The impact of final demand on energy sectors' interregional output

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Abstract

This study investigates the influence of aggregate demand on the interregional energy sector in Indonesia, aiming to ascertain whether the proximity of regions impacts the demand within the energy sector. Utilizing data from the Input-Output Indonesia Interregional Table, this research encompasses six regions: Sumatra, Java, Bali & Nusa Tenggara, Kalimantan, Sulawesi, and Maluku & Papua. The energy sectors analyzed include oil, gas & geothermal mining, coal & lignite mining, coal industry & oil, gas refinery, and electricity and gas procurement & ice production. Findings indicate that the electricity sector exhibits relatively high sensitivity and dispersion power indices, whereas the gas procurement & ice production sectors display low sensitivity and dispersion power indices. Exports are identified as the primary contributors to the Oil, Gas, & Geothermal Mining and Coal & Lignite Mining sectors. Conversely, household consumption has the most significant impact on the other sectors. Crucially, the study reveals that the effect of a region's final demand on the output of another region is not directly correlated with geographical proximity. This insight leads to the recommendation that energy supply procurement policies should consider other regions' demands and economic developments, particularly those substantially influencing output enhancement.

Keywords: *Aggregate demand, Energy, Interregional*

JEL Classification: Q41, Q43, R11.

INTRODUCTION

Energy serves as a fundamental resource for human livelihoods and industrial activities (Wang, 2022). Beyond the immediate energy demands of residential sectors, individuals' consumption behaviours indirectly impact energy utilization across various production domains (Ding et al., 2017). Nevertheless, in terms of supply, the construction industry emerges as the principal beneficiary of energy within the economic framework (Gao et al., 2021; Li et al., 2023). The scenario of energy availability varies significantly across different nations and regions, with some achieving energy self-sufficiency while others are heavily reliant on external sources. This dichotomy showcases regions abundant in energy resources juxtaposed against those grappling with energy shortages.

Additionally, the issue of energy scarcity is not solely attributable to inadequate supplies but is also aggravated by inefficient distribution and transfer mechanisms. An illustrative case is Germany, which confronts an energy crisis partly due to restricted energy inflows in the wake of the Russia-Ukraine conflict (Hutter & Weber, 2023). Such scarcity escalates the costs associated with production and living, thereby impeding economic expansion. For instance, in Pakistan, a diminution in the electrical energy supply by one kilowatt-hour is predicted to contract the overall economic output by 24.89 rupees (Rani et al., 2023).

Hasanov et al. (2017) introduced four theoretical propositions in the scholarly discourse on the energy-growth nexus. The growth hypothesis posits that a unidirectional causality flows from energy consumption to economic expansion. Conversely, the conservation hypothesis suggests that economic growth is a pivotal driver of energy consumption, where economic prosperity stimulates heightened energy usage. The feedback hypothesis advocates for a bidirectional causality, indicating that energy consumption and economic growth mutually reinforce. Lastly, the neutrality hypothesis contends that there is no significant causal linkage between energy consumption and economic growth, suggesting independence of economic performance from energy utilization patterns.

Empirical evidence lends support to the hypotheses concerning the energy-growth nexus. The growth hypothesis, which posits that energy consumption drives economic expansion, is validated by Zou's research (2022). Additionally, the conservation hypothesis, suggesting that economic growth fuels energy consumption, has found backing through studies conducted by Konuk et al. (2021), Bui Minh & Bui Van (2023), Kim & Park (2022), and Li & Leung (2021). This hypothesis underscores the role of economic expansion in elevating energy demand.

Further exploration into the feedback hypothesis, which advocates for a reciprocal influence between energy consumption and economic growth, reveals a broad spectrum of support. Notable contributions include the works of Kevser et al. (2022), Marques et al. (2017), Le & Sarkodie (2020), Kahouli (2019), Zhao et al. (2023), and Zou & Chau (2023). Marques et al. (2019) examined the dynamics between China's energy consumption and its economic growth spillover effects across various global regions (America, Europe and Central Asia, Asia Pacific, Africa, and the Middle East) from 1970 to 2016. Their findings corroborate the short-run feedback hypothesis, with long-term feedback effects observed in the Americas and the Asia Pacific. Conversely, the outcomes align more closely with the conservation hypothesis in Europe, Central Asia, Africa, and the Middle East.

Dinç & Akdoğan (2019) established the feedback hypothesis's validity between renewable energy consumption and economic growth, identifying a bidirectional causality both in the short and long term. This body of research collectively supports the dynamic interplay between energy usage and economic performance. Pala (2020) extended this analysis to the G20 countries from 1990 to 2016, confirming a two-way relationship between energy consumption and GDP, thereby reinforcing the feedback hypothesis within this group.

On the other hand, the neutrality hypothesis, which asserts a lack of causal relationship between energy consumption and economic growth, finds evidence in Inal et al.'s (2022) and László (2023) studies. Inal et al. (2022) focused on African oil-producing countries between 1990 and 2014. László (2023) examined the European

Union member states from 2010 to 2019, concluding the absence of a significant causal link in their respective contexts.

Esen & Bayrak (2017) investigated the dynamics between energy consumption and economic growth across various countries, categorized by their income levels. Their research elucidated a positive and significant long-term correlation between energy consumption and economic growth, revealing an intriguing nuance: as a country's income level elevates, the impact of energy consumption on its economic growth tends to diminish. This suggests that while energy remains a pivotal growth driver, its influence is moderated by the economic maturity of a nation.

Further exploring this relationship within a specific context, Dat et al. (2020) focused on Indonesia, analyzing data from 2000 to 2019. Their findings corroborated the close linkage between economic growth and energy consumption, with energy consumption emerging as a predictive factor for economic growth in Indonesia. This indicates a direct and tangible effect of energy usage on the nation's economic performance, highlighting energy's critical role in the Indonesian economy.

A comprehensive examination of the nexus between energy consumption and economic output was conducted through a systematic literature review by Al Khars et al. (2020). Their meta-analysis, which included 59 sampled articles, revealed a diverse array of findings: 43% supported the feedback hypothesis, indicating a bidirectional causality between energy consumption and economic growth; 26% aligned with the conservation hypothesis, suggesting economic growth as a driver for increased energy consumption; 18% validated the growth hypothesis, where energy consumption propels economic expansion; and the remaining 13% found adherence to the neutrality hypothesis, implying no significant causal link between energy consumption and economic growth.

Mutumba et al. (2021) extended this line of inquiry by examining research from 1974 to 2021 focusing on country-specific studies. Their analysis found predominant support for the growth hypothesis at 43.8%, followed by the conservation hypothesis at 27.2%, the feedback hypothesis at 18.5%, and the neutrality hypothesis at 10.5%. These findings suggest a slight shift in the hypothesis's support distribution, particularly highlighting a stronger inclination towards the growth hypothesis in country-specific contexts.

