On Extending Composite Leading Indicators by International Economic Series

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Abstract

Composite leading indicators (CLIs) are recognized as eligible tools for business cycle analysis. When the Organization for Economic Co-operation and Development (OECD) constructs CLI, its composition depends on national data only. However, European economies are often small and open and therefore their business cycles relate to situations in other countries. The approach described in this paper reflects these characteristics. The international CLIs for Austria, the Czech Republic, Germany, Poland and Slovakia are constructed and the leading influences on these countries are discussed.

The methodology of the CLI construction is described in detail by several organizations. It, therefore, comes as a surprise, that there are no publicly available software programs, R packages or Python libraries, that would support the whole computational process or its automation. A new Python-based framework is proposed to fill this gap and it is demonstrated on the international CLI construction. It is introduced for the very first time in this paper and it enables users to quickly analyze and visualize larger volumes of data than any other available solution.

Keywords	***JEL code***
Business cycle analysis, leading indicators, automation	*C32, E32*

INTRODUCTION

Although we are now in the phase of economic expansion, the public attention has been focused on the possibilities of forecasting the business cycle movements since the recent Great Recession in 2007. One of the methods used for the business cycle analysis is based on the study of composite indicators (CI) which combine several individual economic time series. The series can be divided into groups of leading, coincident and lagging ones with regard to the reference time series (usually gross domestic product (GDP) or industrial production index).

The composite leading indicator (CLI) draws most of the attention because it should be able to predict the future states of economic activity – when the economy is going to switch from the expansion phase into the contraction phase or vice versa. Astolfi et al. (2016, p. 15) study the performance of the real-time CLI warnings during the Great Recession in 2007 and state that "in both cases, at peak and trough,

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the OECD (Organization for Economic Co-operation and Development) was able to signal the approaching turning points thanks to the continuous monitoring of the CLI growth rates, which initially recorded a significant reduction and then turned negative. With hindsight, the CLI for the OECD area as a whole peaked in June 2007, hence seven months ahead of the corresponding peak for GDP, which took place in December 2007".

The construction of composite indicators usually follows methodology created by OECD or the Conference Board. Most of the analyses of the Czech business cycle use the OECD methodology which is employed in this paper as well. The OECD methodology according to Gyomai and Guidetti (2012) consists of five steps: 1. *pre-selection phase*, which is passed only by long time series of indicators that have justified economic relationship with the reference series, broad coverage of economic activity and high frequency of observations, 2. *filtering phase*, when the time series are seasonally adjusted and de-trended, 3. *evaluation phase*, when only the best individual indicators with the strongest relationship with the reference series are selected to be included in the composite indicator, 4. *aggregation phase*, when the composite indicators are created and 5. *presentation of the results*. For the detailed description of these processes, see section 3.

OECD publishes CLI for most of its 35 member countries and for some partner countries (e.g., Brazil, India, the People's Republic of China). It also compiles the CLI of the whole G7, NAFTA, Euro area, European OECD and all OECD countries. However, the composition of each country's CLI depends on the national input data only. For example, Czech OECD CLI consists of Czech individual economic indicators. The European economies are nevertheless often small and open and therefore their business cycles relate to the situation in other countries.

This paper aims to construct the international CLI, which is based on input data from multiple countries and assess:

- if considering international data changes the structure of OECD CLIs,
- whether international CLIs can be used to analyze the relationships between business cycles of several countries,
- how can these relationships be interpreted and visualized.

This is not the first time when the researchers use international data to construct national CLI; however, this is the first case, to the best of my knowledge, where the structure of international CLI is visualized on maps and used to interpret the relationships between the countries.

Such analyses cannot be performed in any of the publicly available software programs. Therefore, the new Composite Indicators Framework (CIF) is proposed and introduced for the very first time in this paper. This framework is described and compared with the current solutions in section 2.

Section 4 utilizes the framework and demonstrates the international CLI construction on data from 5 countries: Austria, the Czech Republic, Germany, Poland and Slovakia. These countries were selected to simplify the interpretations and visualizations of the results. However, deploying the proposed framework guarantees that the international CLI could be easily based on all European data or data available all over the world.

1 BRIEF HISTORY OF COMPOSITE BUSINESS CYCLE INDICATORS

In 1930's two American economists, Arthur Frank Burns and Wesley Clair Mitchell, worked on new methods how to measure business cycles and determine recessions. In 1946 they published work on business cycle indicators which contained one of the first lists of leading, coincident and lagging indicators as well as a set of instructions how to track the cycle. Burns and Mitchell's methodology spread worldwide in the following years. It was executed manually and required lots of personal judgment and therefore it wasn't quite objective.

In 1969 Ilse Mintz proposed a new definition of business cycles, which became later known as growth or deviation cycles. The deviation cycle was obtained by removing trend from the reference time series and could be interpreted as output gap (the difference between the actual and potential economy output). Mintz also brought up new terms: speedups and slowdowns of the economy instead of expansions and contractions known from Burns and Mitchell's classical cycles.

In 1971 Gerhard Bry and Charlotte Boschan introduced their algorithm to automate the turning points detection. It was one of the first programmed approaches that were published and, with the fast development of information technologies, was then widely implemented.

