DYNAMIC ECONOMETRIC MODELS
DOI: http://dx.doi.org/10.12775/DEM.2014.004 Vol. 14 (2014) 71−91

Submitted October 20, 2014 ISSN
Accepted December 23, 2014 1234-3862

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Oil Prices, Production and Inflation in the Selected EU Countries: Threshold Cointegration Approach**

A b s t r a c t. This paper applies the threshold cointegration technique developed by Enders and Siklos (2001) to investigate the impact of an oil price changes on changes in production and inflation in the presence of structural break in seven European Union countries. This technique will allow for a different speed of adjustment to the long-run equilibrium depending on whether production in selected economies is above or below the long-run relationship. Given the presence of asymmetric cointegration between oil prices, production and inflation, we estimate threshold error correction models to examine long- and short-run Granger causality. We found evidence for cointegration with asymmetric adjustment in the case of France, Denmark and the total EU.

K e y w o r d s: asymmetric adjustment, oil price shocks, threshold cointegration, non-linearity, threshold error correction model.

J E L Classification: C32, E23, E32, Q43.

Introduction

The relationship between oil prices and macroeconomy has drawn attention in many recent studies. Oil shocks have important effects on economic activity and macroeconomic policy of many countries. Barsky and Kilian

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** This work was financed from Faculty of Economic Sciences and Management research grant no. 1844-E.

(2004) shows that the economic slowdowns and increases of inflation rates can be leaded by huge and sudden increases in oil prices. Also, Brown and Yucel (2002) and Lardic and Mignon (2006) presented explanations of the oil price shocks on economic activity. The rises in the crude oil prices are transferred on the energy prices through the price of petroleum products. The rise in the energy price causes an decrease in productivity, which is passed on to real wages, unemployment, inflation, investment or stock prices. Therefore, it is important to investigate how the oil price shock are transmitted into economic activity, both in the short-run and long-run perspective.

The main goal of this study is to examine the dynamics between Brent oil prices and economic activity (described by the production and inflation) in the presence of structural break due to financial crisis. The error correction model with threshold cointegration is employed for the analysis of short-run relationship with non-linear long-term adjustment between production, inflation and oil prices. We assume two long-run relationships: first equation without taking into account a structural break and second equation including a structural break due to financial crisis in 2008. The analysis uses the nonlinear threshold cointegration elaborated by Enders and Granger (1998) and Enders and Siklos (2001). This technique will allow for a different speed of adjustment to the long-run equilibrium depending on whether production in selected economies is above or below the long-run relationship. At the end, an error correction model with threshold cointegration is utilized to analyze the short-run and long-run Granger causality. In the analysis the monthly data of Brent crude oil prices from 1995:01 to 2014:04, industry production index and consumer price index for the European Union economy and six European countries: Germany, France, Denmark, Nederland, Poland and Czech Republic are used. The data were taken from the U.S. Energy Information Administration database, the OECD database and Eurostat database. These economies have been selected on the basis of three criteria: level of economic growth, structure of net imports of crude oil and gas, and structure of final energy consumption in industry. Characteristics of countries according to selected criteria is presented in Table 1.

Besides these six economies, the total EU was taken into account when investigating the relationship between oil prices, production and inflation. This will allow to compare the results for chosen six economies and total average for the EU.

Table 1. Characteristics of countries according to selected criteria

Country	Description
Germany (DE) France (FR)	Two highly developed countries in the EU with the highest GDP in 2012, the highest net imports of crude oil and gas in 2012 and the highest final energy consumption in industry (Germany 61.15 Mtoe; France 29.58 Mtoe).
Nederland (NL) Denmark (DN)	Two highly developed countries in the EU economies with different structure of imports and exports of crude oil and/or gas. Nederland is a gas net exporter and crude oil net importer. Denmark is a net exporter of both, crude oil and gas.
Poland (PL) Czech Republic (CZ)	Two developing countries in the EU with the highest economic growth in 2012 among Central and Eastern Europe countries (CEE). Poland and Czech Republic are countries with the highest net imports of crude oil and gas in 2012 and the highest final energy consumption in industry among the CEE countries.

The plan of this paper is as follows. Section 1 presents the empirical literature review. Section 2 reviews the methodology applied in this paper. Empirical results of threshold cointegration and Granger-causality test based on threshold error correction model are presented in Section 3 and Section 4. The last section draws some conclusions.

1. A Brief Overview of the Empirical Studies

Many studies are available which offer different theoretical explanations for the relationship between oil price changes and the level of economic activity. Hamilton (1983) using post-war data found a statistically significant relationship between oil price changes and GDP in US economy. Gisser and Godwin (1986) and Burbridge and Harrison (1984), among others, confirm the Hamilton's results. They identified the causal relationship between oil prices and economic variables, i.e. real GDP, general price level, rate of unemployment and real investment. Gisser and Goodwin (1986) indicated for the analyzed period from 1961 to 1982 that the oil prices had not lost its potential to predict GDP growth. They showed also, that oil shocks have an impact on production by other means than inflationary cost-push effects. They confirmed Hamilton's (1983) results about negative correlation between oil prices and real output in United States. Burbidge and Harrison (1984) found similar correlations for other industrialized countries.

