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Studying the cross elasticity of demand between fluctuations in the price of crude oil and the quantities of consumption and production of natural gas for different regional groups

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Abstract

The research addresses the state of the energy consumption market in relation to changes in crude oil prices on one hand, and the consumption and production of natural gas on the other. This is based on the assumption that natural gas is one of the energy sources relied upon in times of energy supply shortages and rising costs resulting from increases in crude oil prices. The study explores the impact of these changes on the growth rates of natural gas production. Notably, the growth rate of any energy source primarily crude oil and natural gas is a key factor in sustaining supply and supporting economic development across selected regional groups (North America, European countries, the Middle East, Asian countries, and the world as a whole).

Keywords: Crude oil prices, natural gas, energy consumption, production growth, regional analysis

Introduction

This research addresses the state of the energy consumption market amidst changes in crude oil prices, considering natural gas consumption and production. It operates under the assumption that natural gas is a key energy source relied upon in situations of energy supply shortages and increased costs due to rising crude oil prices, and examines how this impacts natural gas production growth rates. The study highlights that the growth rate of any energy source, particularly crude oil and natural gas, is a crucial factor in the continuity of supply shortages and economic development in selected regional groups (North America, European countries, the Middle East, Asian countries, and the world).

Importance of the Research

The importance of this research stems from a comprehensive view of the energy market, emphasizing the need to diversify energy sources to control cost increases resulting from rising energy asset prices and supply shortages of some energy assets due to political and climatic disturbances in production and consumption areas. This study focuses on two main energy sources: natural gas and crude oil, as they are currently the primary energy sources for most countries.

Research Hypothesis

This research is based on the following hypotheses

1. Oil and gas are alternative commodities in the energy market, and one can replace the other if crude oil prices rise.
2. Natural gas is currently an important energy source and competes with crude oil in meeting the world's energy needs according to production rates in different regions.
3. The cross elasticity of demand for natural gas consumption does not align with changes in crude oil prices in the oil market, according to economic theory on elasticity studies in some years and for some different international regional groups.
4. The cross elasticity of supply in natural gas production does not align with changes in crude oil prices in the oil market, according to economic theory on elasticity studies in some years and for some different international regional groups.

Previous Studies

Many studies have addressed the relationship between natural gas consumption and production and crude oil price changes. However, these studies did not analyze the relationship between the two variables according to the economic theory commonly recognized in economic literature. In this research, the author attempts to shed light on the relationship between natural gas production and consumption and crude oil price changes through an economic theoretical lens, specifically the theory of elasticity, in terms of the supply and demand for natural gas in relation to crude oil price changes.

Studies and Research

Study by Hasdi Aimon, Anggi Putri Kurniad, and others, published in the *International Journal of Energy Economic and Policy*, Vol 12, No. 6, 2022, pages 96-100, linked natural gas consumption to the carbon emission index. This index is crucial for achieving sustainable development. Carbon emissions worsen with reliance on crude oil as an energy source, particularly since uncontrolled use of oil for energy results in decreased air quality due to combustion-related pollution.

Study by Guong-Jing He and others, presented at the *International Conference on Automation, Mechanical, Control, and Consumption Engineering 2015*, considered natural gas the world's primary energy pillar, prompting nations to develop it. The study identified five factors affecting natural gas consumption: GDP, total industrial production value, urban population, increase in industrial output, and the share of natural gas in energy. Based on data from 2001-2011, the study attributed the global increase in natural gas consumption and demand to these five indicators without considering the impact of crude oil price changes on natural gas consumption and production.

Study by Jose A. Villar and Frederick Ljontz ^[1], titled *Relationship Between Crude Oil and Natural Gas Consumption*, covered the period from 1998-2005. It concluded that rising oil prices might have conflicting effects on natural gas supplies and consequently on natural gas prices. Natural gas production may increase as a co-product of oil or decrease due to higher production costs. The net effect of rising oil prices on natural gas supplies may be ambiguous, indicating a positive relationship between oil and natural gas prices. Due to the relative inflexibility of natural gas supplies in the short term, influenced by delays ranging from 12-18 months, oil prices' effect on natural gas demand is predominant in the short term.