Prior research predominantly employed econometric methodologies to explore the relationship between energy consumption and economic growth, underscoring the significant link between energy utilization and economic output as demonstrated by studies such as those by Rehman & Deyuan (2018), Sriyana (2019) and Waheed, Sarwar, & Wei (2019). These studies have contributed valuable insights into the dynamics of energy consumption and its impact on economic development. However, there is a notable gap in the literature concerning applying the Input-Output (I-O) analysis approach to investigate the interconnections between energy output and demand. This analytical gap underscores the limited exploration of energy and economic growth through the I-O lens, providing a comprehensive framework for understanding the complex economic interdependencies.

Among the studies employing the Input-Output analysis, Guevara et al. (2017) delved into the Mexican economy over the period 2003–2012, identifying three pivotal factors influencing the evolution of primary energy use: final non-energy demand, direct energy intensity, and the economic structure. Their findings also highlighted the precarious state of the energy sector in terms of its structural and efficiency challenges.

Similarly, Zuhdi (2015) utilized input-output analysis to evaluate the impact of changes in final demand on Japan's total energy output, offering insights into the responsiveness of the energy sector to shifts in economic demand.

Liu et al. (2021) expanded the application of I-O analysis by examining the influence of household consumption on the industrial sector's energy consumption in China and assessing the potential for energy savings through changes in consumer lifestyles. Their study also projected future household energy consumption under various scenarios, providing a forward-looking perspective on energy demand. Further advancing the application of I-O models, Li et al. (2021) employed a multi-regional input-output (MRIO) approach to estimate the embodied energy use within China's transportation sector, offering a nuanced understanding of energy flows from provincial and sectoral viewpoints. Additional studies that have utilized Input-Output analysis to investigate the linkage between energy and other economic sectors include the works of Lee et al. (2021), Mukaramah et al. (2018), He et al. (2019), and Owen et al. (2018).

The escalating energy demand, juxtaposed with its limited availability, underscores the necessity of examining the impact of demand dynamics on the energy sector. This is particularly pertinent in Indonesia, an archipelagic nation characterized by disparate energy availability across its regions. Some areas within Indonesia continue to grapple with restricted energy supplies, making studying inter-regional energy demand relationships a critical area of inquiry. Despite the significance of these linkages, scholarly exploration into the energy connections between various Indonesian regions remains scant.

This study adopts an interregional Input-Output (I-O) approach to delve into Indonesia's energy sector dynamics. The interregional research framework provides a comprehensive perspective on how modifications in final demand from one region can influence energy output in another. This approach sheds light on the impact of final demand on regional energy output and probes whether increases in the energy sector's output are predominantly driven by final demand emanating from geographically proximate regions. The findings of this study are poised to offer valuable insights for formulating energy availability plans in Indonesia's regions, aiming to foster regional and national economic development.

The latter portion of this article delineates the methodology employed in this research, specifically focusing on the Interregional Input-Output (IRIO) model within the energy sector. Subsequently, the discussion progresses to the results, conclusions, and recommendations derived from the study.

METHODS

The interregional study of Indonesia focuses on an analysis based on six main islands, categorized as follows: (1) Sumatra, (2) Java, (3) Bali & Nusa Tenggara, (4) Kalimantan, (5) Sulawesi, and (6) Maluku & Papua. Utilizing the 2016 Interregional Input-Output data published by Statistics Indonesia (BPS, 2021), this research offers a detailed exploration of the energy sector across these distinct geographical areas. The energy sector under investigation encompasses the entire spectrum based on categorizing 52 industries, further divided into primary and secondary sectors.

The primary energy sector includes industries such as Oil, Gas, and Geothermal Mining (I-08) and Coal and Lignite Mining (I-09). The secondary energy sector, or processing industry, comprises the Coal Industry, Oil and Gas Refinery (I-12), Electricity (I-28), and Gas Procurement and Ice Production (I-29). The interregional dynamics within Indonesia's energy sector are examined through the lens of an Inter-Regional Input-Output Matrix, as illustrated in Table 1.

Table 1. Format of interregional I-O table of Indonesia

		Intermediate Use				Final Use					
		Region 1	Region 2	…	Region m	Domestic Final Use				Foreign Demand	Total Output
		$S_1….S_n$	$S_1….S_n$		$S_1….S_n$	Region 1	Region 2	…	Region m	Exports	
Region 1	S_1										
	S_2										
	…										
	S_n										
Region 2	S_1										
	S_2		x_{ij}^{rs}				F_{iz}^{rs}			e_i^r	F_i^r
	…										
	S_n										
…											
Region m	S_1										
	S_2										
	…										
	S_n										
Direct input			X_{ij}^{rs}								

In this context, X_{ij}^{rs} represents the intermediate monetary input from sector *i* in region *r* to sector *j* in region *s*, indicating the flow of goods or services between sectors across different regions. F_{iz}^{rs} denotes the monetary value of domestic final uses in region *s* provided by sector *i* in region *r*, reflecting the domestic consumption, investment, and government spending on the outputs of sector *i*. e_i^r refers to the exports of sector *i* in region *r*, which represents the foreign demand for the products of sector *i*, indicating the sector's contribution to the external market. Finally, F_i^r is the total output of sector *i* in region *r*, encompassing the total value of goods and services produced, serving as a measure of the sector's overall economic activity.

The analysis conducted in this research is structured into several stages.

1. The calculation of input coefficients. This involves determining the input coefficient for inputs from region *r* to sector *j* in region *s* (a_{ij}^{rs}), as described by Equation 1.

   $$a_{ij}^{rs} = \frac{x_{ij}^{rs}}{X_{ij}^{rs}} \quad \text{……………………………………………………………………..} \quad (1)$$

   Then a_{ij}^{rs} are arranged in an A matrix, F_{iz}^{rs} in an F matrix. The input coefficient matrix describes the composition of intermediate inputs used by each sector in production. The calculation of the multiplier matrix (B) is carried out by inverting the matrix resulting from the reduction of the identity matrix (I) and the input coefficient matrix (A) or A = (I-A)-1.
2. The second stage involves calculating the backward and forward linkages of the energy sector within each region. This is achieved through Input-Output analysis, which identifies forward and backward linkages between sectors. Backward linkages refer to the connections of a sector with other sectors that provide inputs to it. In contrast, forward linkages describe a sector's connections that produce outputs to serve as inputs for other sectors. The values for backward linkages (BL) and forward linkages (FL) are determined through specific calculations.

$$BL(i)_j = \sum_{i=1} I_{ij} \quad \ldots\ldots (2)$$

$$FL(i)_j = \sum_{j=1} I_{ij} \quad \ldots\ldots (3)$$

Where $BL(i)_i$ represents the backward linkage value for the j^{th} industry, $FL(i)_i$ denotes the forward linkage value for the ith industry, and I_{ij} signifies the cell value located at the intersection of industry row i and industry column j in the Leontief inverse matrix.