A number of authors have suggested that the relation between oil price shocks and economic variables is nonlinear. Linear approximation to the relation between oil price shock and macroeconomic activity may appear unstable over time. It is caused by shifts in the process generating oil prices (Mork, 1989; Hamilton, 1996; Davis and Haltiwanger, 2001). This means that the economic activity may respond asymmetrically to positive and negative oil price shocks, i.e. the increases of oil prices slow the economy more than the decreases of oil prices stimulate it (Brown and Yucel, 2002). The impact of oil price decreases is not always positive, indeed these decreases may slow output growth down. Mork (1989) shows that the relationship between oil price changes and real GNP growth for the U.S. economy breaks down when the analysis is extended to include the oil price collapse of 1986. Hence, Mork (1989) decided to test the influence of declines and increases in oil price on the economic growth, he showed that the coefficient on oil price increases are highly significant and negative. In another work, Mork et al. (1994) showed that for the most of European countries a negative relationship between oil price increases and GDP growth occurs. However, evidence for the causal relationship between oil prices and economic growth was not always confirmed in empirical studies. For example Hooker (1996) found some evidence that oil prices are no longer Granger cause of GDP. In direct response to this empirical work, Hamilton (1996) showed new measure (net oil price increases-NOPI- difference between oil price level and the maximum price of the previous four quarters) which was able to detect a significant relationship between oil prices and real GDP. The NOPI-measure from assumption is the measure of rapid and huge changes in oil prices.

According to most empirical studies the rising oil prices lead to real GDP loses and it is consistent with the economic theory, though, it is possible to find the positive response of production to changes in oil prices. This kind of findings, however, should not be treated as inconsistent with economic theory since, as Bernanke et. al (1997) showed on the example of the U.S. economy, the response of production to an oil price shock may be different depending on the response of monetary policy to oil prices shocks (i.e. whether the federal funds rate is constrained to be constant than in the case in which monetary policy is unconstrained). If the federal funds rate is held constant, a positive oil price shock leads to an increase in real GDP. In the unconstrained case, a positive oil prices shock leads to a decline in real GDP. Similar findings concern the response of GDP to changes in inflation, i.e. although the economic theory indicates that movements in inflation cause a decrease in production, there are some empirical findings indicating the opposite direction of relationship. The reason why increases in inflation have positive influence on economic growth can be explained in the framework of the optimal rate of inflation (Friedman, 1976; Belka, 1986; Barro, 1995). If the inflation is below the optimal level, then the reaction of production is positive (slight increase to the optimal level of inflation stimulates the economic growth). While, the impact of inflation on production is negative (an increase in inflation causes a decrease in production) when consumer price level is higher than the optimal one.

Most of empirical literature on relationships between oil prices and economic activity focuses on the US economy. Europe, despite of economic size and huge oil import, has received relatively less attention. Only few studies focus on this issue, e.g. Scholtens and Yurtsever (2012) and Arouri (2011) investigated how European industries responded to oil price shock. They found that the impact of oil price shocks substantially differed along the different industries. They also found that the significance of the result differs along the various oil price specifications. To studies considering this relationship for some European countries belong the papers by Jimenez-Rodriguez and Sanchez (2005) and Papapetrou (2001). The former confirmed positive effects of oil price decreases on output for Japan, Germany, France, Canada, Norway and the United Kingdom. And the latter found causal relationship from oil prices to industrial production, employment and share prices in Greek economy. To our knowledge, there is no such study which considers the relationship between oil prices changes and economic activity using threshold cointegration methodology with non-linear adjustment for the countries studied in this paper.

2. Methodology

To test the relationship between Brent oil prices and economic activity (described by the production and inflation) in the asymmetric framework the threshold cointegration technique developed by Enders and Granger (1998) and Enders and Siklos (2001) is used. Similarly to Engle-Granger (1987) procedure, this is indeed a residual-based two-stage estimation. In the first stage the long-run relationship between production, inflation and oil prices is considered, e.g. in the following form:

$$P_t = \beta_0 + \beta_1 B_t + \beta_2 In_t + \mu_t, \tag{1}$$

where P_t − stands for production, B_t − for oil prices and In_t − for inflation, μ_t − disturbance term.

The second stage focuses on the coefficient estimates of ρ_1 and ρ_2 in the following regression:

$$\Delta\mu_t = I_t \rho_1 \mu_{t-1} + (1 - I_t)\rho_2 \mu_{t-1} + \sum_{i=1}^{r} \theta_i \Delta\mu_{t-i} + \varepsilon_t, \qquad (2)$$

where ε_t is a white noise disturbance.

Term I_t is the Heaviside indicator function I_t such that $I_t = 1$ if $\mu_{t-1} \geq \tau$ and $I_t = 0$ if $\mu_{t-1} < \tau$, where τ is the threshold value.

Then, equation (2) is a threshold autoregressive (TAR) model of the disequilibrium error. If the Heaviside indicator depends not on levels but on changes of μ_{t-1}, then it is specified as $I_t = 1$ if $\Delta\mu_{t-1} \geq \tau$ and $I_t = 0$ if $\Delta\mu_{t-1} < \tau$. This model is termed the momentum threshold autoregressive (M-TAR) model. The TAR framework is designed to capture potential asymmetric movements in residuals μ_t when they are above or below the long-run equilibrium, while the M-TAR framework − the direction of these movements, in other words their momentum (Fosten et. al, 2012).

The necessary and sufficient condition for μ_t to be stationary is: $\rho_1 < 0$, $\rho_2 < 0$, $(1+\rho_1)(1+\rho_2) < 1$ for any threshold value τ (Petruccelli, Woolford, 1984). If these conditions are satisfied and threshold value τ is set to zero (as occurs in many economic applications), $\mu_t = 0$ can be considered as the long-run equilibrium value of the sequence. If μ_t is higher than the long-run equilibrium, the adjustment is $\rho_1\mu_{t-1}$, but if μ_t is lower than the long-run equilibrium, the adjustment is $\rho_2\mu_{t-1}$. In general, the threshold value τ has to be estimated along with the values of adjustment parameters ρ_1 and ρ_2. In our studies we follow Enders and Siklos (2001) and Yau and Nieh (2009) by employing Chan's (1993) methodology of searching the consistent estimates of threshold value.