Study by Narges Zamani ^[2], titled *How the Crude Oil Market Affects the Natural Gas Market? Demand and Supply Shocks*, examined the global structural relationship between crude oil and natural gas prices using a structural autoregressive model with four key variables for oil and natural gas markets. The study found that the crude oil market influences the natural gas market primarily through demand shocks rather than supply shocks. Uncertainty about future oil supplies leads to unpredictability in the oil market, which then affects the natural gas market, causing natural gas prices to rise as an alternative to oil. Global demand shocks result in similar price fluctuations for crude oil and natural gas.

Study by Abbas Khan, Mahmud Yar Khan ^[3], and **Others**, titled *How Do Oil and Natural Gas Prices Affect US Industrial Production? Utilizing Wavelet Nonlinear Denoised-Based Quantile Analysis*, examined the relationship between US industrial production, West Texas crude oil prices, and natural gas prices. It identified a time-varying symmetrical relationship between crude oil, natural gas, and industrial production from 1986-2018. The study used the least squares method to illustrate the variables without detailing the complex relationship between crude oil, natural gas, and industrial production in the short and long term.

Study by Karol Szafranek and Michal Rubaszek ^[4], titled *Have European Natural Gas Prices Decoupled from Crude Oil Prices? Evidence from VAR Analysis*, used a structural vector autoregressive model to analyze the relationship between oil prices, US natural gas prices, and European natural gas prices from 1933-2022. The study investigated whether these prices are determined together or evolve independently and concluded that oil price fluctuations are minimally influenced by natural gas market shocks.

Technical Report by Abdirasak Mohammed Said ^[5], titled *Global Natural Gas Demand*, published in January 2024, emphasized the importance of natural gas as an energy source and the difficulty of accurately estimating its quantities beneath the earth's surface. According to contemporary estimates, the Middle East, Europe, and the former Soviet Union hold the largest natural gas reserves and will play a crucial role in providing a quarter of the world's energy supplies. The report highlighted the absence of specific criteria for selecting key variables suitable for predicting natural gas demand. The study did not thoroughly analyze crude oil price changes as a cause of variations in natural gas consumption and production. The report projected a 30% increase in global natural gas demand by 2050, driven by continuous legislation aimed at reducing emissions, particularly in China and India.

Section One: Theoretical Aspect of Cross Price Elasticity of Demand

Cross price elasticity of demand is defined as the relative change in the quantity demanded of one good in response to a relative change in the prices of other goods. The sign of the elasticity coefficient indicates the type of relationship between the two goods ^[6]. Cross price elasticity of demand refers to the percentage change in the quantity of one good relative to the percentage change in the price of another good, serving as an indicator of the relationship between the two goods. A negative sign indicates that the goods are substitutes in consumption ^[7], whereas a positive sign indicates that the goods are complements.

For instance, the cross price elasticity of demand between electricity and electrical appliances is positive, indicating that these items complement each other. If the elasticity value is greater than one, the demand is considered elastic; if it is less than one ^[8], the demand is inelastic. Cross price elasticity of demand is calculated as the percentage change in the quantity demanded of one good divided by the percentage change in the price of another good. This concept applies to labor markets and financial capital markets just as it does to goods and services markets ^[9].

Thus, the elasticity indicator can be used to understand the

relationship between the consumption of quantity of one good (X) and changes in the price of another good (Y) without considering changes in the price of good (X). This application is relevant in the energy market, where different energy sources interact.

Time also affects the demand elasticity for a particular good. Demand tends to be more elastic over a longer period because consumers can substitute goods in the long term. In the short term, substituting one good for another is not easy. The longer the time period, the easier it is for both consumers and businesses to substitute one good for another [10]. Therefore, studying the problem aims to determine the time period, with this study relying on a one-year period and a lag of one year between the variables.

$$\frac{\Delta Q_x}{\Delta P_y} * \frac{P_{y1}}{Q_{x1}} = \frac{Q_{x2} - Q_{x1}}{P_{x2} - P_{x1}} * P_{y1}/Q_{x1}$$

This formula helps in quantifying the responsiveness of the quantity demanded of one good to changes in the price of another good within the energy market [11].

