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Contact to corresponding author: zlatko.kovacic@openpolytechnic.ac.nz, The Open Polytechnic of New Zealand, 3 Cleary Street, Lower Hutt 5040, New Zealand

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Zlatko J. Kovačić

The Open Polytechnic of New Zealand, New Zealand

Miloš Vilotić

My Statistical Consultant Ltd., New Zealand

Characterising and testing European business cycles asymmetry

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Abstract

Research background: One of business cycles stylised facts is that contractions are shorter than expansions, but less persistent, more volatile, and therefore asymmetric. Investigating existence and type of business cycles asymmetry is important for analysis of economic policy and statistical modelling. Economic implication of business cycles asymmetry is that economic policy should be different in a period of contractions than in one of expansion. Statistical implication is that linear models of business cycles cannot capture this stylised fact.

Purpose of the article: The article has two objectives: extend the literature on the business cycles asymmetry by testing data from 36 European countries including countries never been analysed before and test robustness of the results to extraction methods and asymmetry tests used.

Methods: Quarterly GDP series from Eurostat database covering period 2000q1–2016q3 were used with two exceptions. In the case of Bosnia and Herzegovina and Montenegro quarterly industrial productions indexes were used. Series were prepared by removing seasonal component using X13-ARIMA procedure. To assess robustness of asymmetry tests results to alternative methods of detrending business cycles were extracted using two filters: Corbae-Ouliaris ideal band filter and double Hodrick-Prescott filter. For testing the deepness and steepness asymmetry of the business cycles three tests were used: Mills, Mira and Sichel tests.

Findings & Value added: Weaker evidence of deepness asymmetry was found in Cyprus, Montenegro and Turkey cycles, where all three tests statistics for both filters have a negative sign. However, only for one of the tests in each country the result was statistically significant. For two other countries, Germany and Sweden, four out of six tests indicated deepness asymmetry, but only one of these tests results was statistically significant. Most of the cycles show steepness asymmetry, with the exception of Ireland business cycles, and to a certain extent cycles of Poland, Malta, Montenegro and Spain.

Introduction

Business cycle analysis has a long tradition in economics. Numerous studies (e.g. Calderón & Fuentes, 2014; Caraianni, 2012; Konstantakopoulou & Tsionas, 2014; Male, 2010; Rand & Tarp, 2002) identified a few stylised facts. One of these facts is that recessions are shorter than expansions, but less persistent, more volatile, and therefore asymmetric. Investigating the existence and type of business cycles asymmetry is important for analysis of economic policy and statistical modelling. Economic implication of business cycles asymmetry is that economic policy should be conditional on the stage of the cycle. Statistical implication is that linear models of business cycles cannot capture this stylised fact, and therefore would be inefficient when applied. The main objective of this study is to explore whether European business cycles are asymmetric. More specifically the time series from the Eurostat database were used to achieve the following objectives:

- extend the literature on the business cycles asymmetry by characterising and testing data from 36 European countries including countries never been analysed before
- test the robustness of the results to extraction methods and asymmetry tests used.

The paper is organised as follows. First, a brief review of the latest empirical studies on business cycle asymmetry is presented. A description of methodology and data is presented next describing the data preparation, cycle extraction methods and briefly outlining the asymmetry tests and their computation. Empirical results are presented and discussed in the section that follows. The conclusion section discusses the main results.

Literature review

The main findings of individual empirical studies published after 2010 are summarised in Table 1. Majority of these studies used quarterly GDP

and/or industrial production index seasonally adjusted. The most commonly used cycle extraction method was Hodrick-Prescott filter.

The results vary and depend on the period covered, series and cycle extraction method used. There is no pattern in these results and sometimes for the same country (e.g. Turkey) the studies reached an opposite conclusion (Astolfi *et al.*, 2015; Tanrıöver & Yamak, 2015). For most Central and Eastern European cycles no evidence of asymmetric behaviour was found.

Research methodology

There are three methodological problems that have to be addresses when conducting research on business cycle asymmetry. They are related to preparation of time series, selection of cycle extraction methods and selection of asymmetry tests. These three issues are addressed in the following subsections.

Data

The quarterly time series of GDP at market prices (chain linked volumes, index 2010 = 100) seasonally unadjusted are extracted from the Eurostat Database. The sample period for most of the GDP series used in this study runs from 2000q1 to 2016q3. For Bosnia & Herzegovina and Montenegro quarterly GDP time series were not available, so the quarterly index of industrial production was used instead.

Since the focus in this study is on economic fluctuation at business cycle frequencies rather than short-term, seasonal fluctuations and long-term growth it was necessary to remove all seasonal fluctuations and trend. Series were prepared by removing seasonal component using X13-ARIMA procedure. The logarithm of seasonally adjusted real GDP was used, so that the deviations around trend are expressed as percentages.

