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Impact of oil prices on CO_2 emissions in Iraq: empirical methodology using ARDL versus NARDL methods

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Abstract
The objective of this work is to evaluate the impact of increasing the taxation of petroleum products on economic activity in Iraq, CO_2 emissions and household welfare. To this end, two methods, linear (ARDL) and non-linear (NARDL), were applied to the Iraqi economy, based on the period from 1970 to 2021. The results show that, among the various scenarios simulated, CO_2 emissions have a greater ecological impact on petroleum products. The price of oil ensures both a reduction in CO_2 emissions and an improvement in household welfare. This is due to the composition of macroeconomic variables, corresponding to an increase in the subsidy of this product.
Keywords: Oil prices, CO_2 emissions, ARDL, NARDL, Iraq.
Classification JEL: C32, E32, F42, F43.

1. Introduction

Regional integration of an energy system offers the potential to contribute to reliable and cost-effective energy services that support national and regional economic development aspirations (World Bank, 2013). From a technical perspective, an integrated power system could leverage the comparative advantages of regional players in terms of capital stocks, resource bases and disparities in marginal production costs to improve reliability, reduce capacity reserves and avoid redundant capital investments that could be made in autarky (i.e. when one is self-sufficient and programs investments in isolation). If more efficient production units are used, or if renewable technologies meet new demand in a regional market, integration can also be expected to reduce fuel consumption and, subsequently, CO_2 emissions.

From a non-technical point of view, political decision-makers often have conflicting social objectives. The success of a public policy may differ according to which objective is favoured. A policy may, for example, prioritize economic or social gains to the detriment of technical efficiency. It is therefore crucial that public policies take into account both technical and non-technical costs and benefits. The design of such policies requires the establishment of rules and incentives for agents (producers and consumers), to ensure that they achieve their main objective while minimizing unintended consequences.

There are many economic and regulatory policy considerations that influence the integration of a regional energy system. Price and quantity controls are a common form of intervention in the energy systems of low-, middle- and high-income economies. Price controls can take the form of subsidies on certain fuel sources for electricity producers, guaranteed purchase contracts, preferential financing for project development, etc. This thesis focuses on the technical feasibility of electricity trading as part of market interventions in the form of price and/or quantity controls on the fuels used as inputs.

Low-cost electricity production encourages over-consumption, while low-cost inputs, notably fuels, encourage inefficient production. In the case of Saudi Arabia, domestic oil consumption is encouraged by the low administered price of fuel inputs in the energy sector. The trajectory and scale of this incentive structure is described in detail by Lahn and Stevens in Burning Oil to Keep Cool (Lahn and Stevens, 2011). In many ways, this document is the source of the research presented here. Other studies by researchers at the Oxford Institute for Energy Studies provide complementary insights from Saudi Arabia's neighbour Kuwait (Fattouh and El-Katiri, 2013; Mezher et al., 2011; Poudineh et al., 2020).

Oil accounts for almost 40% of the world's energy consumption, and is set to account for a further 35% by 2020. It is the world's leading energy source, and a strategic one, since it has no substitutes for certain needs (in transport, in particular). Almost A third of oil reserves are located in the eleven OPEC countries; 2/3 are in the Middle East: Saudi Arabia alone holds 25% of the world's proven reserves, produces 12% of the world's oil and contributes almost 17% of world exports; Iraq is the world's second-largest country in terms of reserves (10.6%), contributing less than 4% of world production and just over 5% of exports. The Middle East is the main export zone, accounting for almost 44% of world oil trade, while the United States and the European Union are the main import zones (with 26.0% and 26.4% respectively).

However, other countries are set to play a growing role in the global oil and gas market, notably Russia and the Caspian littoral states. The military conflict in Iraq is directly linked to the oil stakes in the region. Moreover, the United States cannot ignore Russia's ambitions in this area, and indeed the "arm wrestling" game being played out between the United States and Russia does not appear to be without effect on American strategy in Iraq.

The consequences of the recent Iraq war on the oil market can be analysed from two angles: the conflict can be seen as the United States' concern to re-establish political stability in a country that constitutes an important reserve for its future oil supplies; it can also be interpreted in the context of Russian-American relations of cooperation - rivalry in a region vital to both countries. The war in Iraq has not led to a significant and lasting rise in the price of oil, because the oil market is structurally in surplus. In all likelihood, the end of the conflict and a return to peace will not cause prices to fall either, as the increase in Iraq's market share will be managed smoothly by the rest of

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OPEC, and the discipline of quotas may pay off. On the other hand, a deterioration in the military situation would destabilize the region and could, through a "domino effect", compromise American efforts to guarantee political stability in a region vital for oil supplies to OECD countries.
This paper aims to analyse, from a systemic perspective, the interactions between policies to stabilize atmospheric CO2 concentrations and the fundamentals of the Iraqi oil scene. We will show that ambitious climate policies can both reduce CO2 emissions (and thus safeguard the global climate), and reduce tensions on the oil market (and thus limit the rise in oil prices). The "carbon value" used in modelling systems is an artifice that allows us to synthesize in a single variable the signal required to trigger investment in CO2 emissions reduction. It enables us to measure the effort required to limit emissions, and gives a good account of the socially responsible investment effort required to safeguard the planet's climate.
After all this analysis, it is legitimate to ask ourselves the following question in the context of our research: Following the gradual rise in the price of oil, what are the consequences for CO2 emissions in Iraq?
Thus, the aim of our paper is to investigate the nature of the relationship between oil price and CO2 emission in Iraq. In order to propose an answer to this question, our objectives are, on the one hand, to identify the different relationships between oil price and CO2 emission and, on the other hand, to study the symmetrical and asymmetrical effects of oil price and Iraqi CO2 emission using a linear model (ARDL) and a non-linear one (NARDL).
To meet the objectives of our article, we organize our work into five parts, structured as follows: Section 2 is a review of the theoretical and empirical literature or background on the link between oil prices and CO2 emissions. Data and preliminary tests on the variables used, as well as the methodology, are presented in the Section 3. The results of the study are discussed in Section 4. As agreed, we end this article in the section 5 with the main conclusions and recommendations in terms of economic policy.

2. Literature review

This article aims to contribute theoretically and empirically to the research work on the method of identifying and measuring the effect of oil price on CO2 emission. In addition, this article encompasses a public policy element, which aims to provide additional input to the discussion and design of climate change policies, in particular efficiency improvement policies.

2.1. Theoretical approaches

For the classics, such as Adam Smith, if the essence of the price of goods is to be found in the labour factor, profit (income from capital) and rent (income from land) must also be incorporated. However, the use of machines generates significant productivity gains that can no longer be ignored. The energy factor posed a problem for existing theoretical models. Theorists of the time were embarrassed by the emergence of something that could not be considered a factor of production in its own right. To solve this problem, Smith assumed that productivity gains (due to the use of machines) would be diluted in the remuneration of conventional inputs, i.e. in wages and profits.
Technical progress made it necessary to propose a more pertinent analysis of the energy question. J-B. Say explicitly notes the productivity gains derived from the use of machines and attempts to determine their nature. But his laborious explanations, aimed at reintroducing energy into the

known factors of production, were hardly convincing. Ricardo also tried to analyse the energy aspect by adding a new chapter on the existence of machines, in the third edition of his book on "Principles of Political Economy and Taxation". For the neoclassicals, energy really has no role in the production process, as the classical scheme of production is limited to the exclusive combination of factors - labour, capital and land. We find Solow, Barro and Romer. However, the real work on the place of energy in the production system is mentioned as early as the 1960s in the KLEM production function (Daly, 1994 and Faucheux and O'Connor, 2003).