3. The third step in the analysis involves calculating the Distribution Power Index and the Degree of Sensitivity Index for the energy sector in each region. This step is critical because the unique nature of final demand across sectors necessitates a normalized measure to compare impacts accurately. This normalization involves dividing the average impact of a sector by the average impact across all sectors, thereby adjusting for sectoral differences in demand dynamics.

   The Backward Linkages (BL) and Forward Linkages (FL) of each sector are normalized against the average intensity value of all sectors, yielding two key indices: the Indices of Backward Linkage (IBL), also known as the indices of the power of dispersion, and the Indices of Forward Linkage (IFL), or the indices of the sensitivity of dispersion.

   The Indices of the Power of Dispersion (pd) compare the total impact on the output of each sector due to changes in final demand for that sector against the average impact of all sectors. A value greater than 1 indicates that the sector's relative final demand significantly stimulates production growth in the energy sector of a region, marking it as strategic with a strong influence on economic growth. Conversely, a value less than 1 suggests that the sector's dispersion power is below the average, indicating a lesser role in driving economic growth.

   The Indices of the Sensitivity of Dispersion (sd) assess the total impact of changes in final demand for each economic sector on the output of a sector relative to the average impact of all sectors. An sd value greater than 1 implies that the energy sector in a region is capable of meeting the final demand of other sectors at an above-average capacity, highlighting its pivotal role in the regional economy. If sd is less than 1, the sector's sensitivity to dispersion is lower than the average, suggesting a limited ability to respond to changes in final demand.

4. The fourth analysis stage involved performing calculations to assess the impact of final demand on the energy sector across regions, utilizing Equation 4 for this purpose.

$$X_F = (I - \mathrm{A})^{-1} F \quad \ldots\ldots (4)$$

RESULTS AND DISCUSSION

Input and output structure of Indonesia's energy sector

The structural composition of Indonesia's energy sector, as delineated in Table 2, reveals that the gross operating surplus constitutes the predominant input across all sectors, with the sole exception of the I-28 sector, which primarily relies on domestic intermediate inputs. Notably, the electricity sector emerges as the segment with the minimal proportion of gross value added within the country. This value-added component encompasses worker compensation, gross operating surplus, and the balance of taxes after subtracting subsidies. Specifically, the share of labour compensation stands at 4.56%, while the gross operating surplus accounts for 15.51%. The sector identified as I-08 boasts the highest proportion of gross value added, exceeding 70%, closely followed by sector I-29, which approximates 65%. Indonesia's energy sector continues to exhibit a significant reliance on imported resources. Sector I-12 records the highest import ratio among its counterparts, with the principal imports encompassing crude oil, fuel oil, liquefied natural gas (LNG), and liquefied petroleum gas (LPG). Notably, crude oil imports have been on an upward trajectory, registering an average annual growth rate of 4.3%, whereas fuel oil imports have increased at approximately 4.2% per annum (BPPT, 2020).

Table 2. Structure of Indonesia's energy sector input and output

	I-08	I-09	I-12	I-28	I-29
Domestic Intermediate Input	22.75	37.07	35.45	87.32	34.29
Import Domestic Intermediate Input	2.34	4.36	13.40	2.35	0.58
Labor Compensation	14.50	10.69	8.28	4.56	9.66
Gross Operating Surplus	59.81	47.28	43.62	15.51	55.33
Other Production Tax	0.61	0.60	(0.76)	(9.74)	0.14

Source: I-O 2016 Indonesia Table (2021), processed.

Backward and forward linkages of the energy sector in Indonesia

The analysis of dispersion power indices within Indonesia's energy sectors reveals that the I-28 sector surpasses the average dispersion power across all sectors in Indonesia and exhibits the highest sensitivity to dispersion. Further examination of the sensitivity dispersion indices specific to the energy sectors uncovers that solely the I-29 sector registers a sensitivity level beneath the collective average sensitivity of all sectors. The categorization into four quadrants based on the energy sector's characteristics delineates the relative positioning of these sectors in terms of sensitivity and power of dispersion. Specifically, sectors within the first quadrant are characterized by relatively high sensitivity and dispersion power indices. Conversely, the second quadrant encompasses sectors that, while demonstrating relatively high sensitivity, show low dispersion power, a trait that is inverted in the third quadrant. The fourth quadrant group's sectors are marked by comparatively low levels in both dispersion and sensitivity. Within this framework, the I-28 sector is distinguished as the lone energy sector in the first quadrant. Meanwhile, sectors I-08, I-09, and I-12 are allocated to the second quadrant, indicating a pronounced sensitivity index juxtaposed with minimal dispersion power indices. The sector denoted as I-29 finds its place in the fourth quadrant, indicative of its lower standing in both dispersion power and sensitivity indices.

The electricity sector, positioned within the first quadrant, is a pivotal component of Indonesia's economy, whereas the coal sector is in the second quadrant. Despite the electricity supply industry being identified as the least labour-intensive sector, it has a comparatively limited impact on job creation opportunities, as highlighted by Maris (2021). This sector's growth does not uniformly benefit communities, especially those with low electrification ratios, underscoring a disparity in economic advantages, as Jayanthi (2021) noted. Conversely, when focusing on a provincial scale, research conducted by Putri et al. (2021) presents a different perspective, identifying the coal sector as crucial for the economic framework of South Kalimantan.

In contrast, studies on Thailand by Muangthai et al. (2016) revealed that the electricity generation sector is characterized by significant forward and relatively minor backward linkage effects. This implies that while the electricity generation sector plays a substantial role in providing inputs to other industries, it exhibits a lower propensity to utilize the outputs from these industries. Such dynamics suggest that the electricity generation sector, despite its low labour intensity, acts as a critical driver in the inter-industry flow of goods and services, albeit with varying degrees of impact on employment and regional economic development.

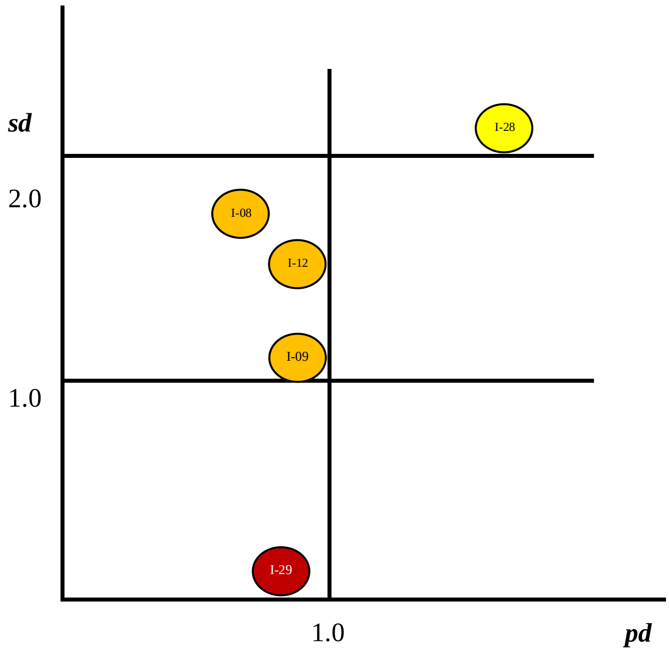

Figure 1. The power and sensitivity of dispersion indices of energy sectors in Indonesia
Source: BPS (2021), processed.