Cycle extraction methods

Non-parametric approach is one of the business cycles extraction methods discussed with other methods in Massmann *et al.* (2003). The most commonly used non-parametric approach is the filtering method. It is well-known that business cycle analysis results depend on the cycles extraction methods (e.g. Massmann & Mitchell, 2004). In order to assess how robust the asymmetry tests results are on using different extraction methods two

filters were applied: Hodrick-Prescott (hereafter HP) and Corbae-Ouliaris (hereafter FD) filters.

The starting point of the HP filter (Hodrick & Prescott, 1980) is the following representation of time series

$$y_t = \tau_t + c_t \quad (1)$$

where τ_t is a trend component, and c_t cyclical component we want to extract using HP filter. HP filter minimises variance of the cyclical component penalising the variability in the trend, relative to the cyclical component:

$$\min_{\tau_t} \sum_t (y_t - \tau_t)^2 + \lambda \sum_t (\tau_{t+1} - 2\tau_t + \tau_{t-1})^2 \quad (2)$$

where parameter λ controls the smoothness of the trend. When applying HP filter, a two-step procedure was used. The most common value used for smoothing parameter for quarterly series in the first step is $\lambda = 1600$. Since the extracted cycles still contain random component HP filter was applied for the second time on the extracted cycle from the first step. This time smoothing parameter $\lambda = 10$ was used. With this two-step procedure all the random variations were smoothed out. There is no recommendation in the literature for the value of parameter λ in the second step. After conducting experiment with different values for this parameter $\lambda = 10$ was chosen. HP filter has been subject of many critics (e.g. Kaiser & Maravall, 2001). In one of the latest critics Phillips & Hin (2015) demonstrated that against common expectation, HP filter does not eliminate unit root in time series and, what is even more critical, it could generate cycles that do not exist in the original series.

The other cycle extraction method used is FD filter (Corbae & Ouliaris, 2006), which is an approximation of so-called ideal band pass filter. This filter isolates components of time series within a given range. In business cycle analysis that would be cycles from 1.25 years (5 quarters) to 8 years (32 quarters). The advantage of FD filter over other filters is that it can handle series with nonstationarity (e.g. unit root and heteroscedasticity) without prior testing for type of nonstationarity as it was requested by Christiano-Fitzgerald and Baxter-King filters.

Asymmetry tests

Sichel (1993) considers two different types of asymmetric patterns of cycle, i.e. deepness (business cycle troughs are deeper than peaks are tall) and steepness (business cycle contractions are shorter and sharper than expansions). Deepness asymmetry of business cycle is illustrated in Figure 1(a) and cycle highness on panel (c). Boxplots on panels (b) and (d) illustrate how asymmetric distributions are when there is deepness or highness in business cycles.

Steepness asymmetry is illustrated in Figure 2. The first difference of the cycle series would have the same graph as the graph in Figure 1(a). The null hypothesis in these tests is that a given distribution is symmetric about some unknown median, against a very broad class of asymmetric alternatives. More specifically, null hypothesis is that the business cycles have no deepness/steepness asymmetry against the alternative that cycles do have deepness/steepness asymmetry.

For testing the deepness and steepness asymmetry of the business cycles three tests were used: Sichel, Mills and Mira tests.

Sichel test

The asymmetry test proposed by Sichel (1993) is based on skewness of a cyclical series:

$$S = \frac{\frac{1}{N} \sum_{t=1}^N (c_t - \bar{c})^3}{\sigma(c)^3} = \frac{\mu_3}{\mu_2^{3/2}} \quad (3)$$

where c_t is a cyclical component of time series; N is the length of time series; $\bar{c}$ and $\sigma(c)$ are mean value and standard deviation of a cyclical component c_t respectively and μ_j is j -th central moment of series c_t . When calculating the standard error of the test statistic (3) Sichel addressed the issue of possible autocorrelation and heteroscedasticity by using the following variable in the regression on a constant:

$$z_t = \frac{(c_t - \bar{c})^3}{\sigma(c)^3} \quad (4)$$

The estimated regression coefficient is identical to S statistic, and for testing its significance the Newey-West standard error was used. Though, as pointed out by Mills (2001), this adjustment still does not adjust variance

for non-normality. Such modified t statistic follows an asymptotic normal distribution.

Mills test

To address the problem of non-normality, autocorrelation and heteroscedasticity of series c_t Mills (2001) suggested two corrections in the Sichel's test. The first correction addresses the problem of non-normality, and the variance of the test statistics could be written:

$$\sigma_S^2 = \frac{1}{N} \left(\frac{\mu_6}{\mu_2^3} - 6K + 9 + \frac{S^2}{4} (9k + 35) - \frac{3\mu_5\mu_3}{\mu_2^4} \right) \quad (5)$$

where S is the measure of skewness and $K = \frac{\mu_4}{\mu_2^{3/2}}$ is the measure of kurtosis. The second correction addresses the problem of autocorrelation by using the Newey-West adjustment. The variance of the test statistic S at lag l takes the following form:

$$\sigma_S^2(l) = \sigma_S^2 \left(1 + \frac{2}{N} \sum_{j=1}^l \omega_j \rho_j \right) \quad (6)$$

where ρ_j is the j -th autocorrelation of series $\frac{c_t^3}{(\mu_2)^{3/2}}$ and ω_j is the weight $\omega_j = 1 - \frac{j}{l+1}$, with $l = 4 \left(\frac{N}{100} \right)^{2/9}$. Statistic $Z_S = \frac{S}{\sigma_S(l)}$ has an asymptotic normal distribution. Statistically significant negative value of this statistic indicates deepness, while statistically significant positive value indicates highness of the business cycle.

