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Statistical estimation using dynamic panel models: applied study.

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Abstract:

This study aimed to use panel dynamic models (Panel NARDL, Panel ARDL) in statistical estimation to measure the effects of time variation and cross-sectional data simultaneously. its application is to measure the impact of GDP, exchange rate and oil price on inflation rate for North African countries (Egypt, Libya, Tunisia, Algeria, Morocco) during the period from 1990 to 2022. Using Hsiao test was done for ensuring non-total homogeneity and non-homogeneity of parameters and constants of the panel model. By estimating both the Panel ARDL and Panel NARDL models for five countries, the results indicate that the Panel NARDL model is better than the Panel ARDL and it is more suitable for the data, it has the highest asymmetric error correction term (ECT (-1)) =-.57911 , R^2=0.601, and is lower in terms of the AIC=1.833 criterions. The empirical results clearly show also that only in the long run, the positive shocks of oil price and exchange rate affect inflation rate in the NARDL model. In the short run, there is no effect of exchange rate or oil price shocks in the NARDL model.

Keywords: Dynamic panel models, Panel ARDL, Panel NARDL, Exchange rate, Hsiao, Inflation rate.

الملخلص:

هدفت هذه الدراسة إلى استخدام النماذج الديناميكية اللوحية (Panel NARDL, Panel ARDL) في التقدير الإحصائي لقياس تأثيرات تباين الزمن والبيانات المقطعية في وقت واحد.
تم التطبيق علي قياس تأثير الناتج المحلي الإجمالي وسعر الصرف وسعر النفط على معدل التضخم لدول شمال أفريقيا (مصر، ليبيا، تونس، الجزائر، المغرب) خلال الفترة من 1990 إلى 2022.
تم استخدام اختبار Hsiao لضمان عدم التجانس التام وعدم التجانس لمعلمات وثوابت نموذج اللوحة. من خلال تقدير نموذجي لوحة ARDL ولوحة NARDL للدول الخمس .
تشير النتائج إلى أن نموذج لوحة NARDL أفضل من لوحة ARDL وأكثر ملاءمة للبيانات، وله أعلى مدة لتصحيح الخطأ غير المتماثل .0.57911 - = ((ECT (-1 ، R2=0.601، وهي أقل من حيث معايير AIC=1.833. تظهر النتائج التجريبية بوضوح أيضًا أنه على المدى الطويل فقط، تؤثر الصدمات الإيجابية لأسعار النفط وسعر الصرف على معدل التضخم في نموذج NARDL. على المدى القصير، لا يوجد أي تأثير لصدمات سعر الصرف أو أسعار النفط في نموذج NARDL.

الكلمات المفتاحية: نماذج اللوحات الديناميكية، لوحة ARDL، لوحة NARDL، سعر الصرف، ، معدل التضخم .

1. Introduction:

The use of panel data models is considered a modern and widely used approach in quantitative analysis. In recent years, these models have gained significant attention, particularly in economic studies, because they consider the effects of time variation and cross-sectional differences. They combine the characteristics of both time series and cross-sectional data simultaneously. As described by Edward (2004), panel data analysis can be seen as a marriage between regression analysis and time series analysis. Consequently, most economists have incorporated panel data models in their applied research to compare economic performance among countries. Panel data models can be classified into static and dynamic models. Static models assume homogeneity among cross-sectional units, while dynamic models don't.

Understanding of oil price, exchange rate, and GDP shocks and their effect on inflation rate is crucial for energy policy makers, hedging price fluctuations during crises and for economy policy makers to reduce the inflation rate as a main object.

To measure the impact of GDP, exchange rate and oil price on inflation rate for North African countries, this study concerned two panel dynamic models which are also used for panel data.

1. **the Panel Autoregressive Distributed Lag (Panel ARDL) model.**
2. **the Panel Nonlinear Autoregressive Distributed Lag (Panel NARDL) model.**

There were many previous studies that addressed these models as:

(Sek & Mukherjee (2024)) employed Panel ARDL and NARDL models to analyze the relationship between agriculture and economic growth in 10 Asian countries from 1980 to 2018, and there was a positive relationship between agriculture and economic growth in the long run, while there was no impact in the short run. (Widarjano A. and Rafik A. (2023)) measured the impact of the bank lending rate on the financing rate for a group of Islamic banks in Indonesia and Malaysia using ARDL and NARDL. it found that, reducing the lending rate in the long run has a greater impact on Islamic financing rates than increasing the lending rate. Also, (Dramani et al., (2023)) examined the asymmetric effects of energy consumption on human capital using data from 22 African countries from 2000 to 2018 Using NARDL. They said that energy consumption has a significant impact on long-term human capital development, particularly positive and negative shocks in the long run energy consumption. Additionally, (Sanl D., et al. (2023)) investigated the asymmetric impact of renewable energy (RE) and non-renewable energy (NRE) on carbon emissions (CO_2) in OECD countries using a