Figure 2 offers a regional quadrant analysis of Indonesia's energy sectors, illustrating the variability in the dispersion power and sensitivity indices across different regions. Sector I-28 emerges as a prominent player, showcasing high dispersion power and sensitivity indices across all Indonesian regions. This indicates its significant influence and responsiveness within the energy sector landscape nationwide. Conversely, sector I-09 is characterized by lower dispersion power and sensitivity indices, with this trend being particularly pronounced in the Sumatra region. This suggests that sector I-09's impact and responsiveness are relatively diminished, especially within Sumatra.

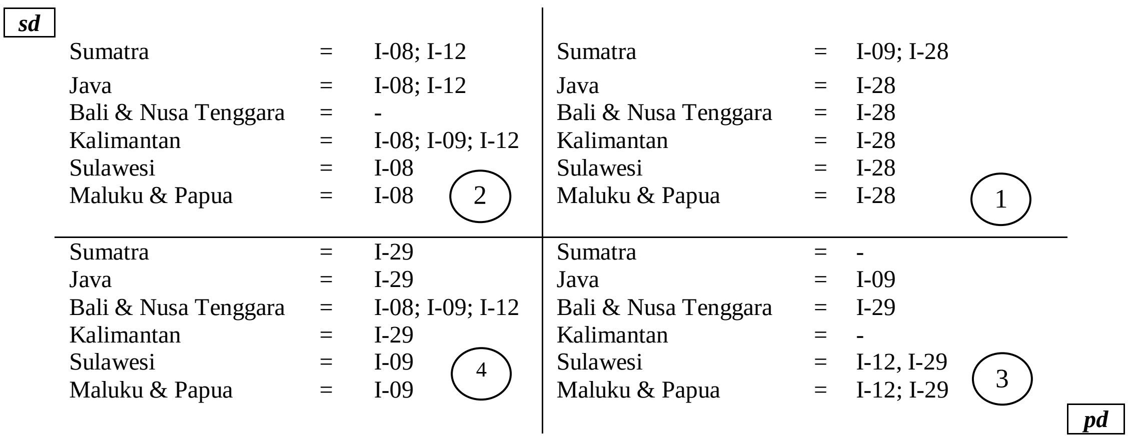

Figure 2. The power and sensitivity of dispersion indices of energy sectors based on region in Indonesia
Source: BPS (2021), processed.

Sector I-08 is notable for its high sensitivity of dispersion indices in all Indonesian regions except for Bali & Nusa Tenggara. It indicates a heightened responsiveness to changes in the sector across most of the country, albeit with a notable exception in Bali & Nusa Tenggara. On the other hand, sector I-29 is distinguished by its high dispersion power indices coupled with low sensitivity indices in regions such as Bali & Nusa Tenggara, Sulawesi, and Maluku & Papua, illustrating its strong influence but limited responsiveness in these areas. However, in other regions, sector I-29 is positioned in quadrant four, characterized by low power and sensitivity of dispersion indices, indicating both a limited influence and responsiveness.

Interregional effect of final demand

Impact of household consumption

Figure 3 elucidates the interregional effects of changes in final demand on the output of industries across different regions of Indonesia, focusing on the energy sector. This analysis reveals that household consumption demand exerts the greatest influence on the energy sector in Java, followed by Sumatra and Kalimantan. Specifically, in the Java region, the sectors most impacted by consumption demand are I-28, I-12, and I-08, in that order. This indicates a pronounced responsiveness of these sectors to household consumption patterns within Java.

In Sumatra, the sequence of sectors most affected by household consumption demand mirrors that of Java to some extent, with I-12, I-28, and I-08 being the most influenced. This suggests a similar, albeit distinct, pattern of demand impact on the energy sector across these two regions. Kalimantan's energy sector experiences the highest impact from household consumption on the I-12 sector, followed by I-09 and I-08, highlighting a slightly different priority in sectoral impact compared to Java and Sumatra.

Interestingly, in regions such as Bali & Nusa Tenggara, Sulawesi, and Maluku & Papua, the I-28 sector predominantly absorbs the impact of consumption demand. This uniformity across diverse regions underscores the significant influence of the I-28 sector in responding to household consumption changes.

The detailed analysis further indicates that within the Sumatra Region, the energy sector's output surge due to consumption demand is largely fueled by the region's household consumption, particularly affecting the I-28, I-12, and I-08 sectors. Conversely, the increase in output for the I-09 and I-29 sectors in Sumatra is chiefly driven by household consumption demand from the Java region, highlighting interregional dependencies.

Java's energy sector output increase is predominantly supported by its regional consumption demand across all energy sectors, with a minor contribution from other regions. However, the output increase for the I-09 sector in Java is specifically attributed to consumption demand within Java and Sumatra, indicating targeted regional dependencies.

The analysis also reveals that the impact of increased consumption in other regions on Bali & Nusa Tenggara's energy sector output is minimal, with only the I-28 sector showing a significant response to external consumption demand. In contrast, the Kalimantan region's energy sector output boost is driven by consumption demand from Java, followed by internal and Sulawesi demands, illustrating a broader interregional influence.

Sulawesi's energy sector output increase due to consumption demand is primarily propelled by the region's demand, with subsequent contributions from Java and Sumatra. However, the impact of Sulawesi's and other regions' consumption on the I-08, I-12, and I-29 sectors in Sulawesi is minimal, and there is no noticeable impact on the I-09 sector. Similarly, in the Maluku & Papua regions, the consumption demand does not significantly affect the output increase of the I-09 sector, indicating regional specificities in sectoral responsiveness to consumption patterns.