Mira test

Mira (1999) proposed a test based on the Bonferroni's measure of skewness. This test is based on the following statistic:

$$Z_g = \frac{g}{\sigma_g} \quad (7)$$

The focus in this test is on the difference between the mean and median values, i.e. $g = \bar{c} - c_{med}$, where $\bar{c}$ and c_{med} are mean and median values respectively. Mira shown that Z_g statistic is asymptotically standard normal

with $\sigma_g = \frac{(4\hat{\sigma}^2 + D^2 - 4DE)}{4N}$, with $\hat{\sigma}^2 = \frac{\sum_{t=1}^N (c_t - \bar{c})^2}{(N-1)}$, $E = \bar{c} - \frac{2}{N} \sum_{t=1}^N c_t I(c_t \leq c_{med})$ and $D = N^{1/5} (c_{1/2(N+N^{4/5})} - c_{1/2(N-N^{4/5}+2)})$.

The first difference of business cycles would show negative skewness if the cycle shows steepness. So, the same three tests could be used to test the hypothesis of steepness asymmetry by simply replacing c_t with its first difference, i.e. Δc_t .

Results

Summary statistics of European business cycles are presented in Table 2. We shall briefly comment on the volatility of business cycles measured with standard deviation, asymmetry of the business cycles measured with skewness coefficient and flatness of the business cycles distribution measured with kurtosis coefficient. The most volatile business cycles in the last 17 years are in the Baltic countries (Estonia, Latvia and Lithuania), with the average standard deviation of 6.08, which is more than 5 times larger than the volatility in three countries with the least volatile cycles (Belgium, France and Norway). Business cycles of the new EU members, those who joined EU after 2004, are twice as volatile as the cycles of the EU founding members. These results are consistent with the findings obtained for developing countries (Agénor *et al.*, 2000; Rand & Tarp, 2002).

When it comes to asymmetry of business cycles the EU founding members and old EU members (joined EU before 2004) are less asymmetric with skewness coefficient 0.26 and 0.23 respectively, than the cycles of New EU members with skewness coefficient 0.57. Only five countries (Montenegro, Turkey, Sweden, Germany and Cyprus) had negative skewness coefficient (only 14% of all countries in this study), but not all of these coefficients were statistically significant. Negative skewness coefficient implies asymmetry deepness. This will be further investigated using three asymmetry tests.

Excess kurtosis was identified in the business cycles of Slovakia, Croatia, Luxembourg and Slovenia (kurtosis coefficient ranging from 3.90 to 5.26). This means that big positive and negative values in deviation around trend in these countries are more likely than the normal distribution would suggest. Platykurtic distributions, i.e. distributions with light tails were identified in Cyprus, Poland, Portugal and Hungary cycles with kurtosis coefficients ranging from 1.51 to 1.80. Mesokurtic distributions, i.e. distri-

butions with absence of kurtosis were identified in Latvia, Belgium, Iceland and Sweden cycles with kurtosis coefficients ranging from 2.94 to 3.14.

Table 3 shows the results of the deepness asymmetry tests conducted for 36 European countries plus cycles of European Union (EU28) and Euro Area (EA19). Results vary across the tests and filters used. Negative values of the test statistics are in bold font. Only a few countries has all negative values for both filters and for all three tests. They are Cyprus, Montenegro and Turkey. For two other countries (Germany and Sweden), four out of six tests indicated deepness asymmetry. However, as the p -values in parenthesis show, not all of these tests results are statistically significant. For instance, significant results were observed for the following countries: Cyprus (Mills test & HP filter), Germany (Mills & HP), Montenegro (Mira & FD), Portugal (Mills & HP) and Turkey (Mira & HP).

Overall, we can conclude that the business cycles for a majority of European countries exhibit cycle symmetry, and that the evidence of deepness asymmetry is very weak, depending on the tests and filters used.

Table 4 shows the results of the steepness asymmetry tests were negative values of the test statistics are in bold font. With a few exceptions (most prominent case is Ireland), a majority of European countries have a negative sign for all three tests and for both filters. That would strongly support the claim that European cycles exhibit steepness asymmetry. However, such a claim should be made with caution because not all these negative values indicate statistically significant result. For example, Sichel test for both filters shows that none of the results are significant. This could be a result of the test weakness and its sensitivity to outliers. As pointed out by Mills (2001), less evidence of asymmetries of Sichel test could be the result that the variance in the test statistic is not adjusted for non-normality.

