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Fluctuations of Oil Prices and Gross Domestic Product in Spain

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ABSTRACT

The objective of this research is to analyze the asymmetric impact of crude oil prices on the real per capita gross domestic product (GDP) between 1945 and 2018 in Spain. The decomposition of oil prices into positive and negative partial sums in a nonlinear autoregressive distributed lag model allows examining the results derived from the fluctuations of oil prices in the international markets. The effects of those movements on per capita GDP are primarily long range, having the long-run oil price decreases a larger impact on the per capita GDP than the oil price increases. In spite of these asymmetric effects, the energy policy agenda should address some issues related to not only tax handling but to market competition and efficient wages mechanisms as well.

Keywords: Per Capita Gross Domestic Product, Asymmetric Oil Prices, Nonlinear Autoregressive Distributed Lag, Spain
JEL Classifications: C22, O40, Q41

1. INTRODUCTION

Petroleum remains the main source of energy at world level in spite that different international agreements bet on actions for cleaner energies and a sustainable low carbon future. The International Energy Agency (ww.iea.org) predicts a growing world demand for crude oil until 2040. The major cause is the lack of alternatives to the use of oil in especially these three sectors: Road transport for goods, aviation and petrochemical. The current dependency for most countries is so large that all goods and services of an economy in one way or another are affected by the fluctuations of crude oil prices. These finally influence a household economy because one needs to fill the car with gasoline or diesel, go on public or private transportation, buy oil derivative products or simply buy food, clothes, and other goods which in their turn need oil energy to be transported and be sold in stores. Oil prices instability has always been a matter of concern for economists and politicians. At a macroeconomic level, higher oil prices as Lardic and Mignon (2008) indicate, aside from causing inflation and reduction on consumption, slow down output through the cost increases, deteriorate the terms of trade of importing-oil countries, they may cause a change of productive structure generating unemployment and impact a country's monetary policy because there is more money demand, the interest rates augment and investments are forced to cut back.[1]

Spain only produces 0.17% of the oil that it consumes (www.energia.gob.es, 2016) and therefore is a net importer country. The origin of crude imports is quite diversified for security reasons. From OPEP countries comes about 60% while the other 40% is shared with countries such as Rusia, Mexico, Noruega and others. It can be observed in Figure 1 the structure of energy consumption in the economy where oil-based energy is used in more than half the rest of energies. Despite the efforts that the authorities are doing to develop renewable energies, Spain is still highly dependent on crude oil. The economy has also failed to diversify and now is strongly vulnerable to the volatility of oil prices.

1 Some of these oil price effects at macroeconomic level are examined by Donaire and Wilmot (2016), Davari and Kamalian (2018), Rostin et al. (2019).

When talking about oil prices and how these can affect an economy we mostly tend to think about the rise of prices and its negative consequences as seen in the first paragraph. However, a fluctuation means that the price can increase or decrease in an alternating manner. The formation of prices takes place as the result of different factors but mostly have to deal with supply and demand of oil in the financial markets. Those two elements are driven, for example, by news on tapping oil reserves and discoveries of oil fields, geopolitical conflicts and terrorist attacks, alternative energies, exchange rates, energy market speculation and economic growth. All in all, a lower oil price will mean paying less for oil having lesser inflation and leading to more purchasing power and all the way around in the case of a rise in oil prices. It is in the context of this asymmetry where the present study fits in where purchasing power will be approximated by the real per capita gross domestic product (GDP).[2]

The objective is to analyze the asymmetric impacts of real oil prices on the Spanish real per capita GDP along the period 1945-2018.

The following graph (Figure 2) shows the evolution that the two variables of interest in this study had between 1945 and 2018. Oil prices were quite stable during the beginning of the period and then have undergone sharp movements especially from the seventies onward. Whereas per capita GDP has an increasing trend during the whole period, being quite smooth between 1945 and 1985, moves hereunder at an increasing rate and stops during the financial crisis in 2008 keeping almost the same level until 2018. This apparently nonlinear path of oil prices has to reconcile with the long-run upward trend of the per capita GDP in a model that are able to explain different elasticities associated to the asymmetrical shocks of crude oil prices. The incorporation, first, of asymmetries of oil prices in a nonlinear autoregressive distributed lag (NARDL) growth model for Spain and the comparative between static and dynamic models to better examine different effects and secondly, the use of a long time series that includes 73 years (1945-2018) make of this paper its greatest strengths.