Panel ARDL model applied to 30 OECD member countries. The results showed that there was an asymmetric impact of RE and NRE on CO2 emissions in the long run, while there was no impact in the short run. (Mensah & Abdul-Mumuni (2023)) examined the asymmetric effect of remittances and financial development on carbon emissions in Sub-Saharan African countries using Panel NARDL approach from 1995 to 2018, The results revealed the positive impact of remittances on carbon emissions was found to be greater than the negative impact. Conversely, the negative impact of financial development on carbon emissions was found to be larger than the positive impact. (Mezouri E., (2022)) measured the impact of oil and natural gas prices on industrial production in a group of countries during the Russia-Ukraine war, Using NARDL methodology. It found that positive oil shocks in the long run have a more significant effect than negative shocks, and negative shocks to natural gas prices have a more significant effect than positive shocks. (Zhang D., et al. (2022)) tested the impact of institutional factors (corruption, law, government stability) on carbon dioxide emissions in BRICS countries from 1996 to 2019, using NARDL methodology. They found that positive shocks in corruption and law have a negative effect on carbon emissions in the long run, while negative shocks have a positive effect on both. But Negative shocks to government stability and political stability have a negative impact on carbon emissions in the long run. Moreover, (Odugbesan et al. (2021)), examined the impact of financial development and financial transfers on economic growth in Mexico, Indonesia, Nigeria, and Turkey from 1980 to 2019 Using the Panel NARDL methodology. They found a significant relationship between financial development, financial transfers, and economic growth. Positive and negative shocks to financial development were found to contribute to long-term economic growth. Additionally, Sheikh et al. (2020) analyzed the impact of exchange rates and stock indices on unemployment in South Asian countries from 2000 to 2020 Using the Panel NARDL. A significant long-term effect of positive shocks to exchange rates on unemployment was found.

This research is important because panel data models can improve the accuracy and reliability of statistical predictions by accounting for the temporal and cross-sectional dimensions of the data, as well as the heterogeneity and nonlinearity of the economic relationships.

The remainder of this paper is organized as follows: Section 2 gives research Methodology, in section 3 real data application are present. Finally, conclusions are drawn in Section 4.

2. Methodology:

The research methodology is based on using dynamic panel models (Panel NARDL, Panel ARDL) for statistical estimation.

3. Dynamic panel model

The dynamic panel models that we will discuss are based on the Panel ARDL (Autoregressive Distributed Lag) and the Panel NARDL (Nonlinear Autoregressive Distributed Lag) models. This is done by the following steps:

a. testing homogeneity, Unit root test, and CO – integration test

b. estimating Panel NARDL, Panel ARDL

2.1.1. The linear panel ARDL

Pesaran et al. (1996; 2001) introduced the linear panel ARDL technique. According to it, The Panel ARDL model is formulated based on the research variables as follows: (Pesaran et al. (1996; 2001)

$$\Delta \text{Ln INF}_{it} = C_{io} + \rho_{i1} \text{ Ln Inf}_{it-1} + \beta_{i1} \text{ Ln EXC}_{it-1} + \beta_{i2} \text{ Ln OP}_{it-1} + \sum_{j=1}^{P} \pi_{ij} \Delta \text{Ln Inf}_{i\,t-j} + \sum_{j=1}^{q_1} \lambda_{ij} \Delta \text{Ln EXC}_{it-j} + \sum_{j=1}^{q_2} \alpha_{ij} \Delta \text{Ln OP}_{it-j} + u_{it} \quad (1)$$

$\rho_i, \beta_{i1}, \beta_{i2}$: are the long-run parameters.

$\pi_{ij}, \lambda_{ij}, \alpha_{ij}$: are the short-run parameters.

ρ, q_1, q_2: are the optimal lag lengths.

Δ is the first difference operator, C_{io} is the constant term

2.1.2. The nonlinear panel (NARDL)

The NARDL model is a generalization or extension of ARDL, but it is distinguished by the assumption of nonlinearity in the relationship between the independent variables and the dependent variable. However, when examining the existence of asymmetric correlations between variables, a linear panel ARDL model is inappropriate. In these cases, Shin et al. (2014)'s asymmetric panel NARDL approach is a better fit.

