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SCIENTIFIC AND PRACTICAL SIGNIFICANCE OF THE TAPIO DECOUPLING MODEL IN ASSESSING THE INTERDEPENDENCE BETWEEN REGIONAL ECONOMY AND ENERGY CONSUMPTION

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Abstract. This article explores issues related to improving the mechanism of energy resource utilization within the framework of regional economic development. To analyze the correlation between economic growth (GRP) and energy consumption, the decoupling model developed by Petri Tapio is examined. This model is proposed as a vital indicator for assessing the state of sustainable regional development and formulating energy policies. Furthermore, using the regions of Uzbekistan as a case study, the relationship between economic growth and energy consumption is analyzed through the Tapio elasticity model. Based on statistical data from 2023–2024, the energy efficiency levels of the regions are evaluated, and differentiated economic mechanisms are proposed to enhance the "decoupling" effect.

Keywords: Regional economy, Tapio model, energy efficiency, elasticity coefficient, strong decoupling, sustainable development.

HUDUDIY IQTISODIYOT VA ENERGIYA ISTE’MOLI O‘RTASIDAGI O‘ZARO BOG‘LIQLIKNI BAHOLASHDA TAPIO DECOUPLING MODELINING ILMIY VA AMALIY AHAMIYATI

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Annotatsiya. Ushbu maqolada hududiy iqtisodiy rivojlanish doirasida energiya resurslaridan foydalanish mexanizmini takomillashtirish bilan bog‘liq masalalar tadqiq etilgan. Iqtisodiy o‘sish (YAMM) va energiya iste’moli o‘rtasidagi korrelyatsiyani tahlil qilish uchun Petri Tapio tomonidan ishlab chiqilgan dekapling (ajralish) modeli o‘rganilgan. Ushbu model hududlarning barqaror rivojlanish holatini baholash va energetika siyosatini shakllantirishda muhim indikator sifatida taklif etilgan. Shuningdek, O‘zbekiston hududlari misolida iqtisodiy o‘sish va energiya iste’moli o‘rtasidagi bog‘liqlik Tapio elastiklik modeli orqali tahlil qilingan. 2023–2024-yillardagi statistik ma’lumotlar asosida hududlarning energiya samaradorligi darajasi baholangan hamda "dekapling" effektini kuchaytirish uchun tabaqalashtirilgan iqtisodiy mexanizmlar taklif etilgan.

Kalit so‘zlar: Hududiy iqtisodiyot, Tapio modeli, energiya samaradorligi, elastiklik koeffitsiyenti, kuchli dekapling, barqaror rivojlanish.

НАУЧНО-ПРАКТИЧЕСКАЯ ЗНАЧИМОСТЬ МОДЕЛИ ДЕКАПЛИНГА ТАПИО В ОЦЕНКЕ ВЗАИМОСВЯЗИ МЕЖДУ РЕГИОНАЛЬНОЙ ЭКОНОМИКОЙ И ПОТРЕБЛЕНИЕМ ЭНЕРГИИ

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Аннотация. В данной статье исследуются вопросы совершенствования механизма использования энергетических ресурсов в рамках регионального экономического развития. Для анализа корреляции между экономическим ростом (ВРП) и потреблением энергии рассматривается модель декаплинга, разработанная Петри Тапио. Данная модель предлагается в качестве важнейшего индикатора для оценки состояния устойчивого регионального развития и формирования энергетической политики. Кроме того, на примере регионов Узбекистана с помощью модели эластичности Тапио проанализирована взаимосвязь между экономическим ростом и потреблением энергии. На основе статистических данных за 2023–2024 годы оценена энергоэффективность регионов и предложены дифференцированные экономические механизмы для усиления эффекта «декаплинга».

Ключевые слова: Региональная экономика, модель Тапио, энергоэффективность, коэффициент эластичности, сильный декаплинг, устойчивое развитие.

Introduction

In the current phase of transitioning to a modern economy, enhancing regional competitiveness has become directly contingent upon the efficiency of energy resource utilization. Under the conditions of modernizing the national economy, maintaining sustainable growth rates of the Gross Regional Product (GRP) while simultaneously reducing the energy intensity of the economy is considered a strategic priority.