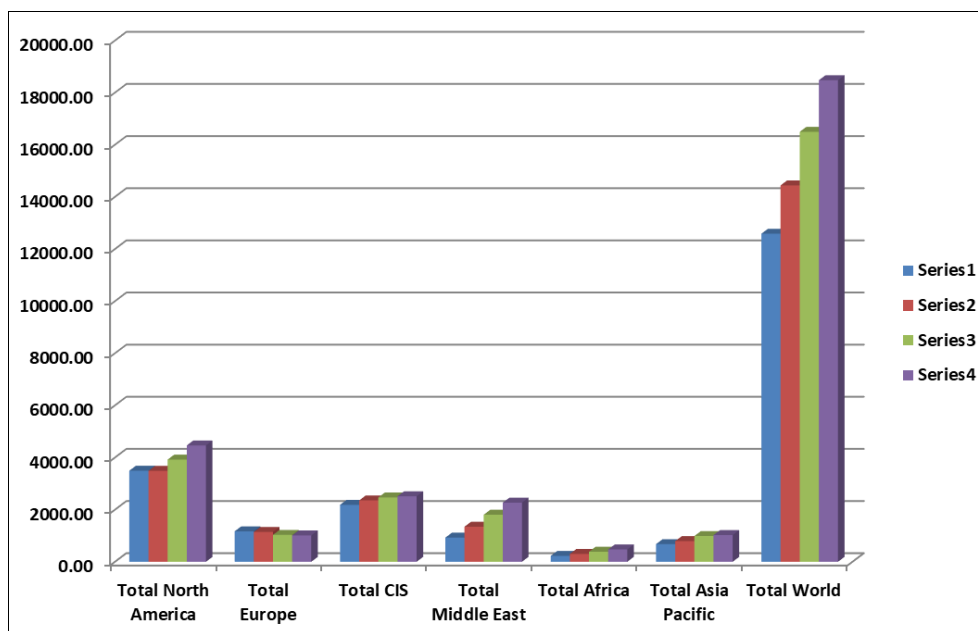
Section Two
Development in Natural Gas Consumption, Changes in Crude Oil Prices, and Natural Gas Production Rates

From Table and Figure (1), we can extract the development in natural gas consumption for different regional groups during the period (2000-2019) with an average of every five years (billion cubic feet).

Table 1: Development in Natural Gas Consumption for Regional Groups (2000-2019)

years	2000-2004	2005-2009	2010-2014	2015-2019
Total North America	3494.31	3491.03	3920.69	4463.11
Total Europe	1168.62	1145.92	1033.53	1013.54
Total CIS	2184.32	2356.56	2468.83	2514.99
Total Middle East	928.23	1346.80	1806.76	2270.18
Total Africa	227.54	301.92	387.75	474.47
Total Asia Pacific	678.47	794.49	989.22	1027.37
Total World *	12587.12	14439.85	16495.81	18476.48

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Source: Prepared by the researcher based on Table 1

Fig 1: Development of Natural Gas Consumption for Regional Groups and the World for the Period (2000-2019)

From Table (1) and Figure (1), we can deduce that the natural gas consumption for different regional groups, according to the indicator of total consumption every five years during the study period, is continuously increasing. North America leads the consumption chart, followed by Russia and Belarus. Ultimately, global natural gas consumption is continuously rising, reflecting an increasing demand for natural gas in the coming years. This indicates a global trend towards relying on natural gas as an energy source and expanding its consumption. Due to the environmental advantages of natural gas compared to other fossil energy sources, there has been a notable increase in global demand for natural gas and a significant expansion in

its usage. However, the quantities of gas entering international trade still represent a low percentage locally from the producing countries themselves, with approximately 75% of the world's gas production being consumed, while the quantity of gas entering international trade represents only about 25% of total global production [12].

Regarding the developments in crude oil prices, according to the price category adopted for each regional group, we can refer to Table (2) and Figure (2). The general trend during the study period tends to increase, with some decreases in certain periods, as illustrated more clearly in the figure.

Table 2: Development of Crude Oil Prices for the Period (2000-2019) in USD/Barrel