For a long time, economic theory confined itself to analysing the technical and social conditions of growth, regarding the environment as a natural and inexhaustible good, and ignoring the probable irreversible degradation of the natural environment. It was not until the 20th century that economic science integrated environmental issues into its analyses, taking into account the disastrous effects of economic activity on the atmosphere. Pollution in all its forms is considered a negative externality.

In the absence of any regulation, economic agents produce or consume large quantities of the good that gives rise to pollution. To overcome this shortcoming, environmental economists propose the internalization of these externalities, i.e. that the costs resulting from pollution should be financially compensated. Several instruments and measures are available to public authorities to carry out their environmental policies, notably incentives. Pigou (1929) considers in his book "EconomicWelfare" that negative external effects cause a gap between the private and social costs of economic activities. He advocates state intervention through the levying of a tax paid by the polluter, which must be proportional to the negative effect it emits, leading to a change in the behaviour of economic agents to achieve the social optimum.

Other economists, including Baumol et al. (1988), advocate the use of economic incentives, such as royalties and subsidies, for environmental protection. Coase (1960) proposed the use of tradable emission permits. Emission permits are quotas or emission authorizations imposed on polluting companies. A polluter can only emit the quantity of pollution that corresponds to the quantity of permits at his disposal. This is a market where the polluter has the choice between cleaning up pollution or buying additional permits.

Throughout the literature, we found unanimity on the existence of a causal link between CO_2 emissions and energy consumption. Taxes on polluting goods, especially if they already exist, may be easier to implement than taxes on pollution (Eskeland et al., 1996). Thus, levying or increasing taxes on energy products is strongly recommended (McDougall, 1993).

2.2. Empirical approaches

The objective is first and foremost purely fiscal, insofar as increasing energy consumption generates additional tax revenues for the state, which could be allocated to new investments in renewable energy sources. It also corrects environmental externalities by considerably reducing energy consumption and, consequently, GHG emission levels. Sundqvist, (2007) evaluates the relationship between CO_2 emissions and energy taxes in Sweden and OECD countries. His results indicate that energy taxes have indeed reduced CO_2 emissions in Sweden, and that countries with the highest taxes on petroleum products emit fewer CO_2 emissions on average.

In the same vein and using a dynamic general equilibrium model, Bor et al. (2010) evaluate the effects of an energy tax proposed by the Taiwanese government, together with revenue recycling tax measures, on the macroeconomic variables of energy consumption and CO_2 emissions. The results show that the latter did indeed fall in all the scenarios simulated, and that the simple use of an energy tax policy has negative effects on macroeconomic variables. The results are different, however, when the taxation scheme is implemented simultaneously with revenue redistribution measures, notably the reduction of corporate and income taxes. This measure not only offset the negative impact on real GDP, but also led to positive GDP growth.

Devarajan et al. (2011) assess the welfare implications of selected energy tax policies aimed at reducing CO2 emissions by 15 in South Africa through the following scenarios: levying a carbon tax, increasing the consumption tax on energy products (coal, oil and electricity), or increasing the consumption tax on the most CO2-emitting products (iron, basic steel, transport, basic non-ferrous metals and metal products, excluding machinery). They also examine the re-use of tax revenues to reduce direct taxes. The results show that all taxes generally increase energy costs and reduce CO2 emissions through their negative impact on production, thus reducing welfare in all scenarios. The authors also note that when tax revenues are redistributed to reduce tax distortions, the net welfare loss becomes negligible.

In Malaysia, the government is committed to reducing its emissions by 40 from 2005 levels by 2020, through the implementation of certain fiscal policies. In this sense, Yahoo et al. (2017) seek to assess the impact of levying a carbon tax as well as taxes on energy consumption, on the economy and on household welfare through a static CGEOM. The results indicate that the negative macroeconomic impacts of carbon and energy taxes are small in relation to the level of emissions reduction achieved. They also report that a double dividend effect is obtained when carbon tax revenues are recycled through a subsidy on household purchases. In effect, welfare rises as carbon emissions fall.

Solaymani (2017), carrying out a similar study for the same country, found that in terms of reducing fossil fuel consumption and consequently carbon emissions, the carbon tax is more effective than the energy tax. However, both tax policies lead to an increase in household welfare.

Peng et al. (2019) used a CGE model to simulate the collection of an energy excise tax in Jiangsu province, China. The results show that levying the tax is beneficial for reducing energy consumption and resulting emissions, but it is likely to negatively affect macroeconomic variables and household welfare. The results are controversial when accompanied by a policy of revenue redistribution, resulting in a double-dividend effect.

The Vietnamese government had planned to increase the current tax rates on petroleum products and/or coal to the maximum levels previously set. Thus, Nong et al. (2018) used a CGE model to assess the effects of these increases on the Vietnamese economy. The results show that an increase in the tax on petroleum products reduces pollutant emissions, but negatively affects the country's economic situation. This negative effect is less significant when coal is taxed. In fact, taxes on petroleum products and coal lead to higher energy prices, so consumers reduce their demand, and production in the energy sector follows the same trend. This taxation is likely to have a negative impact on GDP, but may also encourage all economic agents to make greater use of renewable energy sources, and thus reduce CO2 emissions. Tri et al. (2019) proposed the same tax measures with different rates in Indonesia. Using a CGEOM, they found that levying both taxes simultaneously significantly reduces energy consumption and consequently CO2 emissions.

The literature shows that adjustments in water use can be observed not only following an improvement in irrigation technology, but also following a change in the cost of irrigation, notably

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due to higher energy consumption. Since more efficient irrigation systems are directly associated with higher energy demand, any variation in the level of irrigation efficiency will have an effect on both water and energy demand (Belaud et al., 2020).

The hypothesis proposed for this study is presented as follows (**H1**): Through macroeconomic mechanisms, the relationship between oil price and CO2 emission in Iraq is mixed. In other words, this hypothesis suggests that oil price fluctuations do not necessarily have a direct and immediate impact on CO2 emissions in Iraq. This could involve mechanisms such as exchange rates, capital flows, foreign investment, or other elements that intervene in the way oil price variations affect the Iraqi economy.

3. Empirical methodology: model, variables and estimation techniques

3.1 Model and variables

Our purpose here is to see whether between 1970 and 2021, the rise in oil prices will have a significant impact on CO2 emissions in Iraq, given the several important indicators recorded in the area. As we focus on macroeconomic relationships, we need to treat oil price and economic growth as interactive variables.

Moreover, given the forward-looking nature of economic decisions, it is important to use a framework that allows for more detailed dynamic analysis. The aim of this article is to study all the variables linking oil prices and CO2 emissions between 1970 and 2021, i.e. a total of T = 52 observations.

Given the availability of data and the characteristics of each country's economy, and with reference to Olamide, et al. (2022) and Adigun and Ogunleye (2021), Eq.1 of the environment model is as follows:

$$LnCO2_t = \beta_0 + \beta_1 LnM2_t + \beta_2 LnExchange_t + \beta_3 LnExpense_t + \beta_4 LnLE_t + \beta_5 LnOP_t + u_t \quad (1)$$

By the same token, CO2 emissions (an endogenous variable) will be close to the price of oil (OP). As explanatory factors, we have retained Iraq's money supply (M2), official exchange rate (Exchange), public expenditure (Expense), life expectancy at birth (LE) and "u" is the hypothesis error term that satisfies the Gauss-Markov rule. We summarise all the variables in Table 1.