Overall, Mills test does not reject the null hypothesis of symmetric distribution in 19% (FD filter) and 11% (HP filter) cases, while this percentages raise to 83% in case of Mira's test for both filters. Two tests (Mills and Mira) yielded for both filters statistically significant result indicating steepness asymmetry only for the Czech Republic, Macedonia FRY and Turkey cycles. Three tests results were significant for Bulgaria, France, Italy, Lithuania, Sweden, EU28 and EA19 indicating that for these countries the contraction period in the economic activities were generally faster and shorter than expansionary phases.

When comparing our results with results in other studies, it is evident that results even for the same country depend on the period covered, changing nature of asymmetry, series, filters and tests used. However, the overall results confirmed the results and main conclusion of Astolfi *et al.* (2015) and Chirila and Chirila (2012) studies.

Conclusions

This paper analysis 36 European countries GDP data in order to detect the presence and type of asymmetries in their business cycles. Two cycle extraction methods were used: HP and FD filters, with three asymmetry tests to address the second objective of the study, i.e. robustness of the results. In spite of the differences in the period covered and countries include between our study and other studies, our results confirm previous results that only a few European countries cycles show deepness asymmetry. At the same time, most of the countries cycles show steepness asymmetry.

More specifically, weaker evidence of deepness asymmetry relative to trend was found in Cyprus, Montenegro and Turkey cycles, where all three tests statistics for both filters have a negative sign. However, only for one of the tests in each country the result was statistically significant. For two other countries, Germany and Sweden, four out of the six tests indicated deepness asymmetry, but only one of those tests results was statistically significant. Most of the cycles show contractionary steepness relative to trend, with the exception of Ireland business cycle, and to a certain extent the cycles of Poland, Malta, Montenegro and Spain.

Variations in the test results across three tests and two filters indicated sensitivity of the test results suggesting that the results should be interpreted and used with great caution.

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Annex

Table 1. Summary of literature after 2010 and main findings

Authors	Data used	Measure of cycle	Asymmetric measure/test	Conclusions
Astolfi et al (2015)	Period: 1960-2015:6 Countries: All OECD countries and key partners Series: GDP and composite leading indicator (CLI)	Two step Hodrick-Prescott filter	Three types of asymmetry: steepness, deepness and sharpness. Sichel, Mills, Mira, growth rates and Markov chain tests	GDP contractionary steepness (negative skewness) in 84% of cases. 16% symmetric. CLI symmetric in 68% cases. Only in New Zealand expansion steepness detected. Majority of European OECD have high and steep cycles. CLI shows deepness only. Denmark, Sweden and Turkey have symmetric cycles. Strong evidence of sharpness symmetry has been found in both GDP & CLI
Chirila (2012)	Period: 1998q1-2011Q3 1996m1-2012m12 Countries: Romania Series: major economic time series seasonally adjusted	Hodrick-Prescott filter	Two types of asymmetry: steepness and deepness. Sichel, Mills, and Mira tests	Romanian macroeconomic time series are not characterised by steepness and deepness asymmetry.
Chirila & Chirila (2012)	Period: 1998q1-2011q3 Countries: Central and Eastern European countries Series: industrial production index seasonally adjusted	Hodrick-Prescott filter	Two types of asymmetry: steepness and deepness. Sichel, Mills, and Mira tests	Both deepness and steepness asymmetries were not statistically significant for all Central and Eastern European countries
Manap (2010)	Period: 1975q1-2006q4 Countries: Malaysia Series: GDP seasonally adjusted	Hodrick-Prescott and band pass filters, first differencing and Markov-Switching autoregressive model	Three types of asymmetry: steepness, deepness and sharpness. Triplets test and parametric tests of Clements and Krolzig (2003)	Strong evidence of steep asymmetry but not deep and sharp asymmetry.

Table 1. Continued

Authors	Data used	Measure of cycle	Asymmetric measure/test	Conclusions
Mejía-Reyes & Díaz-Carreño (2010)	Period: 1970-2007 Countries: Mexico Series: Major monthly economic time series seasonally adjusted	Hodrick-Prescott filter	Two types of asymmetry: steepness and deepness. Sichel test	Asymmetric steepness was identified only in industrial and manufacturing production and real exchange rate.
Tanrıöver & Yamak (2015)	Period: 1987q1-2014q1 Countries: Turkey Series: real GDP, industrial and manufacturing production seasonally adjusted	Hodrick-Prescott filter	Two types of asymmetry: steepness and deepness. Sichel test	All three series have strong both deepness and steepness asymmetry.
Yilanci (2012)	Period: Mostly from 1991q1-2011q1 Countries: Bulgaria, Croatia and Romania Series: CPI, lending rate, M3, nominal exchange rate, real GDP and unemployment rate	Hodrick-Prescott filter	Two types of asymmetry: steepness and deepness. Triplets test	Most of the series for Bulgaria and Croatia are characterised by asymmetric behaviour; a small number of series for Romania were found to be asymmetric.