Testing for threshold cointegration is performed in two steps. First, the null hypothesis of no cointegration $H_0 : \rho_1 = \rho_2 = 0$ is tested, and when it is rejected, then the null hypothesis of symmetric adjustment, $H_0 : \rho_1 = \rho_2$, is verified. To test the first hypothesis Enders and Siklos (2001) proposed the Φ_μ statistics which under the null of no cointegration has a non standard distribution. The critical values for this non standard Φ_μ statistics are tabulated in their paper. The second null hypothesis of asymmetric adjustment is tested using the standard F statistics. Rejecting both the null hypotheses implies the existence of threshold cointegration with asymmetric adjustment.

Given the threshold cointegration is found, the next step proceeds with the Granger-causality test using threshold (or momentum-threshold) error correction model (TAR-ECM or M-TAR-ECM) (Enders, Granger, 1998; Enders, Siklos, 2001). This model is expressed as the following:

$$\Delta Y_{jt} = \beta + \gamma_{j1} Z_{t-1}^{+} + \gamma_{j2} Z_{t-1}^{-} + \sum\nolimits_{i=1}^{q_1} \delta_{ji} \Delta P_{t-i} + \sum\nolimits_{i=1}^{q_2} \theta_{ji} \Delta In_{t-i} + \sum\nolimits_{i=1}^{q_3} \varphi_{ji} \Delta B_{t-i} + v_t \tag{3}$$

where $\Delta Y_{jt} = (\Delta P_t, \Delta In_t, \Delta B_t)$, $j = 1, 2, 3$, $Z_{t-1}^{+} = I_t \mu_{t-1}$ and $Z_{t-1}^{-} = (1 - I_t)\mu_{t-1}$, I_t − Heaviside indicator function, v_t is a white noise disturbance. The long-run causality is determined by the parameters γ_1 and γ_2. The short-run causality is governed by the parameters δ_i, θ_i and φ_i and may come either from its own history of lagged dynamics or from the lagged effects of changes in real GDP (and square real GDP) and/or some additional explanatory variables (e.g. energy consumption). It is also desirable to check whether this two sources of causation are jointly significant.

3. Threshold Cointegration – Empirical Analysis

In this section, an integration and threshold cointegration analysis between Brent oil prices, production and inflation in German, France, Nederland, Denmark, Poland, Czech Republic and European Union economies are discussed. The data consist of seasonally adjusted monthly industrial production index at constant prices of 2010, consumer price index for the EU countries (corresponding month of previous year = 100) and Brent crude oil prices from January 1995 to April 2014. For seasonal adjustment the TRAMO/SEATS procedure was used. Each time series has been transformed using the natural logarithm. Then empirical threshold error correction models for oil prices, inflation and production are constructed to study short and long-run causality.

To assess the time series properties of the data, we examine the order of integration for all variables involved. We run the conventional unit root test, the Augmented Dickey-Fuller test.

Findings from the ADF test, as shown in Table 2, reveal that each series is integrated of first order, $I(1)$, at least at the 5% significance level.

Since the studied time span includes the period 2008-2009 when the financial crisis occurred[1] and the presence of a structural break may change the nature of the long-run relationship between production, inflation and oil prices, from the very start we assume both the log-run relationship without

[1] Visual inspections of production suggests that the shift in mean occurred about September 2008.

taking into account a structural break (eq. (4)) and long-run relationship in the presence of structural break (eq. (5)). The first model takes the following form:

$$P_t = \beta_0 + \beta_1 B_t + \beta_2 In_t + \beta_3 time + u_t , \tag{4}$$

where P_t, I_t denote respectively the industrial production index and consumer price index in selected economies, B_t stands for Brent crude oil prices; all variables are in natural logarithms;
and the second model has the form:

$$P_t = \beta_0 + \beta_1 B_t + \beta_2 In_t + \beta_3 time + \beta_4 DT_t^*(\lambda) + \mu_t , \tag{5}$$

where $DT_t^*(\lambda)$ is the dummy variable for the break in constant term of production from the chosen exogenously breakpoint λ so $DT_t^*(\lambda) = 1$ if $t > 2008{:}09$ and 0 otherwise.

Table 2. Results of the ADF test

Country	Variable	ADF		
		Levels		First differences
		C only	C and t	C only
–	Brent Oil Price	–1.04 [1]	–3.23 [1]*	–9.51 [1]***
Germany (DE)	Production	–0.96 [1]	–2.18 [1]	–9.89 [1]***
	Inflation	–3.03 [1]**	–3.07 [1]	–10.51 [1]***
France (FR)	Production	–1.14 [1]	–1.58 [1]	–11.12 [1]***
	Inflation	–3.02 [1]**	–3.00 [1]	–10.01 [1]***
Nederland (NL)	Production	–2.18 [1]	–2.23 [1]	–15.69 [1]***
	Inflation	–2.57 [1]*	–2.63 [1]	–10.54 [1]***
Denmark (DN)	Production	–2.51 [1]	–2.43 [1]	–13.34 [1]***
	Inflation	–2.82 [1]*	–2.95 [1]	–9.95 [1]***
Poland (PL)	Production	–0.80 [1]	–2.19 [1]	–11.52 [1]***
	Inflation	–3.13 [1]**	–3.15 [1]*	–7.71 [1]***
Czech Republic (CZ)	Production	–0.76 [1]	–2.02 [1]	–13.04 [1]***
	Inflation	–2.10 [1]	–2.50 [1]	–7.71 [1]***
European Union (EU)	Production	–1.12 [1]	–1.69 [1]	–6.09 [1]***
	Inflation	–2.97 [1]**	–3.05 [1]	–8.61 [1]***

Note: asymptotical critical values for the ADFmax test statistics: –3.46 (1%); –2.88 (5%); –2.57 (10%) (ADF regression with drift – C only); asymptotical critical values for the ADFmax test statistics: –3.99 (1%); –3.43 (5%); –3.13 (10%) (ADF regression with an intercept and trend – C and t); ***, ** and * denote significant at 1%, 5% and 10% levels, respectively.

