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Original Research Article

Analyzing the Asymmetric Effect of Oil Price Shocks on Energy-intensive Industries in Emerging and Developed Economies

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The rapid growth of Emerging Economies in previous decades has made them an important player in the international arena, along with Developed Economies, which have a significant impact on international economic transactions. This study investigates the way oil price fluctuations affect energy-intensive sectors in Emerging and Developed economies using quarterly data from 2005 Q1 to 2024 Q2. Particularly, in this study the NARDL framework is employed to examine the asymmetric impact of changes in oil prices by decomposing oil price shocks into positive and negative partial sums. The results show a significant and asymmetric effect of oil price shocks on energy-intensive industrial sectors. The results show that the effect of negative changes in oil prices on both economics is similar, while Developed economies react differently to positive changes in oil prices compared to Emerging Economies. Overall, industries in Developed economies show better management and are less vulnerable to oil price fluctuations in comparison with Emerging economies.

Keywords: Oil Price, Industrial Sector, Nonlinear ARDL Model, Asymmetry
JEL Classification*:* C23, L60 or L16, Q43, P51, Q13

1 Introduction

For both exported and imported countries, crude oil has been a crucial economic factor for decades. The effect of this non-renewable energy prices on economic activities is still an important issue for the global economic growth. Many studies have been done about the relation between oil prices and different economic indexes. Darby (1982) and Hamilton (1983) note that many recessions are accompanied by a sudden rise in oil prices, though recent

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studies have shown that oil prices have less of an impact on economic output than previously thought.

Despite much research that have been done in this field, there is no consensus on the transmission channel of oil prices' impact on economic activities. The impact of oil price fluctuations on the economy, its reasons and intensity, is determined over time. Findings show that the price shocks that occurred in the 1970s are quite different from the shocks that occurred after 2000.

Considering crude oil price shocks as negative supply shocks were conventional interpretation in literature until millennials (e.g. Kim and Loungani, 1992; Rotemberg and Woodford, 1996; Finn, 1995). The fluctuations in global oil prices, since energy is an intermediate input, are likely to have a notable impact on manufacturing costs, especially in energy-intensive sectors, which, affects macroeconomic factors (Long & Liang 2018). For example, if the price of oil increases, the costs of producing goods and services will soar and thereby reduce supply. This direct cost mechanism was expected to dominate in the aggregate economy as well as at the industry-level.

Lee and Ni (2002) discovered that this conventional interpretation did not generally conform and industry doesn't response to oil price shocks as it was described before. Supply effect is dominant where shares of energy costs are high in the industry. Oil price shocks effects in the other industries are mostly through demand channels. Net supply or net demand shocks in a given industry are mostly determined by the energy share in production. Their inference from the econometric models was confirmed by the narrative accounts expressed by industry experts in trade journals during the oil crises of 1973-74 and 1978-81. (Jo et al. 2018)

Therefore, this paper investigates the specific industrial sectors responses of both advanced and emerging economies to oil price changes using quarterly data from 2005 Q1 to 2024 Q2. Peltzman (2000) found that across a broad sample of 242 markets, prices increase faster than they decline in around two thirds of markets. This finding is more seen across markets that are perfectly competitive and those with market power. Other studies have found asymmetric cost pass-through, with notable examples including markets for gasoline, various agricultural products, deposit markets in retail banking, and carbon emissions permits (Ritz, 2015). So we investigate whether the adjustment paths of industrial sectors are asymmetric when oil prices go up and down.

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This research contributes to the extant literature by considering economic responses at the sectoral level and investigating asymmetries therein. The primary contributions of this study are threefold:

First, whereas most research focuses on overall economic growth, this study examines the repercussions on industrial sectors. Such an investigation illustrates shock transmission mechanisms throughout the economy, which is critical for industrial optimization and economic stability. The focus here is specifically on the impacts on individual industrial sectors, particularly those with high energy intensity.

Second, oil prices are disaggregated into positive and negative components to scrutinize the asymmetries present in their relationship. The recently advanced nonlinear ARDL modeling approach (Shin et al., 2014) is employed to estimate both short- and long-term effects, detailing the adjustment paths in response to positive and adverse shocks.

Moreover, most of prior research focused on advanced economies like United States, leaving out potential heterogeneity between advanced and emerging economies. This paper tries to fill in the gap in the literature by providing a systematic analysis of the effect of global oil price shocks on energy-intensive industries covering both advanced and emerging economies for sufficiently long time. In this paper BRICS and G7 data is used for emerging and developed economies, respectively.

The BRICS, namely Brazil, Russia, India, China, and South Africa are the world's large emerging economies, and they are experiencing rapid growth. These nations cover over one-quarter of the world's land (or over 68.5 million square kilometers) and are home to nearly 3 billion people – about 40% of the world's total population. With a combined GDP of $20 trillion, the nations of BRIC could one day become the largest entity in the world. "Group of Seven" (G7), a coalition of seven countries that have the largest and most advanced economies in the world: United States, Germany, Japan, United Kingdom, France, Italy, and Canada. These countries represent over 32% of the GDP based on purchasing power parity. In 2018, the countries in this group comprised more than 60% of the global net wealth for a total of $317 trillion[1].

The remainder of this paper is organized as follows. Section 2 reviews the literature, and Section 3 introduces the data and nonlinear ARDL method. Section 4 provides the empirical results, and Section 5 summarizes findings and the last section reports main conclusions.

[1] https://worldpopulationreview.com/country-rankings/g7-countries

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2 Literature Review

Hamilton (1983) shows that there's a causal relationship between oil prices and United states GDP. Rodríguez and Sánchez (2004) find same results for countries like Germany, Japan, Canada, France, United Kingdom and Norway. Unlike many studies that investigate short-term interaction among oil prices and aggregate economic indexes, Hooker (2002) examines the long-term relationship between oil price, unemployment and interest rate for United States.