CRUDE OIL PRICES	2000	2001	2002	2003	2004
Total North America (W.T)	30.37	25.93	26.16	31.06	41.49
Total Europe (BRENT)	28.50	24.44	25.02	28.83	38.27
Total CIS (BRENT)	28.50	24.44	25.02	28.83	38.27
Total Middle East (DUBA)	26.20	22.81	23.74	26.78	33.64
Total Africa (NEGRIA)	28.42	24.23	25.04	28.66	38.13
Total Asia Pacific (NEGRIA)	26.20	22.81	23.74	26.78	33.64
Total World (W.T)	30.37	25.93	26.16	31.06	41.49
CRUDE OIL PRICES	2005	2006	2007	2008	2009
Total North America (W.T)	56.59	66.04	72.20	100.06	61.92
Total Europe (BRENT)	54.52	65.14	72.39	97.26	61.67
Total CIS (BRENT)	54.52	65.14	72.39	97.26	61.67
Total Middle East (DUBA)	49.35	61.50	68.19	94.34	61.39
Total Africa (NEGRIA)	55.69	67.07	74.48	101.43	63.35
Total Asia Pacific (NEGRIA)	49.35	61.50	68.19	94.34	61.39
Total World (W.T)	56.59	66.04	72.20	100.06	61.92
CRUDE OIL PRICES	2010	2011	2012	2013	2014
Total North America (W.T)	79.45	95.04	94.13	97.99	93.28
Total Europe (BRENT)	79.50	111.26	111.67	108.66	98.95
Total CIS (BRENT)	79.50	111.26	111.67	108.66	98.95
Total Middle East (DUBA)	78.06	106.18	109.08	105.47	97.07
Total Africa (NEGRIA)	81.05	113.65	114.21	111.95	101.35
Total Asia Pacific (NEGRIA)	78.06	106.18	109.08	105.47	97.07
Total World (W.T)	79.45	95.04	94.13	97.99	93.28
CRUDE OIL PRICES	2015	2016	2017	2018	2019
Total North America (W.T)	48.71	43.34	50.79	65.20	57.03
Total Europe (BRENT)	52.39	43.73	54.19	71.31	64.21
Total CIS (BRENT)	52.39	43.73	54.19	71.31	64.21
Total Middle East (DUBA)	51.20	41.19	53.13	69.51	63.43
Total Africa (NEGRIA)	54.41	44.54	54.31	72.47	64.95
Total Asia Pacific (NEGRIA)	51.20	41.19	53.13	69.51	63.43
Total World (W.T)	48.71	43.34	50.79	65.20	57.03

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Fig 2: Developments in Crude Oil Prices for Different Regional Groups during the Period (2000-2019)**Source: Prepared by the researcher from Table (2)**

As shown in the figure, the fluctuations in crude oil prices were less volatile for the North America group and the European countries group. Consequently, the cross elasticity coefficient indicator for these two groups is less variable compared to the other groups, as illustrated in Table (3). It is noteworthy that the price index rose according to the energy price index by 3.1% in December 2019, compared to a decrease of 12.7% in ^[13] 2018. According to the formula used to derive the elasticity degree, which represents the indicators of cross elasticity coefficients for the demand for natural gas based on changes in crude oil prices, the table shows that the elasticity coefficients did not yield a negative sign as per economic theory. The theory states that the elasticity coefficient for substitute goods should be negative. Since oil and gas are substitute goods, an increase in crude

oil prices should lead to an expansion in gas consumption. However, in other years within the study period, the sign was positive, indicating that oil and gas are complementary goods according to the elasticity coefficient, particularly for the African regional groups and the Asia-Pacific group. This reflects that the energy market does not consistently show a clear quality relationship between crude oil and natural gas. At times, the relationship for some regional groups and certain years appears substitutive due to energy supply shortages, as evident from the natural gas consumption development for regional groups during the study period. In many instances, the relationship appears complementary. The inevitable conclusion is that the consumption outlook for any energy source, whether oil or natural gas, is less affected relatively by price due to the heightened demand for energy and the implications of global supply shortages.

Table 3: Cross Elasticity of Demand Coefficient for Different Regional Groups during the Study Period (2000-2019)

	2000	2001	2002	2003	2004	average
Total North America (W.T)	0.00	0.31	3.76	-0.12	0.00	0.79
Total Europe (BRENT)	0.00	-0.14	-0.29	0.05	0.05	-0.06
Total CIS (BRENT)	0.00	-0.16	0.29	0.12	0.07	0.06
Total Middle East (DUBA)	0.00	-0.57	2.92	0.37	0.44	0.63
Total Africa (NEGRIA)	0.00	-0.88	1.15	0.64	0.16	0.21
Total Asia Pacific (NEGRIA)	0.00	-0.30	0.33	0.48	-0.09	0.08
Total World (W.T)	0.00	-0.09	3.34	0.15	0.11	0.70
	2005	2006	2007	2008	2009	average
Total North America (W.T)	-0.04	-0.09	0.69	0.01	0.05	0.12
Total Europe (BRENT)	-0.03	-0.11	-0.14	0.07	0.13	-0.02
Total CIS (BRENT)	0.03	0.20	0.18	-0.07	0.09	0.09