Building the nonlinear model provides the objective of using the asymmetric error correction model to identify both short- and long-term asymmetric actions. The Panel NARDL model is formulated as follows:

$$\Delta \text{ Ln Inf}_{it} = C_{io} + \rho_{i1}\text{Ln INF}_{it-1} + \rho_{i2}\text{Ln GDP}_{it-1} + (\alpha_i^{+}\text{ Ln EXC}_{it-1}^{+} + \alpha_i^{-}\text{ Ln EXC}_{it-1}^{-}) + (\theta_i^{+}\text{Ln OP}_{it-1}^{+} + \theta_i^{-}\text{Ln OP}_{it-1}^{-} + \sum_{j=1}^{p}\beta_{ij}\Delta\text{ Ln InF}_{it-j} + \sum_{j=1}^{q_1}\phi_{ij}\Delta\text{ Ln GDP}_{it-j} + \sum_{j=1}^{q_2}\lambda_{ij}^{+}\ \Delta\text{Ln EXC}_{it-j}^{+} + (\lambda_{ij}^{-}\ \Delta\text{Ln EXC}_{it-j}^{-}) + \sum_{j=1}^{q_3}(\pi_{ij}^{+}\ \Delta\text{Ln OP}_{it-j}^{+} + (\pi_{ij}^{-}\ \Delta\text{Ln OP}_{it-j}^{-}) + u_{ij} \quad (2)$$

Where:

$\rho_{i1}, \rho_{i2}, \alpha_i^{+}, \alpha_i^{-}, \theta_i^{+}, \theta_i^{-}$: are the long-run parameters.

$\beta_{ij}, \phi_{ij}, \lambda_{ij}^{+}, \lambda_{ij}^{-}, \pi_{ij}^{+}, \pi_{ij}^{-}$: are the short-run parameters.

ρ, q_1, q_2, q_3: are the optimal lag lengths.

$$EXC_t^{+} = \sum_{j=1}^{t}\Delta\, EXC_{ij}^{+} = \sum_{j=1}^{t} max\left(\Delta\, EXC_{ij}\,, 0\right) \quad (3)$$

$$EXC_t^{-} = \sum_{j=1}^{t}\Delta\, EXC_{ij}^{-} = \sum_{j=1}^{t} min\left(\Delta\, EXC_{ij}\,, 0\right) \quad (4)$$

$$OP_t^{+} = \sum_{j=1}^{t}\Delta\, OP_{ij}^{+} = \sum_{j=1}^{t} max\left(\Delta\, OP_{ij}\,, 0\right) \quad (5)$$

$$OP_t^{-} = \sum_{j=1}^{t}\Delta\, OP_{ij}^{-} = \sum_{j=1}^{t} min\left(\Delta\, OP_{ij}\,, 0\right) \quad (6)$$

2.1. Testing homogeneity, Unit root test, and CO – integration test

Before estimating Panel NARDL, Panel ARDL, we need to do the following tests.

2.2.1 homogeneity test:

The use of panel models requires first to verify the homogeneity of the data under study and the possibility of applying the models or not. This is done through three stages, (Hsiao, 2014).

1. **stage one of testing homogeneity is shown in table (1)**

table (1) the first stage -overall homogeneity

hypothesis	H0: $\alpha_i = \alpha \ \ , B_i = B$ H1: $\alpha_i \neq \alpha \ \ , B_i \neq B$
Fisher Test statistic	$F_1 = (\frac{SCR_{1.C} - SCR_1)/((N-1)(k+1))}{(SCR_1/(NT-N(k+1))}$
decision	**Accept H0, overall homogeneity.** $y_{it} = \alpha + \acute{\beta}X_{it} + e_{it}$ **reject H0: proceed to stage 3**

2. stage two of testing homogeneity is shown in table (2)

Table (2) homogeneity of parameters $B_i$test

hypothesis	H0: $B_i = B$ H1: $B_i \neq B$
Fisher Test statistic	$F_1 = (\frac{SCR_{2.C} - SCR_1)/((N-1)(k+1))}{(SCR_1 /(NT-N(k+1))}$
decision	Accept H0; proceed to stage 3 reject H0; $y_{it} = \alpha + \beta'_j X_{it} + e_{it}$

3. stage three of testing homogeneity is shown in table (3)

Table (3) homogeneity of parameters $\alpha_i$test

hypothesis	H0: $\alpha_i = \alpha$ H1: $\alpha_i \neq \alpha$
Fisher Test statistic	$F_1 = (\frac{SCR_{1.C} - SCR_{2.c})/(N-1)}{(SCR_{2.c} /(N(T-1)-k)}$
decision	Accept H0;$y_{it} = \alpha_i + \acute{\beta} X_{it} + e_{it}$

Where:

$SCR_{1.c}$: Calculate an equation for each country and estimate the sum of the squares of the residuals, $SCR_{1.c} = \sum_{i=1}^{N} SCR_i$

$SCR_{2.c}$: is the sum of squared residuals for the pooled data set.