Table 3. Estimated parameters of long-run equilibrium for production

Country	Estimated parameters of long-run equation					ADF
	Const.	B_t	In_t	*time*	$DT_t(\lambda)$	Levels (C+t)
Long-run relationship without structural break (4)						
Germany (DE)	–17.02	0.020	4.616	0.001	–	–3.29*
	(–7.63)***	(1.65)*	(9.48)***	(10.27)***		
France (FR)	–10.839	–0.022	3.373	0.0001	–	–2.05
	(–4.21)***	(–1.38)	(6.00)***	(19.8)***		
Nederland (NL)	0.936	0.053	0.718	0.001	–	–4.64***
	(0.74)	(6.49)***	(2.62)***	(5.99)***		
Denmark (DN)	–1.965	0.003	1.428	0.0001	–	–2.48
	(–0.54)	(0.14)	(1.81)*	(0.62)		
Poland (PL)	5.083	0.110	–0.351	0.003	–	–2.78
	(15.31)***	(9.20)***	(–4.85)***	(21.92)***		
Czech Republic	1.605	0.132	0.466	0.002	–	–2.81
(CZ)	(2.12)**	(8.87)***	(2.84)***	(8.47)***		
European	9.645	0.132	–1.172	–0.001	–	–3.73**
Union (EU)	(6.7)***	(10.98)***	(–3.74)***	(–7.12)***		
Long-run relationship with structural break (5)						
Germany (DE)	–11.67	0.017	3.455	0.002	–0.077	–3.65 ***
	(–5.97)***	(1.67)*	(8.11)***	(15.11)***	(–9.78)***	
France (FR)	0.509	–0.031	0.909	0.001	–0.017	–3.78***
	(0.40)	(–4.13)***	(3.27)***	(11.65)***	(–28.3)***	
Nederland (NL)	1.387	0.036	0.626	0.001	–0.063	–5.94***
	(1.29)	(4.97)***	(2.67)***	(11.33)***	(–9.61)***	
Denmark (DN)	–6.748	–0.069	2.484	0.002	–0.245	–6.82***
	(–3.97)***	(–6.92)***	(6.73)***	(17.12)***	(–28.67)	
Poland (PL)	3.287	0.064	0.047	0.005	–0.07	–2.73
	(6.05)***	(3.93)***	(0.4)	(14.49)***	(–4.1)***	
Czech Republic	–1.012	0.074	1.046	0.003	–0.154	–4.48***
(CZ)	(–1.84)*	(6.75)***	(8.74)***	(19.32)***	(–15.67)***	
European	1.771	0.025	0.576	0.001	–0.142	–4.37***
Union (EU)	(1.95)*	(2.91)***	(2.90)***	(8.14)***	(–20.47)***	

Note: ***, ** and * denote significance at 1%, 5% and 10% level respectively; in parentheses the *t*-statistics are given.

Table 3 presents the estimation results of eq. (4) and eq. (5). It is worth noting that for the long-run equation without a structural break only in the case of France the response of production to the change in oil prices is negative ($\beta_1 < 0$). Having included the dummy variable for a structural break in eq. (5), except France, only in the case of Denmark the negative response of production is additionally observed and for the rest of countries (Germany, Nederland, Poland, Czech Republic and European Union) the positive response of production to changes in oil prices is found. The response of GDP to changes in inflation is positive too. Positive impact of oil prices on pro-

duction can be explained by the monetary policy carried out by the European Central Bank (ECB). While the ECB reacting to the financial crisis in 2008 increased the interest rates and then in recession phase reduced them, the interest rates before the financial crisis were held constant. This may explain why the response of production to oil price shocks (Table 3) is positive as suggested by Bernanke et. al (1997) − see comments in Section 1.
But the positive response of GDP to changes in inflation can be explained by low inflation rate, near to optimal one (the general price level was comparatively stable, except 2008 when inflation increased near to 4 per cent (increased by 4 percentage points in Euro Zone) – see comments in Section 1.

While in the case of long-run equilibrium relationship without a structural break the cointegration is found for Germany, Nederland and the EU, in the case of long-run relationship allowing for a structural break the cointegration is found for Germany, France, Netherlands, Denmark, Czech Republic and the European Union.

However, the standard cointegration framework (Engle-Granger approach) assuming symmetric adjustment toward equilibrium is misspecified if the adjustment is asymmetric. Therefore, to test for cointegration with non-linear (asymmetric) adjustment, we use the threshold cointegration approach proposed by Enders and Siklos (2001). In further analysis we use only the results based on residuals from long-run relationship with a structural break in 2008. Table 4 contains cointegration test results based on the long-run equilibrium relationships for production in selected countries in the form of equation (5), when considering threshold and momentum adjustment. We consider threshold autoregressive (TAR) model and momentum threshold autoregressive (M-TAR) model with zero-value of threshold, $\tau = 0$, and also with non-zero value of threshold $\tau \neq 0$ which should be estimated. The table reports values of the adjustment coefficients ρ_1 and ρ_2, the Φ_μ statistics for the null hypothesis of no cointegration against the alternative of cointegration with asymmetric adjustment, the F statistics for testing the symmetric adjustment, AIC and Ljung-Box statistics.

The results for the threshold cointegration tests present some interesting relations among oil prices, production and inflation in selected economies.