In investigating the role of crude oil in modern economy and its interaction, some studies focus on the oil industry and define different shock sources that change oil prices to "explain why relation between macroeconomic aggregates and oil prices tend to be unstable" over time (Kilian (2009); Ratti & Vespignani (2015) and Hamilton (2013)). However, this is more complicated and requires more detailed studies for oil-importing and oil-exporting (or developed and emerging) economies (Yang et al. 2017). Aastveit et al. (2014) find that emerging economics' demand for oil is more than twice as important as developed countries' demand.

Some scholar, for example Ferderer (1996), claim that oil prices have negative effects on economic growth. Hamilton and Herrera (2001) offer evidence that downturn effect of oil shocks on growth cannot be averted by even aggressive Federal Reserve policies. There have been made studies on the significant impact of oil prices on stock markets (Jones and Kaul, 1996; Kilian and Park 2009; Driesprong et al., 2008). Zhu et al. (2021) analyze how oil price shocks affect stock market anomalies. Their study shows that while oil supply shocks and oil-specific demand shocks cause few anomalies the aggregate demand shocks play important role in the spread of anomalies. However, the anomaly of some certain industries is caused by all three types of oil price shocks.

Jiranyakul (2025) reveals that oil price shocks have asymmetric effects on macroeconomic variables due to factors like income, uncertainty, and irreversible investment. Studies examining this asymmetry in Asia reveal mixed results. Japan and South Korea show asymmetric output growth responses to oil price shocks, while inflation responses appear symmetric. Evidence of asymmetry is growing in China, but inflation responses don't support the hypothesis. The ASEAN5 economies largely support symmetry. South Asia has limited support for asymmetry. Research is lacking for other Asian countries. Notably, even oil-exporting Asian countries like Indonesia, Malaysia, and Vietnam can experience negative impacts on output growth from oil price shocks. Researchers often suggest accommodative monetary and exchange rate policies to stabilize output and prices during periods of high

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oil prices. Bachmeier and Keen (2023) find that a rising oil price leads to a larger output decline, especially when prices reach a near-term peak. A New Keynesian model with energy considerations and downward nominal wage rigidity explains this asymmetry. High energy prices significantly depress real wages, triggering a downward nominal wage constraint that persists for several periods, further reducing firm output. This mechanism is largely absent during falling oil prices, resulting in an asymmetric output response to oil price shocks.

A series of studies extend the linear impact to nonlinear model and insist on asymmetric effect of oil price fluctuations on economic activities. Herrera et al., (2011) test nonlinear feedback from the real oil price to U.S. industrial production. Results show evidence of sensitivity of feedback to estimation period. At the disaggregate level, especially energy-intensive industrial, they find strong evidence of asymmetric effects. Their analysis suggests that these asymmetries may be obscured in the aggregate data. while most of papers investigate the effects on economic aggregates, ignoring industrial sectors.

Identifying the sectoral responses is crucial, which can help us to understand how oil price shocks are transmitted throughout the economy. Lee and Ni (2002) find that in short term oil price shock decline output in most industries. Their findings lend support to the theory that increased operating cost of durable goods and heightened uncertainty are major reasons for oil price shocks to induce recessions. Jo et al., (2018) confirm Lee and Ni(2002) findings that only in the energy-intensive industries, oil price shocks are transmitted largely through supply. Most of the other industries experience oil price shocks mainly through reduction in demand.

This paper fills the research gap in three main directions. First, this paper separates the effects of oil price increases and decreases and employs the recently developed nonlinear ARDL model (Shin et al., 2014). This approach is flexible and is very popular for asymmetric cases. Second, in this paper the responses of energy–intensive industrial sectors and economic movement at a disaggregated level are considered, which is useful for policy makers. Three, instead of investigating one country, like U.S. or China, two groups of countries, emerging and developed economies, is considered. These countries can be assumed the major agents in demand side of crude oil market.

3 Data

Quarterly data from 2005Q1 to 2024 Q2 are used in this empirical analysis. The reason for selected time period is due the available data on UNIDO site which is used to obtain data for industrial data for selected countries.

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According to International Energy Outlook 2016 from U.S. Energy Information Administration (EIA), about 54 percent of the world's total energy is used in industrial sector. In this report, the industrial sector categorizes to three distinct industry types: energy-intensive manufacturing, non-energy-intensive manufacturing, and non-manufacturing. energy-intensive manufacturing consists of Food, Pulp and Paper, Basic Chemicals, Refining, Iron and Steel, Nonferrous metals and Nonmetallic minerals. These groups are considered for selected energy-intensive industries in this paper. Quarterly Index of Industrial Production (IIP) at the 2-digit level of ISIC Revision 4, which are obtained from United Nations Industrial Development Organization (UNIDO), are used for industries data. This data is seasonally adjusted. The mentioned groups of energy-intensive industries, according the 2-digit level of ISIC Revision 4, are 10, 11, 12, 17, 18, 19, 20, 23, 24 and 25. Thus, this paper considers these ten sectors as energy-intensive sectors and for more examination total manufacturing data is included as well. P10, P11, P12, P17, P18, P19, P20, P23, P24 and P25 are variables that represent these sectors output and TM represents total manufacturing variable. Detailed information of selected industries is shown in Table 1.

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Table 1
Selected Industries Information

Industry grouping	Representative industries	2-digit ISIC Codes
Food	Food, beverage, and tobacco product manufacturing	10: Food Products
		11: Beverage
		12: Tobacco Products
Pulp and Paper	Paper manufacturing, printing and related support activities	17: Paper and Paper Products
		18Printing and Reproduction of Recorded Media
Refining	Petroleum refineries and coal products manufacturing, including coal and natural gas used as feedstocks	19: Coke and Refined Petroleum Products
Basic Chemical	Inorganic chemicals, organic chemicals (e.g., ethylene propylene), resins, and agricultural chemicals; includes chemical feedstocks	20: Chemicals and Chemical Products
Nonferrous minerals	Primarily cement and other nonmetallic minerals, such as glass, lime, gypsum, and clay products	23: Other non-Metallic Mineral Products
Nonmetallic metals	Primarily aluminum and other nonferrous metals, such as copper, zinc, and tin	
Iron and Steel	Iron and steel manufacturing, including coke ovens	24: Basic Metals

Source: https://stat.unido.org/content/dataset_description/quarterly-iip

According to dataset description on UNIDO's site[1], Index of Industrial Production (IIP) measures the growth of the volume of industrial production in real terms, free from price fluctuations. Opposite the monthly or quarterly indices which reflect the growth of gross output, generally annual industrial growth rates refer to changes in manufacturing value added (MVA), i.e. output net of intermediate consumption. Due to the estimates' temporal nature, output growth provides the best approximation of value added growth, assuming that the input-output relationship is relatively stable during the observation period.