N: is the number of cross-sectional units, and T is the number of time periods.

2.2.2. Unit root test

After ensuring that the data is not homogeneous, the second step is to use dynamic panel models. Before this use, the degree of integration for each time series is determined through a set of tests, which are: (Levin Lin, Chu, 2002 (LLC)), (Breitung, 2002), (Im, Pesaran, shin, 2003 (Ips)), (Augmented Dickey Fuller, 1981 (ADF)), (Hardi (Kaddour Hardi; 2005). The Hardi test is used in case of doubt about the results of previous tests. Its statistical assumptions are the opposite of the assumptions of the remaining tests.

2.2.3. CO – integration test:

To test whether there is a long-run equilibrium relationship between variables, we use the following tests: (Pedroni, 2004), (Kao,1999), (Wester Lunds & Edgertan, 2003). The previous tests are valid in the

case of large heterogeneity and cross-sectional correlation (Persyn, D., & Westerlund, J. (2008).

2.3. estimating Dynamic Panel Models

After doing the previous tests, now it's the time to estimate the appropriate dynamic panel model, there are three estimation methods as shown in table (4)

Table (4): three estimation methods of dynamic panel model

method	difference
Mean Group (MG) method	1. provides consistent estimates of the mean parameters of the panel model. 2. considers the lack of homogeneity in the short and long term. 3. it allows for differences in the model parameters by country
Pooled Mean Group (PMG)	combines the MG method with the traditional estimation method.
Dynamic Fixed Effect (DFE)	indicates the homogeneity of the relationship in both the short and long term for all countries.

The Husman test is used to test the optimal method among them in static panel models.

The dynamic panel models Panel ARDL, Panel NARDL require that there are no second-degree integrated time series or I (2). to ensure the symmetry or asymmetry of the relationship in the short and long term between the effects of the independent variable on the dependent variable.

2.4. Asymmetry Test for Panel NARDL Model

The Wald test is used to test the symmetry or asymmetry of the effects of positive and negative shocks of independent variables on dependent variables in both the short and long run. The test is based on these equations as shown table (5).

Table (5): Asymmetry Test for Optimal Model

Relationship	Long Run	Short Run	Optimal Model
Hypotheses	$H_0: \frac{-\alpha_i^+}{\rho_j} = \frac{-\alpha_i^-}{\rho_j}$ $H_0: \frac{-\theta_i^+}{\rho_j} = \frac{-\theta_i^-}{\rho_j}$	$H_0: \sum \lambda_{ij}^+ = \sum \lambda_{ij}^-$ $H_0: \sum \pi_{ij}^+ = \sum \pi_{ij}^-$	
Test result Symmetry in both	Accept H_0	Accept H_0	ARDL
Asymmetry in long run	Accept H_0	Reject H_0	
Asymmetry in Short run	Reject H_0	Accept H_0	NARDL
	Reject H_0	Reject H_0	

3.Application

for using dynamic panel models (Panel NARDL, Panel ARDL) to have statistical model to measure the impact of GDP, exchange rate and oil price on inflation rates in North African countries (Egypt, Libya, Tunisia, Algeria, Morocco) during the period 1990-2022 using the statistical packages EViews 13 and Stata 15. The fact that the countries of North Africa have comparable economic and social structures to other country groupings is a key factor in the construction of the data set from these countries. In addition, the data they provide are available in world bank at www.worldbank.org.

3.1 Research Variables:

To reduce the variation in economic variables and prevent heteroskedasticity and erroneous regression findings, the series are converted to natural logarithms. The model to explore the connection that exists between is.

$$\text{InF} = \text{F}(\text{Ln GDP} \;, \text{Ln EXC} \;, \text{Ln OP} \;)$$

where:

- Ln InF_t: The dependent variable, The natural logarithm of the inflation rate.

  The independent variables are:
- Ln GDP_t: The natural logarithm of the gross domestic product.
- Ln EXC_t: The natural logarithm of the exchange rate.
- Ln OP_t: The natural logarithm of the oil price.

to examine the long run relationship, The log linear equation between variables is given as follow:

$$\mathbf{InF_t = (Ln\ G}DP_t^{+} \mathbf{+ Ln\ GDP}_t^{-} \mathbf{+\ Ln\ EXC^{+}{}_t + Ln\ EXC^{-}{}_t + Ln\ OP}_t^{+} \mathbf{+ Ln\ OP}_t^{-}) \quad (7)$$

It is essential to conduct a set of descriptive statistics using EViews 13 on the variables of the study model for a sample of 5 countries, as shown in table (6).