Table 1 Variable definitions and data sources

Variables	Description	Definition	Source
		Endogenous variable	
CO2 emissions	CO2	Emissions resulting from the provision of energy services have clearly contributed to a historic increase in the concentration of greenhouse gases (GHGs) in the atmosphere.	Data Stream
		Explanatory variables	
Money supply	M2	Represents the ratio of the economy's monetary aggregate or liquid liabilities to GDP, i.e. M2/GDP.	Data Stream
Official exchange rate	Exchange	They show that productivity is negatively related to the degree of trade	Data Stream

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		flexibility for a group of countries, and consider it preferable to the adoption of a fixed regime.	
Public expenditure	Expense	An indication of the size of these administrations in each country.	Data Stream
Life expectancy at birth	LE	Calculated from age-specific mortality quotients, i.e. the probability of dying in a given year for people reaching a given age.	Data Stream
Oil price	OP	The oil price is the evolution of the price of oil, which is the basis of the oil market.	Data Stream

3.2 ARDL model

ARDL modelling is the most widely used method for evaluating variables in panel data environmental analysis. It is independent of the order of integration of the different variables. It differs from the Johansen (1991) method (co-integration model on time series data), which is the classic average. It requires all variables to be integrated to first order.

On the one hand, the ARDL model provides a precise method for dealing with long-range relationships by focusing on the logic of a classical relationship, in which relationships to long- and short-range dynamics are evaluated jointly. Furthermore, it enables us to deal with variables that may have different orders of integration, such as I(0) and I(1), not just I(1). In fact, the ARDL model cannot insist on this. According to the ARDL method of Pesaran et al. (1999), the various variables are deemed endogenous. Thus, the overall formula of these models consists of:

$$y_t = \alpha_0 + \alpha_1 t + \sum_{j=1}^{p} \lambda_j y_{t-j} + \sum_{m=0}^{q} \delta_k{}' x_{t-m} + u_t \qquad (2)$$

where x represents the set of regressors, which are assumed to be uncorrelated with the residual u. An equivalent specification is often found:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \phi y_{t-1} + \beta' x_t + \sum_{j=1}^{p-1} \lambda_j{}^{*} \Delta y_{t-j} + \sum_{m=0}^{q-1} \delta_m{}^{*'} x_{t-m} + u_t \qquad (3)$$

By dissociating the equation of y from those of the other elements of x and adding the divisions of the other corresponding matrices, we can write the equation in the form of an ECM error response model:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \pi_{yy} y_{t-1} + \pi_{yx} x_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta Z_{t-j} + \varepsilon_{y_t} \qquad (4)$$

where $\Pi = \begin{pmatrix} \pi_{yy} & \pi_{yx} \\ \pi_{xy} & \Pi_{xx} \end{pmatrix}$ the variance-covariance matrix of $\varepsilon_t = \left(\varepsilon_{y_t} \ \varepsilon_{x_t}{}'\right)$ and $Z_t = \left(y_t \ x_t{}'\right)$.

If $\phi = \pi_{yy}$ and $\beta = \pi_{yx.x}$, after redefining the polynomial delay in Z in order to obtain the contemporary value of *x* in the equal part, this yields to the equation of Pesaran et al. (2001) of the ARDL approach:

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$$\Delta y_t = \alpha_0 + \alpha_1 t + \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{j=1}^{p-1} \tilde{\psi}_j^{'} \Delta Z_{t-j} + \omega^{'} \Delta x_t + \varepsilon_{y_t} \qquad (5)$$

where $\pi_{yx.x} = \pi_{yx} - \omega^{'} \Pi_{xx}$ (matrix 1 x k), $\omega = \Omega_{xx}^{-1} \omega_{xy}$, $\Omega = \begin{pmatrix} \omega_{yy} & \omega_{yx} \\ \omega_{xy} & \Omega_{xx} \end{pmatrix}$ the variance-covariance matrix of ε_t and $u_t = \varepsilon_{y_t} - \omega_{yx} \Omega_{xx}^{-1} \varepsilon_{x_t}$. It's worth pointing out that the ARDL model has been used to ensure that all elements of the relationship between supply and demand can be taken into account from Z are I(1) according to the requirements of the VECM specifications.

More precisely, we write the following background equation for each period *t*:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \phi\, y_{t-1} + \beta^{'} x_t + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{t-j} + \sum_{i=0}^{q-1} \delta_i^{*'} x_{t-i} + u_t \qquad (6)$$

Pesaran et al. (1999) propose that u_t residuals are assumed to be independent across individuals and x_t regressions and for each individual *i*, the long term relationship is given by:

$$y_t = \theta_0 + \theta_1 t - \frac{\beta_i^{'}}{\phi_i} x_t + v_t \qquad (7)$$

First, we briefly discuss the ARDL cointegration method, implementing two steps to be followed in order to make this method effective for the cointegration process. At this stage, we need to check whether there is indeed a genuine long-run relationship between these variables. Next, the null hypothesis that there is no integration or long-run relationship between the variables $H_0 : \phi_i = \beta_i = 0$ is tested against the alternative hypothesis $H_1 : \phi_i \neq 0; \beta_i \neq 0$.

The "*Bounds tests*" procedure is based on Fisher's "F" statistic. Since the system variables are I(0) or I(1), this statistic used in this process has a non-standard distribution. Consequently, Pesaran et al. (2001, p.300) have calculated two sets of critical values at a given significance level. One set assumes that all variables are I(0), and the second assumes that they are all I(1). When the calculated value of the "F" statistic is greater than the critical value, H_0 is rejected.

At the end of the second step, if a long-term relationship is created, the long-term error correction model (ECM) estimates of the ARDL model can be obtained from the initial short-term equation. Estimation of the ARDL model involves first determining the amount of delay to be introduced. Akaike information criteria (AIC) and Schwartz criteria (SBC) are often used. The general expression formula for the error correction model (ECM) of the initial short-term equation is as follows:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \delta\, EC_{t-1} + \sum_{i=1}^{p} \lambda_i \Delta y_{t-i} + \sum_{k=1}^{K} \sum_{j=0}^{q_k} \delta_j\, \Delta x_{ki,t-j} + \zeta_t \qquad (8)$$

with δ is the speed of fit parameter and *EC* are the residuals from the estimation of the cointegration model of the initial short-run equation. Since we use annual estimates, we run tests with up to "p" lags on the first order difference of each variable, and use the F statistic to calculate the joint significance of variable lags in the initial short-run equation.

The long-term condition model can be extracted from the initial short-term form of the simplified solution, which is written as follows:

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$$y_t = \theta_0 + \sum_{k=1}^{K} \theta_k x_{kt} + \mu_t \tag{9}$$

with $\theta_0 = -\alpha_0 / \delta_0$ and $\theta_k = -\beta_k / \delta_0$.