Table 2. Summary statistics of European business cycles (2000q1-2016q3)

Country	Mean	Median	Max	Min	SDev	Skew.	Kurt.	JB-test	p-value
Austria	0.03	0.11	3.53	-3.06	1.51	0.25	2.65	1.06	0.59
Belgium	0.00	-0.13	2.89	-2.39	1.22	0.37	2.94	1.54	0.46
Bosnia & Herz.	0.00	-0.55	6.71	-5.73	3.05	0.31	2.49	1.17	0.56
Bulgaria	-0.21	-1.04	6.02	-3.91	2.97	0.74	2.27	7.54	0.02
Croatia	0.00	-0.14	5.02	-3.16	1.70	0.88	4.38	13.99	0.00
Cyprus	0.03	0.40	3.57	-3.62	2.36	-0.05	1.51	6.19	0.05
Czech Republic	-0.10	-1.01	6.01	-4.40	2.91	0.63	2.18	6.28	0.04
Denmark	-0.04	-0.17	3.85	-3.71	1.79	0.17	2.65	0.66	0.72
Estonia	-0.24	-0.49	12.46	-14.24	5.91	0.09	3.44	0.61	0.74
Finland	-0.05	-0.28	5.96	-5.00	2.44	0.35	2.69	1.67	0.43
France	0.04	-0.09	2.45	-2.41	1.13	0.01	2.60	0.44	0.80
Germany	0.06	-0.14	4.35	-4.52	1.79	-0.10	3.24	0.27	0.87
Greece	-0.25	-0.33	5.71	-6.40	3.33	0.02	2.01	2.73	0.26
Hungary	-0.10	-1.02	4.62	-4.64	2.65	0.24	1.80	4.67	0.10
Iceland	-0.22	-0.74	10.24	-6.10	4.09	0.70	3.09	5.50	0.06
Ireland	-0.29	-0.77	10.64	-8.24	4.85	0.35	2.35	2.57	0.28
Italy	0.04	-0.09	3.24	-3.16	1.47	0.08	2.42	1.01	0.60
Latvia	-0.44	-2.09	15.37	-13.47	7.00	0.46	2.98	2.39	0.30
Lithuania	-0.44	-0.71	13.07	-11.11	5.33	0.49	3.31	2.99	0.22
Luxembourg	0.00	-0.16	7.90	-5.05	2.61	0.96	4.31	15.17	0.00
Macedonia	0.00	-0.26	6.71	-4.40	2.74	0.61	2.82	4.24	0.12
Malta	0.00	-0.47	4.09	-3.35	2.01	0.27	2.04	3.41	0.18
Montenegro	0.00	1.74	6.70	-9.63	4.74	-0.53	2.16	2.04	0.36
Netherlands	0.00	-0.39	4.32	-3.42	2.02	0.23	2.40	1.58	0.45
Norway	-0.09	-0.18	2.77	-2.44	1.25	0.21	2.71	0.74	0.69
Poland	0.00	-1.10	4.50	-3.08	2.42	0.39	1.61	6.23	0.04
Portugal	-0.01	-0.11	3.56	-3.23	2.04	0.11	1.75	4.49	0.11
Romania	-0.18	-1.01	10.25	-6.74	4.60	0.49	2.34	3.94	0.14
Serbia	-0.25	-0.86	6.29	-5.80	2.80	0.52	2.78	3.14	0.21
Slovakia	-0.37	-1.56	8.96	-3.10	2.92	1.74	5.26	47.93	0.00
Slovenia	-0.15	-0.44	8.22	-4.45	2.90	1.05	3.90	14.68	0.00
Spain	-0.06	-0.07	4.18	-3.30	1.94	0.30	2.28	2.46	0.29
Sweden	-0.02	-0.51	4.36	-5.58	2.12	-0.18	3.14	0.43	0.81
Switzerland	0.04	-0.13	3.53	-2.64	1.53	0.35	2.60	1.81	0.40
Turkey	-0.35	0.30	7.92	-9.72	4.83	-0.22	2.19	2.37	0.31
UK	-0.06	-0.39	4.24	-3.54	1.68	0.49	3.15	2.78	0.25
EU28	-0.01	0.02	3.96	-2.87	1.46	0.63	3.35	4.79	0.09
EA19	0.01	-0.06	3.88	-2.71	1.51	0.48	2.81	2.64	0.27

Note: All series are filtered using the Corbae-Ouliaris (FD) filter. In case of Bosnia and Herzegovina and Montenegro industrial cycles were used. Period covered in case of Bosnia and Herzegovina 2006q1-2016q3, Montenegro 2010q1-2016q3 and Poland 2002q1-2016q3. SDev denotes standard deviation of the cycle; Skew is a skewness coefficient; Kurt is a kurtosis coefficient; JB-test is the Jarque-Bera test statistic for testing normality of the cycle distribution and p -value is the Jarque-Bera test statistics p -value.