Total Middle East (DUBA)	0.15	0.23	0.78	0.25	-0.07	0.27
Total Africa (NEGRIA)	0.04	0.48	0.36	0.16	-0.14	0.18
Total Asia Pacific (NEGRIA)	0.08	0.24	0.34	0.17	0.02	0.17
Total World (W.T)	0.07	0.16	0.44	0.06	0.05	0.16
	2010	2011	2012	2013	2014	average
Total North America (W.T)	0.16	0.13	-3.90	0.80	-0.53	-0.67
Total Europe (BRENT)	0.25	-0.31	-8.62	-0.57	1.19	-1.61
Total CIS (BRENT)	0.21	0.09	-3.21	0.56	-0.01	-0.47
Total Middle East (DUBA)	0.33	0.17	1.54	-0.56	-0.78	0.14
Total Africa (NEGRIA)	0.08	0.21	15.02	-0.70	-0.09	2.91
Total Asia Pacific (NEGRIA)	0.27	0.14	2.63	-0.43	-0.16	0.49
Total World (W.T)	0.26	0.12	-2.65	0.40	-0.14	-0.40
	2015	2016	2017	2018	2019	average
Total North America (W.T)	-0.05	-0.02	-0.05	0.43	-0.24	0.01
Total Europe (BRENT)	-0.06	-0.56	0.05	-0.04	-0.19	-0.16
Total CIS (BRENT)	0.04	-0.11	0.10	0.22	0.15	0.08
Total Middle East (DUBA)	-0.14	-0.21	0.18	0.18	-0.06	-0.01
Total Africa (NEGRIA)	-0.04	-0.26	0.43	0.29	-0.11	0.06
Total Asia Pacific (NEGRIA)	0.01	0.07	-0.03	0.01	0.04	0.02
Total World (W.T)	-0.05	-0.21	0.19	0.23	-0.16	0.00

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Studies and research focusing on energy affairs predict that the global demand for natural gas, particularly for the OECD group, will increase until 2040. The share of international trade from this increase among consumer countries within the OECD group is expected to rise, with consumption increasing from 2 trillion cubic meters in 2012 to 29 trillion cubic feet in 2040^[14]. Thus, the elasticity degree results in the table theoretically align with the elasticity indicators for some groups and specific periods. However, the absolute values of the cross elasticity coefficients indicate low elasticity, suggesting that the demand for gas is inelastic relative to changes in crude oil prices. The elasticity coefficient values were more evident for the Europe and Africa groups, aligning with economic theory, particularly for the Europe group.

The discrepancy in cross elasticity according to theoretical logic for certain years and regions might be due to the relationship between energy consumption and real GDP growth. The phenomenon reflects a complex relationship between energy consumption and growth, encompassing various probabilities. The relationship between the two can deviate from a unidirectional to a bidirectional and neutral causal relationship. The expansion of energy consumption may be a consequence of economic growth or, conversely, energy conservation policies could result in reduced economic growth. Each country's energy consumption policy impacts the energy consumption map, with natural gas being a key energy source^[15].

This reinforces the research hypothesis that the changes in natural gas consumption do not align with crude oil price changes due to the global energy supply crisis and the high demand for both commodities. Oil and gas remain critical short-term energy sources.

Another reason for the variation in cross elasticity demand indicators among different regional groups is the implementation of development policies based on each country's specific energy consumption vision and strategy. Countries focusing on reducing toxic gas emissions, as natural gas consumption generates less carbon emission compared to crude oil consumption, have seen clearer and

more influential policies supporting the shift towards natural gas consumption. Consequently, the move towards natural gas as an energy source is becoming more pronounced, regardless of price changes^[16].

Studies conducted by researchers in China have shown that the increased demand for gas is driven by improvements in macroeconomic indicators, such as rising GDP growth rates and increased total industrial output. The demand for natural gas is rising in basic material and fuel industries, with increased production in these sectors boosting natural gas consumption. Additionally, urban population growth and demographic shifts favoring urban areas have led to increased demand for cooking and hot water services, contributing to the rise in natural gas consumption^[17].