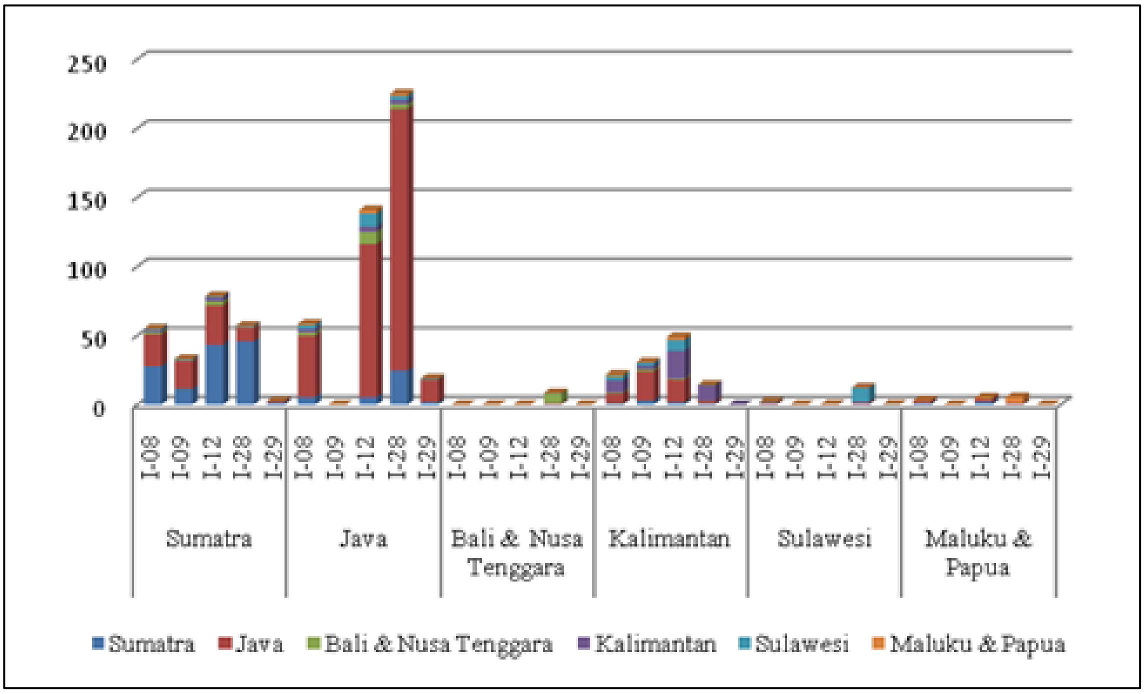

Figure 3. Interregional effect of consumption in Indonesia
Source: BPS (2021), processed

Impact of government consumption

Figure 4 illustrates the significant influence of government consumption demand on Indonesia's energy sector, with the most pronounced effects observed in Java, followed by Sumatra, and then Kalimantan. In that order, the sectors most impacted by government consumption demand are identified as I-28, I-12, and I-08 within the Java region. A similar trend is noted in the Sumatra region, where sectors I-28, I-12, and I-08 are the most affected. Conversely, in the Kalimantan region, the impact of government expenditure on the energy sector is greatest for the I-12 sector, followed by I-09, and then I-28. Additionally, in the regions of Bali & Nusa Tenggara, Sulawesi, and Maluku & Papua, the influence of government consumption on the energy sector is predominantly seen in the I-28 sector.

The expansion of the energy sector's output in the Sumatra region is primarily attributed to the demand for government consumption, with a significant portion of this demand originating from the Sumatra region itself, followed by demand from the Java region. The local government's consumption in Sumatra notably fosters a surge in energy production, surpassing the demand from other regions, particularly in the I-28 sector, alongside the coal and I-12 sectors, with I-28 again being notably mentioned. Furthermore, the growth in output of the I-09 sector within Sumatra is largely propelled by government spending from the Java region.

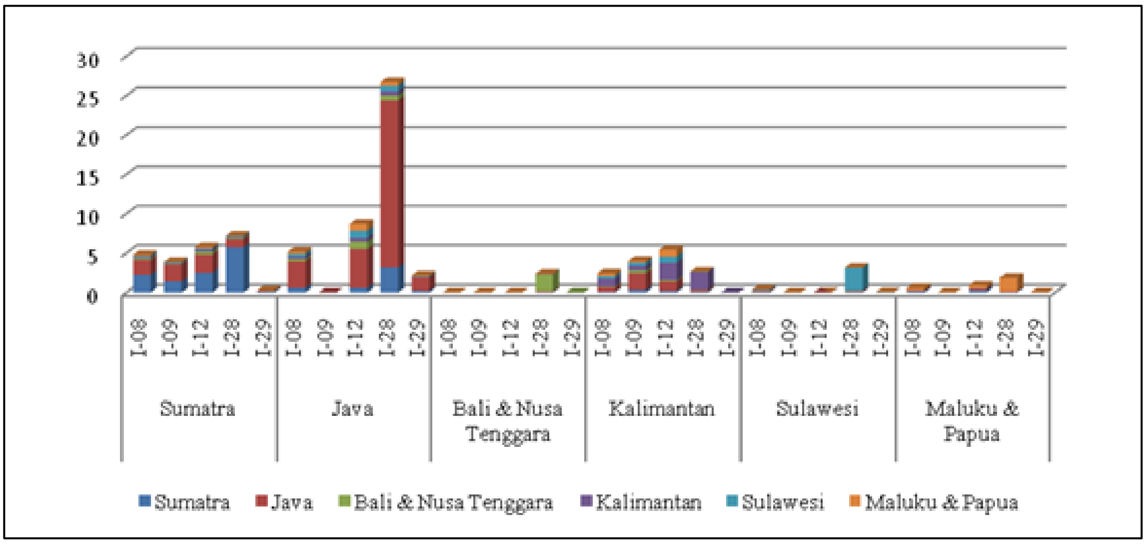

Figure 4. Interregional effect of government expenditure
Source: BPS (2021), processed

In the Java Region, the augmentation in energy sector output, as a consequence of government expenditure, is predominantly supported by the expenditure of the Java region's own government across the entire energy sector.

Contrastingly, the influence of consumption by other regional governments on the escalation of energy sector output in the Bali and Nusa Tenggara regions is minimal. Among the five energy sectors analyzed, only the I-28 sector experiences an impact from the demand for government consumption originating from external regions.

The enhancement of the energy sector's output in the Kalimantan region emerges from the demand for government consumption, with the largest share stemming from Kalimantan itself, followed by contributions from Java and Sulawesi. Similarly, the Sulawesi region's energy sector output growth is driven by local government consumption demand, with subsequent contributions from the Java and Sumatra regions. It is noted that government consumption demand in Sulawesi and other regions does not affect the I-09 sector. This pattern is replicated in the Maluku & Papua regions, indicating a consistent trend across different geographic areas.

Impact of investment

Figure 5 illustrates that the most significant investment demand impacts Indonesia's Java, Sumatra, and Kalimantan energy sectors. Within the Java region, the energy sector experiencing the greatest influence from changes in investment is sector I-28, followed by sectors I-12 and I-08, respectively. In Sumatra, the sectors most affected are I-12, I-28, and I-08, in that order. For the Kalimantan region, the energy sector's investment demand impact is highest in sector I-12, then in sector I-09, and subsequently in sector I-08. The influence of investment within the energy sector in both Bali & Nusa Tenggara and Sulawesi is predominantly seen in sector I-28. Conversely, in the Maluku & Papua regions, the impact is primarily dominated by sector I-12.

The analysis of the interregional effect of investment demand reveals that the surge in the energy sector's output in the Sumatra region is primarily driven by the demand originating from Sumatra itself, with a significant contribution also coming from the Java region. This local and neighbouring demand for investment stimulates a notable increase in energy output within Sumatra, surpassing the effects of investment from other regions across the entire energy sector. Similarly, in the Java region, the escalation in energy sector output is predominantly fueled by investments within Java, indicating a strong intra-regional impact on the sector's growth.