Table 3. Deepness asymmetry tests of the business cycles (2000q1-2016q3)

Country	Mills test		Mira test		Sichel test	
	FD	HP	FD	HP	FD	HP
Austria	2.68 (0.00)	15.52 (0.00)	-0.61 (0.54)	1.05 (0.30)	0.23 (0.89)	0.33 (0.91)
Belgium	15.40 (0.00)	5.05 (0.00)	1.13 (0.26)	1.78 (0.07)	0.34 (0.83)	0.35 (0.87)
Bosnia & Herz.	0.43 (0.33)	-1.31 (0.10)	1.05 (0.29)	1.37 (0.17)	0.27 (0.79)	-0.47 (0.51)
Bulgaria	2.73 (0.00)	52.18 (0.00)	3.20 (0.00)	2.64 (0.01)	0.77 (0.84)	1.31 (0.74)
Croatia	5.85 (0.00)	801.5 (0.00)	0.89 (0.37)	3.71 (0.00)	0.89 (0.78)	1.40 (0.76)
Cyprus	-0.25 (0.40)	-5.41 (0.00)	-0.78 (0.44)	-0.68 (0.50)	-0.04 (0.97)	-0.47 (0.93)
Czech Republic	2.32 (0.01)	6.85 (0.00)	3.72 (0.00)	0.58 (0.56)	0.66 (0.83)	0.71 (0.84)
Denmark	1.01 (0.16)	3.67 (0.00)	0.88 (0.38)	0.57 (0.57)	0.16 (0.93)	0.13 (0.96)
Estonia	0.06 (0.48)	0.12 (0.45)	0.89 (0.37)	0.87 (0.38)	0.09 (0.98)	0.13 (0.98)
Finland	1.11 (0.13)	2.90 (0.00)	0.60 (0.55)	1.97 (0.05)	0.32 (0.86)	0.41 (0.90)
France	0.54 (0.30)	0.26 (0.40)	0.79 (0.43)	1.55 (0.12)	0.00 (1.00)	0.02 (0.99)
Germany	-0.55 (0.29)	-1.68 (0.05)	1.06 (0.29)	0.37 (0.71)	-0.09 (0.96)	-0.07 (0.98)
Greece	0.12 (0.45)	-0.91 (0.18)	0.72 (0.47)	1.38 (0.17)	0.05 (0.98)	-0.22 (0.96)
Hungary	1.18 (0.12)	4.93 (0.00)	2.64 (0.01)	1.83 (0.07)	0.26 (0.85)	0.27 (0.92)
Iceland	1.08 (0.14)	2.54 (0.01)	1.26 (0.21)	0.95 (0.34)	0.73 (0.81)	0.87 (0.82)
Ireland	0.50 (0.31)	-0.28 (0.39)	1.11 (0.27)	0.55 (0.58)	0.38 (0.83)	-0.14 (0.97)
Italy	1.70 (0.04)	8.49 (0.00)	0.72 (0.47)	0.51 (0.61)	0.10 (0.95)	0.15 (0.94)
Latvia	0.33 (0.37)	0.51 (0.31)	2.44 (0.01)	2.05 (0.04)	0.47 (0.91)	0.53 (0.91)
Lithuania	0.44 (0.33)	0.78 (0.22)	0.42 (0.67)	0.50 (0.62)	0.49 (0.87)	0.57 (0.89)
Luxembourg	2.78 (0.00)	11.93 (0.00)	0.55 (0.58)	1.32 (0.19)	0.97 (0.74)	1.21 (0.77)
Macedonia FRY	1.80 (0.04)	5.22 (0.00)	0.95 (0.34)	-1.04 (0.30)	0.64 (0.62)	0.72 (0.20)
Malta	1.98 (0.02)	60.80 (0.00)	2.15 (0.03)	0.26 (0.79)	0.30 (0.82)	0.21 (0.93)
Montenegro	-0.29 (0.38)	-0.06 (0.48)	-1.68 (0.09)	-1.36 (0.17)	-0.44 (0.72)	-0.05 (0.95)
Netherlands	1.07 (0.14)	29.23 (0.00)	2.12 (0.03)	0.82 (0.41)	0.20 (0.90)	0.43 (0.83)
Norway	12.89 (0.00)	3.25 (0.00)	0.32 (0.75)	-0.74 (0.46)	0.24 (0.92)	0.24 (0.94)
Poland	2.17 (0.02)	3.40 (0.00)	3.10 (0.00)	1.00 (0.32)	0.36 (0.86)	0.25 (0.90)
Portugal	0.66 (0.25)	-38.3 (0.00)	0.39 (0.69)	-0.44 (0.66)	0.09 (0.95)	-0.26 (0.91)
Romania	0.77 (0.00)	43.74 (0.00)	1.41 (0.16)	1.92 (0.06)	0.51 (0.86)	1.47 (0.73)
Serbia	1.39 (0.08)	-1.12 (0.13)	1.86 (0.06)	0.36 (0.72)	0.49 (0.92)	-0.11 (0.92)
Slovakia	9.37 (0.00)	10.02 (0.00)	4.19 (0.00)	3.43 (0.00)	1.69 (0.68)	1.79 (0.73)
Slovenia	3.01 (0.00)	8.74 (0.00)	1.35 (0.18)	1.65 (0.10)	1.05 (0.74)	1.15 (0.77)
Spain	2.08 (0.02)	2.49 (0.01)	-0.06 (0.95)	0.16 (0.88)	0.33 (0.90)	0.12 (0.99)
Sweden	-0.60 (0.27)	-0.84 (0.20)	2.01 (0.04)	0.65 (0.51)	-0.15 (0.94)	-0.07 (0.98)
Switzerland	3.57 (0.00)	26.31 (0.00)	1.38 (0.17)	1.36 (0.17)	0.33 (0.87)	0.34 (0.89)
Turkey	-0.27 (0.39)	-1.01 (0.16)	-1.19 (0.23)	-3.08 (0.00)	-0.19 (0.91)	-0.38 (0.88)
UK	4.06 (0.00)	11.35 (0.00)	2.10 (0.04)	2.69 (0.01)	0.49 (0.83)	0.40 (0.91)
EU28	8.71 (0.00)	20.83 (0.00)	0.60 (0.55)	1.03 (0.30)	0.63 (0.79)	0.55 (0.86)
EA19	6.19 (0.00)	28.55 (0.00)	0.76 (0.45)	0.61 (0.54)	0.48 (0.81)	0.47 (0.86)