Table 4. Results of TAR and M-TAR test for threshold cointegration on the long-run equation with one structural break in production

	Threshold cointegration test			
	$\tau = 0$		$\tau \neq 0$	
	TAR	M-TAR	TAR	M-TAR
	Germany (DE)			
τ	0	0	–0.016	–0.013
ρ_1	–0.123 (2.23)**	–0.037 (0.69)	–0.089 (1.65)*	–0.100 (2.30)**
ρ_2	–0.161 (3.06)***	–0.243 (4.64)***	–0.196 (3.68)***	–0.286 (3.66)***
Φ_μ	6.882**	10.865**	7.859**	9.057**
$F(\rho_1–\rho_2=0)$	0.266 [0.61]	7.875 [0.01]**	2.109 [0.15]	4.447 [0.04]**
Lag	1	1	1	1
AIC	–1207.7	–1215.2	–1209.5	–1211.9
LB(4)	3.87 [0.42]	4.88 [0.30]	4.13 [0.39]	4.40 [0.36]
	France (FR)			
τ	0	0	–0.022	–0.008
ρ_1	–0.114 (2.01)**	–0.067 (1.07)	–0.118 (2.19)**	–0.096 (1.91)*
ρ_2	–0.197 (3.05)***	–0.219 (3.76)***	–0.207 (2.94)***	–0.290 (3.72)***
Φ_μ	6.208**	7.423**	6.247*	8.17**
$F(\rho_1–\rho_2=0)$	1.048 [0.31]	3.41 [0.07]*	1.121 [0.29]	4.834 [0.03]**
Lag	2	2	2	2
AIC	–1281.3	–1283.7	–1281.4	–1285.1
LB(4)	1.47 [0.83]	1.75 [0.78]	1.44 [0.84]	1.26 [0.87]
	Netherlands (NL)			
τ	0	0	0.011	0.022
ρ_1	–0.337 (3.93)***	–0.278 (3.04)***	–0.334 (3.87)***	–0.373 (2.69)**
ρ_2	–0.318 (3.54)***	–0.371 (4.36)***	–0.322 (3.61)***	–0.321 (4.52)***
Φ_μ	11.404**	11.715**	11.395**	12.191**
$F(\rho_1–\rho_2=0)$	0.031 [0.86]	0.688 [0.41]	0.013 [0.91]	1.551 [0.21]
Lag	2	2	2	2
AIC	–1090.3	–1091	–1090.3	–1090.5
LB(4)	0.80 [0.94]	0.77 [0.94]	0.81 [0.94]	0.84 [0.93]
	Denmark (DN)			
τ	0	0	0.031	–0.020
ρ_1	–0.38 (4.69)***	–0.47 (4.73)***	–0.386 (4.48)***	–0.357 (5.14)***
ρ_2	–0.458 (5.56)***	–0.394 (5.53)***	–0.443 (5.52)***	–0.572 (5.52)***
Φ_μ	23.671**	23.517**	23.524**	25.26**
$F(\rho_1-\rho_2=0)$	0.517 [0.47]	0.431 [0.51]	0.272 [0.60]	3.323 [0.07]*
Lag	1	1	1	1
AIC	–975	–974.9	–974.8	–977.8
LB(4)	1.96 [0.74]	2.54 [0.64]	2.05 [0.73]	4.50 [0.83]

Table 4 (continued)

		Poland (PL)		
τ	0	0	-0.012	0.015
ρ_1	–0.126 (2.67)***	–0.136 (2.84)***	–0.134 (2.85)***	–0.124 (1.67)*
ρ_2	–0.061 (1.26)	–0.053 (1.13)	–0.052 (1.08)	–0.086 (2.27)**
Φ_μ	4.256	4.546	4.546	3.846
$F(\rho_1–\rho_2=0)$	0.972 [0.33]	1.572 [0.21]	1.533 [0.22]	0.212 [0.65]
Lag	1	1	1	1
AIC	–1136.2	–1136.8	–1136.8	–1135.4
LB(4)	0.05 [0.99]	0.08 [0.99]	0.05 [0.99]	0.05 [0.99]
		Czech Republic (CZ)		
τ	0	0	0.03	–0.017
ρ_1	–0.184 (2.79)***	–0.24 (3.48)***	–0.203 (2.87)***	–0.192 (3.65)***
ρ_2	–0.192 (2.95)***	–0.148 (2.37)**	–0.179 (2.88)***	–0.173 (1.68)*
Φ_μ	7.437**	8.092**	7.408**	7.353**
$F(\rho_1–\rho_2=0)$	0.005 [0.94]	1.296 [0.26]	0.074 [0.79]	0.032 [0.86]
Lag	2	2	2	2
AIC	–1026.2	–1010.1	–1026.3	–1026.2
LB(4)	0.11 [0.99]	0.07 [0.99]	0.10 [0.99]	0.11 [0.99]
		European Union (EU)		
τ	0	0	0.003	–0.006
ρ_1	–0.155 (2.84)***	–0.061 (1.07)	–0.153 (2.79)***	–0.082 (1.75)*
ρ_2	–0.200 (3.44)***	–0.274 (5.21)***	–0.203 (3.48)***	–0.368 (5.61)***
Φ_μ	9.901**	14.117**	9.942**	17.037**
$F(\rho_1–\rho_2=0)$	0.333 [0.56]	8.126 [0.004]***	0.407 [0.52]	13.465 [<0.01]***
Lag	1	1	1	1
AIC	–1238	–1245.6	–1238.1	–1250.7
LB(4)	2.76 [0.60]	2.59 [0.63]	2.47 [0.65]	3.30 [0.51]

Note: ***, ** and * denote significance at 1%, 5% and 10% level respectively; in parentheses the *t*-statistics are given; in brackets the *p*-values are given.