OECD, Conference Board and other organizations still use Bry-Boschan algorithm with only slight changes. In their first proposal, Bry and Boschan used a 12-month moving average, Spencer curve and a short-term moving average of 3 to 6 month to detect the turning points. Nowadays, none of these are necessary because some other techniques (like Hodrick-Prescott filter) are used to smooth the time series without shifting the turning points.

The OECD methodology was described in detail by Gyomai and Guidetti (2012). For more information on the Conference Board methodology see its Business Cycle Indicators Handbook (2001) or Ozyildirim et al. (2010). General findings on composite indicators as well as detailed remarks on OECD, Conference Board and other methodologies were elaborately summarized in Eurostat (2017).

Authors all around the world used OECD or Conference Board methodologies and proposed their own improvements to the specific parts of these processes. Svatoň (2011) proposed Granger causality test to limit the number of candidate series during the pre-selection phase. Zarnowitz and Ozyildrim (2006) compared the application of phase-average trend with Hodrick-Prescott and Baxter-King band pass filters during the filtering phase of composite indicators construction. Nilsson and Gyomai (2011) then added Christiano-Fitzgerald filter into the comparison. The evaluation phase also drew plenty of suggestions: Hamilton (1989) introduced Markov switching approach later modified by Levanon (2010) to compare the recession signal across many indicators. Bruno and Otranto (2004) studied combinations of parametric and non-parametric methods and their impact on business cycle dating. Gallegati (2014) proposed wavelet-based composite indicator, which provided early warning signals of turning points. The aggregation phase was also subject of research: Zhou et al. (2009) introduced a mathematical programming approach to optimize the weights of individual indicators for human development index and the similar technique could be used to analyze business cycles as well.

2 COMPUTATIONAL FRAMEWORKS

The methodology of CLI construction is described in detail by several organizations. It, therefore, comes as a surprise, that no publicly available software program supports the whole computational process or its automation. A new framework is proposed to fill this gap and it is demonstrated in this paper for the very first time. The construction of the international CI, performed in this paper, would otherwise be very difficult. The new framework enables users to analyze and visualize larger volumes of data than any other available solution.

In this section, software programs suitable for constructing composite indicators and the newly proposed Composite Indicators Framework (CIF) are described and compared.

2.1 Available software programs

This paper overviews some of the existing software solutions suitable for analyzing business cycles: CACIS, EViews, Python and R (in alphabetical order). These are selected as they cover most of the tasks required to construct composite indicators.

Python and R are free and general software environments very popular in data science. They provide a great selection of libraries (Python) and packages (R) with many functions and methods, so users do not need to write them from the scratch. Moreover, it is also possible (although sometimes time-consuming) to program the missing pieces.

EViews is oriented mainly on time series analyses and forecasting. It provides a basic graphical user interface, but also requires the knowledge of its own programming language. It is the only commercial software discussed in this paper.

OECD offers its own Cyclical Analysis and Composite Indicators System (CACIS). It is designed directly to compute the composite indicators and, therefore, it provides the most exhaustive pallet of functions. However, the publicly available version has not changed much since 2010, and its user interface and generated visualization are obsolete.

CACIS and EViews run only on Windows operating system.

2.2 Newly proposed computational framework

None of the existing solutions provides all the tasks required to analyze the business cycle. Because the switching between several software programs is uncomfortable, slow and makes the automation of the process impossible, the new solution needs to be proposed. This paper introduces the new framework attempting to fill the gap in currently available software repertoire.

CACIS was developed to analyze the cycle, but it is now obsolete and does not meet certain basic requirements like loading the data directly from OECD API, adjusting the graphs or automating the whole process. EViews provides even less of the specified tasks, and its results are only slightly more controllable by the user. Therefore, the new framework could be based either on Python or R. After some experiments, Python was selected as it provided elegant syntax, better performance and its existing libraries were more compatible with each other.

If users miss some functions, the Python-based interface of CIF guarantees that they can write them by themselves and easily integrate them into the computing process. For example, creating CLI from international data and visualizing them as leading influence maps (as is described in section 4.3) would not be possible with any other described framework.

The current version of CIF is available on GitHub[2] (internet platform for sharing, collaboratively developing and documenting code) as a Python file, which nowadays contains thousands of lines of code in 33 functions to support and automate the entire process of CI construction. See the GitHub repository for the complete list of available functions and minimal functional pipeline to help the users start analyzing with CIF for the first time. CIF is soon going to be available as a classical Python library installable via pip command.

Table 1 overviews the selected software solutions and CIF and evaluates them in the fields most essential for constructing composite indicators.

EViews, Python and R load data from versatile data sources (databases as well as data files). Python and R can also communicate with other applications via application programming interface (API), which enables them to download data directly from organizations like OECD when connected to the internet. However, they do not process such data automatically so additional steps are needed to transform it into general data table format. CACIS can load data from excel and csv files only, so it requires lots of manual work while downloading and preparing input data.