Note: Negative values (bold font) indicate the deepness asymmetry. In case of Bosnia and Herzegovina and Montenegro industrial cycles were used in the period 2006q1-2016q3 and 2010q1-2016q3, respectively. In the case of Poland, quarterly GDP series was available in the period 2002q1-2016q3. Test results with *p*-values within parenthesis are based on cycles extracted using Corbae-Ouliaris (FD) and Hodrick-Prescott (HP) filters.

Table 4. Steepness asymmetry tests of the business cycles (2000q1-2016q3)

Country	Mills test		Mira test		Sichel test	
	FD	HP	FD	HP	FD	HP
Austria	-4.13 (0.00)	-3.21 (0.00)	-0.11 (0.91)	-0.45 (0.65)	-0.91 (0.66)	-0.85 (0.76)
Belgium	-3.39 (0.00)	-3.31 (0.00)	-1.42 (0.15)	-1.48 (0.14)	-0.71 (0.63)	-0.80 (0.64)
Bosnia & Herz.	-4.52 (0.00)	1.19 (0.12)	-1.48 (0.14)	-0.87 (0.38)	-0.36 (0.71)	0.26 (0.72)
Bulgaria	-14.0 (0.00)	-17.3 (0.00)	-1.94 (0.05)	-1.55 (0.12)	-1.41 (0.67)	-1.45 (0.69)
Croatia	-15.4 (0.00)	-4.81 (0.00)	-0.41 (0.68)	-0.69 (0.49)	-1.42 (0.58)	-0.92 (0.74)
Cyprus	-1.02 (0.15)	-0.19 (0.42)	-0.41 (0.68)	0.40 (0.69)	-0.15 (0.92)	-0.04 (1.00)
Czech Republic	-15.3 (0.00)	-6.41 (0.00)	-2.01 (0.04)	-2.84 (0.00)	-1.28 (0.57)	-0.98 (0.65)
Denmark	-5.53 (0.00)	-4.43 (0.00)	-0.67 (0.50)	-1.86 (0.06)	-1.08 (0.69)	-0.92 (0.74)
Estonia	-36.5 (0.00)	-161 (0.00)	-1.14 (0.25)	0.54 (0.59)	-1.65 (0.68)	-1.15 (0.74)
Finland	-7.09 (0.00)	-5.33 (0.00)	-0.94 (0.35)	-0.57 (0.57)	-0.91 (0.68)	-0.97 (0.72)
France	-4.16 (0.00)	-3.43 (0.00)	0.16 (0.87)	-2.16 (0.03)	-0.94 (0.62)	-0.88 (0.72)
Germany	-6.03 (0.00)	-2.89 (0.00)	-0.29 (0.77)	-0.40 (0.69)	-1.14 (0.69)	-0.74 (0.77)
Greece	-2.29 (0.01)	-3.93 (0.00)	-1.19 (0.23)	-0.60 (0.55)	-0.15 (0.88)	-0.52 (0.87)
Hungary	-132 (0.00)	-13.5 (0.00)	-1.77 (0.08)	-1.23 (0.22)	-1.71 (0.59)	-1.41 (0.57)
Iceland	-15.2 (0.00)	-5.65 (0.00)	-0.91 (0.36)	-1.64 (0.10)	-0.42 (0.83)	-0.76 (0.82)
Ireland	53.39 (0.00)	13.25 (0.00)	1.71 (0.09)	0.20 (0.84)	1.27 (0.59)	1.03 (0.67)
Italy	-4.20 (0.00)	-3.03 (0.00)	-2.36 (0.02)	-1.09 (0.28)	-0.87 (0.64)	-0.67 (0.75)
Latvia	-152 (0.00)	-46.9 (0.00)	-1.76 (0.08)	0.25 (0.80)	-1.50 (0.72)	-1.06 (0.80)
Lithuania	-5.0 (0.00)	-45.5 (0.00)	-2.19 (0.03)	-1.28 (0.20)	-2.27 (0.64)	-1.64 (0.68)