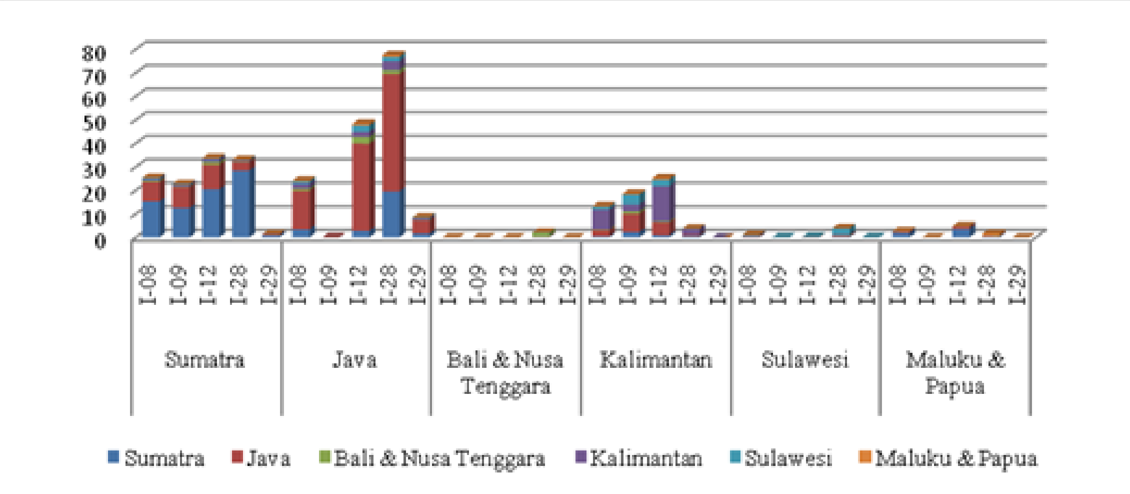

Figure 5. Interregional effect of investment
Source: BPS (2021), processed

In contrast, changes in investment have a minimal influence on the growth of energy sector output in the Bali & Nusa Tenggara regions, with only the I-28 sector being responsive to investment changes both from within these regions and other areas. The increase in energy sector output in the Kalimantan region is largely attributed to investments made within Kalimantan, with subsequent contributions from Java and Sulawesi, showcasing a mix of intra- and inter-regional influences.

For the Sulawesi region, the rise in energy sector output is chiefly supported by investments from within Sulawesi, followed by Java and Sumatra, highlighting the significance of local and external investments. On the other hand, the Maluku & Papua regions experience a majority of their energy sector output increase due to investments from external regions, particularly Java and Sumatra, underscoring the impact of inter-regional financial inflows on their energy sector.

It is also noted that changes in investment across all regions do not affect the output of the I-09 and I-29 sectors, indicating certain sectors' resilience or independence from inter-regional investment dynamics.

Energy consumption in Indonesia exhibits a pronounced concentration in the Java region, which serves as the epicentre of the country's economic activities. This region has reaped substantial benefits from the development of electricity, primarily because it hosts most of the industrial sector (Girik Allo et al., 2022). The correlation between energy usage and a region's economic structure is well-documented, underscoring the economic framework's integral role in determining energy consumption patterns (Guevara et al., 2017).

The conservation hypothesis posits that economic growth is a pivotal driver of energy consumption, suggesting that as economies expand, their energy consumption escalates accordingly. Conversely, the feedback hypothesis posits a bidirectional relationship between energy use and economic growth, indicating that each can influence the other (Le, 2020). This interconnection between energy use and economic growth in Indonesia has been corroborated by research, highlighting their mutual dependency (Dat et al., 2020).

Interestingly, the research findings indicate that the influence of a region's final demand on the output of another region is not necessarily contingent upon geographical proximity. For instance, the Kalimantan Region saw a significant uptick in energy sector output primarily due to the final demand emanating from the Sulawesi Region, despite Sulawesi being the closest region to Kalimantan. This observation suggests that the reciprocal impact is not guaranteed, highlighting Indonesia's inter-regional economic and energy dynamics complexity.

The Sulawesi region exhibits a more pronounced impact from the final demand originating in the Sumatra region than from the Kalimantan region. This phenomenon is consistent across various types of demand, including household consumption, government consumption, and investment. Furthermore, the regions of Maluku and Papua have seen an increase in energy sector output primarily driven by final demand from Java and Sumatra rather than from geographically closer regions like Sulawesi and Bali & Nusa Tenggara. This observation underscores the necessity for energy independence in Maluku and Papua, especially given the substantial demand for electricity in Maluku Province, which is experiencing an annual growth rate of 7.1% (Isnaniawardhani et al., 2018).

Contrary to the findings of Li et al. (2021), which suggest that geographical proximity influences energy transfer, the increased energy sector output in Maluku and Papua due to demand from Java and Sumatra indicates a different dynamic. This discrepancy highlights the complexity of energy distribution and consumption patterns across Indonesia's regions. The research by Wu et al. (2022) aligns with the idea that energy dynamics are influenced by development levels, showing that energy is imported by more developed regions and exported by less developed ones or those with heavy industry. Additionally, Sener & Karakas (2019) find a negative correlation between economic growth and energy intensity, which becomes more pronounced as regions transition from lower to higher income levels. This relationship suggests that as regions develop economically, their energy efficiency increases, possibly due to more stringent energy conservation measures or technological advancements. In terms of energy conservation, the findings of Li et al. (2022) reveal that the least developed provinces are the most engaged in energy-saving practices.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The electricity sector emerges as a pivotal driver of economic growth within Indonesia, distinguished by its higher average power and sensitivity dispersion index compared to all other sectors across all regions. This sector's strategic significance is underscored by its capacity to fulfil energy requirements more efficiently than any other industry, positioning electricity as a cornerstone of the regional economy. Conversely, the Coal and Lignite Mining sector plays a vital role in the Sumatra region, though its importance does not extend similarly across other regions. The analysis further reveals that the impact of household consumption, government consumption, and investment on the energy sector is most pronounced in Java, succeeded by Sumatra and Kalimantan. Additionally, the influence of a region's final demand on the output in another region is not inherently linked to geographical proximity, as demonstrated by the unique interregional dynamics affecting Kalimantan, Sulawesi, Maluku, and Papua. These findings illustrate the complex interplay between economic activity, energy consumption, and regional development in Indonesia.

Recommendations

Given the observed disparities in energy sector output influenced by regional demand and the minimal impact of geographical proximity on energy transfer, there is a clear imperative for the Indonesian government to prioritize energy independence, particularly in regions such as Sulawesi, Maluku, and Papua. Promoting accelerating renewable energy development is a crucial strategy towards achieving this goal. Energy independence not only has the potential to mitigate energy distribution costs but also enhances the resilience of regional economies against supply chain disruptions. To further understand the underlying factors that decouple regional proximity from energy transfer efficiency, this study advocates for additional research focusing on the reasons behind the dependency of energy output in the Sulawesi, Maluku, and Papua regions on the final demand from Sumatra and Java. Exploring these dynamics can provide valuable insights into optimizing energy distribution and consumption patterns across Indonesia's diverse geographic and economic landscape.