The new framework (CIF) focuses mainly on the automation of the construction. It is designed to save the time of the users, so they can just load the input data and the result is delivered with their minimal

2 Available at: <https://github.com/LenkaV/CIF>.

effort and without manual intervention. Alternatively, the user can specify only the country of the interest and the available data are downloaded directly from OECD API (other APIs will be added in the future). These functions allow the users to quickly compare results across many countries and eliminate the time needed for the bothersome data transformations.

Table 1 Overview of software functions necessary for composite indicators construction (available = fully supported, generic = supported, but some adjustments needed, x = not supported)

actions	CACIS	EViews	Python	R	CIF
loading data from files	excel or csv only	available	available	available	available
loading data from databases	x	available	available	available	available
loading data from generic API	x	x	available	available	available
loading data from OECD API	x	x	x	x	available
convert quarterly to monthly time series	available	available	x	available	available
seasonal adjustment and outlier detection (TRAMO/SEATS)	available	available	available	available	available
de-trending and smoothing (Hodrick-Prescott filter)	available	available	available	available	available
normalization	available	generic	generic	generic	available
turning-point detection (Bry-Boschan alg.)	available	x	x	quarterly data only	available
turning-point matching	available	x	x	x	available
aggregation	available	x	x	x	available
visualization	available	generic	generic	generic	available
custom development	x	x	available	available	available
evaluation (ex-post)	available	x	x	x	available
evaluation (real time)	x	x	x	x	available
automation	x	x	generic	generic	available
logs	x	x	generic	generic	available

Source: Own construction

All the presented software solutions can perform the time series transformations: seasonal adjustments, detrending, smoothing and normalization. The other tasks which are necessary to construct CI (turning points detection, turning points matching and aggregation) are offered only by CACIS, but often require substantial manual interventions. R also contains package BCDating for turning points detection, but it works only with quarterly time series.

Python and R offer a vast number of visualization libraries and packages and, therefore, enable almost any type of diagrams. EViews also provide some visualization capabilities but (compared to the previously mentioned solutions) they are limited. None of these programs contains the exact charts needed to illustrate the cycle analyses and CLI construction. As CACIS is the only existing program developed directly to analyze the business cycle, it contains the necessary visualizations, but it doesn't enable the users to alter them in any way. In contrast, newly proposed CIF provides a great variety of fully adjustable charts and other diagrams that can accompany the cycle analysis.

CACIS offers only the ex-post analysis of CI performance. The ex-post analysis usually overestimates the quality of constructed indicator and therefore should be accompanied by the real-time analysis, which considers also the historical revisions of economic series and lags between the events and their publication. For more information on the real-time evaluation, see Astolfi et al. (2016). CIF offers both the ex-post and the real-time quality assessment.

CIF also thoroughly records the whole computation process and saves the logs for later examination. One of CIF's main goals is to enable users to run the analysis automatically, without any manual interventions to the process.

3 METHODOLOGY

This section describes the OECD methodology which is employed in this paper with slight changes in pre-selection and evaluation phases. These modifications enable to construct international composite indicators in section 4.

3.1 Pre-selection

When constructing the composite indicators, the eligible individual series has to be selected first. According to Gyomai and Guidetti (2012) only long-time series of indicators that have the justified economic relationship with the reference series, broad coverage of economic activity, high frequency of observations (preferably monthly), that were not subject to any significant revisions and are published soon, should pass the pre-selection phase.

The easiest way when deploying CIF is to automatically download the whole table of main economic indicators supplied by OECD.[3] When OECD constructs its CLI, it takes into account only data from the analyzed country. The other way would be to consider also individual indicators from other countries (e.g., neighboring ones). The latter approach is described in section 4 herein.

The construction of composite indicators is highly dependent on the selection of reference time series. Usually, GDP or index of industrial production is used as reference series. GDP should respond to the cyclical movements better but it is quarterly statistics and it needs to be converted to the monthly estimates. OECD had used the industrial production index until March 2012 and then switched to the adjusted monthly GDP, which is also used in this paper.

3.2 Filtering

The second phase of the composite indicator construction is called the filtering. The main task of this stage is to decompose the individual time series and find their cyclical component. This means that the series have to be seasonally adjusted with their trend component removed.

The quarterly series need to be converted to a monthly frequency. Gyomai and Guidetti (2012, p. 6) describe, that OECD uses simple linear interpolation: "This conversion from quarterly to monthly is achieved via linearly interpolating quarterly series and aligning them with the most appropriate month of the quarter, depending on the nature/construction of the quarterly series (…), for most series this is the central month of the quarter (...)."

OECD uses TRAMO module from TRAMO/SEATS provided by the National Bank of Belgium to identify outliers, seasonally adjust the series and provide short horizon stabilizing forecasts before detrending the series (OECD, 2010). CIF utilizes the X-13ARIMA-SEATS Seasonal Adjustment Program developed by the United States Census Bureau because it is already integrated into Python in the Statsmodels library.