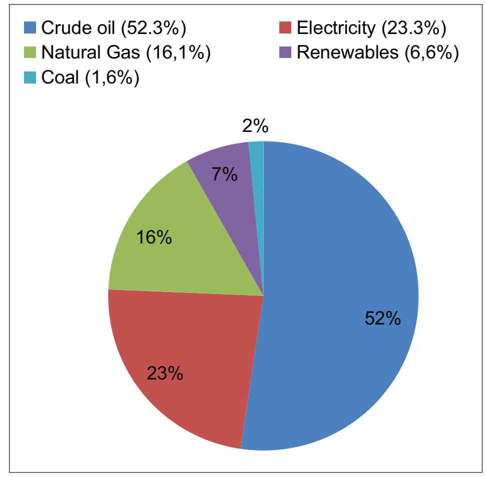
The structure of the paper is as follows: Section 2 reviews the literature that is important to the paper. Section 3 reports data sources and describes the model and the methodology. Section 4 analyzes the time series data, shows the main findings and provides a discussion of them. Section 6 ends the paper with concluding remarks.

2. LITERATURE REVIEW

The benchmark for the incorporation of asymmetric oil prices is an economic growth model. This is the chosen context where the per capita GDP can be analyzed. Traditional neo-classical growth models argued that steady-state income per capita was independent of initial conditions on capital stock. This is what is known as exogenous growth (Solow, 1956). Nevertheless, later authors such as Romer (1986), Lucas (1988, 1993) and Barro (1990) introduced the endogenized growth and asserted that increasing returns would be caused by the use of physical capital, human capital and knowledge which would be related to those two types of capitals. This paper goes more in the line of the latter authors because we also consider that economic growth can be different for each country and do not necessarily have to converge.

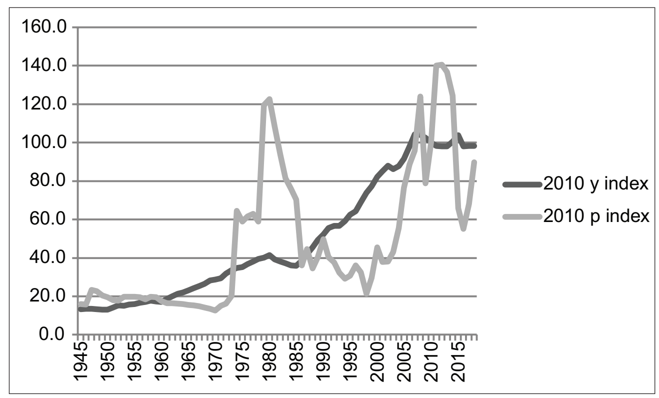
2 The real per capita GDP is a broad measure of an economy's performance regarding to the production of goods and services. We are aware that it is an imperfect metric for well-being and prosperity but for the sake of such a long time series analysis it has an intuitive usability.

Figure 1: Energy consumption in Spain



Own elaboration from ww.energia.gob.es 2016 data

Figure 2: Evolution of per capita gross domestic product (y) and crude oil prices (p)



Own elaboration from the Maddison Project Database (www.ggdc.net/maddison). The two variables are expressed in terms of 2010 indices

Regarding the relationship between oil prices and economic growth there exist a vast amount of literature mainly boosted by different oil shock episodes that we have witnessed since the 1970's to the present. It should be mentioned the earliest and the most representative works. Thus, several theoretical models that tried to explain the role of those oil impacts on macroeconomic variables were developed by Rasche and Tatom (1981), Bruno and Sachs (1982) and Hamilton (1983; 1988). They modeled the link between oil shocks and different macroeconomic variables mainly through non-linear specifications. From a practical point of view, those models proved the fact that economic fluctuations took place on the face of an oil shock with some exceptions like Hooker (1996), who obtained no positive results on the so-called relationship. Other authors such as Mork (1989), Mory (1993), Mork et al. (1994), Ferdered (1996), Hamilton (1996), Huntington (1998) Brown and Yücel (2002), and Lardic and Mignon (2006; 2008) among others, supported the fact that oil impacts could be modeled as a non-linear and asymmetric link to economic performance. Ferdered (1996), for example, explained the non-linearity on economic activity through the reallocations of resources between different economic sectors or investment cutbacks due to the oil market uncertainty.