For the crude oil prices data, West Texas Intermediate (WTI) crude oil price is considered and obtained from the Energy Information Administration (EIA) website. Moreover, one control variable, Gross domestic product (GDP) in constant price, is considered in our model. The GDP data were

[1] https://stat.unido.org/content/dataset_description/quarterly-iip

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obtained from the Federal Reserve Economic Data (FRED) database maintained by the Federal Reserve Bank of St. Louis.

4 Methodology

One of the innovation of this paper is that it employs the NARDL model of Shin et al., (2014) to investigate the dynamic short-and long-run asymmetrical response of the Energy-intensive industrial's production growth to oil prices' changes. This method has advantages that makes it popular. In addition to describing the short-run and long-run asymmetries, it allows for integration of I(0) and I(1), or a combination of both, in underlying variables which is able to produce valid results and performs well even with a small sample of data. The nonlinear ARDL (NARDL) model is an expansion of the linear autoregressive distributed lag (ARDL) model of Pesaran et al., (2001). The ARDL approach of Pesaran et al., (2001) assumes a linear adjustment process which means positive and negative oil price shock have symmetric effects on industry. Though industry may respond differently to negative and positive shocks. The dynamic multipliers of the NARDL modeling approach can observe the path and time length of adjustments. The conditional format of the linear ARDL model can be written:

$$y_t = \alpha_0 + \sum_{i=1}^{q-1} \alpha_{1i} \Delta y_{t-i} + \sum_{i=0}^{p-1} \alpha_{2i} \Delta x_{t-i} + \alpha_3 y_{t-1} + \alpha_4 x_{t-1} + \omega_t \qquad (1)$$

where y and x are dependent and independent variables, respectively. Lag orders of dependent and independent variables are q and p, respectively. In the first step of ARDL approach, the Equation (1) is estimated by employing standard ordinary least squares (OLS). The second step is consisted of doing F-test of Pesaran et al., (2001) to test the null hypothesis of no-integration ($\alpha_3 = \alpha_4 = 0$) against the alternative of cointegration between variables ($\alpha_3 \neq \alpha_4 \neq 0$). If null hypothesis is rejected and there is cointegration among variables, the long-run coefficients are estimated.

Full representation of the NARDL model, following the approach used in Shin et al., (2014), can be written as:

$$y_t = \alpha_0 + \alpha_1^+ x^+ + \alpha_2^- x^- + u_t \qquad (2)$$

Where α_1^+ and α_2^- are the long-run parameters associated with positive and negative oil price shocks, respectively. Dependent variable x_t is decomposed as

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$$x_t = x_0 + x_t^+ + x_t^- \quad (3)$$

x_t^+ and x_t^- are positive and negative partial sums of oil prices, respectively, and are defined as:

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j , 0) \quad (4)$$
$$x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j , 0) \quad (5)$$

where $\Delta x_j = x_j - x_{j-1}$. The general NARDL model for this paper with both short run and long run asymmetries can be written as follows:

$$\Delta y_t = \alpha + \theta y_{t-1} + \beta^+ oil_price_{t-1}^+ + \beta^- oil_price_{t-1}^- + \sum_{i=1}^{q-1} \gamma_i \Delta y_{t-i} + \sum_{i=0}^{p-1} (\delta_i^+ \Delta oil_price_{t-i}^+ + \delta_{t-i}^- oil_price_{t-i}^-) + \omega_t \quad (6)$$

where oil_price is WTI crude oil spot price and dependent variable, y, is the growth of the volume of production in real terms of ten selected energy-intensive industries. As it was mentioned before, one controlling variable (GDP) are considered in our model.

For implementing the NARDL model, first, equation (6) is estimated by standard OLS approach. In the second step, the presence of nonlinear cointegration (long-run relationship) among variables is tested. Shin et al., (2014) develop two procedures for this purpose: Using F-test of Pesaran et al. (2001) with null hypothesis of no-cointegration ($\theta = \beta^+ = \beta^- = 0$) against ($\theta \neq \beta^+ \neq \beta^- \neq 0$) and t_test ($t_{BDM}$) proposed by Banerjee et al., (1998) with null hypothesis of no-cointegration ($\theta = 0$) against ($\theta < 0$). Pesaran et al., (2001) provide the critical values for the F-test and t_{BDM}-statistic and for rejecting the the null of no cointegration, the test statistic of t_{BDM} or F_{PSS} needs to be exceeded the upper bound which means there is a cointegration relation. Long-run and short-run symmetry is tested by using standard Wald test. The null hypothesis for long-run symmetry is $\alpha_1^+ = \alpha_2^-$, where $\alpha_1^+ = -\beta^+/\theta$ and $\alpha_2^+ = -\beta^-/\theta$ and for short-run symmetry is $\sum_{i=0}^{p-1} \delta_i^+ = \sum_{i=0}^{p-1} \delta_i^-$(Nusair 2016).

5 The results

Panel unit root test is applied, before estimation, to rule out the possibility of the presence of I(2) variables. The time series cannot be integrated beyond I(1), because of biased results might be seen once I(2) or higher level of integration appears (Shin et al., 2014). Cross-sectional dependence test is the first step and if the test result shows the presence of cross-sectional

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dependence, first-generation panel unit root tests (the Levin–Lin–Chu test (Levin et al., 2002), the Im–Pesaran–Shin test (Im et al. 2003), the Breitung test (Breitung, 2001), the Fisher-ADF (Maddala and Wu 1999) and the Hadri (Hadri 2000) Lagrange multiplier (LM) test) will be no longer reliable. In case of cross-sectional dependence, second-generation panel unit root test like cross-sectional augmented IPS Panel unit root test developed by Pesaran (2007) is employed. Table 2 and 3 show the results of the Cross-sectional dependency test for emerging and developed economies, respectively. The null hypothesis of this test is no cross-section dependence for our model variables. According to the results, there is a cross-sectional dependency and it seems that the variables of all countries in our model depict some dynamisms common.