It can be seen that both the null hypotheses of $\rho_1 = \rho_2 = 0$ and $\rho_1 - \rho_2 = 0$ (the null of no cointegration and the null of symmetric adjustment respectively) are rejected for Germany, France, Denmark and European Union. This finding implies the existence of threshold cointegration with asymmetric adjustment for these countries and the EU what means that the adjustment back to equilibrium between production, inflation and oil prices is non-linear. To select the best adjustment mechanism (TAR or M-TAR) the Akaike information criterion (AIC) is used (the minimum AIC is reported in bold in Table 4). In case of Germany the M-TAR model with zero-value of threshold is selected, and in case of France, Denmark and the EU − the M-TAR model with non-zero threshold value. Selection of M-TAR model indicates that the direction in which production is moving (its momentum) matters more than whether production is above or below the equilibrium (as in TAR model). It is worth noting that all adjustment coefficients (ρ_1 and ρ_2) have negative signs acting to eliminate deviations from the long-run relationship and are significant for either or both regimes. The point estimates ρ_1 and ρ_2 in the case of above mentioned countries indicate that deviations below the threshold adjust faster toward the long-run equilibrium than the deviations above the threshold (since $|\rho_1| < |\rho_2|$). In other words, deviations below the threshold from the long-run equilibrium resulting from decreases in production or increases in inflation and oil prices are corrected (eliminated) more quickly than deviations above the threshold). These models differ with regard to the magnitude of ρ terms in regimes (below and above the threshold value. The largest discrepancy between the elimination of below and above threshold deviations occurs for Germany, France and the EU, e.g. for the EU the deviations below the threshold are eliminated at 36.8% rate per month, while deviations above the threshold are eliminated only at a rate of 8.2%.

Although for Nederland and Czech Republic the null hypothesis of no cointegration is rejected, no support is found for cointegration with asymmetric adjustment (since the null of symmetric adjustment is not rejected, see *F* statistics in Table 4). The results for Polish economy show that both the null hypothesis of no cointegration and symmetric adjustment are not rejected, suggesting oil prices, production and inflation in Poland are not cointegrated.

These results showed that the threshold cointegration occurs only for the developed countries (i.e. Germany, France, Denmark) those contribution to the total production of the EU is the highest. This is the reason why for the total EU the threshold cointegration has been also confirmed. Since the speed of adjustment is faster in the lower regime (deviations in production below the threshold), these countries and the EU as a whole have the mechanism that enable them to quickly revert to equilibrium after moving away from it or in other words, economies remain shorter period of time in the regime of slower economic activity. For Poland and Czech Republic belonging to the developing countries with lower level of GDP than averagely for the total EU or developed countries no evidence in favor of the threshold cointegration with asymmetric adjustment has been found.

4. Granger Causality Analysis form Threshold Error Correction Model

Given the threshold cointegration results found in the previous Section, the next step proceeds with Granger causality test using the momentum threshold error correction model (M-TAR-ECM). In our case, the M-TAR-ECM models take the following forms:

$$\Delta P_t = \alpha + \gamma_{11} Z^{+}_{t-1} + \gamma_{12} Z^{-}_{t-1} + \sum_{i=1}^{3} \delta_{1i} \Delta P_{t-i} + \theta_{11} \Delta In_{t-i} + \varphi_{11} \Delta B_{t-1} + \xi_t, \quad (6)$$

$$\Delta In_t = \alpha + \gamma_{21} Z^{+}_{t-1} + \gamma_{22} Z^{-}_{t-1} + \sum_{i=1}^{3} \delta_{2i} \Delta P_{t-i} + \theta_{21} \Delta In_{t-i} + \varphi_{21} \Delta B_{t-1} + \zeta_t, \quad (7)$$

$$\Delta B_t = \alpha + \gamma_{31} Z^{+}_{t-1} + \gamma_{32} Z^{-}_{t-1} + \sum_{i=1}^{3} \delta_{3i} \Delta P_{t-i} + \theta_{31} \Delta In_{t-i} + \varphi_{31} \Delta B_{t-1} + \nu_t, \quad (8)$$

where ΔP_t, ΔIn_t denote log first differences of production and inflation in Germany (DE), France (FR), Denmark (DN) and European Union (EU) respectively, ΔB_t stands for the log differences of Brent crude oil prices. Here, $Z^{+}_{t-1} = I_t \Delta\mu_{t-1}$ and $Z^{-}_{t-1} = (1 - I_t)\Delta\mu_{t-1}$, given $I_t = 1$ if $\Delta\mu_{t-1} \geq \tau$, and $I_t = 0$ if $\Delta\mu_{t-1} < \tau$. Furthermore, μ_t is the residual from long-run equation (5) for a given country and ξ_t, ζ_t, ν_t are the white noise disturbance.

This approach allows us to distinguish between short-run and long-run Granger causality. Since Granger causality tests are very sensitive to the selection of lag length, we apply the AIC criterion to determinate the appropriate lag lengths. It is found that the lag length of production equals 3 and for both inflation and Brent oil prices is equal to one for all the economies.

The Wald *F*-statistics for Granger causality is employed to examine whether all the coefficients of a given first differenced variable are jointly statistically different from zero (short-run causality) and *t*-statistics for the γ_1, γ_2 coefficients of error correction term to test their significance (long-run causality). Moreover, the jointly significance of the γ coefficients and all the coefficients of a given explanatory variable is tested in order to indicate which variables bear the burden of short-run adjustment to restore the long-run equilibrium given a shock to the system.

Tables 5 and 6 present the results of the Granger-causality test based on M-TAR-ECM models for oil prices, inflation and production.

Table 5. Estimates of threshold ECM models and Granger-causality analysis (case of Germany and France)