There are far less references on the oil price-economy research for Spain which is the country object of our analysis. Cuñado and de Gracia (2003) analyze the impact of oil shocks on inflation and industrial production for many European countries between 1960 and 1999. They found short run and asymmetric effects on production growth rates for Spain but not in the long run. Lardic and Mignon (2006) use an asymmetric model unlike to cointegration symmetric models of many studies until then and this is done for 12 European countries, Spain among them, with quarterly data between 1970 and 2003. They prove that rising oil prices retard economic activity by more than falling oil prices stimulates it. Gómez-Loscos et al. (2011) determine a non-constant oil price shock over total GDP and inflation for Spain and her regions. The effects of oil shocks on the economy progressively loose importance although they recover its initial effects at some moment in time (1990s). For a long sample between 1870 and 2013 Van Eyden et al. (2019) test the relationship between oil price volatility and economic growth for OECD countries. In the case of Spain the authors obtain an overall negative elasticity and significant for the whole period of −0.0352. The study is based on a panel cointegration. As we can see there are mixed results. It is no easy to compare all studies given that there are different subtleties which depend on the econometric model approach, different samples and different econometric methodologies. The present paper aims at contributing to the vast body of literature with a different approach (asymmetric cointegration) and different results for the Spanish case.

3. DATA, MODEL AND METHODOLOGY

3.1. Data

The sample period extends from 1945 to 2018 for which annual time series for GDP, population, international oil prices, human capital and physical capital are available. They are collected from different data sources. GDP, in US dollars (2011 base year), and population are from Maddison Historical Statistics (http://www.ggdc.net/maddison/maddison-project/home.htm) and Instituto Nacional de Estadística (INE) (http://www.ine.es/). Crude oil prices measured in US dollars (2010 base year) were gathered from the Statistical Review of World Energy 2017 and latest statistics provided by the British Petroleum company (http://www.bp.com/). Between 1945 and 1983 the oil price reference is Arabian light posted at Ras Tanura and from 1984 to 2018 the reference taken is Brendt dated. Human capital is expressed as a ratio between higher education enrollments over total population and stems from Estadísticas Históricas de España (http://www.fbbva.es) and completed by INE. The same data sources were used for physical capital which is approximated by and index of gross fixed capital formation.

3.2. Model

The model specification tries to explain the role of real oil price fluctuations on the evolution during three fourths of a century of the per capita income in Spain which is proxied by the per capita GDP. This is implemented in an economic growth model context so that human capital (higher education enrollments over population) and physical capital (gross fixed capital formation) are the control variables.

Before the final model is written, we, first take an important step where fluctuations in oil prices may have an asymmetric impact on the per capita GDP and therefore they should be reflected in a proper way. Thus, following Schorderet (2004), the oil price series is decomposed into partial sums of P^+ and P^-, that is, the cumulative positive prices which are supposed to capture the upward fluctuations of P_t and the cumulative negative prices that would do the same for downward fluctuations of P_t for the whole period (1945-2018):

$$P_t^+ = \sum_{j=1}^{t} \Delta P_j^+ = \sum_{j=1}^{t} \max\left(\Delta P_j, 0\right) \text{ and}$$

$$P_t^- = \sum_{j=1}^{t} \Delta P_j^- = \sum_{j=1}^{t} \min\left(\Delta P_j, 0\right) \quad (1)$$

From (1), the asymmetric long-run equilibrium relationship would be:

$$y_t = \beta^+ P_t^+ + \beta^- P_t^- + \varepsilon_t \quad (2)$$

The final econometric model is indicated in natural logarithms (lower case).[3] This way, the interpretation of estimated parameters through elasticities is easier:

$$y_t = \beta_0 + \beta_1^+ p_t^+ + \beta_1^- p_t^- + \beta_2 h_t + \beta_3 k_t + \varepsilon_t \quad (3)$$

where y represents per capita GDP, and p^+ captures the evolution of real crude oil price increases, p^- the same for price decreases, h represents human capital and k depicts physical capital. Lastly, ε_t is the error term which is assumed to be independent and normally distributed.

3.3. Methodology

The methodology employed in this research is that of asymmetric cointegration in an ARDL bounds test framework, what Shin et al. (2014) name as NARDL method. It combines all the econometric advantages that the ARDL model (Pesaran and Shin, 1998 and Pesaran et al., 2001) has with the idea that some macroeconomic variables can better reflect their behavior through their decomposition into positive and negative cumulative partial sums (Schorderet, 2004) so that asymmetric effects can be captured.[4]

3 Note that no logarithms exist when they are applied to a negative number. This is the reason why the natural logarithm was applied to the P variable before its decomposition into P^+ and P^-.