Table 2
Cross-sectional dependency test – Emerging Economies

Variable	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
P10	271.6442	58.50542	58.46811	10.04766
P11	244.9583	52.53827	52.50096	10.79902
P12	91.87263	24.78929	24.75944	-1.978867
P17	212.3049	45.23675	45.19944	4.720856
P18	191.0724	40.48902	40.45171	-0.28077*
P19	140.5763	29.19775	29.16043	2.324984
P20	167.1156	35.13211	35.09480	9.660763
P23	71.38312	13.72568	13.68837	0.66752*
P24	193.4236	41.01476	40.97745	1.44221*
TM	148.3890	30.94471	30.90740	2.850604
Oil_price	552.0000	121.1949	121.1576	23.31188
GDP	256.6935	55.16234	55.12503	13.47714

* Indicates not significant, even at 0.1 level. Source: Research Findings

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Table 3
Cross-sectional dependency test – Developed Economies

Variable	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
P10	449.0342	66.04711	65.99487	8.586404
P11	392.9372	57.39115	57.33891	-1.416006*
P12	301.0392	65.07833	65.04102	16019889
P17	618.1488	92.14206	92.08982	10.91042
P18	875.4150	131.8391	131.7869	29.18770
P19	442.1065	64.97814	64.92591	15.28901
P20	328.2676	47.41243	47.36019	8.142177
P23	486.2219	71.78529	71.73305	20.05687
P24	806.5856	121.2185	121.1663	28.06596
TM	492.2973	72.72276	72.67052	19.52524
Oil_price	552.0000	121.1949	121.1576	23.31188
GDP	684.1418	102.3250	102.2728	19.30668

* Indicates not significant, even at 0.15 level. Source: Research Findings

Table 4 exhibits the results of second-generation panel unit root (Pesaran, 2007) for both economics. None of the variables are I(2) and are either stationary at the level or become stationary after the first difference, hence, panel NARDL can be applied to investigate long-run relationship among production of energy-intensive industries productions and oil price as it was described in previous section.

Table 4
The Second Generation Panel Unit Root (Pesaran, 2007) Results

Variable	Emerging Economics				Developed Economies			
	Intercept		Trend		Intercept		Trend	
	t-stat	Critical value	t-stat	Critical value	t-stat	Critical value	t-stat	Critical value
P10	-0.40	-2.33	-2.65	-2.83	-2.46	-2.33	-3.52	-2.83
P11	-0.63	-2.33	-3.74	-2.83	-1.15	-2.33	-2.56	-2.83
P12	4.88	-2.33	8.35	-2.83	-3.01	-2.33	-3.14	-2.83
P17	-1.01	-2.33	-1.36	-2.83	-2.76	-2.33	-2.83	-2.83
P18	-1.95	-2.33	-2.28	-2.83	-1.24	-2.33	-2.08	-2.83
P19	-1.15	-2.33	-0.76	-2.83	-2.53	-2.33	-4.22	-2.83
P20	-1.11	-2.33	-2.24	-2.83	-2.03	-2.33	-2.93	-2.83
P23	-1.41	-2.33	-4.96	-2.83	-2.28	-2.33	-2.92	-2.83
P24	-2.05	-2.33	-3.25	-2.83	-2.62	-2.33	-2.94	-2.83
TM	-2.31	-2.33	-4.94	-2.83	-1.65	-2.33	-2.58	-2.83
Oil_price	-0.63	-2.33	0.00	-2.83	-0.63	-2.33	0.00	-2.83
GDP	-1.34	-2.33	-2.04	-2.83	-1.07	-2.33	-3.14	-2.83

Note: The Critical Value is for 5% significate level. Source: Research Findings

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To test if there is long-run relationship between the dependent and explanatory variables, cointegration test is conducted. Table 5 and 6 show results of panel cointegration which are proposed by Pedroni (1999, 2004) for emerging and developed economies, respectively. Among seven statistics in Pedroni test Panel ADF and group ADF statistics are more reliable (Akinsola and Odhiambo, 2020). Results for emerging economies in table 4 show that all variables, except P17 and P18, panel ADF and group ADF statistics are significant and reject the null hypothesis of no cointegration. These two statistics for P10 reject the null hypothesis of no integration at 10% level of significant. Panel PP and group PP statistics can reject the null hypothesis of no integration for P17 and P18. Overall it can state from seven statistics that there is long-run relationship among dependent and explanatory variables in emerging economies.