Two steps are required to implement the Pesaran et al. (2001) cointegration test, such as (i) Determining the optimum delay using the AIC and SIC criteria; (ii) Fisher's test of relationship (Eq.6) to validate the following hypotheses:

$$\begin{cases} H_0 : \phi = \beta' = 0 & : \text{Absence of a cointegration relationship} \\ H_0 : \phi \neq 0; \beta' \neq 0 & : \text{Existence of a cointegration relationship} \end{cases} \tag{10}$$

Similar to the dynamic approach, we can use the information criteria to decide on the optimal delay numbers p^* and q^*. An optimal delay is one for which the model evaluated proposes the smallest value of one of the above criteria. The most commonly used information criteria are those of Akaike (AIC) and Schwarz (SIC). Their formulations are evaluated as follows:

$$AIC(p) = \log\left|\hat{\Sigma}\right| + \frac{2}{T} n^2 p \text{ and } SIC(p) = \log\left|\hat{\Sigma}\right| + \frac{\log T}{T} n^2 p \tag{11}$$

with $\hat{\Sigma}$ the variance-covariance matrix of the estimated residuals, T the number of observations, p the lag of the estimated model and n the number of regressors.

Post-estimation statistical tests have become almost obligatory companions in scientific studies. The best-known of these is a Student's t-test or χ^2 test. In fact, a statistical hypothesis test is a decision-making tool, used as a decision rule between two hypotheses. It implies an inference: from the result of an experiment on a finite sample of observations (source population), we try to infer a truth that would be observed on our target population, i.e. the population to which we would like the results of our study to be applied.

To this end, before proceeding with model estimation, we must point out that we will go through a series of tests, namely the Ljung-Box serial correlation test of order 1 (Ljung and Box, 1979, LB) and Breusch and Godfrey (1978), the ARCH test for heteroskedasticity of order 1 (McLeod and Li, 1983), the Jarque-Bera test (Jarque-Bera, 1987, JB) for normality of residuals, the Durbin and Watson test (1950 and 1951), and the Ramsey functional form test (Ramsey, 1969, RESET) of order 1.

3.3 NARDL model

The nonlinear autoregressive distributed lag (NARDL) model proposed by Shin et al. (2014) is used to examine the strength of the transmission of inflation and unemployment in the short and long term. This methodology offers important advantages over existing modelling techniques (such as the error correction model (ECM), threshold ECM, Markov switching ECM and smooth transition ECM) by jointly modelling cointegration dynamics and asymmetries. In addition to its simplicity of estimation, the NARDL model offers greater flexibility by relaxing the assumptions that time series must be integrated of the same order, unlike the ECM model, which is restrictive in this sense. It also enables us to accurately distinguish between no cointegration, linear cointegration and non-linear cointegration (Katrakilidis and Trachanas, 2012), and is more efficient for testing cointegration in small samples (Romilly et al., 2001). It is now widely accepted that short-term deviations of first-order integrated variables from their long-term joint

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equilibrium can be reproduced by the linear ECM developed by Granger (1981), Engle and Granger (1987) and Johansen (1988). The linear ECM takes the following form:

$$\Delta y_t = \mu + \rho_y y_{t-1} + \rho_x x_{t-1} + \sum_{i=1}^{p=1} \alpha_i \Delta y_{i-1} + \sum_{i=0}^{q=1} \beta_i \Delta x_{t-1} + \varepsilon_t \quad (12)$$

where y_t is the endogenous variable and x_t is the explanatory variable. The symbol Δ indicates first differences. The model can be used to study short- and long-term relationships between variables when these relationships are well defined when they are linear and symmetrical. However, the model will be poorly specified when they are non-linear and/or asymmetrical. In this context, Granger and Yoon (2002) introduce the concept of hidden cointegration, which is detected if two time series are not cointegrated in the classical sense, but their positive and negative sums are cointegrated with each other. The NARDL model by Shin et al. (2014) allows us to jointly examine the short- and long-term response of inflation to unemployment and detect hidden cointegration. This methodology employs the decomposition of the exogenous variable x into its positive and negative partial sums, namely, x_t^+ and x_t^- of increases and decreases such that :

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0) \text{ and } x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j, 0) \quad (13)$$

Taking into account short- and long-term asymmetries in the linear ECM model, as presented in Eq.12, Shin et al. (2014) extend this model to the general NARDL model, which is expressed as follows:

$$\Delta y_t = \mu + \rho y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{i=1}^{p-1} \alpha_i y_{t-i} + \sum_{i=0}^{q-1} (\omega_i^+ \Delta x_{t-1}^+ + \omega_i^- x_{t-1}^-) + \varepsilon_t \quad (14)$$

The superscripts (+) and (-) in Eq.13 represent the decomposition into positive and negative partial sums as defined above. The symbols *p* and *q* denote the respective shift orders of the dependent variable and the exogenous variable in the distributed-shift part. In the distributed-shift part, respectively. In particular, long-run symmetry can be tested using a Wald test for the dependent variable tested using a Wald test of the null hypothesis $\theta^+ = \theta^-$. We can then calculate the positive and negative long-run coefficients as follows: $L_{x^+} = -\theta^+ / \rho_x$ and $L_{x^-} = -\theta^- / \rho_x$ the short-run adjustments to positive and negative shocks affecting inflation and unemployment are captured by the parameters ω_t^+ and ω_t^- respectively. Short-term symmetry can also be tested using a standard Wald test of the null hypothesis such that $\omega_t^+ = \omega_t^-$ for $i = 0, \ldots, q-1$. Eq.14 is reduced to the traditional (linear) ECM if the two null hypotheses of short-term and long-term symmetry cannot be rejected of short-term and long-term symmetry cannot be rejected. Failure to reject either the null hypothesis of long-term symmetry or short-term symmetry gives rise to NARDL with short-term asymmetry (Eq.15) and with long-term asymmetry (Eq.16), respectively:

$$\Delta y_t = \mu + \rho y_{t-1} + \rho_t x_{t-1} + \sum_{i=1}^{p-1} \alpha_i y_{t-i} + \sum_{i=0}^{q-1} (\omega_i^+ \Delta x_{t-1}^+ + \omega_i^- x_{t-1}^-) + \varepsilon_t \quad (15)$$

$$\Delta y_t = \mu + \rho y_{t-1} + \rho_y^+ x_{t-1}^+ + \rho_y^- x_{t-1}^- + \sum_{i=1}^{p-1} \alpha_i y_{t-i} + \sum_{i=0}^{q-1} \omega_t \Delta x_{t-1} + \varepsilon_t \quad (16)$$

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When asymmetry is detected in the NARDL model, either in the short term, the long term or both. Asymmetric responses to positive and negative *x* are taken into account in the short term and the long term or both), the asymmetric responses to positive and negative shocks of one unit (i.e. increases and decreases) in y are respectively the following to positive and negative x of one unit (i.e. increases or decreases) in y are respectively $x^+$and x^- :

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^+} \text{ and } \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^-} \text{ with } h = 0,1,2,.... \qquad (17)$$

where $h \to \infty, m_h^+ \to Lx^+$, et $m_h^- \to Lx^-$ with Lx^+ and Lx^- are the long-run asymmetric positive and negative coefficients, respectively. Based on the estimated multipliers, we can observe the nonlinear dynamic adjustments of the two variables from their initial equilibrium to their new equilibrium state over time, following a shock affecting the cointegrating system. Overall, the NARDL model accounts for short-term dynamics via the distribution and long-term dynamics via a single common cointegrating vector. Both parts are allowed to be asymmetric. In addition, the NARDL model allows combinations of I(1) and I(0) variables using a boundary-testing procedure for the presence of the equilibrium vector. This means we are not constrained by the normal requirement of cointegration models that all variables must be I(1).