However, economic growth in many regions is accompanied by a proportional increase in energy consumption, which leads to resource scarcity and an intensified environmental burden. To address this issue, there is a substantial need to scientifically justify "decoupling" mechanisms—breaking the traditional correlation between economic growth and energy consumption. The decoupling model proposed by Petri Tapio serves as one of the most reliable methodological tools for diagnosing the energy efficiency of a regional economy. By utilizing the Tapio model, it is possible to evaluate the current state of a region through precise quantitative indicators: whether economic development is achieved through energy conservation or, conversely, if energy waste is outstripping economic growth.

From this perspective, formulating regional energy policies in a differentiated manner, based on the diagnostic results of the Tapio model, serves as a fundamental basis for ensuring the long-term sustainable growth of the territory.

Literature review

The analysis of the interdependence between economic development and energy resource utilization remains a central issue in modern economic

science. The "Environmental Kuznets Curve" (EKC) model[1], developed based on Simon Kuznets' hypothesis, serves as a fundamental framework for research in this field. Scholars such as G. Grossman and A. Krueger [2] have scientifically demonstrated that in the early stages of economic growth, resource consumption and environmental pressure increase; however, upon reaching a certain level of prosperity, this process reverses due to technological innovation. Nevertheless, because the EKC model primarily reflects long-term tendencies, it possesses certain limitations in the dynamic analysis of annual changes at the regional level[3].

In this context, the concept of "decoupling" the link between economic growth and energy consumption was introduced into scientific discourse[4]. The elasticity analysis model proposed by Petri Tapio in 2005 marked a revolutionary stage in economic literature. In his seminal work, *"Towards a theory of decoupling,"* P. Tapio critically analyzed the index-based approach promoted by the OECD and mathematically modeled eight possible scenarios between the rate of economic growth and resource expenditure. According to his findings, for a sustainably developing region, "Strong Decoupling"—a state where GRP grows while absolute energy consumption decreases—should be the primary strategic objective[5].

Subsequently, Chinese scholars, notably Wang and his co-authors, refined the Tapio model within the context of regional industrial sectors, specifically highlighting "structural changes" and "technical progress" as key factors in increasing energy efficiency[6]. Their research indicates that the main driver is not merely resource conservation, but reducing the share of energy-intensive industries within the regional economic structure.

Regarding the management mechanisms of regional economies, foreign researchers (e.g., J. Sachs et al.) emphasize the importance of combining market instruments with state regulation to improve energy resource utilization.[7] They argue that the liberalization of energy prices and the introduction of "green" tariffs are the primary mechanisms forcing enterprises to invest in energy-efficient technologies.

Uzbekistan’s scholars have also paid significant attention to reducing the energy intensity of the national economy and optimizing regional energy balances. Local research has primarily focused on implementing energy management systems (ISO 50001)[8] in industrial enterprises and utilizing the renewable energy potential of regions. However, the quantitative assessment of the nexus between economic growth and energy consumption in the regions of Uzbekistan using the Tapio model, and the subsequent improvement of differentiated management mechanisms based on this analysis, has yet to find a comprehensive scientific solution.

In conclusion, the literature review demonstrates that in global practice, the Tapio model is considered the most reliable tool for diagnosing sustainable regional development. Our research aims to adapt this model to the specific economic conditions of Uzbekistan, envisioning a transition of the

regional energy consumption mechanism toward an economic incentive system based on elasticity indicators.

Research methodology

The scientific novelty and advantage of the Tapio model lie in its ability to express the relationship between economic growth and resource consumption through the concept of "elasticity" rather than simple indices. This approach enables the precise classification of even minor changes within the economic system, providing an accurate diagnosis of a region's developmental trajectory. Furthermore, it allows for the monitoring of a state's or region's transition toward a "Green Economy," identifying whether economic growth is driven by increased energy consumption or technological advancements, and evaluating the degree of decoupling between energy expenditure and economic output.[9]

In particular, the model does not limit the assessment of the economic state to a binary "positive or negative" view; instead, it identifies eight distinct scenarios, such as strong decoupling, weak decoupling, and expansive coupling. The elasticity analysis method proposed by P. Tapio is based on comparing the percentage changes in economic growth and energy consumption[4]. This term represents the decoupling elasticity coefficient (ε), which is calculated using the following formula:

$$\epsilon = \frac{\%\Delta E}{\%\Delta GDP} = \frac{\frac{E_t - E_{t-1}}{E_{t-1}}}{\frac{GDP_t - GDP_{t-1}}{GDP_{t-1}}}$$