Table (6): Descriptive Statistics

Variables	Ln inf	Ln GDP	Ln EXc	Ln OP
n	160	165	167	165
Mean	1.5768	4.1806	1.7014	-0.9141
Median	1.5592	4.0019	1.7377	-1.0498
Std.Dev	0.9063	0.7812	1.6132	0.7688
Skewness	-0.2267	0.3638	0.3925	-0.1760
Kurtosis	3.0333	2.5959	2.4269	1.9723

The correlation matrix test between the explanatory variables in panel data analysis allows us to identify pairs of explanatory variables that are strongly correlated with each other. This is done by calculating the multiple correlation coefficients between all pairs of explanatory variables. Using Eviews13, we obtained table (7).

Table (7): The correlation matrix

Variables	Ln inf	Ln GDP	Ln EXC	Ln OP
Ln inf	1			
Ln GDP	0.013895 (0.8620)	1		
Ln EXc	-0.134283 (0.8620)	0.590981 (0000)	1	
Ln OP	-0.462557 (000)	0.007789 (0.9263)	0.187922 (0.0177)	1

From Table (7), we noticed that the correlation matrix between these variables is less than 80%, and therefore it is statistically acceptable.

However, to further increase our confidence, we conducted a cross-section dependence test is shown in Table (8)

Table (8) cross sectional dependency test results:

Variables	CD Test	P – value
Ln inf	7.5412	0.000
Ln GDP	15.8917	0.000
Ln EXc	10.7807	0.000
Ln OP	3.7303	0.000

Based on the results of the independence cross sectional test table, we noticed that the P-value is less than the significance level of 0.05. Therefore, we reject the null hypothesis of no cross-sectional correlation between countries.

3.2. Tests of dynamic panel models

To build panel models we should do the following tests before the estimation of the proposed models to indicate the suitability of dynamic panel models for the data under study.

3.2.1. Homogeneity Test:

homogeneity test (Hsiao, 1986) is used to verify the overall homogeneity so, this test is using to:

1. **choose the appropriate model for the study data.**
2. **determine the quality of the used model.**
3. **verify whether the model is identical for all countries under study or if there is a special feature for each country.**

the homogeneity of the parameters and constants for all countries, and then the most appropriate model for the study data can be determined. Hsiao test for homogeneity results is shown in Table (9) (Seghiri, S. A., et al (2021))

Table (9) Hsiao test for homogeneity

Test	H_0	F – stat	P – value
Overall homogeneity	$H_o: \beta_i = \beta$ $\alpha_i = \alpha$	$F_1 = 22.736$	0.000
Homogeneity Of parameters	$H_o: \beta_i = \beta$	$F_2 = 2.375$	0.000
Homogeneity Of Constants	$H_o: \alpha_i = \alpha$	$F_3 = 14.657$	0.000

From Table (9), the results of the homogeneity test show that the P-value is less than 0.05. Therefore, the null hypothesis is rejected:

1. **For F_1, there is no overall homogeneity.**
2. **For F_2, no homogeneity of the parameters (β_i)**
3. **For F_3, no homogeneity of constants (α_i).**

This is one of the indicators of the inappropriateness of static panel models for the data. Therefore, dynamic panel models are more appropriate, as there are differences between North African countries in terms of parameters and constants. (Majnagh F., Chekli A.A., (2022))

To increase certainty, the Pesaran-Yamagata test is used to verify the homogeneity of the slope parameters (Slope) for all North African countries as shown in Table (10). (Pesaran, M. H., et al (1999)).

Table (10) Pesaran test

Test	Test statistic	P – value
Delta	18.761	0.0001
Delta adj	22.938	0.000

From Table (10), we note that the P-value is less than 0.05. Therefore, the null hypothesis that the slope parameters are homogeneous is rejected. This means that there is no homogeneity of the slope parameters at the 5% level. This also means that there is no homogeneity of all study variables. All of this indicates the suitability of dynamic panel models for the data under study.

3.2.2. Stationarity of Time Series Tests:

After ensuring the feasibility of using dynamic panel models, the next step is to ensure the stability of the time series and determine their degree of integration. This is done using the following unit root tests as shown in Table (11).