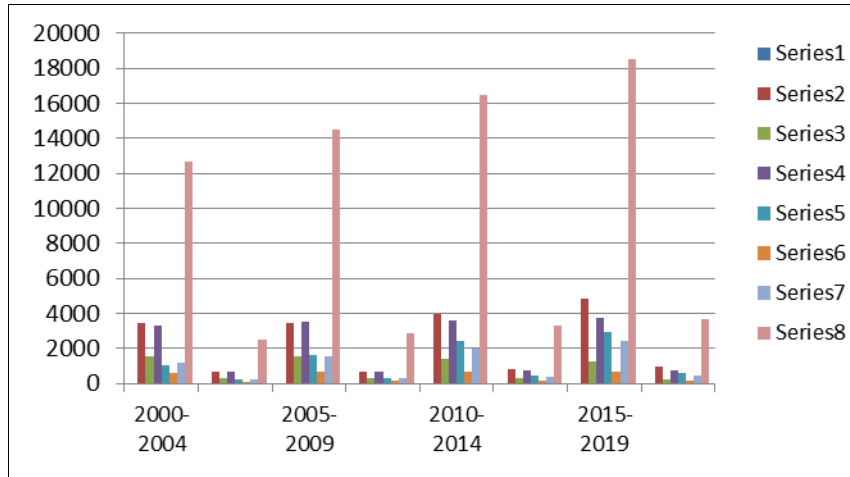
Section Three Development in Natural Gas Production and Changes in Crude Oil Prices

The topic of natural gas production refers to the capabilities available in regional groups to produce natural gas in cubic feet units. These groups vary in their natural gas production, with production serving as a channel to meet their energy needs. Production may exceed demand, leading to exports, or be less than needed, resulting in imports. Table 5 shows natural gas production in these regional groups. It appears that the supply response to the growing demand for natural gas is relatively low in the short term, while the response in reducing supply is relatively higher. This indicates that supply elasticity towards increasing production for market stabilization purposes is weak. The possible response to changes in consumption is sustained and growing with a contraction in production, especially in Europe, given the shift away from fossil fuels. Europe is the largest market with active gas (traded gas)^[18].

Table 4 illustrates the development of natural gas production during the study period, showing an increase to meet the energy market's growing demand. During the study period, the United States and the Belarus group led in natural gas production.

Table 4: Development of Natural Gas Production (Total and Average) for the World and Regional Groups during the Study Period (2000-2019)

2000-2004		2005-2009		2010-2014		2015-2019	
Total production	Production rate	Total production	Production rate	Total production	Production rate	Total production	Production rate
3471.92	694.38	3471.48	694.30	3963.94	792.79	4830.87	966.17
1542.10	308.42	1578.40	315.68	1429.32	285.86	1270.74	254.15
3277.71	655.54	3503.08	700.62	3583.10	716.62	3743.45	748.69
1077.74	215.55	1633.31	326.66	2417.43	483.49	2968.36	593.67
584.69	116.94	671.28	134.26	672.64	134.53	701.02	140.20
1208.14	241.63	1557.70	311.54	1984.90	396.98	2401.12	480.22
12670.63	2534.13	14487.93	2897.59	16500.81	3300.16	18560.36	3712.07



Source: Prepared by the researcher from Table (5)

Fig 4: Evolution of production during the study period distributed over five years
 المصدر : اعداد الباحث من الجدول (5)

As shown in the figure, the global production of natural gas has been continuously increasing during the study period due to supply shortages and growing energy consumption. Natural gas is an important energy source, and the need and demand for it have remained high. This explains the continued increase in its production and flow into energy markets, despite supply shortages. Consequently, the response of natural gas production changes as a result of changes in crude oil prices may be minimal. Table (5) shows the cross supply elasticity indicators during the period (2000-2019), where cross supply elasticity in most years and for most groups recorded values less than one, especially in the years (2001), (2013), and (2016). This reflects the impact of crude oil price changes on natural gas production. The direction of change is sometimes inconsistent with the expected direction, showing a negative sign in accordance with economic theory, as seen in 2001 for all regions except the African group, where the sign was positive in most years. The instability in cross elasticity indicators reflects the irregularity of the energy market between consumption and supply in the short term. The need for natural gas increases in some years, regardless of oil price fluctuations. When oil prices drop, natural gas consumption shifts to crude oil, particularly in the years with negative cross elasticity indicators, such as 2001, when all regions had low price indicators.