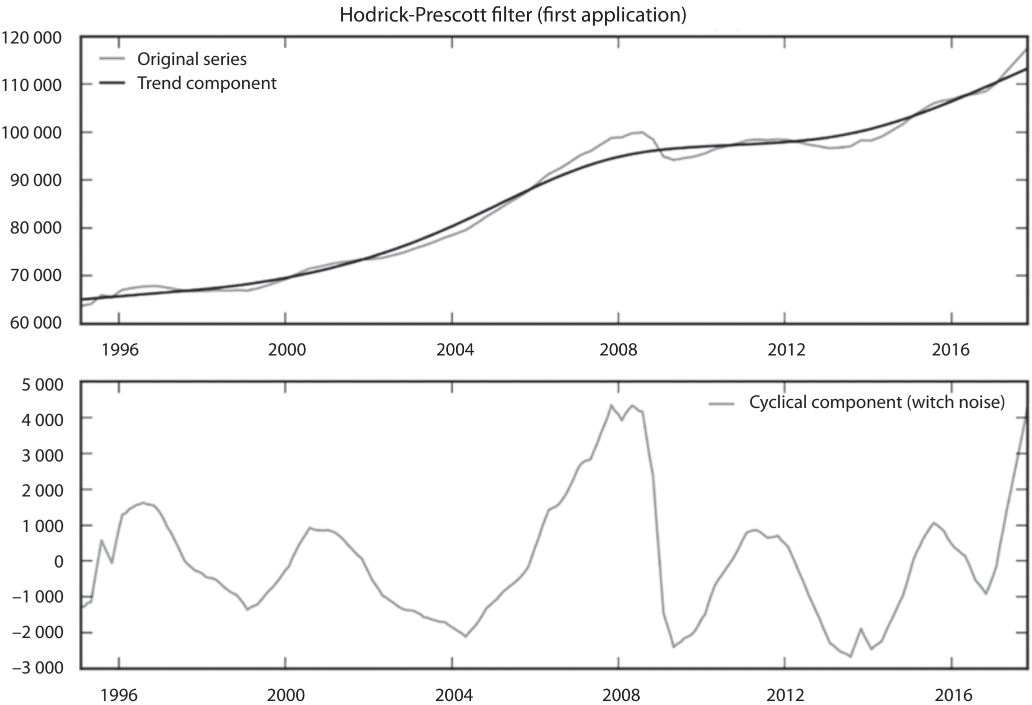
[3] Available at: <http://www.oecd-ilibrary.org/economics/data/main-economic-indicators_mei-data-en>.

Hodrick-Prescott filter divides the series into two parts (τ_t – trend component and c_t – the cyclical component) and optimizes expression:

$$\min_{\tau_t}\left[\sum_t\left(y_t-\tau_t\right)^2+\lambda\sum_t\left(\tau_{t+1}-2\tau_t+\tau_{t-1}\right)^2\right]. \tag{1}$$

It minimizes the difference between the trend and the original series and smooths the trend as much as possible at the same time. The λ parameter prioritizes the latter from the two contradictory goals – the higher the λ, the smoother the trend.

Figure 1 First application of Hodrick-Prescott filter on the Czech gross domestic product (in US dollars, monthly estimates, seasonally adjusted) with high lambda parameter to remove the trend

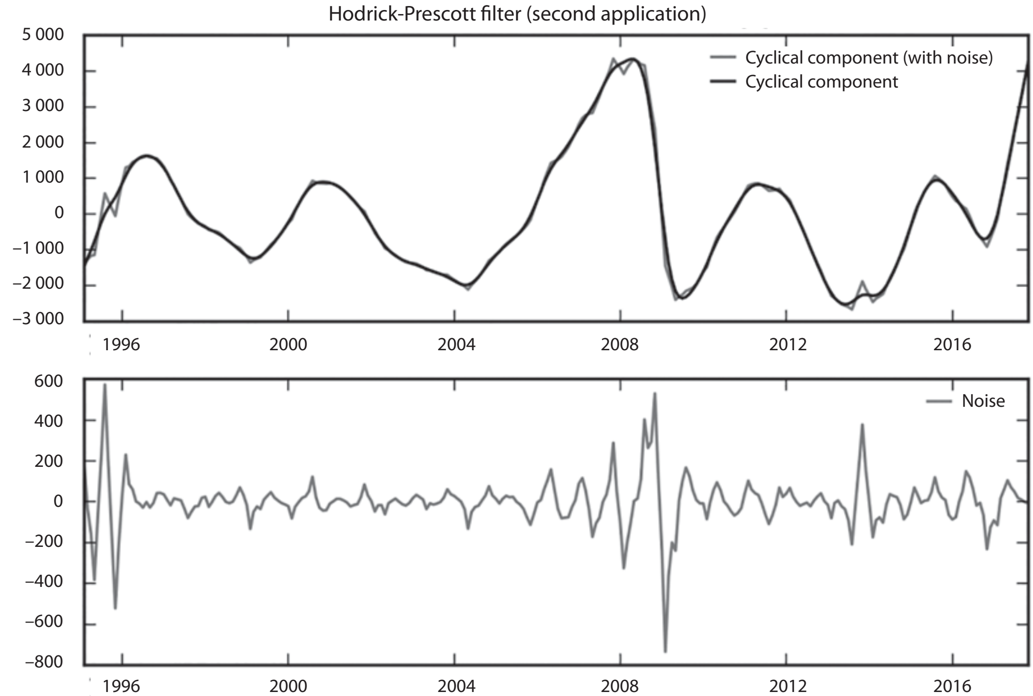


Source: Data from OECD (2017), processed by CIF

Hodrick-Prescott filter deals with the series as with the system of sinusoids and it keeps in the trend only those with low frequency (high wave length). According to OECD the business cycles last 10 years at maximum, therefore the fluctuations with lower wave length should be kept in the cycle component. Ravn and Uhlig (2002) recommend setting the λ parameter equal to 129 600 for monthly series. Nilsson and Gyomai (2011) use the Hodrick-Prescott filter twice: first with high λ to find the trend and then with low λ to smooth the cycle component. They also confirm that Hodrick-Prescott filter gives clear and steady turning point signals. Figures 1 and 2 illustrate the effects of the filter on Czech GDP.