Table (11) Panel Unit Root tests

Variables	LLC		IPS		I (d)
	Level	1st differ	Level	1st differ	
Ln InF_t	-1.817 (0.0346)	-3.65 (.0001)	-.356 (.3609)	-7.422 (0.000)	I (1)
Ln GDP_t	-62572 (.7343)	-3.959 (.000)	1.0776 (.8594)	-3.919 (000)	I (1)
Ln EXC_t	-.664 (.2531)	-3.3919 (.0003)	-.8409 (.2002)	-4.283 (.000)	I (1)
Ln OP_t	1.5739 (.9423)	-3.445 (.000)	.7298 (.7673)	-3.8327 (.0001)	I (1)

From Table (11), using both the LLC and IPS tests to test the stationarity of the time series, which are logarithm of inflation, GDP, exchange rate, and oil price, we note that.

1. **At the original level of the series, the P-value is greater than 0.05. This means that all-time series are unstable at their original level.**
2. **After taking the first difference, we note that the P-value is less than 0.05. Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted that all-time series are stable after their first difference, i.e., they are all integrated of order one I (1).**

3.2.3.Cointegration Test:

After determining the degree of integration of the time series used in the model and ensuring their degree of integration, where they are not integrated of order two I (2) to enable the use of dynamic panel models (Panel NARDL, Panel ARDL), we move to the next step, which is to detect the existence of a long-term equilibrium relationship between inflation, GDP, exchange rate, and oil price. This is done using the cointegration test as shown in Table (12).

Table (12) Cointegration tests

Pedroni	Statistics	test
Within– dimension	Panel V-statistic Panel rho-statistic Panel pp-statistic Panel ADF statistic	0.1965(.422) -2.66(.003) -5.28(000) -1.87(.0301)
Between – dimension	Group rth-stat. Group PP-stat Group ADF-stat	-1.436(.07) -5.72(0000) -1.54(.06)
Kao	- 3.722 (000)	

From Table (12), we note that most of the statistics indicate the rejection of the null hypothesis of no cointegration, where the P-value is less than 0.05. Therefore, there is cointegration and a long-term equilibrium relationship between inflation and both GDP, exchange rate, and oil price in North African countries during the study period.

3.5 Estimation of the Panel ARDL Model:

After studying the degree of integration of the independent variables, which are GDP, exchange rate, and oil price, and the degree of integration of the dependent variable, which is inflation, and ensuring that they are not integrated of order two, we proceed to estimate the Panel ARDL model, which is formulated as formula (1).

Using statistical packages, the following Coefficients were obtained as shown in Table (13).

Table (13) Short – term Panel ARDL Estimation

Variable	Coefficients	t-stat	Prob
Constant	1.809	2.858	0.0049
Δ Ln GDP	1.574	1.2915	0.1988
Δ Ln EXC	1.6412	1.162	0.2473
Δ Ln OP	-0.41747	-1.7198	0.0878
$ECT_{(-1)}$	-0.534373	-7.0668	0.000
R^2	0.579		
F – stat	24.93		0.00
Akaike info	1.855		

From Table (13), in the short run,

1. **The results of the error correction model indicate that there is a positive relationship between both GDP and exchange rate and inflation, but it is not statistically significant.**
2. **There is also an inverse relationship and statistically significant at the 10% level between oil price and inflation rate in the short run.**
3. **We also noted the significance of the error correction coefficient ECT_{-1} at the 1% significance level with the expected negative sign, which confirms the existence of a long-term equilibrium relationship between the model variables.**
4. **The value of the error correction coefficient (-0.53437) indicates that inflation corrects its position towards its equilibrium value in each year by a percentage of imbalance equal to 53.4%. In other words, when inflation deviates from its equilibrium position in the short run, it corrects its position by 53.4% in a year, meaning that it takes about 1.87 years to return to the equilibrium position after any shock from the independent variables, namely GDP, exchange rate, and oil price.**

Table (14) Long – term Panel ARDL Estimation

Variable	Coefficients	t-stat	Prob
Ln GDP	.63450-	-3.4828	0.0007
Ln EXC	0.901326	4.5437	0.000
Ln OP	0.77273	3.4929	0.0007

From Table (14), in the long run, we note that:

1. **There is an inverse and statistically significant relationship between GDP and inflation rate.**
2. **We also found a positive and statistically significant relationship between both the exchange rate and oil price and inflation rate. Therefore, the most influential variable on inflation in the short run**

is oil price, but in the long run it is exchange rate, followed by oil price, and finally GDP.

