in Uzbekistan: Atmospheric Modeling for Understanding Impacts and Mitigation.

Aropitdinovich, V.A. and O'G'Li, M.S.S. (2025) 'Mahsulot tannarxini kamaytirish strategiyasi va uning ahamiyati.' Raqamli iqtisodiyot (Цифровая экономика), (11), pp. 1620–1627.

Arshad, K., et al. (2024) 'Air pollution and climate change as grand challenges to sustainability.' Science of The Total Environment, 928, 172370.

Askarov, F.R. and Numanov, J.O. (2023) 'Necessity of integrating specialists through a combination of education and practical experience in the workplace in the era of the digital economy in Uzbekistan.' Science and Innovation, 2(Special Issue 14), pp. 746–756.

European Commission (n.d.) Industrial emission statistics. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Industrial_emission_statistics

Hydrometeorology Service of Uzbekistan (n.d.) O'zbekiston Respublikasi Ekologiya va iqlim o'zgarishi milliy qo'mitasi huzuridagi gidrometeorologiya xizmati agentligi. Available at: https://gov.uz/oz/hydromet

Ji, W., et al. (2025) 'Trends and regional disparities in the global burden of disease attributable to household air pollution in 204 countries and territories, 1990–2021.' BMJ Open, 15(6), e092162.

Kurmanbekova, M., Du, J. and Sharples, S. (2025) 'A review of indoor air quality in social housing across low-and middle-income countries.' Applied Sciences, 15(4), 1858.

Martins, C., et al. (2025) 'Sources, levels, and determinants of indoor air pollutants in Europe.' Science of the Total Environment, 964, 178574.

Morantes, G., et al. (2023) 'Harm from residential indoor air contaminants.' Environmental Science & Technology, 58(1), pp. 242–257.

Muminova, E.A., et al. (2024) 'The impact of economic growth on environmental pollution: The case of Uzbekistan.' E3S Web of Conferences, 574, 04003.

Nakhjiri, A. and Kakroodi, A.A. (2024) 'Air pollution in industrial clusters: A comprehensive analysis and prediction using multi-source data.' Ecological Informatics, 80, 102504.

Nazir, U., Taj, M., Uppal, M. and Khalid, S. (2023) 'Mitigating climate and health impact of small-scale kiln industry using multi-spectral classifier and deep learning.' arXiv preprint, arXiv:2303.11654.

O'zbekiston Respublikasi Prezidenti (2023) Farmon PF-158-son, 11.09.2023. Available at: https://lex.uz/ru/docs/-6600413

State of the Environment of the Republic of Uzbekistan (n.d.) Available at: https://uz-eco.tilda.ws/en

State Statistics Agency (n.d.) Available at: https://stat.uz/uz/

ugli Sapaev, S.D. and Bakoeva, G.M. (2025) 'Diversifying Uzbekistan's export markets: The potential of South and Southeast Asian countries.' Modern American Journal of Business, Economics, and Entrepreneurship, 1(3), pp. 141–154.

Valiyev, A. (2025) 'Past karbonli iqtisodiyotga o'tish zaruriyati va uning omillari.' Green Economy and Development, 3(5). https://doi.org/10.5281/zenodo.15569757

Vardoulakis, S., et al. (2020) 'Indoor exposure to selected air pollutants in the home environment: A systematic review.' International Journal of Environmental Research and Public Health, 17(23), 8972.

World Health Organization (2026) Air pollution. Available at: https://www.who.int/health-topics/air-pollution

World Health Organization (n.d.) Household air pollution. Available at: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

Yadav, S., Lama, S. and Kapley, A. (2021) 'Urban environmental issues and mitigation by applying ecological and ecosystem engineering.' In: Handbook of Ecological and Ecosystem Engineering, pp. 123–145.