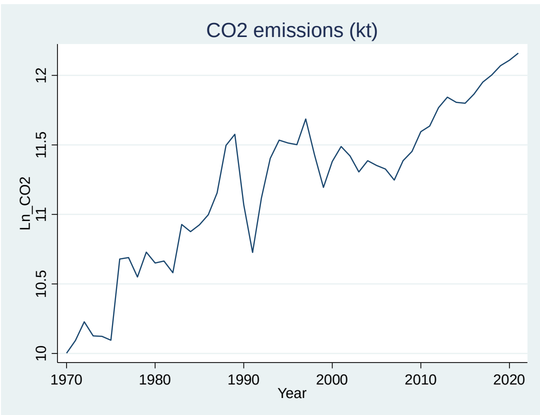
4. Empirical results

4.1. Graphical and descriptive analysis of variables in the sample

In the first panel of Table 2, we present a description of the various variables in the model. To flesh out our analysis, we have added trend changes and histograms for each variable. Indeed, based on the statistical data in Table 2, we will detail the main characteristics of the various variables retained in this study.

In addition, we have added the Jarque & Berra statistics and their probabilities to test the normality and autocorrelation test Q (p = 2) and its series probabilities. Please refer to the deviation correction test by Ljung-Box (1978). The last test clearly shows that all variables have serial autocorrelation problems.

According to Figure 1, the characteristic feature of the CO2 emission variable (LnCO2) is that it has the same upward and downward trends throughout the study period. In general, the overall mean of this variable is 11.205 and the standard deviation is 0.577, making it more heterogeneous (CV = 0.051).



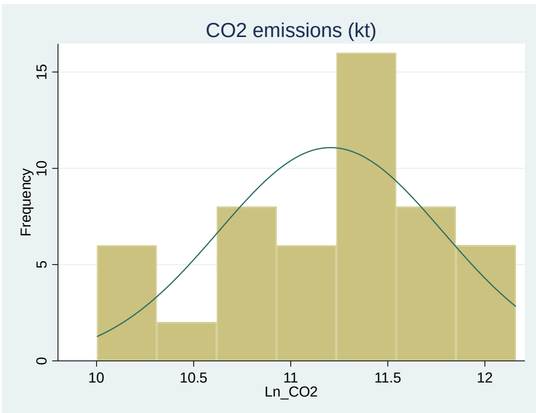


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Figure 1 Trend evolution of LnCO2

Their values range from 10.002 to 12.159, and the high concentration is around 11.366. The unemployment distribution of the sample is highly skewed to the left (skewness = -0.469), and there is also a strong peak (Kurtosis = 2.382). We reject the null hypothesis of normality using the probability of the Jarque-Bera normality test.

Table 2 Overall description of variables

Statistics	**LnCO2**	**LnM2**	**LnExch**	**LnExp**	**LnLE**	**LnOP**
Mean	11.205	3.234	7.377	3.218	4.166	3.263
Standard Deviation	0.577	0.420	0.321	0.317	0.056	0.961
Minimum	10.002	2.254	5.878	2.385	4.051	0.587
p25	10.727	2.980	7.080	3.036	4.115	2.796
p50	11.366	3.232	7.550	3.231	4.174	3.333
p75	11.585	3.553	7.602	3.410	4.205	3.995
Maximum	12.159	4.195	7.670	3.859	4.270	4.715
Skewness	-0.469	-0.181	-2.151	-0.306	-0.179	-0.837
Kurtosis	2.382	2.576	9.959	2.995	2.071	3.879
Coefficient of variation	0.051	0.129	0.043	0.098	0.013	0.294
Jarque-Bera (JB)	2.739	0.674	145	0.816	2.147	7.75
p-value JB	0.254	0.713	3.2e-32	0.664	0.341	0.020
Test Ljung-Box (LB)	196.51	101.68	62.584	87.674	150.17	127.83
p-value LB	0.000	0.000	0.000	0.000	0.000	0.000
Correlation / Probability	**LnCO2**	**LnM2**	**LnExch**	**LnExp**	**LnLE**	**LnOP**
LnCO2	1.000					

LnM2	0.269	1.000				
	0.053	-----				
LnExch	-0.141	-0.375	1.000			
	0.317	0.006	-----			
LnExp	-0.117	0.818	-0.157	1.000		
	0.408	0.000	0.263	-----		
LnLE	0.715	0.073	-0.287	-0.403	1.000	
	0.000	0.606	0.038	0.003	-----	
LnOP	0.726	0.287	-0.126	-0.056	0.522	1.000
	0.000	0.038	0.369	0.689	0.000	-----

Concerning the oil price variable (LnOP), according to Figure 2, this series is determined by the same oscillating trends over the study period. Overall, the global mean of this variable is 3.263 and the standard deviation is 0.961, which reduces its heterogeneity (CV = 0.294). Their values range from 0.587 to 4.715, with a high concentration of around 3.333. The sample distribution of LnOP extends asymmetrically to the left (skewness = -0.837) and has a strong peak state (kurtosis =

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3.879). We reject the null hypothesis of normality using the probability of the Jarque-Bera normality test.

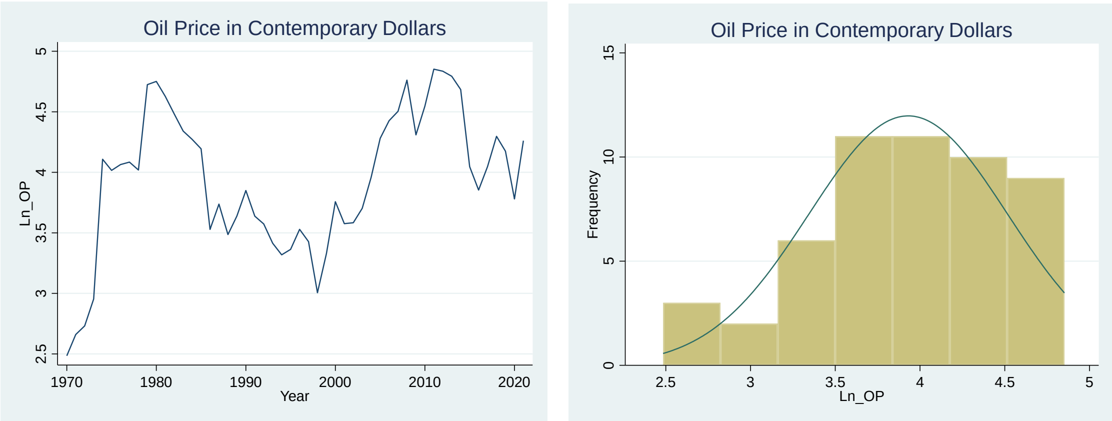

Figure 2 Trend evolution of LnOP

In general, all series present autocorrelation problems and the persistence of strong heterogeneity, which will affect subsequent estimation results.

In the second panel of Table 2, in this first stage of our Multivariate study between model variables, we proceed to describe the relationship between the variables used. We calculate simple linear correlation coefficients between the different variables explaining growth and oil price rises between 1970 and 2021, and when their levels confirm the robustness and reliability of the coefficients obtained.

At model level, the test of simple correlation coefficients cannot be considered conclusive for the study of productivity, but it does provide an overall view of the various relationships, which can be detailed below. The simple correlation coefficients detailed in the second panel of Table 2 show that: CO2 emission (LnCO2) is positively and significantly correlated with life expectancy at birth (LnLE), money supply (M2) and oil price (LnOP). Thus, CO2 emissions (LnCO2) are negatively and non-significantly correlated with trade (LnExchange), but not with public spending (LnExpense).