The Estimating of a Panel ARDL Model for the Inflation Rate of Each Country under Study are shown in table (15)

Table (15): Estimated of a Panel ARDL Coefficients in the Short Run for Each Country

Variables	PMG	Egypt	Morocco
Ln GDP	1.574398 (0.1988)	2.1836 (0.1465)	5.9372 (0.4153)
Ln EXC	1.641266 (0.2473)	2.2220 (0.0102)	6.8884 (0.5980)
Ln OP	-0.41747 (0.0878)	-0.6298 (0.5118)	-0.80258 (0.42711)
ECT	-0.53437 (0.000)	-0.6019 (0.000)	-0.66436 (0.0002)
Variables	Algeria	Tunisia	Libya
Ln GDP	-1.14347 (0.3736)	0.88602 (0.3296)	0.008606 (0.9830)
Ln EXC	0.68477 (0.5024)	-0.8102 (0.1554)	-0.7287 (0.2236)
Ln OP	0.236069 (0.7118)	-0.3525 (0.0377)	-1.1053 (0.1632)
ECT	-0.23816 (0.0004)	-0.5716 (0.0001)	-0.5957 (0.0003)

The short-term PMG estimation results indicate that:

1. **There is a positive relationship between the exchange rate and the inflation rate in all countries except Tunisia, with high statistical significance in Egypt, Morocco, Algeria, and Libya.**
2. **The relationship between the oil price and the inflation rate shows a negative relationship in all countries, with high statistical significance in Egypt and Libya.**
3. **The error correction coefficient indicates the existence of a long-term relationship between the variables, and that the fluctuations or shocks in all countries are corrected quickly by 53.43% in the next period.**

3.5.1.Diagnostic Tests for the Model:

To ensure the validity of the model, we perform some diagnostic tests. The results of the tests were as follows:

Table (16) Diagnostic tests

Test	F – statistic	Prob
Jarque – Bera	2.9615	0.7063
Ramsey RESET	1.839	0.17715
Heteroskedasticity	2.3612	.32160
Serial Correlation	.34780	.70680

From Table (16), we note that the Panel ARDL model is free from all standard problems, which are serial correlation, non-constant variance, and model misspecification.

3.7 Estimation of the Panel NARDL Model:

After ensuring the degree of integration of the time series in the model and that they are all integrated of the first order and there are no time series integrated of the second order. NARDL is an extension or generalization of ARDL, but it assumes non-linearity between the explanatory variables and the dependent variable. to estimate the Panel ARDL model, which is formulated as formula (1) Using statistical packages, the Panel NARDL model was estimated as follows:

Table (17) Short – term Panel NARDL Estimation

Variable	Coefficients	t-stat	Prob
$ECT_{(-1)}$	-.57911	-5.1579	0.000
Δ Ln $Inf_{(-1)}$	-0.2652	-3.032	0.0023
R – square	0.601		
F – stat	21.16		0.00
Akaike info	1.833		

From Table (17), for Short – term we note that.

1. There is no significant effect of the positive and negative effects of both exchange rate and oil price on, as well as the absence of an effect of GDP on inflation.
2. The appearance of the error correction coefficient with a negative and significant sign (-0.2652) at the 1% level confirms the quality of the model and the existence of a long-term equilibrium relationship between inflation and both GDP and exchange rate and oil price.
3. The value of the error correction coefficient (-0.57911) indicates that inflation corrects its position towards its equilibrium value by 57.911% in a year, meaning that it takes about 1.73 years to return to its equilibrium position after any shock in the independent variables, namely GDP, exchange rate, and oil price.

Table (18) Long – term Panel NARDL Estimation

Variable	Coefficients	t-stat	Prob
Ln GDP	-0.7719	-1.884	0.0616
Ln EXC +	0.73336	2.169	0.0317
Ln EXC −	0.70299	0.6079	0.5442
Ln OP +	1.0937	2.88	0.0046
Ln OP −	0.74736	2.48	0.1073

From Table (18), in the long run,

1. **There is an inverse and statistically significant relationship between GDP and inflation at a significant level of 10%.**
2. **As for the positive and negative effects of oil price, the effect of the positive shock of the exchange rate was positive and statistically significant at the 1% level on inflation, in contrast to the insignificance of the effect of the negative shock of the exchange rate on inflation.**
3. **As for the positive shock of oil price on inflation, it was positive and statistically significant at the 1% level, and conversely, the negative shock of exchange rate is insignificant on inflation.**

Therefore, the most influential variables in the long run-on inflation are the positive shocks of both oil price and exchange rate.