	Germany (DE) M-TAR-ECM ($\tau = 0$)			France (FR) M-TAR-ECM ($\tau = -0.008$)		
	ΔB_t	ΔIn_t	ΔP_t	ΔB_t	ΔIn_t	ΔP_t
$\gamma_1 Z^+_{t-1}$	0.027 (0.099)	0.0257 (2.979)***	–0.158 (–3.549)***	–0.242 (–0.793)	0.0042 (0.462)	–0.052 (–1.269)
$\gamma_2 Z^-_{t-1}$	–0.2363 (–0.863)	0.0051 (0.596)	–0.101 (–2.325)***	–0.651 (–0.443)	0.005 (0.38)	–0.244 (–4.104)***
H_0: $\gamma_1=\gamma_2=0$	0.3821 [0.683]	4.544 [0.012]**	8.6267 [<0.01]***	1.398 [0.249]	0.677 [0.509]	9.246 [<0.01]***
H_0: $\gamma_1=\gamma_2$	0.479 [0.49]	3.039 [0.08]*	0.853 [0.357]	0.573 [0.45]	0.0023 [0.96]	7.028 [<0.01]***
H_0: $\delta_1=\delta_2=\delta_3=0$	0.931 [0.336]	0.0275 [0.869]		2.973 [0.086]*	0.0303 [0.862]	
H_0: $\delta_1=\delta_2=\delta_3=\gamma_1=0$	0.5061 [0.604]	5.383 [<0.01]***		1.615 [0.201]	0.673 [0.511]	
H_0: $\delta_1=\delta_2=\delta_3=\gamma_2=0$	0.6792 [0.508]	0.276 [0.759]		2.588 [0.077]*	0.123 [0.884]	
H_0: $\theta_1=0$	0.0026 [0.96]		3.286 [0.071]*	0.025 [0.874]		0.006 [0.938]
H_0: $\theta_1=\gamma_1=0$	0.0056 [0.99]		9.066 [<0.01]***	0.3187 [0.728]		0.806 [0.448]
H_0: $\theta_1=\gamma_2=0$	0.378 [0.69]		4.583 [0.011]**	1.115 [0.329]		8.496 [<0.01]***
H_0: $\varphi_1=0$		17.378 [<0.01]***	4.589 [0.033]**		8.35 [<0.01]***	7.017 [<0.01]***
H_0: $\varphi_1=\gamma_1=0$		12.062 [<0.01]***	9.393 [<0.01]***		4.19 [0.016]**	4.697 [0.011]**
H_0: $\varphi_1=\gamma_2=0$		8.697 [<0.01]***	5.609 [<0.01]***		4.189 [0.018]**	12.808 [<0.01]***
LB(4)	0.91 [0.92]	1.84 [0.77]	3.31 [0.51]	0.85 [0.93]	5.28 [0.26]	1.22 [0.75]

Note: *** (**) (*) indicate significance at 1% (5%) (10%) level. *t*-statistics for λ_1, λ_2 in parentheses. *p*-values for Wald statistics in brackets. LB(4) for Ljung-Box statistics along with p-values.

It is clear (Table 5 and 6) that the point estimates of γ_1 and γ_2 in all M-TAR-ECM models for ΔP_t have a negative sign but only for Germany and Denmark both are significant (for France and the EU only the coefficient γ_2 is significant). In the case of France, Denmark and the EU, similarly to the findings in Table 4, the production deviations below the threshold adjust faster toward the long-run relationship than the deviations above the thresh-

Table 6. Estimates of threshold ECM models and Granger-causality analysis (case of Denmark and the total EU)

	Denmark (DN) M-TAR-ECM (τ = –0.020)			European Union (EU) M-TAR-ECM (τ = –0.006)		
	ΔB_t	ΔIn_t	ΔP_t	ΔB_t	ΔIn_t	ΔP_t
$\gamma_1 Z^+_{t-1}$	–0.79 (–3.58)***	–0.013 (–2.044)**	–0.23 (–3.466)***	0.481 (1.251)	0.016 (1.645)	–0.044 (–1.388)
$\gamma_2 Z^-_{t-1}$	–0.167 (–0.514)	–0.016 (–1.707)*	–0.513 (–5.242)***	–0.992 (–1.943)*	–0.0089 (–0.686)	–0.2701 (–6.48)***
H_0: γ_1=γ_2=0	6.4086 [<0.01]***	3.073 [0.048]**	17.318 [<0.01]***	2.594 [0.077]*	1.553 [0.214]	22.277 [<0.01]***
H_0: γ_1=γ_2	2.9376 [0.088]*	0.0823 [0.774]	6.708 [0.011]**	5.781 [0.017]**	2.574 [0.11]	16.528 [<0.01]***
H_0: δ_1=δ_2=δ_3=0	1.835 [0.177]	5.426 [0.021]**		0.893 [0.346]	0.571 [0.451]	
H_0: δ_1=δ_2=δ_3=γ_1=0	5.804 [0.003]***	3.097 [0.047]**		2.006 [0.137]	1.904 [0.152]	
H_0: δ_1=δ_2=δ_3=γ_2=0	0.9423 [0.391]	3.095 [0.047]**		2.564 [0.079]*	0.704 [0.496]	
H_0: θ_1=0	0.171 [0.697]		2.228 [0.137]	0.172 [0.679]		0.1897 [0.664]
H_0: θ_1=γ_1=0	7.299 [<0.01]***		6.226 [<0.01]***	0.872 [0.42]		1.054 [0.351]
H_0: θ_1=γ_2=0	0.248 [0.781]		14.104 [<0.01]***	1.996 [0.139]		21.175 [<0.01]***
H_0: φ_1=0		6.127 [0.014]**	1.512 (0.22)		5.732 [0.018]**	5.435 [0.021]**
H_0: φ_1=γ_1=0		5.523 [<0.01]***	6.504 [<0.01]***		4.06 [0.019]**	3.825 [0.023]**
H_0: φ_1=γ_2=0		4.98 [<0.01]***	14.001 [<0.01]***		3.534 [0.031]**	27.508 [<0.01]***
LB(4)	2.38 [0.67]	1.85 [0.76]	0.54 [0.97]	0.66 [0.96]	2.68 [0.61]	4.36 [0.36]

Note: see Table 5.

old (since $|\gamma_1| < |\gamma_2|$). We can see that respectively 24.4%, 51.3% and 27.01% of the production deviations from equilibrium is corrected in the next period when they are below the threshold, but only 5.2%, 23% and 4.4% when they are above the threshold. In other words, deviations below the threshold from the long-run equilibrium resulting from decreases in production or increases in inflation and oil prices are corrected more quickly than deviations above the threshold. However, for Germany, unlike the previous results in Table 4, the speed of adjustment is faster in the regime with deviations in production above the threshold but on the other hand both γ-coefficients are similar in magnitude (the hypothesis of symmetric adjustment is not rejected, F=0.853 with p-value=0.357). This rather symmetric adjustment of production may indicate that Germany in general is not negatively influenced by higher energy prices. Although it is one of the important oil importing countries, at the same time it is the leading goods exporting economy with a strong investment goods industry and is currently becoming the leader for some renewable energies and energy efficiency goods. This allows Germany to level off the negative impact of increasing oil prices − see Lutz, Meyer (2009).