REFERENCES

Al Khars, M., Miah, F., Qudrat-Ullah, H., & Kayal, A. (2020). A systematic review of the relationship between energy consumption and economic growth in GCC countries. *Sustainability*, 12(9), Article 3845. https://doi.org/10.3390/su12093845

Badan Pengkajian dan Penerapan Teknologi (BPPT). (2020). *Outlook Energi Indonesia 2020 Edisi Khusus Dampak Pandemi COVID-19 terhadap Sektor Energi di Indonesia*. Jakarta: BPPT. https://www.bppt.go.id/dokumen/outlook-energi

Badan Pusat Statistik (BPS). (2021). *Tabel Inter Regional Input-Output Indonesia Transaksi Domestik Atas Dasar Harga Produsen Menurut 6 Kelompok Pulau dan 52 Industri, 2016 (Juta Rupiah)*. Jakarta: BPS https://www.bps.go.id/subject/105/input-output.html#subjekViewTab3

Bui Minh, T., & Bui Van, H. (2023). Evaluating the relationship between renewable energy consumption and economic growth in Vietnam, 1995–2019. *Energy Reports*, 9(S1), 609-617. https://doi.org/10.1016/j.egyr.2022.11.074

Dat, N. D., Hoang, N., Huyen, M. T., Huy, D. T. N., & Lan, L. M. (2020). Energy consumption and economic growth in Indonesia. *International Journal of Energy Economics and Policy*, 10(5), 601 - 607. https://doi.org/10.32479/ijeep.10243

Dinç, D. T., & Akdoğan, E. C. (2019). Renewable energy production, energy consumption and sustainable economic growth in Turkey: A VECM approach. *Sustainability*, 11(5), Article 1273. https://doi.org/10.3390/su11051273

Ding, Q., Cai, W., & Wang, C. (2017). Impact of household consumption activities on energy consumption in China - Evidence from the lifestyle perspective and input-output analysis. *Energy Procedia*, 105, 3467–3473. https://doi.org/10.1016/j.egypro.2017.03.767

Esen, Ö., & Bayrak, M. (2017). Does more energy consumption support economic growth in net energy-importing countries? *Journal of Economics, Finance and Administrative Science*, 22(42), 75–98. https://doi.org/10.1108/JEFAS-01-2017-0015

Gao, J., Chen, Y., Zhong, X., & Ma, X. (2021). Energy consumption in China's construction industry: Energy driving and driven abilities from a regional perspective. *Journal of Systems Science and Information*, 9(1), Article 45-16. https://doi.org/10.21078/JSSI-2021-045-16

Girik Allo, A., Dwiputri, I. N., & Maspaitella, M. (2022). The impact of electricity investment on inter-regional economic development in Indonesia: An Inter-Regional Input-Output (IRIO) approach. *Journal of Socioeconomics and Development*, 5(1), 1-12. https://doi.org/10.31328/jsed.v5i1.2775

Guevara, Z., Córdoba, O., García, E. X. M., & Bouchain, R. (2017). The status and evolution of energy supply and use in Mexico prior to the 2014 energy reform: An input-output approach. *Economies*, 5(1), 10. https://doi.org/10.3390/economies5010010

Hasanov, F., Bulut, C., & Suleymanov, E. (2017). Review of energy-growth nexus: A panel analysis for ten Eurasian oil exporting countries. *Renewable and Sustainable Energy Reviews*, 73, 369–386. https://doi.org/10.1016/j.rser.2017.01.140

He, H., Reynolds, C. J., Li, L., & Boland, J. (2019). Assessing net energy consumption of Australian economy from 2004–05 to 2014–15: Environmentally-extended input-output analysis, structural decomposition analysis, and linkage analysis. *Applied Energy*, 240, 1049–1064. https://doi.org/10.1016/j.apenergy.2019.02.081

Hutter, C., & Weber, E. (2023). Russia–Ukraine war: A note on short-run production and labour market effects of the energy crisis. *Energy Policy*, 183, 113802. https://doi.org/10.1016/j.enpol.2023.113802

Inal, V., Addi, H. M., Çakmak, E. E., Torusdag, M., & Çaliskan, M. (2022). The nexus between renewable energy, CO emissions, and economic growth: Empirical evidence from African oil-producing countries. *Energy Reports*, *8,* 1634–1643. https://doi.org/10.1016/j.egyr.2021.12.051

Isnaniawardhani, V., Sukiyah, E., Sudradjat, A., & Nanlohy, M. M. (2018). The geothermal potentials for electric development in Maluku Province. *Jurnal Perspektif Pembiayaan Dan Pembangunan Daerah, 5*(3), 129-140. https://doi.org/10.22437/ppd.v5i3.4546

Jayanthi, R. (2021). The effect of electricity development in Indonesia on poverty and income inequality. *Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi Dan Pembangunan, 22*(1), 104-116. https://doi.org/10.23917/jep.v22i1.12076

Kahouli, B. (2019). Does static and dynamic relationship between economic growth and energy consumption exist in OECD countries? *Energy Reports, 5, 104 - 116*. https://doi.org/10.1016/j.egyr.2018.12.006

Kevser, M., Tekbaş, M., Doğan, M., & Koyluoglu, S. (2022). Nexus among biomass energy consumption, economic growth, and financial development: Evidence from selected 15 countries. *Energy Reports, 8, 8372 - 8380*. https://doi.org/10.1016/j.egyr.2022.06.033

Kim, D., & Park, Y. J. (2022). Nonlinear causality between energy consumption and economic growth by timescale. *Energy Strategy Reviews, 44, 100949*. https://doi.org/10.1016/j.esr.2022.100949

Konuk, F., Zeren, F., Akpınar, S., & Yıldız, Ş. (2021). Biomass energy consumption and economic growth: Further evidence from NEXT-11 countries. *Energy Reports, 7*. 4825-4832. https://doi.org/10.1016/j.egyr.2021.07.070

László, T. (2023). Ambivalent changes in the correlation of energy consumption and economic growth in the member states of the European Union (2010–2019). *Heliyon, 9*(3), e14550. https://doi.org/10.1016/j.heliyon.2023.e14550

Le, H. P. (2020). The energy-growth nexus revisited: The role of financial development, institutions, government expenditure, and trade openness. *Heliyon, 6*(7), e04369. https://doi.org/10.1016/j.heliyon.2020.e04369

Le, H. P., & Sarkodie, S. A. (2020). Dynamic linkage between renewable and conventional energy use, environmental quality, and economic growth: Evidence from emerging market and developing economies. *Energy Reports, 6, 965-973* . https://doi.org/10.1016/j.egyr.2020.04.020