Luxembourg	-12.0 (0.00)	-4.74 (0.00)	-1.65 (0.10)	-0.18 (0.86)	-0.97 (0.71)	-0.97 (0.75)
Macedonia FRY	-12.6 (0.00)	-8.13 (0.00)	-1.93 (0.05)	-2.31 (0.02)	-0.98 (0.65)	-1.08 (0.47)
Malta	-2.40 (0.01)	-1.35 (0.09)	0.06 (0.95)	0.04 (0.97)	-0.27 (0.77)	-0.33 (0.83)
Montenegro	-0.32 (0.38)	10.32 (0.00)	0.00 (1.00)	-0.49 (0.63)	-0.18 (0.86)	0.21 (0.85)
Netherlands	-1.06 (0.14)	-3.08 (0.00)	-0.70 (0.48)	-1.33 (0.18)	-0.20 (0.89)	-0.59 (0.72)
Norway	-2.61 (0.00)	-2.28 (0.01)	-1.86 (0.06)	-1.62 (0.11)	-0.45 (0.96)	-0.55 (0.78)
Poland	-0.33 (0.37)	0.63 (0.26)	0.68 (0.50)	0.71 (0.48)	-0.06 (0.97)	0.12 (0.94)
Portugal	-1.10 (0.14)	-3.42 (0.00)	-0.83 (0.41)	-1.97 (0.05)	-0.14 (0.90)	-0.51 (0.73)
Romania	-29.5 (0.00)	-9.86 (0.00)	-0.48 (0.63)	-1.36 (0.17)	-1.19 (0.60)	-1.38 (0.69)
Serbia	-0.52 (0.30)	-3.37 (0.00)	1.37 (0.17)	-0.11 (0.92)	-0.04 (0.97)	-0.60 (0.78)
Slovakia	-16.3 (0.00)	-5.09 (0.00)	-1.14 (0.26)	-1.31 (0.19)	-1.34 (0.60)	-1.19 (0.65)
Slovenia	-12.5 (0.00)	-4.79 (0.00)	-0.48 (0.63)	0.92 (0.36)	-0.98 (0.62)	-0.84 (0.74)
Spain	-1.46 (0.07)	-1.05 (0.15)	1.72 (0.09)	0.64 (0.52)	-0.23 (0.83)	-0.17 (0.92)
Sweden	-3.22 (0.00)	-2.12 (0.02)	-0.83 (0.41)	-2.15 (0.03)	-0.79 (0.77)	-0.57 (0.82)
Switzerland	-4.81 (0.00)	-4.08 (0.00)	-0.47 (0.64)	-1.72 (0.09)	-0.84 (0.58)	-0.80 (0.66)
Turkey	-22.9 (0.00)	-13.9 (0.00)	-2.55 (0.01)	-2.91 (0.00)	-1.22 (0.39)	-1.04 (0.63)
UK	-8.28 (0.00)	-15.2 (0.00)	-1.63 (0.10)	-1.54 (0.12)	-2.15 (0.52)	-1.85 (0.66)
EU28	-14.3 (0.00)	-5.05 (0.00)	-2.23 (0.03)	-0.88 (0.38)	-1.43 (0.57)	-1.05 (0.70)
EA19	-6.35 (0.00)	-3.79 (0.00)	-2.05 (0.04)	-0.75 (0.45)	-1.12 (0.60)	-0.85 (0.72)

Note: Negative values (bold font) indicate the deepness asymmetry. In case of Bosnia and Herzegovina and Montenegro industrial cycles were used in period 2006q1-2016q3 and 2010q1-2016q3 respectively. In case of Poland quarterly GDP series was available in period 2002q1-2016q3. Test results with p -values within parenthesis are based on cycles extracted using Corbae-Ouliaris (FD) and Hodrick-Prescott (HP) filters.

Figure 1. Deepness and Highness in business cycles

Figure 2. Steepness in business cycles