The M-TAR-ECM results for Denmark show that the deviation away from the long-run relationship is corrected not only by movements in production, but also by movements in inflation and oil prices when the production in Denmark is temporarily above the long-run equilibrium. This can be seen by the negative signs and significance of the error correction parameter γ_1 in the M-TAR-ECMs for $\Delta P_t, \Delta In_t$ and ΔB_t. When the production in Denmark is temporarily below the long-run equilibrium, the deviation away from long-run relation is corrected by movements in production and inflation (significance of γ_2 in equation for ΔP_t and ΔIn_t). The M-TAR-ECM models for ΔIn_t and ΔB_t in Germany, France and EU adjust to the 'wrong' direction (the γ coefficients have positive signs) in either or both regimes, and additionally parameters γ_1 and γ_2 are not always significant – see Table 5.

Summing up, the results from threshold error correction model confirmed the previous findings (Table 4) with regard to cointegration with asymmetric adjustment for deviations in production in the case of France, Denmark and the total EU. This can be seen by statistical significance of both or either adjustment coefficients (γ) which are properly signed (are negative). While in the case of Germany the cointegration between production, oil prices and inflation occurs, production adjustments toward equilibrium seem to be symmetric.

The results of Granger-causality test, based on the M-TAR-ECM models for all economies show that there is short-run unidirectional causal relationship running from oil prices (B_t) to production (P_t) and inflation (In_t) (rejection of $H_0: \varphi_1 = 0$ in equations for ΔP_t and ΔIn_t with exception of Denmark for which unidirectional short-run causal relationship running from (B_t) to (P_t) was not confirmed). Bidirectional short-run causal relationship between oil prices and production exists for France (the rejection of $H_0: \varphi_1 = 0$ in equation for ΔP_t and $H_0: \delta_1 = \delta_2 = \delta_3 = 0$ in equation for

ΔB_t, but the latter only at the 10% significance level). In terms of long-run situation, a unidirectional strong causal relationship running from oil prices B_t to production P_t is found for both regimes in the case of Germany and Denmark, and in lower regime (below the threshold) in the case of France and the EU (rejection of $H_0 : \varphi_1 = \gamma_1 = 0$ and/or $H_0 : \varphi_1 = \gamma_2 = 0$). This means that oil prices, among explanatory variables, contributes most to the short-run adjustment to re-establish the long-run equilibrium in the case of all analyzed economies.

Conclusions

This paper investigated the relationship between oil prices, production and inflation in an asymmetric framework in selected European Union economies We tested for the threshold cointegration assuming two types of long-run relationship: firstly, the long-run equation without a structural break and then the long-run relationship taking into account a structural break in 2008 due to financial crisis. While the in the case of long-run equilibrium relationship without a structural break the cointegration was not found (except Germany, Nederland and the total EU), we proceeded with testing threshold cointegration based only on the long-run relationship with a structural break. The results provided evidence that production, oil prices and inflation are cointegrated with non-linear (asymmetric) adjustment process in the case of Germany, Denmark, France and the EU, i.e. for developed countries with the high level of economic growth. Adjustments toward the long-run relationship revert faster when production is below the threshold value and tend to persist more when production is above the threshold. This indicate that all these economies have the mechanism allowing them to quickly revert to equilibrium after moving away from it or in other words, economies remain shorter period of time in the regime of slower economic activity. However, when estimating the threshold error correction models, the findings of threshold cointegration with asymmetric adjustment was fully confirmed in the case of France, Denmark and the total EU.

The estimated threshold error correction models and Granger causality tests provide evidence that there is unidirectional short run causality running form oil prices to production and inflation in the case of Germany, Denmark, France and the EU. Besides, the support for unidirectional long-run causal relationship from oil prices to production is found for Germany, Denmark (in both regimes) and for France and the EU. This evidence suggests that oil prices play an important role in driving economic growth.

In this paper we focused on testing causality using threshold error correction model. In further studies we will concentrate on investigating the relationship between production, oil prices and inflation in the framework of threshold vector error correction model.

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Ceny ropy naftowej, produkcja oraz inflacja w gospodarkach Unii Europejskiej - podejście kointegracji progowej

Z a r y s t r e ś c i. W artykule wykorzystuje się podejście kointegracji progowej, które zostało opracowane przez Endersa i Siklosa (2001) w celu zbadania zależności między cenami ropy a aktywnością gospodarczą (wyrażoną przez produkcję i inflację) z uwzględnieniem wystąpienia zmiany strukturalnej dla sześciu wybranych państw UE. Podejście to pozwala na różną szybkość dostosowań do długookresowej równowagi w zależności, czy produkcja jest powyżej czy poniżej długookresowej zależności. Ponadto, dla zbadania krótko- i długookresowej przyczynowości między produkcją, cenami ropy i inflacją, zostały oszacowane progowe modele korekty błędem. Otrzymane wyniki wskazują, że dla Francji, Danii i całej Unii Europejskiej zmienne te są skointegrowane, przy czym proces dostosowawczy ma asymetrycznych charakter.

S ł o w a k l u c z o w e: asymetryczne dostosowania, cenowe szoki naftowe, kointegracja progowa, nieliniowość, progowy model korekty błędem.