4 The advantages of the ARDL model are basically that one can work with either I(1) or I(0) variables and that serial correlation and endogeneity problems are easily removed when long-run and short-run components are simultaneously taken with appropriate lags (Pesaran and Shin 1998). The NARDL by Shin et al. (2014) takes all these advantages and add a more flexible unrestricted structure where long- and short-run asymmetries can simultaneously be estimated.

The NARDL model is then, an extension of the linear version of the ARDL model and aims at detecting short- and long-run asymmetries. For that purpose the paper first expresses the time path before a long-term nexus is achieved for the relationship between per capita GDP (y), positive oil prices (p^+), negative oil prices (p^-), human capital (h) and physical capital (k). Thus, Equation (3) is rewritten as an unrestricted error correction representation and estimated through ordinary least squares:

$$\Delta y_t = \alpha_0 + \rho y_{t-1} + \theta^+ p_{t-1}^+ + \theta^- p_{t-1}^- + \delta h_{t-1} + \varphi\, k_{t-1} + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + \sum_{i=0}^{q1} \pi_i^+ \Delta p_{t-i}^+ + \sum_{i=0}^{q2} \pi_i^- \Delta p_{t-i}^- + \sum_{i=0}^{s} \mu_i \Delta h_{t-i} + \sum_{i=0}^{t} \tau_i \Delta k_{t-i} + e_t \quad (4)$$

where e_t are the new serially independent errors. Asymmetric long-run parameters will be operated as $-\theta^+/\rho = \beta^+$ and $-\theta^-/\rho = \beta^-$.

In order to implement the NARDL the following steps are followed. In a first step, the unit roots are tested. These should not be of an order of integration higher than I(1), otherwise the method would be invalidated. In a second step and through the bounds test, it will be analyzed whether or not there is evidence of a cointegrating (long-run) relationship from Equation 3 taking into account the optimal lags in the model selection through the Schwarz information criterion (SIC). The third step will involve the long- and short-run asymmetries examination by using Wald tests (Equation 4). The final step will examine the long and short-run dynamics (Equation 4). The asymmetric cumulative dynamic multipliers will indicate the adjustment of an initial equilibrium to a final equilibrium in the face of oil price shocks and per capita GDP responses. The dynamic multipliers effects of say m_h^+ and m_h^- of a unit change in p^+ and p^- are obtained as:

$$m_h^+ = \sum_{i=0}^{h} \frac{\partial y_{t+j}}{\partial p_t^+} \text{ and } m_h^- = \sum_{i=0}^{h} \frac{\partial y_{t+j}}{\partial p_t^-} \; h = 0, 1, 2...$$

whenever $h \to \infty$ then $m_h^+ \to \beta^+$ and $m_h^+ \to \beta^-$ by construction, where those two betas are the asymmetric long-run parameters.

4. RESULTS

When dealing with time series it is fundamental to check whether or not our variables are stationary in order to implement the suitable regression method. It is also important to take into account that the data generation process could be a difference stationary process (DSP) or a trend stationary process. The modified Augmented Dickey Fuller test is the unit root test that is applied here. It takes into account of possible structural breaks given the long time-span of the series (1945-2018). This test allows that levels and trends differ across a single break date. Specifically, Table 1 reports the results from two complementary tests: The innovational outlier (IO) test, which assumes that the break occurs gradually; and the additive outlier (AO) test, which assumes that the break occurs immediately. As can be seen, the results from both approaches by considering the critical values at 5% are quite consistent. All series reject the presence of two unit roots in favor of just one unit root (I(1) variables or DSP). Only the human capital time series (h_t) in the IO test seems stationary or I(0) whereas the AO test indicates that it is stationary or and I(1) variable. However, given that the ARDL methodology and by extension the nonlinear ARDL allows to operate with variables on integration of order 0 and 1, then the possible uncertainty is solved.