After the trend component is estimated, it is subtracted from the original data set (this is called the deviation cycle then) and the series are normalized.

Figure 2 Second application of Hodrick-Prescott filter on detrended Czech gross domestic product with low lambda parameter to smooth the cyclical component



Source: Data from OECD (2017), processed by CIF

3.3 Evaluation

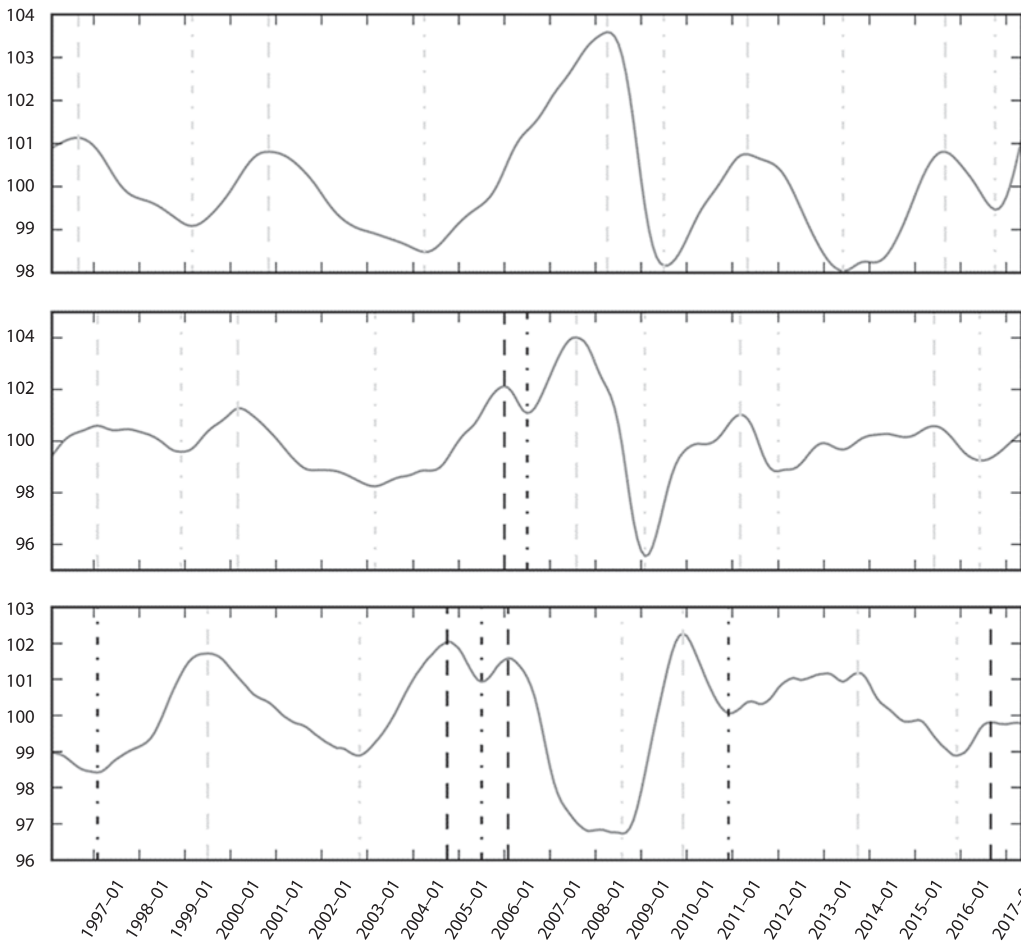
After the cycle components of all the individual indicators are found, turning points are detected. Not every peak or trough of the cycle is considered as the turning point though. OECD uses Bry-Boschan algorithm (Bry and Boschan, 1971) to determine the turning points.

The cyclical components of all the individual indicators are compared to the reference series. OECD uses several methods how to evaluate their relationship: the average lead (lag) times between the turning points, number of extra and missing cycles and cross correlations. Then the selected individual indicators are divided into groups of leading, coincident and lagging ones according to their characteristics.

Figure 3 presents one of the visualizations created by CIF to compare the turning points detected in individual and reference series. It shows the normalized cyclical component of the reference series (Czech GDP) and its turning points found by Bry-Boschan algorithm in the upper chart. The middle and the lower charts depict the normalized cyclical components of Czech share prices and unemployment, respectively. The unemployment shows typical counter-cyclical behavior and the series needs to be inverted before the next steps. The extremes of the individual series are marked in gray, if the corresponding turning points are detected in the reference series, or in black, when these are false signals. The corresponding turning point must occur in the neighborhood of the reference series extreme to be considered as matched: with the maximal lead of 24 months or maximal lag of 9 months according to the Eurostat (2017). CIF also enables to mark each matched extreme in a different color (not all in gray) to better distinguish their chronology and the missingturning points.