For purely empirical logic, and to determine the order of the sequences used, we correct for the existence of the root unit on the selected variables. In fact, this process is very important in convincing the econometric model. Thus, in order to explain the stationarity of the series, various stationarity tests are used, but some classic tests (such as the Dickey and Fuller (1981) or Phillips and Perron (1988) test) do not take structural changes into account. In this respect, the systematic method of unit root testing with the presence of shocks relies in particular on the tests of Zivot and Andrew (1992) and Perron (1997), which consider the null hypothesis of the existence of unit roots of series with the presence of structural breaks. We adopt the presence of a single shock given the small sample size (T=52).

Since 1997, Perron has clarified that the effect of unit radicals on the null hypothesis that level does not change. However, alternative hypothesis assumes that the series has stationarity and increases the impact endogenously with respect to the unknown date.

In fact, Table 3 shows that all the series tested with the Perron and ADF model are non-stationary at the 5% level, with the presence of significant breaks.

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Table 3 Results of the Perron test (1997)

Model	Designation	LnCO2	LnM2	LnExch	LnExp	LnLE	LnOP
		In Level					
ADF	MacKinnonZ (T)	0.527	0.384	0.000	0.026	0.606	0.058
PP	MacKinnonZ (T)	0.586	0.459	0.000	0.027	0.494	0.053
Decision		NS	NS	NS	NS	NS	NS
Model	**Designation**	**In First Difference**					
ADF	MacKinnonZ (T)	0.000	0.000	0.000	0.000	0.000	0.000
PP	MacKinnonZ (T)	0.000	0.000	0.000	0.000	0.000	0.000
Decision		S	S	S	S	S	S

Note: NS: non-stationary. S: stationary.

The results showed that all seven chains were non-stationary, with the presence of breaks associated with various shocks, the effects of which were seen in the 2007 subprime crisis, the 2007 subprime crisis and the 1991 war. However, the second panel of the top panel of the unit in the first difference proves that they are all stationary. So we can consider them as integrated of order 1 (I[1]).

4.2 Effect of oil prices on CO2 emissions

Table 4 shows the short-term evaluations, the recall power of the ECM model and the set of diagnostics relating to the validity of the first growth models using the ARDL approach.

Table 4 Short-term Symmetry estimates by ARDL

ARDL model	ARDL(2;0)		**Maximum number of delays**	2
Endogenous variable : $\Delta LnCO2_t$	**Coefficient**	**Standard Deviation**	**t-Statistic**	**Probability**
Constant	-31.150	8.221	-3.79	0.000
$LnCO2_{t-1}$	-0.580	0.133	-4.34	**0.000**
$LnOP_{t-1}$	-0.182	0.083	-2.18	0.035
$\Delta LnCO2_t$	0.329	0.140	2.33	0.024
$\Delta LnOP_{t-1}$	-0.105	0.057	-1.85	0.071
TREND	0.019	0.004	3.92	0.000
ECT_{t-1}	-0.581	0.134	-4.34	0.000
R^2	0.312			
Adjusted R^2	0.248			
F Statistics (*bounds test*)	9.593	VC à 5% (*k*=5)	-4.341	
Durbin–Watson	2.002			

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Test LM (10)	0.143			0.705
Test McLeod-Li ARCH (p=1)	1.946			0.163
Test White	5.66			0.974
Test RESET de Ramsey	1.77			0.169

Note: LM test = Lagrange Multiplier test (Breusch-Godfrey serial correlation). ARCH = Autoregressive Conditional Heteroscedasticity Test. RESET = Ramsey Regression Equation Specification Error Test. k number of explanatory variables in the bound test of Pesaran et al. (2001) page 301.

The growth model is verified by a 2-lag ARDL with trend, where the F-statistic of the bounds test, with a value of 9.593 and significance equal to 0.032, is well below the 5% critical value of Pesaran et al. (2001, p.301), which is equal to 3.61. This leads us to reject the null hypothesis of no cointegration.

The final short-term estimate of the above growth model, presented by an ARDL(2;0)-type model, shows us that it is globally significant, given that the probability associated with the final Fisher statistic, equal to 9.593, is less than 5%. It is also of average quality, since the value of the adjusted R^2 statistic tends towards 0.4 (0.312), showing the average disparity between the variables chosen.

The results of the various model validation tests - respectively, the 9-order Breusch-Godfrey (LM) serial autocorrelation test, the ARCH first-order heteroscedasticity test and the Ramsey (RESET) functional form validation test - confirm that there is no serial autocorrelation, no heteroscedasticity and the normal distribution of residuals.

Indeed, in the short term, we observe a negative but small positive effect of the LnCO2 lagged variable (-0.581). We can therefore affirm that a CO2 emission versus oil price is a dynamic relationship in the model. In particular, we record the significant lagged impact of two variables.

In addition, the coefficient of the estimated error-correction term is 0.581. Since the error-correction term is positive and significant, this implies that the results support the existence of a long-term relationship between the variables. Thus, the error correction term indicates that the deviation from the short-term CO2 emission path due to a certain shock is corrected by 58.1% each year. In other words, this coefficient, combined with the recall force, allows us to conclude that shocks to CO2 emissions in Iraq are corrected by 58.1% through the feedback effect; in other words, we manage to adjust 58.1% of the imbalance between the desired and actual levels of Iraqi growth. Thus, we can identify an average lag equal to $|1/0.581| = 1.721$. This means that an oil price shock in Iraq is fully absorbed after 1 year, 8 months and 20 days on average.

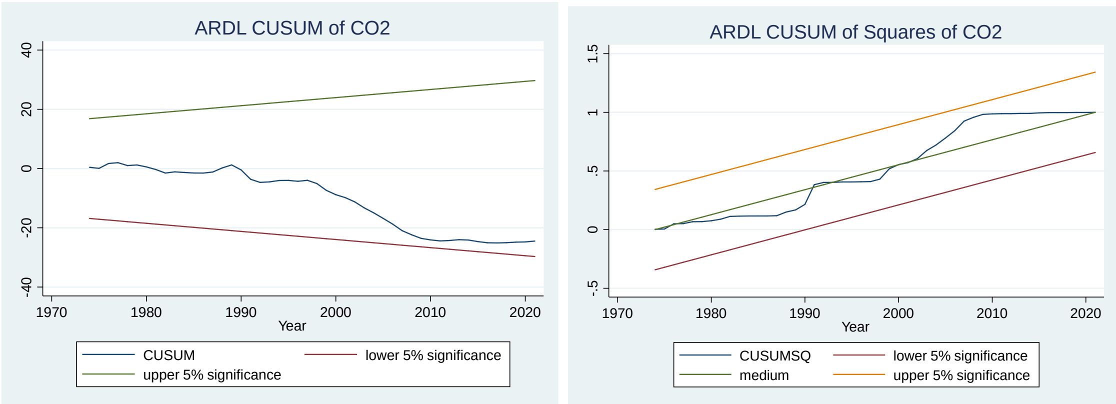

Figure 3 Evolution of CUSUM and CUSUMQ statistics in the LnCO2 model

In the long term, the oil price model on estimated CO2 emissions proves the presence of an error correction mechanism. Consequently, a convergence mechanism towards the long-term objective persists. In addition, the specification functional form chosen is correct, where stability tests on the CUSUM and CUSUM squared parameters prove that the estimated coefficients are stable in mean and variance over the study period (see Figure 3).