Lee, L. C., Wang, Y., & Zuo, J. (2021). The nexus of water-energy-food in China's tourism industry. *Resources, Conservation and Recycling, 164, 105157*. https://doi.org/10.1016/j.resconrec.2020.105157

Li, J., Fang, H., Fang, S., Zhang, Z., & Zhang, P. (2021). Embodied energy use in China's transportation sector: A multi-regional input–output analysis. *International Journal of Environmental Research and Public Health, 18*(15), 7873 . https://doi.org/10.3390/ijerph18157873

Li, R., & Leung, G. C. K. (2021). The relationship between energy prices, economic growth, and renewable energy consumption: Evidence from Europe. *Energy Reports, 7,*. 1712-1719. https://doi.org/10.1016/j.egyr.2021.03.030

Li, Z., Li, Z., & Song, Y. (2022). Identification of key provinces and sectors for energy conservation in China: Linkage analyses based on the modified hypothetical extraction method. *Energy Strategy Reviews, 44, 100998*. https://doi.org/10.1016/j.esr.2022.100998

Li, Z., Lin, Y. Y., Song, Y., & Li, Z. (2023). Linkages and flow paths of energy consumption: Evidence from China's sectors. *Energy Reports, 9, 4594-4603*. https://doi.org/10.1016/j.egyr.2023.03.099

Liu, M., Huang, X., Chen, Z., Zhang, L., Qin, Y., Liu, L., Zhang, S., Zhang, M., Lv, X., & Zhang, Y. (2021). The transmission mechanism of household lifestyle to energy consumption from the input-output subsystem perspective: China as an example. *Ecological Indicators, 122, 107234*. https://doi.org/10.1016/j.ecolind.2020.107234

Maris, M. (2021). Propulsive forces of economic growth in Slovakia: The inference from the input-output table data. *Entrepreneurship and Sustainability Issues, 9*(1), 255 - 267. https://doi.org/10.9770/jesi.2021.9.1(15)

Marques, L. M., Fuinhas, J. A., & Marques, A. C. (2017). Augmented energy-growth nexus: Economic, political and social globalization impacts. *Energy Procedia, 136, 97 - 101*. https://doi.org/10.1016/j.egypro.2017.10.293

Marques, L. M., Fuinhas, J. A., & Marques, A. C. (2019). Are there spillovers from China on the global energy-growth nexus? Evidence from four world regions. *Economies, 7*(2), 59. https://doi.org/10.3390/economies7020059

Muangthai, I., Lin, S. J., & Lewis, C. (2016). Inter-industry linkages, energy and CO2 multipliers of the electric power industry in Thailand. *Aerosol and Air Quality Research, 16*(8), 2033-2047. https://doi.org/10.4209/aaqr.2016.01.0042

Mukaramah, H., Sallahuddin, H., & Mat, S. H. C. (2018). Pursuing more sustainable energy consumption by analyzing sectoral direct and indirect energy use in Malaysia: An input-output analysis. *International Journal of Economics and Management, 12*(2), 501 - 510.

Mutumba, G. S., Odongo, T., Okurut, N. F., & Bagire, V. (2021). A survey of literature on energy consumption and economic growth. *Energy Reports, 7, 9150 - 9239*. https://doi.org/10.1016/j.egyr.2021.10.107

Owen, A., Scott, K., & Barrett, J. (2018). Identifying critical supply chains and final products: An input-output approach to exploring the energy-water-food nexus. *Applied Energy, 210, 632-642*. https://doi.org/10.1016/j.apenergy.2017.09.069

Pala, A. (2020). Energy and economic growth in G20 countries: Panel cointegration analysis. *Economics and Business Letters, 9*(2), 56–72. https://doi.org/10.17811/ebl.9.2.2020.56-72

Putri, K. S., Riswan, & Rahman, I. (2021). Mining sector in the economic structure of South Kalimantan Province: Direct and indirect impacts. *IOP Conference Series: Earth and Environmental Science, 882*(1). https://doi.org/10.1088/1755-1315/882/1/012084

Rani, T., Wang, F., Awad, A., & Zhao, J. (2023). A cross-sectoral analysis of energy shortages in Pakistan: Based on supply-driven input-output model. *Economic Research-Ekonomska Istrazivanja, 36*(3). https://doi.org/10.1080/1331677X.2023.2186910

Rehman, A., & Deyuan, Z. (2018). Investigating the linkage between economic growth, electricity access, energy use, and population growth in Pakistan. *Applied Sciences (Switzerland), 8*(12). https://doi.org/10.3390/app8122442

Sener, S., & Karakas, A. T. (2019). The effect of economic growth on energy efficiency: Evidence from high, upper-middle, and lower-middle income countries. *Procedia Computer Science, 158, 523-532*. https://doi.org/10.1016/j.procs.2019.09.084

Sriyana, J. (2019). Dynamic effects of energy consumption on economic growth in an emerging economy. *International Journal of Energy Economics and Policy, 9*(4), 283–290.. https://doi.org/10.32479/ijeep.7787

Waheed, R., Sarwar, S., & Wei, C. (2019). The survey of economic growth, energy consumption and carbon emission. *Energy Reports, 5, 1103-1115*. https://doi.org/10.1016/j.egyr.2019.07.006

Wang, S. (2022). Differences between energy consumption and regional economic growth under the energy environment. In *Energy Reports, 8, 10017-10024*. https://doi.org/10.1016/j.egyr.2022.07.065

Wu, Y., Huang, H., Hong, J., Wang, X., Wu, Y., & Wu, Y. (2022). Transfer patterns and driving factors of China’s energy use in trade: Evidence from multiregional input–output analysis and structural decomposition analysis. *Energy Reports, 8, 10963 - 10975*. https://doi.org/10.1016/j.egyr.2022.08.239

Zhao, D., Yuan, J., Fu, S., Song, Y., Wang, Y., Liu, Y., & Zhang, J. (2023). Does economic growth stimulate energy consumption? New evidence from national and regional levels in China. *Chinese Journal of Population Resources and Environment, 21*(2), 60 - 70. https://doi.org/10.1016/j.cjpre.2023.06.003

Zou, G. (2022). Relationships between agricultural growth and energy consumption in China: Toda–Yamamoto tests. *Energy Reports, 8(9), 756 - 763*. https://doi.org/10.1016/j.egyr.2022.07.111

Zou, G., & Chau, K. W. (2023). Energy consumption, economic growth and environmental sustainability: Evidence from China. *Energy Reports, 9(S9), 106 - 116*. https://doi.org/10.1016/j.egyr.2023.05.251

Zuhdi, U. (2015). An application of input-output analysis in analyzing the impacts of final demands changes on the total outputs of Japanese energy sectors: A further study. *Journal of Physics: Conference Series, 622*(1). https://doi.org/10.1088/1742-6596/622/1/012041