3.8 Diagnostic Tests for Dynamic Panel Models

To ensure the validity and soundness of the estimated models and their freedom from all standard problems, we can use the following tests:

a. **Jarque – Bera test for normality.**
b. **Breuch – Bagan test for heteroscedasticity.**
c. **Ramsey reset test for model specification.**
d. **Lagrange Multiplier test for autocorrelation.**

Also, to ensure and accuracy of the model, the results of the previous tests for Panel NARDL model are performed as shown in table 19)

Table (19) Diagnostic tests for Panel NARDL model

Test	F – statistic	Prob
Jarque – Bera	3.765	0.1976
Ramsey RESET	1.623	0.204
Heteroskedasticity	2.197	0.2123
Serial Correlation	0.1598	0.8524

From table (19), It is cleared that the Panel NARDL model is also free from all standard problems.

3.9 Symmetry Test (Wald Test)

Wald Test measures the symmetry of positive and negative shocks of both exchange rate and oil price on inflation in the short and long run,

i.e., whether there is symmetry between positive and negative shocks of the same variable, then the relationship between it and the dependent variable is linear, but if there is asymmetry, the relationship is nonlinear. Since the shocks of exchange rate and oil price have no significant effect in the short run, we will discover by measuring symmetry in the long run as follows:

Table (20) Symmetric test

Variable	F – test	P – value	Decision
EXC	1.12120	0.0312	Not Symmetric
OP	.51480	0.04742	Not Symmetric

It is noted from Table (20) that. For both exchange rate, oil price, the p-value is less than 0.05, thus rejecting the null hypothesis and accepting the alternative hypothesis of non-homogeneity of the effect of positive and negative shocks of exchange rate and oil price on inflation in the long run.

3.10 Granger Causality Test:

The Granger causality test developed by Dumitrescu-Hurlin considers non-homogeneity in panel models and performs separate regressions for each cross-sectional data set to find causality. The null hypothesis indicates that there is no homogeneous causality from cross-section to cross-section, but the alternative hypothesis is that there is non-homogeneous causality in at least one cross-section. The Granger causality test results are as shown in table (21)

Table (21) Panel Asymmetric Granger Causality test

Null Hypothesis	Statistic	Prob
Ln GDP does not Cause Ln Inf	1.10012	0.9750
Ln Inf does not Cause Ln GDP	0.6818	0.5843
Ln EXC does not Cause Ln inf	2.583	0.0373
Ln inf does not Cause Ln EXC	1.224	0.8399
Ln OP does not Cause Ln inf	1.90652	.00120
Ln inf does not Cause Ln OP	0.7688	.66950

From Table (21), we found that there is a unidirectional relationship from exchange rate, oil price to inflation, as the p-value is less than 0.05, thus rejecting the null hypothesis and accepting the alternative hypothesis that exchange rate, and oil price cause inflation.

4. Conclusion and Recommendations

The study aimed for using dynamic panel models (Panel NARDL, Panel ARDL) to measure the impact of GDP, exchange rate and oil price on inflation rates in North African countries (Egypt, Libya, Tunisia, Algeria, and Morocco) during the period 1990-2020. This was done through the following:

- **Hsiao's test was used to select the appropriate model for the data, and LLC and IPS tests were used to check for stationarity, and Kao and Padroni tests were used to check for cointegration.**
- **Panel ARDL model and panel NARDL model were estimated to extract the short-run and long-run relationships.**
- **The results indicate that there is no overall homogeneity or homogeneity of parameters or constants among the countries, which supports the use of dynamic models.**
- **The results also indicate that all the variables are integrated of the first order I (1), and that there is a long-run equilibrium relationship between oil price, exchange rate, and inflation rate.**
- **In the short-run, oil price significantly affects inflation rate in the ARDL model, while there is no effect of exchange rate or oil price shocks in the NARDL model.**
- **In the long run, both GDP, oil price, and exchange rate affect inflation rate in the ARDL model, while only the positive shocks of oil price and exchange rate affect inflation rate in the NARDL model.**
- **The symmetry of the effect of oil price and exchange rate shocks on inflation rate in the long run was tested using the Wald test.**
- **The causality between oil price, exchange rate, and inflation rate was tested using the Granger causality test.**

Table (22) showed indicators of Panel ARDL Panel NARDL models.

Table (22), Panel ARDL Panel NARDL models indicators

	Panel ARDL	Panel NARDL
$ECT_{(-1)}$	-0.534373	-.57911
R^2	0.579	0.601
F – stat	24.93	21.16
Akaike info	1.855	1.833

- **All the previous indicators lead to the conclusion that the Panel NARDL model is more suitable for the data than Panel ARDL. This is because it has a higher value of $ECT_{(-1)}$, R^2, and a lower value of AIC criteria.**

Therefore, the researchers recommend expanding the use of dynamic panel models as modern methods in statistical and economic studies. Also, Re-studying and incorporating other variables that are more influential on inflation than exchange rate and oil price.

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