There is a discrepancy between the scales of y-axes, which is intentionally kept in this chart type. This plot should serve mainly to compare the turning points and not the level of the series because the amplitude of the composite indicator (or its normalized component series) can be interpreted only as the confidence of the CLI outlook and never to analyze the level of the economy (Eurostat, 2017).

Figure 3 Turning points detected by Bry-Boschan algorithm in selected Czech indicators. All series have been seasonally adjusted, detrended and normalized. Upper chart: Gross domestic product[4] (reference series). Middle chart: Share prices.[5] Lower chart: Unemployment of persons aged 15–24.[6] Extra turning points are marked in black.



Source: Data from OECD (2017), processed by CIF

[4] Detected dates of the turning points: 1996-09 (Peak), 1999-03 (Trough), 2000-11 (P), 2004-04 (T), 2008-04 (P), 2009-07 (T), 2011-05 (P), 2013-06 (T), 2015-09 (P), 2016-10 (T).

[5] Detected dates of the turning points: 1997-02 (P), 1998-12 (T), 2000-03 (P), 2003-03 (T), 2006-01 (P), 2006-07 (T), 2007-08 (P), 2009-02 (T), 2011-03 (P), 2012-01 (T), 2015-06 (P), 2016-06 (T).

[6] Detected dates of the turning points: 1997-02 (T), 1999-07 (P), 2002-11 (T), 2004-10 (P), 2005-07 (T), 2006-02 (P), 2008-08 (T), 2009-12 (P), 2010-12 (T), 2013-10 (P), 2015-12 (T), 2016 09 (P).

After each indicator is compared with the reference series, only the best-performing ones are selected into the composite indicator. The number of selected indicators may differ across the countries and depends on the criteria setup. OECD (2010, p. 31) defines these criteria quite laxly: "Ideally, potential component series should have a mean lead greater than 2 and a correlation at peak greater than 0.5 (with a peak lead equal or greater than 2). (…) Furthermore, users should bear in mind that a series provides valuable information if it does not flag too many extra cycles and does not miss too many turning points". Unlike some classical models like linear regression, the composite indicator quality does not depend on the number of input individual indicators, and its performance may decrease with additional indicators.

As the turning point detection and evaluation are the parts of the CI construction, which is covered the least in existing software programs, some authors try to avoid it by using only cross correlations which are much easier to compute. However, the Eurostat (2017, p. 286) states, that "the location of the peak of the cross correlation function is a good alternative indicator of average lead time. Whereas the correlation value at the peak provides a measure of how well the cyclical profiles of the indicators match, the size of correlations cannot be the only indicators used for component selection". As CIF contains the proper turning points detection, it can help the researchers to avoid similar quality endangering shortcuts.

3.4 Aggregation

In this phase, the selected individual indicators are aggregated into the leading, coincident or lagging composite indicators. This paper focuses on the leading composite indicator, which can help to predict the next regression or expansion of business cycle.

Different weighting schemes can be utilized during aggregation. However, OECD does not use any weights so all the input series have equal impacts on the constructed CLI. Another possibility during this phase is to lag-shift the input series with the longer lead, so their signals do not get neutralized by series with the shorter lead. This can lead to signals with shorter-lead, but enhanced quality.

CLI is published when at least 60% of selected input indicators are available. The chain linking method is used to prevent jumps and discontinuities when new series are added. For more details, see Eurostat (2017).

3.5 Presentation of the results

OECD publishes the final CLI in 3 forms:

- the amplitude adjusted CLI, which can be compared with normalized values of the cyclical component of the reference series,
- the trend restored CLI, which can be compared with the original values of the reference series,
- the 12-month growth rate of CLI, which can be compared with the 12-month growth rate of the reference series.

This paper goes further and analyzes the structure of the constructed CLI thoroughly. The choropleth maps are suggested as the tool to assess the leading influences between countries.

4 INTERNATIONAL LEADING COMPOSITE INDICATORS

OECD publishes CLIs for most of its 35 member countries and for some partner countries. It also compiles the CLI of the whole G7, NAFTA, Euro area, European OECD and all OECD countries. However, the composition of each country's CLI depends on the national input data only. For example, Czech OECD CLI consists of Czech individual economic indicators. The European economies are nevertheless often small and open and therefore their business cycles relate to the situation in the surrounding countries.

This is not the first time when the authors use international data to construct national CLI. For example, the authors of the Czech CLIs often include German economic series in their indicators, for more details see Svatoň (2011) or Vraná (2013). However, this is the first case, to the best of my knowledge, when the structure of international CLI is visualized on maps and used to interpret the relationships between the countries.

The international CLI construction is demonstrated on data from 5 countries: Austria (AUT), the Czech Republic (CZE), Germany (DEU), Poland (POL) and Slovakia (SVK). Each business cycle is compared with available indicators from all of these countries and the best matching ones are selected as its CLI elements.