Following the ARDL methodology, we first select the adequate lags for each variable in an Equation (3) type. For this purpose the analysis starts from a high enough order of lags to ensure that the optimal range is not exceeded. To choose the optimal order of lags, the SIC is applied, which provides a model with two lags for y_t and none for the rest of the variables. These results can be seen in *Note* of Table 2 where, additionally, the bounds test for cointegration is shown. As can be observed, the computed *F*-statistics supports (at 5% significance level) the existence of a long-run cointegrating relationship among all the variables.

Once the existence of cointegration has been proved, the Wald test for asymmetries is applied. Thus, in Table 3, the null hypothesis for long-run symmetries (W_{LR}) is rejected in favor of long-run asymmetries. An oil price variation has then, a long-run asymmetric effect on the per capita GDP. The result is significant at 1%. The W_{SR}, on the other hand, indicates that there are no short-run asymmetries of oil prices impacts on per capita GDP. In fact, Table 3 indicates that the short run dynamics of p^+ and p^- are not

Table 1: ADFm test

Model variables	Innovational outlier			Additive outlier		
	I(1) versus I(0)	I(2) versus I(1)	DSP versus TSP	I(1) versus I(0)	I(2) versus I(1)	DSP versus TSP
y_t	−2.670(1) 1985	−5.712(0) 2007	−5.772(0) 2007	−4.020(11) 1974	−5.787(0) 2007	−5.889(0) 2007
P_t	−3.304(0) 1972	−9.649(0) 1974	−9.477(0) 1974	−3.166(0) 1970	−9.739(0) 1974	−9.612(0) 1974
h_t	−4.752(2) 1962	-	-	−2.186(11) 1988	−4.661(1) 1975	−10.882(0) 1964
k_t	−3.582(2) 1959	−6.831(0) 1974	−6.841(0) 1974	−2.010(1) 1985	−6.932(0) 1974	−6.990(0) 1974
Critical values (5%)	−4.44	−4.44	−4.85	−4.44	−4.44	−4.85

The numbers in parentheses are the lags used in the ADFm test in order to remove serial correlation in the residuals. Break dates are below the ADF statistic. DSP stands for DSP or I(1), and TSP means trend stationary process or I(0) with a trend process. ADFm: Modified augmented Dickey Fuller, DSP: Difference stationary process, TSP: Trend stationary process even significant in spite of having the expected sign. The model is robust in terms of the diagnostic tests, that is, it does not have problems of serial correlation (Lagrange multiplier test), normality (Jarque Bera test), functional form or misspecification (Ramsey test) and heteroskedaticity (Breusch and Pagan). Moreover, the CUSUM and CUSUM square tests of the residuals (Figures 3 and 4) support the stability of the dynamic NARDL model.

Table 3 also reports the dynamic results of the nonlinear ARDL model with the appropriate lags according to the model section chosen by SIC. The role of the long-run asymmetric effects of oil prices have to be seen in β^{+} and β^{-} which are both negative and significant at 1%. Specifically, a 1% increase in real oil prices has a negative impact on real per capita GDP of 0.110% whereas a 1% decrease in oil prices will have an increase in per capita GDP of a 0.198%. Positive impacts on oil prices have larger effects on the Spanish economy than negative shocks. These findings suggest that incentives on a cheaper oil price, for example through a reduction in domestic taxes, may have beneficial effects on the economy. However, because increases in oil prices generate smaller negative effects on the per capita GDP than oil price decreases then authorities will be always tempted to raise taxes.

Figure 3: Cumulative sum of residuals test for stability of parameters at 5% critical level