Table 5
Results of Pedroni's (2004) Cointegration test – Emerging Economies

		P10	**P11**	**P12**	**P17**	**P18**	**P19**	**P20**	**P23**	**P24**	**TM**
Within-dimension	Panel v-Stat.	1.2727	3.0830	0.1059	-0.245	0.7283	1.7261	2.2880	2.7594	2.3673	1.8819
		(0.101)	(0.001)	(0.457)	(0.597)	(0.233)	(0.042)	(0.011)	(0.002)	(0.009)	(0.029)
	Panel rho-Stat.	-0.443	-3.747	-3.371	-0.222	-0.752	-3.729	-1.488	-2.262	-2.966	-4.259
		(0.328)	(0.000)	(0.000)	(0.412)	(0.226)	(0.000)	(0.068)	(0.011)	(0.001)	(0.000)
	Panel PP-Stat.	-0.750	-4.374	-4.389	-1.153	-1.393	-4.298	-1.798	-2.703	-3.576	-5.327
		(0.226)	(0.000)	(0.000)	(0.124)	(0.081)	(0.000)	(0.036)	(0.003)	(0.000)	(0.000)
	Panel ADF-Stat.	-1.4782	-4.395	-4.823	-0.773	-1.371	-4.344	-2.053	-2.614	-3.511	-4.991
		(0.069)	(0.000)	(0.000)	(0.219)	(0.085)	(0.000)	(0.020)	(0.004)	(0.000)	(0.000)
	Weighted Panel v-Stat.	1.5803	2.3112	-0.123	0.2237	1.030	1.6181	2.0923	2.4606	2.4723	1.9714
		(0.057)	(0.010)	(0.549)	(0.411)	(0.151)	(0.052)	(0.018)	(0.006)	(0.006)	(0.024)
	Weighted Panel rho-Stat.	-0.6763	-3.0219	-0.390	-1.072	-1.843	-2.057	-1.397	-2.893	-2.475	-3.991
		(0.249)	(0.001)	(0.348)	(0.141)	(0.032)	(0.019)	(0.081)	(0.001)	(0.006)	(0.000)
	Weighted Panel PP-Stat.	-1.2255	-3.8388	-1.065	-1.921	-2.879	-2.534	-1.813	-3.308	-3.030	-5.010
		(0.110)	(0.000)	(0.143)	(0.027)	(0.002)	(0.005)	(0.034)	(0.000)	(0.001)	(0.000)
	Weighted Panel ADF-Stat.	-1.8420	-3.8458	-1.762	-1.139	-2.815	-2.945	-1.934	-3.284	-2.917	-4.859
		(0.032)	(0.000)	(0.039)	(0.127)	(0.002)	(0.001)	(0.026)	(0.000)	(0.001)	(0.000)
Between-dimension	Group rho-Stat.	0.1233	-2.9141	0.2040	-1.217	-1.003	-1.827	-1.209	-2.029	-1.873	-3.093
		(0.549)	(0.001)	(0.580)	(0.111)	(0.157)	(0.033)	(0.113)	(0.021)	(0.030)	(0.001)
	Group PP-Stat.	-0.8067	-4.367	-0.334	-2.470	-2.698	-2.930	-2.289	-3.164	-3.257	-5.130
		(0.209)	(0.000)	(0.369)	(0.006)	(0.003)	(0.001)	(0.011)	(0.000)	(0.000)	(0.000)
	Group ADF-Stat.	-1.4521	-4.3945	-1.140	-1.706	-2.656	-3.521	-3.269	-3.072	-3.091	-4.518
		(0.073)	(0.000)	(0.127)	(0.043)	(0.003)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)

Note: numbers in parenthesizes are probability. Source: Research Findings

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Checking the seven statistics of Table 6, the results for developed economies show that, except P11, P24, P25 and TM, panel ADF and group ADF statistics are significant and reject the null hypothesis of no cointegration for the remaining variables. Panel PP and group PP statistics can reject the null hypothesis of no integration for P11, P24 and TM. Panel v-statistic is the only statistic that is significant to reject null hypothesis of no cointegration for variable P25. So upon results of table 6 there is long-run relationship among dependent and explanatory variables in developed economies.

Table 6
Results of Pedroni's (2004) Cointegration test – Developed Economies

		P10	**P11**	**P12**	**P17**	**P18**	**P19**	**P20**	**P23**	**P24**	**TM**
Within-dimension	Panel v-Stat.	0.6885	-2.136	1.4885	2.9447	1.4378	4.3315	2.3601	1.0307	1.2662	1.4217
		(0.245)	(0.016)	(0.068)	(0.001)	(0.075)	(0.000)	(0.009)	(0.151)	(0.102)	(0.077)
	Panel rho-Stat.	0.4321	-2.604	-0.516	-0.723	-1.461	-2.595	-1.003	-0.462	-0.735	-1.088
		(0.667)	(0.004)	(0.302)	(0.234)	(0.071)	(0.004)	(0.157)	(0.322)	(0.231)	(0.138)
	Panel PP-Stat.	-0.306	-3.343	-1.319	-1.380	-2.241	-3.210	-1.517	-1.177	-1.355	-1.874
		(0.379)	(0.000)	(0.093)	(0.083)	(0.012)	(0.000)	(0.064)	(0.119)	(0.087)	(0.030)
	Panel ADF-Stat.	-2.711	0.0759	-1.098	-3.689	-2.640	-3.344	-2.777	-1.356	-1.556	-0.373
		(0.003)	(0.530)	(0.136)	(0.000)	(0.004)	(0.000)	(0.002)	(0.087)	(0.059)	(0.354)
	Weighted Panel v-Stat.	0.5222	1.7626	2.4129	1.9226	0.7987	3.2972	2.4920	0.9055	1.2401	1.2364
		(0.301)	(0.039)	(0.007)	(0.027)	(0.212)	(0.000)	(0.006)	(0.182)	(0.107)	(0.108)
	Weighted Panel rho-Stat.	-3.735	-2.571	-1.941	-0.585	-0.463	-4.231	-1.171	-2.123	-1.574	-0.992
		(0.000)	(0.005)	(0.026)	(0.279)	(0.321)	(0.000)	(0.042)	(0.016)	(0.057)	(0.160)
	Weighted Panel PP-Stat.	-4.768	-3.362	-2.728	-1.250	-1.299	-4.906	-2.313	-3.166	-2.269	-1.816
		(0.000)	(0.000)	(0.003)	(0.105)	(0.096)	(0.000)	(0.010)	(0.000)	(0.011)	(0.034)
	Weighted Panel ADF-Stat.	-5.223	0.2395	-2.530	-1.895	-1.663	-4.782	-3.148	-3.370	-1.372	-1.054
		(0.000)	(0.594)	(0.005)	(0.029)	(0.048)	(0.000)	(0.000)	(0.000)	(0.084)	(0.145)
Between-dimension	Group rho-Stat.	-3.997	-2.923	-1.692	0.2311	-0.732	-4.000	-0.853	-1.176	-0.750	-0.215
		(0.000)	(0.001)	(0.045)	(0.591)	(0.232)	(0.000)	(0.196)	(0.119)	(0.226)	(0.414)
	Group PP-Stat.	-5.762	-3.905	-2.936	-0.907	-1.883	-5.204	-1.942	-2.684	-1.894	-1.441
		(0.000)	(0.000)	(0.001)	(0.182)	(0.029)	(0.000)	(0.026)	(0.003)	(0.029)	(0.074)
	Group ADF-Stat.	-6.435	0.3686	-2.685	-2.383	-2.361	-5.133	-3.435	-2.854	-1.151	-0.157
		(0.000)	(0.643)	(0.003)	(0.008)	(0.009)	(0.000)	(0.000)	(0.002)	(0.124)	(0.437)

Note: numbers in parenthesizes are probability. Source: Research Findings

In the next step the short-run and long-run relationship is estimated using the panel NARDL. As mentioned in methodology section, in this model and for asymmetric effect the real oil price is decomposed into positive and negative partial sums which indicate increase and decrease in real oil prices, respectively. Table 7 and 8 show the results for emerging and developed economies, respectively.