The long-term relationship estimated by the ARDL approach, represented in Table 5, shows us that the majority of the variables in our study have negative effects at 95%.

Table 5 Long-term Symmetry estimation by ARDL

Variable	Coefficient	Standard deviation	t-Statistics	Probability
Constant	-31.150	8.221	-3.79	0.000
$LnOP_t$	-0.182	0.083	-2.18	0.035

CO2 emissions have a negative impact on oil prices. The larger the sector, the higher the CO2 emissions, the lower the oil price, all other things being equal.

Clearly, there is a mixed relationship between these two variables between 1970 and 2021, with phases of negative and phases of positive relationships. This suggests that there is no stability, and we can foresee a mixed relationship which leads us to consolidate the persistence of a non-linear relationship. But first, let us start by stimulating the existence of a linear relationship as developed below.

Based on the above empirical experiments, we have pointed out that certain relationships, such as that between CO2 emissions and the price of oil, are mixed. For this reason, we have taken the step of re-estimating our model using an approach that takes asymmetric effects into account, including that of NARDL.

In what follows, we move on to the non-linear NARDL estimation for the two variables LnOP and LnCO2 to find out the relationship between these two variables.

First, we tested the asymmetry of oil prices on economic growth by subdividing the LnOP variable into two other variables: LnOP_pos denotes positive variations (LnOP_pos = LnCO2 if ΔLnCO2 > 0 and 0 otherwise) and LnOP_neg denotes negative variations (LnOP_neg = LnCO2 if ΔLnCO2 < 0 and 0 otherwise) where Δ represents the first variation. The results are shown in Table 6.

Table 6 Asymmetry tests

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LnCO2	Coefficient	Standard deviation	T-statistic	P-value	[95% Conf. Interval]	
Constant	10.370	0.087	118.54	0.000	10.194	10.546
$LnOP\_neg_t$	-0.269	0.064	-4.21	0.000	-0.398	-0.140
$LnOP\_pos_t$	0.078	0.055	1.42	0.163	-0.032	0.189
R^2	0.088					
F-Statistics	F(1, 49)= 258.21***					
Probability F-Statistic	0.000					

Note: *** denotes significance at 1%.

The results in Table 6 show a negative and significant effect at 5% and 10% respectively for the sub-variable LnOP_neg and a positive and significant effect at 5% and 10% respectively for the sub-variables LnOP_pos and on the independent variable LnCO2. The Fisher test for equality of the two coefficients shows a value equal to F(1; 49) = 258.21 with a probability of 0.000. This leads us to reject the null hypothesis of equality and accept the hypothesis that there is an asymmetrical effect between the two new variables, which is purely negative. We will justify this using the NARDL approach.

The short-term estimation of the above model, represented in Table 7, presented by a final NARDL(4;1;4) model, shows us that it is globally significant, given that the probability associated with the final Fisher statistic is less than 5% (F^c is equal to 60.73). This leads us to reject the null hypothesis of no cointegration.

Table 7 Short-term Asymmetry estimation by NARDL

ΔLnCO2	Coefficient	Standard deviation	T-statistic	P-value
$LnCO2_{t-1}$	0.845	0.144	5.86	0.000
$LnCO2_{t-2}$	-0.801	0.180	-4.44	0.000
$LnCO2_{t-3}$	0.417	0.175	2.38	0.023
$LnCO2_{t-4}$	-0.179	0.140	-1.27	0.211
$LnOP\_neg_t$	0.125	0.136	0.92	0.364
$LnOP\_neg_{t-1}$	-0.335	0.147	-2.26	0.030
$LnOP\_pos_t$	-0.185	0.122	-1.52	0.138
$LnOP\_pos_{t-1}$	-0.229	0.137	-1.67	0.104
$LnOP\_pos_{t-2}$	0.472	0.137	3.43	0.002
$LnOP\_pos_{t-3}$	-0.454	0.144	-3.15	0.003
$LnOP\_pos_{t-4}$	0.405	.106	3.80	0.001
Constant	7.754	1.767	4.39	0.000
ECT_{t-1}	-0.718	0.165	-4.35	0.000

More precisely, the short-term estimates of the NARDL model show us a negative and non-significant effect at 5% of the variable LnOP_neg lagged one period on the variation in short-term LnCO2. However, we record a positive and significant effect of the four-period lagged LnOP_pos

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variable on short-term LnCO2 variation. This proves the previous results of a mixed effect of oil price increase and CO2 emission.
Generally speaking, in the short term, any increase in the negative price of oil leads to a reduction in CO2 emissions.
In addition, the coefficient of the estimated error-correction term is 0.718. Since the error-correction term is positive and significant, this implies that the results support the existence of a long-term relationship between the variables. Thus, the error correction term indicates that the deviation from the short-term CO2 emission path due to a certain shock is corrected by 71.8% each year. In other words, this coefficient, combined with the recall force, allows us to conclude that shocks to CO2 emissions in Iraq are corrected by 58.1% through the feedback effect; in other words, we manage to adjust 71.8% of the imbalance between the desired and actual levels of Iraqi growth. Thus, we can identify an average lag equal to |1 / 0.718| = 1.393. This means that an oil price shock in Iraq is fully absorbed after 1 year, 4 months and 21 days on average.
Similarly, the results of the various model verification tests; respectively: Breusch-Godfrey's (LM) 5-order serial autocorrelation test, the ARCH test for heteroscedasticity of order 1, Jarque-Bera's (JB) residual normality test, McLeod's test for serial autocorrelation and Ramsey's (RESET) test for functional form validation; confirm that there is no serial autocorrelation, no heteroscedasticity and the validity of the model. However, the hypothesis of a normal distribution of residuals was not verified.

Table 8 Long-term Asymmetry estimation by NARDL

	Positive long-term effect			**Negative long-term effect**		
Variables	**coefficient**	**F-statistic**	**p-value**	**coefficient**	**F-statistic**	**p-value**
LnOP	0.025	0.140	0.710	0.274	13.6	0.001
	Long-Term Asymmetry			**Short-term Asymmetry**		
LnOP		191	0.000		1.412	0.243
Cointegration test	**t_BDM**			**F_PSS**		
	-4.206			7.268		
	Statistic	**Probability**			**Statistic**	**Probability**
Jarque-Bera test	1.399	0.496		**Portmanteau test**	16.24	0.803
Ramsey test	1.949	0.143		**Breusch/Pagan heteroskedasticity**	0.100	0.751

Similarly, it is interesting to check whether the variables are cointegrated, otherwise the coefficients would be spurious in the case where the cointegration relationship is absent. To test for cointegration under a NARDL model, Shin et al. (2014) recommended using the joint null hypothesis of level (undifferentiated) variables and comparing the critical values of the tests linked in Pesaran et al. (2001). Then if F calculated is greater than the critical value, then there is evidence of cointegration. Otherwise, no evidence of cointegration is found.
In the long term, the findings in Table 8 justify the previous results of the existence of a strong asymmetry. Indeed, both the Student (t_BDM) and Fisher (F_PSS) statistics support the existence

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of a cointegrating relationship where both values are above the critical values of Pesaran et al. (2001). In addition, the diagnostic tests show the validity of the model where the probability of the Ramsey test is greater than 5% despite the residuals not being normal.
What's more, the specification functional form chosen is correct, where stability tests on the CUSUM and CUSUM squared parameters prove that the estimated coefficients are stable in mean and variance over the study period (see Figure 4).
From the results of the NARDL (4;1;4) model, we observe the presence of a long-term asymmetric effect where the Fisher statistic equals 4.23 with almost zero probability. However, there is no asymmetry in the short term. Likewise, we observe a negative effect of low LnOP (LnOP_neg) in the long term evaluated at 0.025 with a probability of 0.710 and a positive effect of LnOP (LnOP_pos) in the long term evaluated at 0.272 with a probability of 0.001. Thus, the NARDL model succeeded in showing a mixed long-term asymmetric effect linking oil price and CO2 emission in Iraq between 1970 and 2021.