Where:

ϵ- : Decoupling elasticity coefficient;

$\%\Delta E$- The growth rate of energy consumption (in percent);

$\%\Delta GDP$- The growth rate of Gross Regional Product (GRP) (in percent);

$E_t - E_{t-1}$- Energy consumption volume in the current and previous years, respectively;

$GDP_t - GDP_{t-1}$- GRP volume in the current and previous years, respectively (at constant prices).

Unlike traditional elasticity analysis, the Tapio model utilizes threshold values of **0.8** and **1.2** for result evaluation. This range allows for the consideration of minor economic fluctuations and reduces measurement errors[4]. The model's results are categorized into three main groups and eight logical states based on the value of ϵ and the direction of change in $\%\Delta E$ and $\%\Delta GDP$.

Based on this classification matrix, the practical part of the study evaluates the developmental trajectory of the Republic for the years 2023–2024. However, it should be noted that the Tapio model only provides a general overview—identifying whether decoupling has occurred. It does not reveal the underlying factors, such as structural shifts or purely technological innovations.

Table 1

Classification Matrix of the Tapio Decoupling Model

Main Category	Sub-category	Criteria	Economic Significance
A. Decoupling	1. Strong Decoupling	ΔE <0 ΔGDP >0 ϵ < 0	Ideal state. Economy grows while energy consumption decreases. Absolute efficiency.
	2. Weak Decoupling	ΔE > 0, ΔGDP >0 0 < ϵ < 0.8	Both grow, but the economy grows faster. Relative efficiency.
	3. Recessive Decoupling	ΔE < 0, ΔGDP < 0 ϵ > 1.2	Economy is in recession, energy consumption decreases even faster.
B. Coupling	4. Expansive Coupling	ΔE > 0, ΔGDP > 0 0.8≤ ϵ≤1.2	Energy and economy grow at nearly the same rate. Conventional path.
	5. Recessive Coupling	ΔE < 0, ΔGDP< 0 0.8≤ ϵ≤1.2	Economy and energy consumption decrease at the same rate.
C. Negative Decoupling	6. Expansive Negative Decoupling	ΔE > 0, ΔGDP > 0 ϵ > 1.2	Inefficient growth. Energy consumption grows faster than the economy.
	7. Strong Negative Decoupling	ΔE > 0, ΔGDP < 0 ϵ < 0	Worst state. Economy shrinks while energy consumption increases.
	8. Weak Negative Decoupling	ΔE < 0, ΔGDP < 0 0 < ϵ < 0.8	Economy shrinks faster than energy consumption.

Therefore, to conduct a deeper analysis of the root causes of changes in energy efficiency, the study subsequently employs the Index Decomposition Analysis (IDA) method. IDA is used to identify whether the fundamental drivers behind energy consumption changes are scale effects (economic growth), structural effects, or intensity effects (technological updates).

Analysis and results

In evaluating the energy efficiency of regional economic development, analyzing the correlation between the growth of Gross Regional Product (GRP) and the volume of electricity generation is of paramount importance. To quantitatively assess this relationship, the Tapio elasticity model, widely recognized in international practice, was employed. Within the scope of this

study, statistical indicators for all regions of the Republic of Uzbekistan for the 2023–2024 period were processed. The elasticity coefficient (ϵ) was calculated based on the ratio between the GRP growth rate (ΔGDP) and the rate of change in energy resource consumption (ΔE).

Table 2

GRP indicators and electricity generation data of regions for 2023–2024 for calculating Tapio elasticity coefficients.