Cross supply elasticity indicators show that a decrease in oil prices causes a decrease in natural gas supply but to a lesser extent. The numbers in Table (5) indicate that the elasticity degree in most years is less than (0.5), reflecting low elasticity levels except in 2012, where all groups showed strong elasticity in response to oil price changes and a decrease in production quantities. Notably, North America had a value of (-4.216), Belarus (-4.579), and globally (-2.152).

The table indicates that natural gas production is not significantly affected by crude oil price changes, as supply shortages dominate the production side. This implies that quantity effects on price exceed price effects on quantities. The issue of market regulation and balance is challenged by the inability to control quantities amid growing global energy demand. This supports the research hypothesis that cross supply elasticity in natural gas production does not align with crude oil price changes in the energy market, according to economic theory.

According to the Energy Information Administration (EIA) report (IEQ2009) and the reference case, natural gas consumption in the United States is expected to increase by an average of 0.8% annually from 2006 to 2030. However, the global growth rate in natural gas consumption for final use sectors is slower^[19].

Table 5: Cross-Elasticity Supply Indicators during the period (2000-2019)

Rejion / years	2000	2001	2002	2003	2004
Total North America	0	-0.16	-3.06	0.02	-0.06
Total Europe	0	-2.09	1.22	0.07	0.11
Total CIS	0	-0.02	1.09	0.29	0.05
Total Middle East	0	-0.79	2.93	0.43	0.48

Total Africa	0	0.08	1.25	0.46	0.02
Total Asia Pacific	0	-0.05	1.50	0.38	0.21
Total World *	0	-0.16	2.61	0.19	0.10
Rejion / years	2005	2006	2007	2008	2009
Total North America	-0.05	0.11	0.24	0.06	0.00
Total Europe	-0.07	-0.11	-0.40	0.13	0.14
Total CIS	0.04	0.12	0.05	0.05	0.40
Total Middle East	0.18	0.29	0.87	0.20	-0.17
Total Africa	0.04	0.32	0.09	0.08	0.04
Total Asia Pacific	0.16	0.16	0.39	0.15	-0.15
Total World *	0.07	0.20	0.27	0.10	0.08
Rejion / years	2010	2011	2012	2013	2014
Total North America	0.060	0.307	-4.216	0.249	-1.445
Total Europe	0.076	-0.206	2.550	0.966	0.536
Total CIS	0.373	0.123	-4.579	-0.621	0.282
Total Middle East	0.510	0.268	2.196	-0.588	-0.491
Total Africa	-0.011	0.046	-0.461	1.374	0.489
Total Asia Pacific	0.445	0.032	0.575	-0.733	-0.343
Total World *	0.254	0.171	-2.152	0.286	-0.422
Rejion / years	2015	2016	2017	2018	2019
Total North America	-0.09	0.02	0.15	0.36	-0.62
Total Europe	0.05	0.02	0.05	-0.14	0.61
Total CIS	0.02	-0.01	0.25	0.17	-0.14
Total Middle East	-0.09	-0.21	0.13	0.18	-0.19
Total Africa	0.05	-0.34	0.35	0.22	0.08
Total Asia Pacific	-0.08	-0.23	0.21	0.18	-0.82
Total World *	-0.05	-0.10	0.22	0.18	-0.27

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From Table (5), we deduce that cross supply elasticity aligns with economic theory in terms of the positive sign, except for some years and some regions. Overall, the indicators suggest that an increase in crude oil prices leads to an increase in natural gas production. However, the elasticity degree is generally low, except in some years (2012) for North America, Europe, Belarus, and the Middle East, where the elasticity degree is greater than one. This indicates that natural gas production may not be significantly affected by changes in crude oil prices. Additionally, a negative sign appeared, especially for North America and Belarus, indicating that an increase in crude oil prices reduces natural gas production, contrary to economic theory. This relationship might be due to the capacity of North America and Belarus to adjust oil production in response to price changes, potentially aiming to achieve financial gains and savings. With the increase in oil prices, the reduction in natural gas production aligns with the logic of maintaining high prices, particularly since these regions can produce oil similarly to OPEC countries.