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Table 7
Results of NARDL Model – Emerging Economies

P10		**P11**		**P12**[1]		**P17**[2]	
			Short-term				
ECT	-0.2271**	ECT	-0.4960*	ECT	-0.2803***	ECT	-0.3582*
$\Delta(P10(-1))$	-0.0804	$\Delta(oil_price^-)$	0.1553	$\Delta(oil_price^-)$	-0.0712**	$\Delta(P17(-1))$	-0.2029
$\Delta(P10(-2))$	-0.0799	$\Delta(oil_{price}{}^-(-1))$	0.0435**	$\Delta(oil_price^+)$	0.0889	$\Delta(P17(-2))$	-0.0251
$\Delta(oil_price^-)$	0.0364**	$\Delta(oil_price^+)$	-0.0581	GDP	-1.43e-9	$\Delta(P17(-3))$	0.1025***
$\Delta(oil_price^+)$	0.0256**	$\Delta(oil_{price}{}^+(-1))$	-0.0455	constant	45.6403	$\Delta(oil_price^-)$	0.0724*
GDP	9.00e-10	GDP	4.34e-9	trend	-0.2415	$\Delta(oil_{price}{}^-(-1))$	-0.0043
constant	10.0278	constant	-3.1908			$\Delta(oil_price^+)$	0.1094*
						$\Delta(oil_{price}{}^+(-1))$	0.1433
						GDP	1.30e-9
						constant	21.1035
						trend	-0.1919
			Long-term				
$\Delta(oil_price^-)$	-0.0346	$\Delta(oil_price^-)$	-0.0021	$\Delta(oil_price^-)$	0.3302*	$\Delta(oil_price^-)$	-0.0219
$\Delta(oil_price^+)$	-0.0967**	$\Delta(oil_price^+)$	-0.0661***	$\Delta(oil_price^+)$	0.4024*	$\Delta(oil_price^+)$	-0.1287**
P18		**P19**		**P20**		**P23**	
			Short-term				
ECT	-0.2591**	ECT	-0.2540**	ECT	-0.1857**	ECT	-0.4811**
$\Delta(P18(-1))$	-0.0274	$\Delta(P19(-1))$	-0.0925	$\Delta(P20(-1))$	-0.1400**	$\Delta(P23(-1))$	-0.0666
$\Delta(oil_price^-)$	0.1175*	$\Delta(P19(-2))$	-0.1279	$\Delta(oil_price^-)$	0.1087*	$\Delta(oil_price^-)$	0.0735
$\Delta(oil_price^+)$	-0.0095	$\Delta(P19(-3))$	0.0157	$\Delta(oil_{price}{}^-(-1))$	-0.0275	$\Delta(oil_{price}{}^-(-1))$	0.0551
GDP	4.85e-9	$\Delta(oil_price^-)$	0.0836*	$\Delta(oil_price^+)$	0.1336**	$\Delta(oil_price^+)$	0.1540**
constant	-20.2293	$\Delta(oil_price^+)$	0.0596*	$\Delta(oil_{price}{}^+(-1))$	0.1032***	$\Delta(oil_{price}{}^+(-1))$	0.1814
		GDP	9.54e-10	GDP	1.34e-9	GDP	4.71e-9
		constant	9.6604			constant	-4.9094
						Long-term	
$\Delta(oil_price^-)$	0.2194*	$\Delta(oil_price^-)$	-0.0437**	$\Delta(oil_price^-)$	-0.1271*	$\Delta(oil_price^-)$	-0.1855*
$\Delta(oil_price^+)$	-0.1752**	$\Delta(oil_price^+)$	-0.2486*	$\Delta(oil_price^+)$	-0.3438*	$\Delta(oil_price^+)$	-0.4811**

P24		**TM**	
	Short-term		
ECT	-0.4715*	ECT	-0.5420*
$\Delta(oil_price^-)$	0.1362***	$\Delta(TM(-1))$	-0.1238
$\Delta(oil_{price}{}^-(-1))$	0.0423	$\Delta(oil_price^-)$	0.0844*
$\Delta(oil_price^+)$	0.1764	$\Delta(oil_{price}{}^-(-1))$	-0.0238
$\Delta(oil_{price}{}^+(-1))$	0.1896	$\Delta(oil_price^+)$	0.1021**
GDP	3.00e-9	$\Delta(oil_{price}{}^+(-1))$	0.1145
constant	6.9836**	GDP	4.01e-9
trend	0.5288***	constant	-0.0656
	Long-term		
$\Delta(oil_price^-)$	0.1423*	$\Delta(oil_price^-)$	0.0387*
$\Delta(oil_price^+)$	-0.2902*	$\Delta(oil_price^+)$	-0.1786*

Note: Results of short term and long term asymmetric relationship between oil price and energy-intensive industrial sectors' output is shown in this table. Rejection of null hypothesis at 1%, 5% and 10% significant levels are determined by *, ** and ***, respectively. Source: Research

[1] South Africa has no data for this variable so for estimation this equation only South Africa data was removed from sample.
[2] In this equation time period is considered 2008Q1 to 2024Q2