These countries were selected to simplify the interpretations and visualizations of the results. However, deploying the newly proposed framework guarantees that the international CLIs could be easily based on all European data or data available all over the world.

The data for this paper were downloaded[7] from OECD API via CIF.

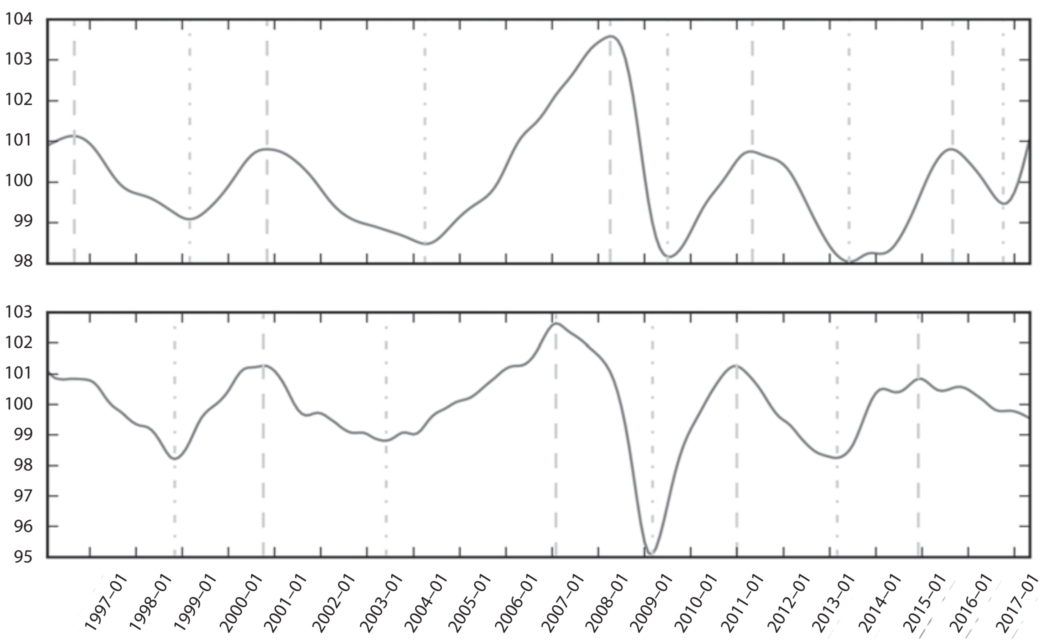
Another important data source for this chapter is GADM (Global Administrative Areas) spatial database, which provides mapping files (Hijmans et al., 2015).

4.1 Construction and basic characteristics

The analysis follows the OECD methodology and was performed completely with the CIF described in section 2.2. Only minor parts of the pre-selection and evaluation phases need to be altered for this use case:

- the pre-selection phase contains input data from multiple countries,
- the number of individual economic indicators selected to be aggregated into CLI is fixed to 15 during the evaluation phase.

Figure 4 Comparison of turning points of Czech GDP (upper chart) and OECD CLI[8] (lower chart)



Source: Data from OECD (2017), processed by CIF

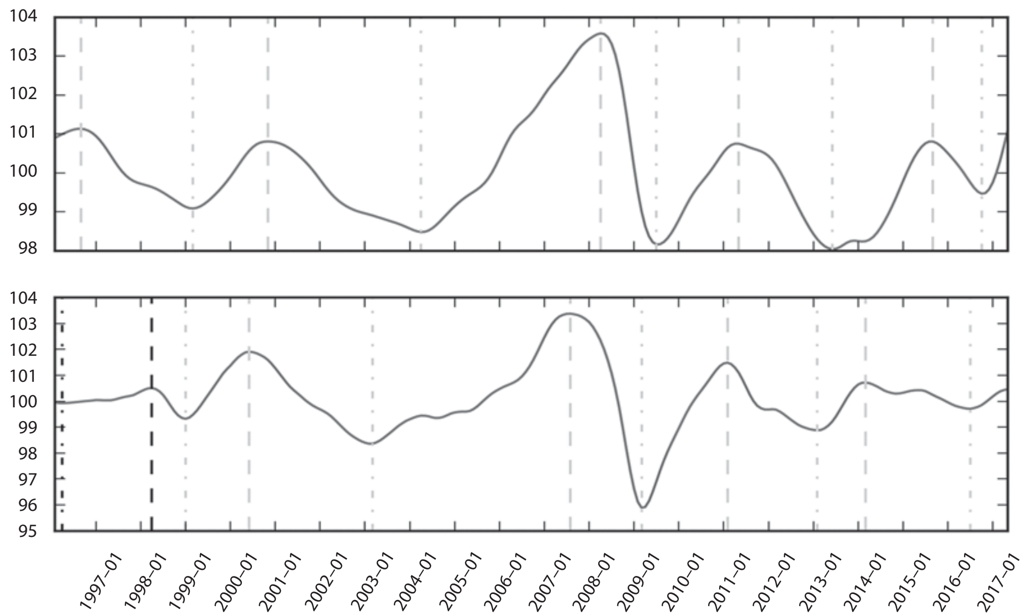
7 On the 17th September 2017.