No.	Regions	GRP (billion UZS)		Electricity Generation (million kWh)	
		2023	2024	2023	2024
1	Republic of Karakalpakstan	40805,2	46299,8	5152,1	5079
2	Andijan region	80337,5	93026,3	658,1	820
3	Bukhara region	63693,4	73434,1	2029,3	2582
4	Jizzakh region	38570,3	43545,9	0,5	1,1
5	Kashkadarya region	71425	83950	8174,9	10099,9
6	Navoiy region	93651,5	130439,5	10718,9	10847,1
7	Namangan region	61074,9	71869,1	7025,3	6561,6
8	Samarkand region	86313,3	103882,7	482,8	515
9	Surxondaryo region	49208,9	56553,9	433,6	653,7
10	Sirdaryo region	24873	28655,5	16855,5	17532,8
11	Tashkent region	124087,1	151251,8	20445,1	20003,2
12	Fergana region	81573,3	93605,7	401,1	479,2
13	Khorezm region	45358,6	53640	1415,9	1291,1
14	Tashkent city	222926,1	302878,5	4211,7	6273,4

The results allowed for the classification of regions into several groups based on the degree of economic growth's dependence on resource expenditure: Strong Decoupling, Weak Decoupling, and Expansive Coupling.

Table 3

Tapio Decoupling Status by Region in Uzbekistan (2023–2024)

Region	GRP Growth (ΔG,%...)	Energy Growth (ΔE,%...)	Elasticity (e)	Developmental Stage (Tapio State)
Uzbekistan (Total)	**21.7%**	**6.1%**	**0.28**	**Weak Decoupling**
Namangan Region	22.0%	-6.6%	-0.30	Strong Decoupling
Navoiy Region	19.5%	1.2%	0.06	Weak Decoupling
Samarkand Region	20.4%	6.7%	0.33	Weak Decoupling
Tashkent City	24.1%	8.5%	0.35	Weak Decoupling
Republic of Karakalpakstan	18.9%	2.6%	0.13	Weak Decoupling
Andijan Region	21.2%	11.2%	0.52	Weak Decoupling
Bukhara Region	20.1%	3.4%	0.16	Weak Decoupling
Surxondaryo Region	19.0%	15.1%	0.79	Expansive Coupling (Risk)
Sirdaryo Region	16.8%	14.5%	0.86	Expansive Coupling

Discussion of results

The empirical analysis yields several critical insights into the energy-economic nexus of Uzbekistan’s regions. For the Republic of Uzbekistan as a whole, the GRP grew by 21.7% in 2024 (in nominal terms) compared to the previous year, while energy generation increased by only 6.1%. The resulting elasticity coefficient of 0.28 indicates a state of Weak Decoupling, suggesting that energy efficiency mechanisms are beginning to yield results at the national level. Namangan region demonstrated a unique trajectory where energy indicators showed negative growth (-6.6%) while the economy continued to grow steadily (22.0%). This identifies the region as being in the "Strong Decoupling" phase, the most ideal state of sustainable development where economic progress is achieved alongside an absolute reduction in energy consumption. The data for Surxondaryo and Sirdaryo regions reveal a significant concern. In these territories, energy growth rates (14–15%) are closely tracking economic growth rates (16–19%). With elasticity coefficients exceeding 0.8, these regions fall into the "Expansive Coupling" category. This indicates an extensive growth model, potentially due to a lack of energy-saving technologies or the continued operation of highly energy-intensive, inefficient industrial facilities.

To provide a more comprehensive visualization of these regional disparities, the calculated elasticity coefficients are mapped onto a scatter plot in Figure 1. This graphical representation categorizes each region into specific decoupling sectors, enabling a clearer diagnostic of the relationship between economic expansion and energy consumption trends across the country.