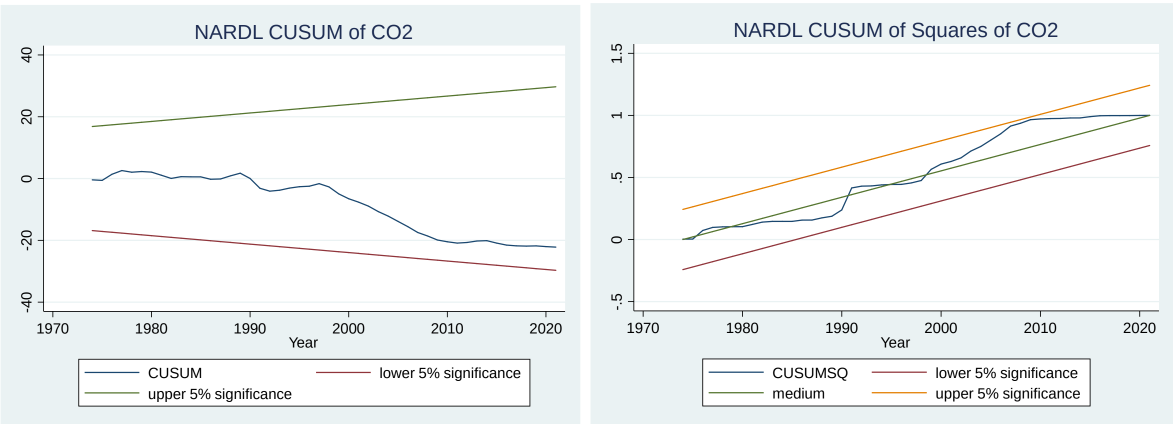

Figure 4 Non-linear evolutions of CUSUM and CUSUMQ statistics

In the present study, we have tried to show that in Iraq there is a problem of oil market dysfunction and imperfections. This analytical option leads us to pay particular attention to oil market policies that could further increase the efficiency of the market's operation. This means that policies aimed at increasing oil demand and CO2 emissions may have less impact because of a problem of institutional inefficiency in the oil market itself.
In the first quarter of 2020, the world trembled in the face of a devastating pandemic. Half the world's population was confined, while governments tried to halt the spread of the virus. After just two weeks of confinement, air quality improved. A year after the first measures were taken, CO2 emissions had fallen to a level that could effectively enable the European Union (EU) to reach its target of 20% renewable energy by 2020 (EEA, 2020b). Unsurprisingly, CO2 emissions are directly linked to economic activity, which is why the highest reductions in carbon emissions coincide with periods of economic crisis. However, once activity recovers, the upward trend resumes (Pindyck, 2020).
The scale of human influence on the planet is such that many scientists consider that the Earth is experiencing a transition to a new geological epoch, significantly determined by human choices and action, called the Anthropocene. Activities such as industrial processes, fossil fuel combustion and deforestation have led to an average temperature rise of 1°C above pre-industrial levels. The

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increase in global CO_2 concentration has been around 20 ppm (parts per million) per decade since 2000, which is faster than any increase in CO_2 recorded in the last 800,000 years (IPCC, 2018; Von Weizsacker, 2009).

Current levels of global warming have already impacted populations, livelihoods and natural ecosystems around the world. The planet is facing extreme weather events, biodiversity loss and rising sea levels, leading to unprecedented risks, especially for the most vulnerable communities. Global warming is likely to reach 1.5°C in the next 10 to 30 years if it continues to increase at the current rate. Moreover, in its latest report, the Intergovernmental Panel on Climate Change (IPCC, 2018) predicts that warming could exceed 1.5°C in the following decades if greenhouse gas (GHG) emissions are not rapidly reduced by 2030.

Enormous progress has been made in recent decades. The ratio of GDP to CO_2, defined as carbon intensity, has fallen considerably over the past 50 years worldwide. Technological advances have made production less energy-intensive and, as a result, smaller quantities of carbon are being released (Pindyck, 2020). This technological progress has also been reflected on the consumption side, by increasing the efficiency of energy-consuming appliances used by households around the world. In fact, policies to improve efficiency have guided much of the action and progress on climate change.

Increasing system efficiency is often seen as a means of reducing the intensive use of natural resources. This strategy is an important pillar of climate change mitigation and adaptation. According to the European Environment Agency (EEA), mitigation policies aim to reduce carbon emissions linked to human activities. These policies mainly target energy production and consumption, for example the development of green energies on the production side, or the development of more efficient (less energy-consuming) vehicles and residential buildings on the consumption side.

Paradoxically, efficiency policies, which have stimulated some of the climate-related advances, may have contributed to the overall slowness of progress. Technical improvements do not necessarily imply resource savings. Economic literature has observed adjustments in producer and consumer behaviour following such improvements, often resulting in increased demand for the resource, an effect opposite to that intended by the policy. The increase in demand following an improvement in the technical efficiency of a resource conversion device, is known as the rebound effect (Font Vivanco et al., 2018).

5. Conclusion and policy implications

At the end of this study, the outlook for oil and refined product prices is rather gloomy. For the next three to five years, unless the economic situation turns around, prices are likely to come under severe pressure. Years of underinvestment not only in new production capacity, but also in the refining industry, combined with a saturated supply in both the parapetroleum and shipping industries, will make it difficult to adapt supply to the growth in world demand. As a result, markets will be highly sensitive to any climatic or political contingency, and their volatility will remain high.

In fact, demand for oil will be structurally strong due to the catch-up effect of the economies of developing countries and the rising living standards of their populations. It should be remembered

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that ¾ of the growth in world demand is expected to come from developing countries, and that transport is likely to absorb 2/3 of the growth in oil consumption.

On the contrary, serious uncertainties remain over producers' ability to meet demand, in both non-OPEC and OPEC countries. Non-OPEC production forecasts are mixed, and even contradictory, depending on the date set for peak production in the biggest producing countries. More generally, these countries face a number of technical, financial and environmental challenges if they are to increase their production capacity and, in the medium term, curb the slowdown. As far as OPEC countries are concerned, the uncertainties relate to both their technical capacity and their political will to fully satisfy the growth in world oil demand.

The need to reduce demand for oil thus gives a new dimension to the policy of combating greenhouse gas emissions. Until now, this policy has been defended exclusively on environmental grounds. The prospect of high oil prices also makes it economically "profitable". Time is running out, however, due to the inertia of our behaviour and energy structure. Yet nothing would be worse than for Iraq to find itself in a situation where, for want of sufficiently effective action by the public authorities, it would not only have to cope with very high oil prices, but would also have to take drastic energy measures to combat the greenhouse effect, because it had not imposed the necessary decisions at the right time.

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