It appears that the rise in crude oil prices due to demand shock effects does not align with economic theory's expectations, as the oil market primarily influences the natural gas market through demand shocks rather than supply shocks. This discrepancy arises from the strong relationship between crude oil prices and natural gas prices. A total energy demand shock resulting from global total demand fluctuations, which may not originate from the oil market but affects both oil and natural gas markets, causes similar price fluctuations for crude oil and natural gas in many countries. This situation leads to a lack of correlation between changes in the prices of these sources and the quantities of oil and natural gas supplied^[20].

This scenario supports the research hypothesis that crude oil prices do not align with the quantities supplied or demanded for natural gas consumption and production in a manner consistent with economic theory.

Conclusions and Recommendations

Conclusions

The study reached several conclusions:

There is a continuous increase in global consumption of natural gas. During the study period, North America leads in the consumption chart, followed by Russia and Belarus, reflecting the rising demand for natural gas in the coming years.

The continuous increase in natural gas production among regional groups that lead in the energy consumption chart is due to the rising demand for natural gas. The relationship between the two commodities (oil and gas) in terms of substitution or complementarity is unclear, according to elasticity indicators. The elasticity coefficients did not show a negative sign, which is contrary to economic theory that states that the elasticity coefficient for substitute goods should be negative. Since oil and gas are substitute goods, an increase in crude oil prices should lead to an expansion in gas consumption. However, in other years of the study period, the sign was positive, suggesting that oil and gas are complementary goods according to the elasticity indicator, particularly for the African and Asia-Pacific regional groups. This data suggests that the energy market does not consistently show a clear quality relationship between crude oil and natural gas. Sometimes the relationship appears substitutive for some regional groups and certain years due to energy supply shortages.

The absolute values of the cross elasticity coefficients indicate low elasticity, suggesting that the demand for gas is inelastic relative to changes in crude oil prices. The elasticity coefficient values were more evident for the Europe and Africa groups, aligning with economic theory, particularly for the Europe group.

The discrepancy in cross elasticity according to theoretical logic for certain years and regions might be due to the relationship between energy consumption and real GDP growth. The phenomenon reflects a complex relationship

between energy consumption and growth, encompassing various probabilities. The relationship between the two can deviate from a unidirectional to a bidirectional and neutral causal relationship.

The global production of natural gas has been continuously increasing during the study period due to supply shortages and growing energy consumption. Natural gas is an important energy source, and the need and demand for it have remained high. This explains the continued increase in its production and flow into energy markets, despite supply shortages. Consequently, the response of natural gas production changes as a result of changes in crude oil prices may be minimal.

Natural gas production is not significantly affected by crude oil price changes, as supply shortages dominate the production side. This implies that quantity effects on price exceed price effects on quantities. The issue of market regulation and balance is challenged by the inability to control quantities amid growing global energy demand.

The cross supply elasticity does not align with economic theory concepts in terms of the sign, except for some years and some regions. Overall, the indicators suggest that an increase in crude oil prices leads to an increase in natural gas production. However, the elasticity degree is generally low, except in some years and for North America, Europe, Belarus, and the Middle East, where the elasticity degree is greater than one. This indicates that natural gas production may not be significantly affected by changes in crude oil prices.

A negative sign appeared, especially for North America and Belarus, indicating that an increase in crude oil prices reduces natural gas production, contrary to economic theory. This relationship might be due to the capacity of North America and Belarus to adjust oil production in response to price changes, potentially aiming to achieve financial gains and savings. With the increase in oil prices, the reduction in natural gas production aligns with the logic of maintaining high prices, particularly since these regions can produce oil similarly to OPEC countries.

Recommendations

1. Implement policies and measures that help restrict global consumption of natural gas in line with the requirements of the vision and strategy for using renewable energy.
2. Neutralize the relationship between using oil or gas as energy sources to enhance the perception that these commodities are substitutes rather than complements. This can be achieved by using one as an alternative to the other, which will only be possible through measures that ensure the continued supply of energy from sources other than oil and natural gas.
3. By implementing the first and second strategies, we can ensure a higher degree of flexibility in using one source over the other when the price of the latter rises. This will support the strategy of diversifying the use of various energy sources while simultaneously curbing the global demand for energy.
4. Conduct comprehensive studies on the relationship between energy consumption and GDP growth, ensuring that growth in agricultural production receives attention comparable to that of industrial production growth.
5. Prepare a study on the application of the strategic

storage concept in storing natural gas to balance supply and demand during energy market disruptions. This is similar to the well-known concept of strategic oil reserves, given that both sources are crucial energy sources.

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