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Findings

Table 8
Results of NARDL Model – Developed Economies

P10[1]		**P11**		**P12**[2]		**P17**	
Short-term							
ECT	-0.3768*	ECT	-0.3127**	ECT	-0.1690**	ECT	-0.1896**
$\Delta(P10(-1))$	-0.1289	$\Delta(P11(-1))$	-0.2170*	$\Delta(oil_price^-)$	-0.0174	$\Delta(P17(-1))$	0.1315***
$\Delta(oil_price^-)$	0.0154***	$\Delta(oil_price^-)$	0.0395**	$\Delta(oil_price^+)$	0.0030	$\Delta(oil_price^-)$	0.0862*
$\Delta(oil_price^+)$	-0.0104	$\Delta({oil_{price}}^-(-1))$	-0.0113	GDP	0.0360	$\Delta(oil_price^+)$	-0.0249*
GDP	0.0320	$\Delta(oil_price^+)$	-0.0109	constant	0.542.7	GDP	0.0002
constant	14.8749***	$\Delta({oil_{price}}^+(-1))$	-0.0135	Trend	-0.3325	constant	-0.4016
		GDP	0.0008				
		constant	1.1511				
Long-term							
$\Delta(oil_price^-)$	-0.0117	$\Delta(oil_price^-)$	0.0403**	$\Delta(oil_price^-)$	-0.0345	$\Delta(oil_price^-)$	0.1105*
$\Delta(oil_price^+)$	-0.0364*	$\Delta(oil_price^+)$	0.0124	$\Delta(oil_price^+)$	0.3094*	$\Delta(oil_price^+)$	0.0669*

P18		**P19**		**P20**		**P23**	
Short-term							
ECT	-0.1951**	ECT	-0.3174*	ECT	-0.3697*	ECT	-0.3735*
$\Delta(oil_price^-)$	0.0539*	$\Delta(P19(-1))$	-0.0145	$\Delta(P20(-1))$	0.2647*	$\Delta(oil_price^-)$	0.0982*
$\Delta(oil_price^+)$	0.0588**	$\Delta(oil_price^-)$	-0.0324**	$\Delta(oil_price^-)$	0.1069*	$\Delta({oil_{price}}^-(-1))$	0.1145*
GDP	0.0148	$\Delta(oil_price^+)$	-0.0124	$\Delta(oil_price^+)$	-0.0318	$\Delta(oil_price^+)$	-0.0115
		GDP	0.0126	GDP	0.0039	$\Delta({oil_{price}}^+(-1))$	-0.0583***
		constant	-4.0305	constant	-0.7158	GDP	0.0021
				trend	0.0951	constant	-24.0570
Long-term							
$\Delta(oil_price^-)$	0.0173	$\Delta(oil_price^-)$	0.0450**	$\Delta(oil_price^-)$	0.0381***	$\Delta(oil_price^-)$	0.0967*
$\Delta(oil_price^+)$	-0.2062*	$\Delta(oil_price^+)$	-0.0798*	$\Delta(oil_price^+)$	-0.0499**	$\Delta(oil_price^+)$	0.0210

P24		**TM**	
Short-term			
ECT	-0.2752*	ECT	-0.4619*
$\Delta(P24(-1))$	0.1911*	$\Delta(oil_price^-)$	0.0589*
$\Delta(oil_price^-)$	0.1861*	$\Delta({oil_{price}}^-(-1))$	0.0743*
$\Delta({oil_{price}}^-(-1))$	0.1062*	$\Delta(oil_price^+)$	-0.0050
$\Delta(oil_price^+)$	0.0018	$\Delta({oil_{price}}^+(-1))$	-0.0407**
$\Delta({oil_{price}}^+(-1))$	0.0077	GDP	0.0048
GDP	0.0015	constant	-18.3517
constant	-9.0654		
Long-term			
$\Delta(oil_price^-)$	0.2160*	$\Delta(oil_price^-)$	0.0893*
$\Delta(oil_price^+)$	0.1453*	$\Delta(oil_price^+)$	0.0475*

Note: Results of short term and long term asymmetric relationship between oil price and energy-intensive industrial sectors' output is shown in this table. Rejection of null hypothesis at 1%, 5% and 10% significant levels are determined by *, ** and ***, respectively. Source: Research Findings

[1] In this equation time period is considered 2008Q1 to 2024 Q2
[2] Italy and France have no data for this variable so for estimation this equation only these two countries data were removed from sample.

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This is widely accepted that oil prices fluctuations always have macroeconomic, policy and financial implication. The results of table 7 and 8 can suggest that, Overall, asymmetric responses of different industrial production to real levels of WTI crude oil prices can be captured by NARDL model. This is apparent that in both economics and majority of cases negative and positive changes of oil prices have significant but different effects in values and/or signs. Ignoring asymmetries may be ended up in misleading results. This is noteworthy that all coefficients are somehow small in value and between two group, values of coefficients of Developed economies are smaller than those of Emerging Economies.

As mentioned in section 3, energy-intensive manufacturing consists of Food, Pulp and Paper, Basic Chemicals, Refining, Iron and Steel, Nonferrous metals and Nonmetallic minerals.

Food: three variables of P10, P11 ,and P12 can be put in Food group.

- Developed Economies: Higher oil prices have no significant immediate effect in P10 and P12. When Higher oil prices motivate the production of P12 but make the production of P10 decline. In P11 higher oil prices have no significant effect in short and long term. Lower oil prices have no significant effects (in short-term and long-term) in P12 production. Immediate effect of lower oil prices motivates both P10 and P11 grow and in long-term has significant positive effect only in P11. So we witness different impacts of oil prices fluctuation in these three groups.
- Emerging Economies: in P10 both negative and positive oil price changes make production grow in short-term while in long-term only positive oil price changes have significant effect and production will decline. In P11 there is immediate positive effect for lower oil prices when higher oil prices have no significant effect in short-term and make P11 production decrease in long-term. A reason for this result can be that by decreasing in oil prices the cost of transportation will be decreased as well and importing becomes more profitable. In P12, negative changes of oil prices have significant adverse effect on production while in long-term both negative and positive changes of oil prices have significant effect. Both effects are positive and the coefficient value of the positive oil prices changes is higher. It can be interpreted as positive oil prices have more influence on this sector production.

Pulp and Paper: two variables of P17 and P18 can be put in this group.