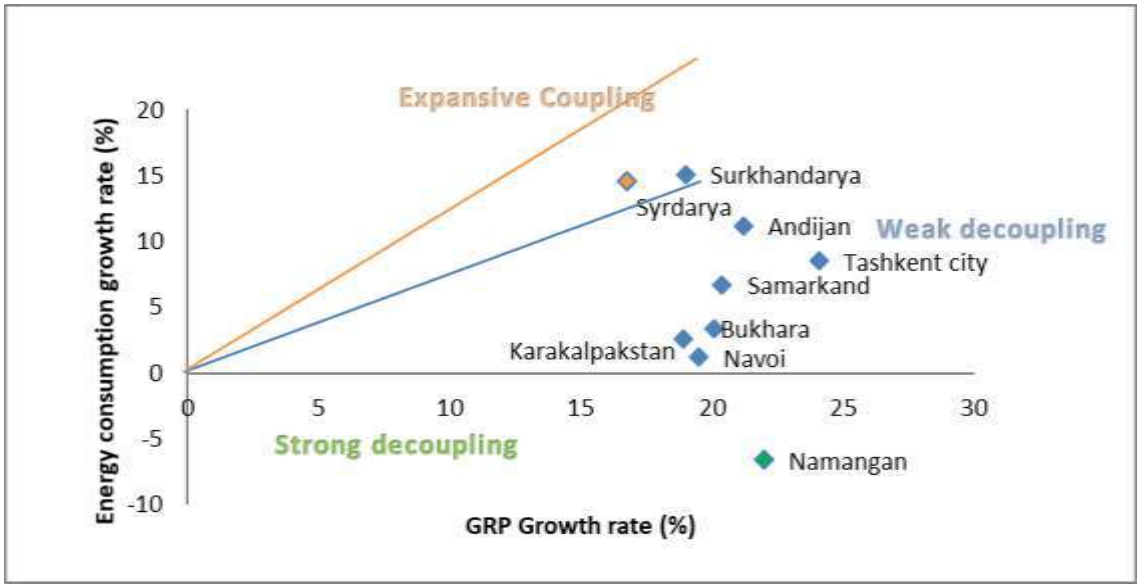

Figure 1. Decoupling states between regional GRP growth and energy consumption in Uzbekistan (2023–2024), based on the Tapio elasticity model.

The visual distribution of regions in Figure 1 highlights a significant spatial imbalance in energy efficiency. While the Namangan region

successfully achieved absolute decoupling, the cluster of regions including Tashkent City and Samarkand remains in the weak decoupling zone. Of particular concern are the Surxondaryo and Sirdaryo regions, located in the expansive coupling sector, where electricity production growth is nearly proportional to economic output, indicating an urgent need for energy-saving industrial upgrades.

Conclusion

The application of the Tapio elasticity model has provided a robust quantitative framework to evaluate the decoupling states between Gross Regional Product (GRP) growth and energy consumption across Uzbekistan’s regions for the 2023–2024 period. The empirical analysis reveals a pronounced spatial heterogeneity in regional energy efficiency, highlighting that the economic essence of energy potential lies not merely in resource abundance, but in the structural efficiency of its utilization.

Notably, the Namangan region has emerged as a benchmark, achieving a state of "Strong Decoupling." In this region, economic expansion is realized alongside an absolute reduction in energy consumption, exemplifying a successful transition towards sustainable green growth. Conversely, a substantial cluster of regions, including Tashkent City, Samarkand, and Navoi, exhibits "Weak Decoupling." While these regions show a relative improvement in energy intensity—where GRP grows faster than energy consumption—they have yet to sever the link between economic output and resource depletion entirely. Of critical concern are the Surkhandarya and Sirdaryo regions, which demonstrate "Expansive Coupling." In these areas, the growth of energy consumption nearly parallels or outpaces economic development, signaling an unsustainable reliance on energy-intensive production factors.

To optimize the economic potential of regional energy resources and accelerate the transition toward sustainable decoupling across all regions, the following strategic and policy measures are recommended:

Targeted Industrial Modernization: Regional development policies must be strictly differentiated based on the decoupling diagnostic. For regions trapped in "Expansive Coupling" (Surkhandarya and Sirdaryo), state investment and foreign direct investment (FDI) should be urgently redirected towards the technological modernization of existing energy-intensive enterprises and the implementation of mandatory energy audits.

Incentivizing Structural Economic Shifts: To elevate "Weak Decoupling" regions to a strong decoupling status, regional governments should introduce differentiated fiscal incentives. Tax rebates and preferential "green" credit lines should be provided to businesses that shift from heavy manufacturing to high-value-added, low-energy sectors, such as IT, advanced services, and precision agriculture.

Cross-Regional Knowledge Transfer: Establish a formal institutional mechanism for sharing best practices. The energy management strategies,

technological upgrades, and structural reforms that enabled the Namangan region's success in achieving "Strong Decoupling" should be systematically studied and replicated in underdeveloped regions.

Integration of the Decoupling Index into Regional Planning: The Tapio decoupling elasticity indicator should be integrated into the national socio-economic forecasting system. It should serve as a mandatory Key Performance Indicator (KPI) for assessing the efficiency of regional administrations in balancing economic growth with energy resource management.

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