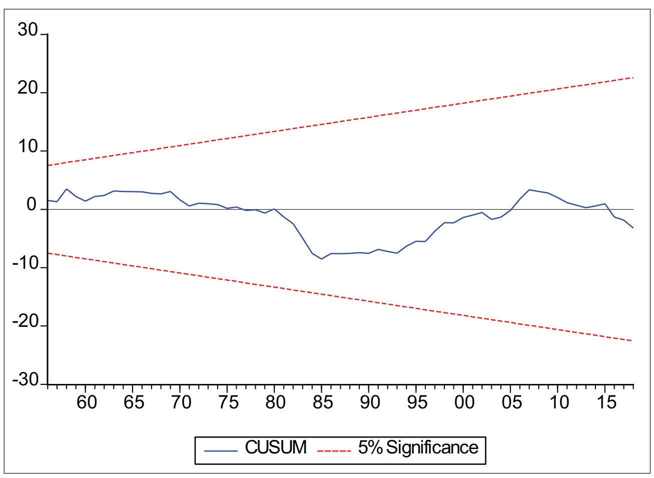
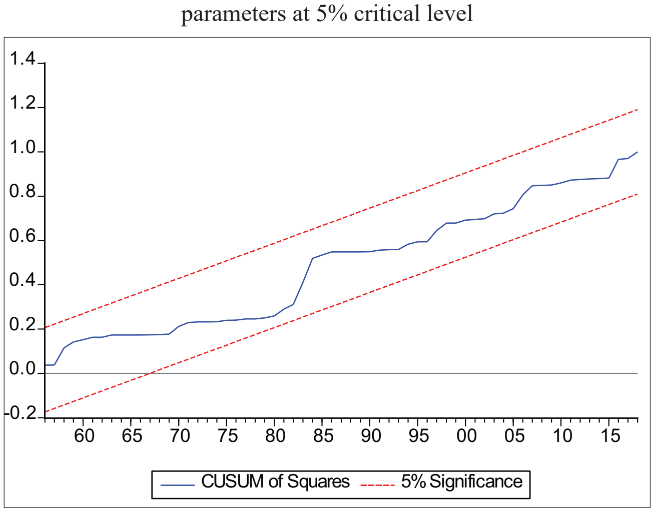


Figure 4: Cumulative sum of residual squares test for stability of parameters at 5% critical level



Cuñado and de Gracia (2003) did not find a long-run relationship between asymmetric oil prices and industrial output growth. However they did find short-run asymmetries between 1960 and 1999. Jiménez-Rodríguez and Sánchez (2005) and Lardic and Mignon (2008) found opposite results to this paper, that is, higher oil prices had a larger impact than lower prices. Their sample data goes from 1972-2001 and 1970 to 2000 respectively on a quarterly frequency. All these authors carried out the analysis for industrialized countries. Nevertheless they did not specifically implemented it for Spain as an individual case.

Although the rest of the variables, human (h) and physical capital (y) that shape the growth model framework are not the objective of this study their estimates are both positive and significant. Human capital and physical capital are expected to perform as long-term determinants of growth and this is proved here. Their long run elasticities, not shown in Table 3 but same calculation as oil prices, are 0.264 for h and 0.372 for k. An increase of 1% in education generates a 0.264% increase in the per capita GDP whereas an

Table 2: Bounds test for asymmetric cointegration

Dependent variable		y		
Explanatory variables	p^{+}	p^{-}	h	k
F-statistic		5.469		
Critical values (5%)				
Upper bounds		3.280		
Lower bounds		2.270		

Cointegration is done on the selected model according to Schwarz information criteria with optimum lag order (2, 0, 0, 0, 0)

Table 3: Dynamic NARDL estimates, statistics and tests (asymmetries in oil prices)

Variables	Coefficient	T-statistics	P-value
c	0.987***	2.733	0.008
y (−1)	−0.121***	−2.660	0.010
p^{+} (−1)	−0.018***	−2.853	0.006
p^{-} (−1)	−0.024***	−2.915	0.005
h (−1)	0.032***	2.835	0.006
k (−1)	0.045**	2.357	0.021
$dypc$ (−1)	0.271***	2.915	0.005
$dypc$ (−2)	−0.012	−0.125	0.901
dp^{+}	−0.015	−1.610	0.112
dp^{-}	−0.025	−1.277	0.206
dh	−0.110	−1.582	0.119
dk	0.158**	2.610	0.012
β^{+}	−0.149**	−2.086	0.040
β^{-}	−0.198***	−3.849	0.000
Statistics			
Adj. R^2	0.405		
S.E. of regression	0.028		
F-statistics	5.334		0.000
W_{LR}	7.200***		0.009
W_{SR}	0.126		0.723
Diagnostic tests			
Serial correlation			0.455
Functional form			0.114
Normality			0.869
Heteroscedasticity			0.478