- Developed Economies: both negative and positive changes of oil prices affect P17 in short-term which are positive and negative, respectively. In long-term both of changes has significant and increasing effect on

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production. The coefficient value of the negative oil prices changes is higher in value. P18 responds positively in short-term to both positive and negative changes of oil prices and only positive changes have adverse significant long-term effect on production.

- Emerging Economies: both negative and positive changes of oil prices effect P17 only in short-term and make production grows. Only higher oil prices have significant long-term effect which make production declines. P18 responds positively in short-term and long-term to negative changes of oil prices. In long-term positive changes of oil prices have adverse significant effect.

Refining: variable P19

- Developed Economies: higher oil prices have no significant short-term effect on production of P19. But in long-term refining cost increase and eventually ends up in production declining. Lower oil prices will quickly affect production negatively. However, in the long run and by adjustment of production costs, the drop in oil prices has led to increase in P19 production.
- Emerging Economies: The rapid effect of oil prices decline leads to an increase in production of P19 by drop in production costs. While over time, this effect is reversed and in the long run, it causes a decrease in production. This can be due to the available less costly competitors' goods and less demand for domestic products. Long-term negative effect of higher oil prices can be explained by increase in production costs while in short-term there is slight positive significant effect of higher oil prices. It can be stated this way that the prominent effect in short-term belongs to drop in oil prices and rise in oil prices for long-term.

Basic Chemical: variable P20

- Developed Economies: decrease in oil prices courage to produce more of P20 in short-term. In long-term, and by adjusting in costs, rise in oil prices lead to drop in production. Negative oil price changes have long-term positive effect at 10% level of significant on production as well.
- Emerging Economies: the positive responses of P20 to negative and positive changes in oil prices in short-term can be seen while the opposite responses for both type of changes occur in long-term. Effects of oil price fluctuations on chemicals are somehow similar to refining's.

Nonferrous minerals and Nonmetallic metals: variable P23

- Developed Economies: Nonferrous minerals and Nonmetallic metals are industrial production basic materials, and they are connected with considerable share of trades. Rise in oil prices put high pressure on

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production costs and with eventually lower profits of P23, the output of P23 falls. On the other hand, fall in oil prices has positive significant effect on P23 production in both short-term and long-term.

- Emerging Economies: higher oil prices indicate rise in demand. So when oil prices increase P23 production will increase as well in short-term. But soaring production costs limit profit more and more and eventually production will decline in long-term. There is no significant short-term effect for lower oil prices while have adverse effect on production in long-term.

Iron and steel: variable P24

- Developed Economies: this variable covers different sub-sectors of Iron and steel. Major producers of these different sectors are mostly belong to BRICS and G7 which are considered economies in this study. Rise in oil prices do not affect P24 production in short-term. Production cost consists of different elements like freight cost, raw material cost, energy cost and so on. The weight of any of these elements is varied across different economies. Accordingly, different forms of production cost adjustment and eventually long-term effect is seen which encourage the growth in P24 production. The decline in oil prices has positive effect on P24 in short-term and long-term.
- Emerging Economies: when oil prices drop production of P24 increases in short-term and long-term. Oil price increases have no immediate effect but in long-term cause decreasing output of P24 by putting pressure on the cost of production. Upon results we can presume that the structure of production costs and their long term adjustment in Emerging Economies are different from Developed Economies.

Total manufactured: variable TM

- Developed Economies: positive changes of oil prices cause adverse effects on TM in short-term but in long term increase production. Negative changes of oil prices bring larger output of TM in short term and long-term.
- Emerging Economies: TM responds positively to oil price decline in both the short and long term. But when oil prices increase the output of TM grows in short-term, however, in long term adjusting the production costs makes production fall.

6 Conclusion

This study investigates the way oil price fluctuations affect energy-intensive industrial sectors in Emerging and Developed Economies using quarterly data

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from 2005 Q1 to2024 Q2. Particularly, in this study the NARDL framework is employed to examine the asymmetric impact of changes in oil prices by decomposing oil price shocks into positive and negative partial sums. The results show significant and asymmetric effect of oil price shocks on energy-intensive industrial sectors which is heterogeneous between sectors and two economics. The findings of this study can provide policy makers with better insight of the oil price shocks impact mechanism in highly competitive economics.

This is noteworthy that all coefficients are somehow small in value and between two groups, values of coefficients of Developed economies are smaller than those of Emerging Economies. positive changes in oil prices mostly have no significant effect in short term in developed economies. While the response of each sector is not necessarily adverse in long-term: production of industries like refining and chemicals decreases where there is growth in production of sectors like Iron and steel. Emerging Economies react kind of different to increase in oil prices. The immediate effects are mostly significant and positive. But the production of all sectors (except P11 and P12) falls when oil prices increase in long-term.

When oil prices decline most of industrial sectors in both Emerging and Developed Economies respond positively in short-term. In long-term positive effect of negative changes of oil prices on industrial sectors remains in Developed Economies while the different trend is seen in Emerging Economies. Production of industries like refining and chemicals decreases where there is growth in production of sectors like Iron and steel. Final and noteworthy result is about total manufactured products (variable TM). The positive effect of negative changes in oil prices is same for both economics and growth in production is seen in both short and long term. Whereas, higher oil prices make different production effect on Developed and Emerging Economies.

In conclusion energy-intensive sectors in Developed Economies are less volatile to oil prices shocks in comparison with Emerging Economies, especially in positive oil price shocks. Higher oil prices have negative effect on the production of energy-intensive industrial in Emerging Economics, whereas, might make production grows in long-term in Developed Economies. Negative changes in oil prices favor energy-intensive industrial production in Developed Economies mostly while it is not the case in Emerging Economies.

In this study, energy-intensive industries at the 2-digit level of ISIC Revision 4 is used. For future studies, a specific category of energy industries

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at the 3 or 4-digit level of ISIC can be considered for a more detailed examination and comparison of the response of two economics to oil prices changes. Another suggestion can be investigating different types of oil shocks according to Kilian (2009) on the production responses of different industries, or to examine the impact of monetary and fiscal policies on oil fluctuations pass through mechanism.

7 Statements and Declarations

The authors did not receive support from any organization for the submitted work. The authors have no conflicts of interest to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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