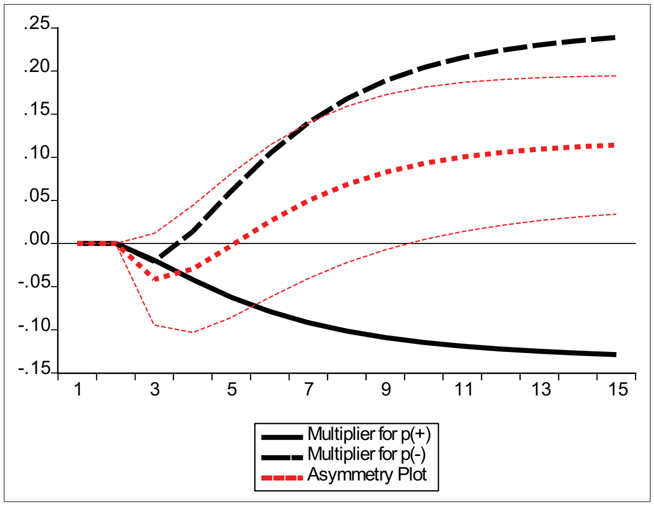
Variables starting with a d means differenced once; variables lagged one period are expressed as (−1). β^{+} and β^{-} are the asymmetric long-run parameters. S.E is standard error. W_{LR} and W_{SR} denote Wald test on long and short-run symmetry null hypotheses. *, **, *** Denote significance at 10%, 5%, 1% respectively. The NARDL model with the optimum lags is selected according to the Schwarz information criteria. NARDL: Nonlinear autoregressive distributed lag

Table 4: Static autoregressive distributed lag long-run estimates (no asymmetries in oil prices)

Variables	Coefficients	T-statistics	P-value
c	10.085***	11.626	0.000
p	−0.319*	−1.953	0.055
h	0.584***	3.803	0.000
k	0.182	1.235	0.220

*, **, *** Denote significance at 10%, 5%, 1% respectively

Figure 5: Dynamic multipliers



increase of 1% in investments would increase the economy in 0.372%. Short-run elasticity for *h* is not significant.

A quick comparison with the static ARDL model with no asymmetries (Table 4) shows that the long-run real oil price has a negative and significant value of 0.319 at 10%. The result with no asymmetries would tell us that a rise of 1% in oil price would operate as a lowering of 0.319 in per capita GDP and the same magnitude but all the way around with a decrease in oil prices. This obviously would be misleading if no asymmetries were tested and properly modeled.

The final step is the analysis of the short-run adjustment to either positive and/or negative impacts in real oil prices through the dynamic multipliers. The dynamic multipliers assume the adjustment asymmetry from an initial period to the new long-run equilibrium following an economic impact (positive/negative) on oil prices. The adjustment asymmetry strives from the interaction on a shock in oil prices and the reaction asymmetries in the per capita GDP (Equation 4). Thus, Figure 5 shows the predicted asymmetric path for the per capita GDP. As can be observed, unitary decreases in oil prices (dash line) have larger effects than unitary increases in oil prices (continuous line). This happens after the third period (no short-run asymmetries) as shown by the confident bands. The adjustment is remarkably slow and takes about 10 periods to observe the correction (asymmetric plot line with no increasing trend).

5. CONCLUSIONS AND POLICY

This paper examined the asymmetric effects of real oil prices on real per capita GDP in a growth model framework for the Spanish case between 1945 and 2018. The level of international real oil prices has been proved to have a meaningful long-run impact on the Spanish economy. Lower prices (p^-) increase the per capita GDP while higher prices (p^+) decrease it. However, the effects of negative (lower) prices are larger than those of positive (higher) prices leading this way to a more agile economic growth when oil prices are depressed. However, the adjustment asymmetry after an oil shock remains slow. Control variables as human capital and physical capital have a positive and significant impacts on the economy as it was expected.

Regarding energy policies, incentives on cheaper domestic oil prices like a reduction in taxes, might have beneficial effects on the economy. However, because oil price increases generate smaller negative effects on the per capita GDP than oil price decreases then authorities might be tempted more often than not to raise taxes. This is what they usually do more frequently. Many times, those decisions may be disguised in form of protection to the environment or as a spur to increase environmental awareness. Thus, by raising taxes on oil, authorities will discourage use of fuel oil in order to favor cleaner energies and, in general, change market agents' behavior. Such decisions not always have the aim at looking for greener alternatives but for obtaining further resources for the Estate.

Aside from managing taxes, authorities could take action in different directions. Making the necessary policy changes might minimize the negative effects of oil price increases over the long-term growth of the economy. Examples might be based on effectively increasing market competition and improving mechanisms for determining wages. According to the results of the present study, those mechanisms should work as an asymmetric way to better adjust to any perturbation in order for the economy to continue its steady-state path.

6. ACKNOWLEDGMENTS

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