8 Detected dates of the turning points: 1998-11 (T), 2000-10 (P), 2003-06 (T), 2007-02 (P), 2009-03 (T), 2011-01 (P), 2013-03 (T), 2014-12 (P).

The number of selected individual indicators is fixed to enable the comparison of international influences between several countries. Usually, this kind of prerequisite is not necessary because the quality of constructed CLI does not depend on the number of selected indicators as was explained in section 3.3. However, it is the structure, not the performance quality, which is the main focus of this paper.

Figures 4 and 5 display OECD CLI and international CLI of the Czech business cycle, respectively. Each figure shows reference series (GDP) with detected turning points in the upper chart and CLI with the matched (or unmatched) turning points in the lower chart. If the CLI contains any extra turning points, they are marked in black.

Figure 5 Comparison of turning points of Czech GDP (upper chart) and international CLI[9] (lower chart). 2 extra turning points detected in the beginning of the international CLI are marked in black.



Source: Data from OECD (2017), processed by CIF

This paper aims to analyze and visualize the leading influence between multiple countries. Its primary goal is not the improvement or assessment of current OECD CLI quality. However, the comparison with the OECD results should not be avoided entirely: Tables 2 and 3 show basic statistics of OECD CLIs and international CLIs, respectively. They summarize the number of missing and extra turning points, mean and medium lead time of turning points, maximum and location of the peak of the cross correlation function and the cross-check (the difference between the correlation peak location and the median lead). Eurostat (2017, p. 286) states that "the lead at which the highest correlation occurs should not be too different from the median lead if the composite leading indicator is to provide reliable information about approaching turning points and the evolution of the reference series."

[9] Detected dates of the turning points: 1996-04 (T), 1998-04 (P), 1999-01 (T), 2000-06 (P), 2003-03 (T), 2007-08 (P), 2009-03 (T), 2011-02 (P), 2013-02 (T), 2014-03 (P), 2016-07 (T).

Table 2 Basic characteristics of OECD CLIs

	missing	extra	mean lead time	median lead time	cross correlation maximum	cross correlation peak location	cross-check
AUT	0	2	3.00	3.00	0.77	6	3.00
CZE	1	0	6.78	4.00	0.83	6	2.00
DEU	0	5	5.00	5.00	0.77	6	1.00
POL	1	0	9.85	11.00	0.41	12	1.00
SVK	0	5	7.40	9.50	0.78	1	8.50

Source: Data from OECD (2017), processed by CIF

Table 3 Basic characteristics of international CLIs

	missing	extra	mean lead time	median lead time	cross correlation maximum	cross correlation peak location	cross-check
AUT	0	2	6.83	6.00	0.85	8	2.00
CZE	0	2	7.70	4.50	0.82	5	0.50
DEU	0	2	6.60	7.00	0.88	6	1.00
POL	0	1	4.64	3.50	0.79	7	3.50
SVK	0	2	5.25	6.00	0.75	5	1.00

Source: Data from OECD (2017), processed by CIF

The CLI is computed when at least 60% of individual indicators are available. The international time series tend to vary in lengths substantially. E.g., OECD provides the first German main economic indicators from January 1955 and first Czech ones not sooner than January 1990. That means that if German CLI is composed mainly of Czech economic indicators (which of course is a hypothetical situation), it could not be calculated sooner than January 1990 (and probably even later, as only a few Czech indicators are available right from the beginning of this timespan). Therefore, the length of the OECD CLI and international CLI may differ and their lengths are adjusted to the shorter one of the two to enable comparison.

Tables 2 and 3 report that the Austrian and German international CLIs show longer leads (and the German one also gives less false signals) than the OECD CLIs, which is based on their national data only. The Czech international CLI also displays improvement in the leading time measured by mean and median, but not by cross correlation (for comparison, see also Figures 4 and 5). The Slovak OECD CLI seems to perform better in mean and median lead time, but the difference between median and location of the peak cross correlation is high and, therefore, the international CLI would probably provide more stable results. The only OECD CLI clearly outperforming the international CLI is the Polish one with more than 3 times longer median lead time (although with the lower correlation coefficient). However, even the Polish CLI could still be improved by adding international data from other countries, then those selected in this paper.

More than 5 countries should be analyzed to achieve the proper comparison of the OECD and international CLIs performance. Such analysis should not be based on a single time instant, but it should also involve historical data. However, the general comparison is not the goal of this paper and it remains for a future work. The aim of this paper – analysis of international influence – is the subject of the following section.

4.2 Leading influence maps

The international CLIs can be used to analyze the relationships, similarities and differences between business cycles of selected countries. Table 4 summarizes the structure of each constructed CLI (for the complete overview see the Appendix). The input number of selected individual economic indicators was artificially set to 15 as was explained in section 4.2, therefore the total equals 15 for each column. The row totals represent the frequency of the national individual indicators in all of the constructed CLIs. The higher this number is, the more common it is for the individual indicators of this country to appear in the leading indicators. This could also be interpreted as the economic lead or influence the country has when it is compared to the others.

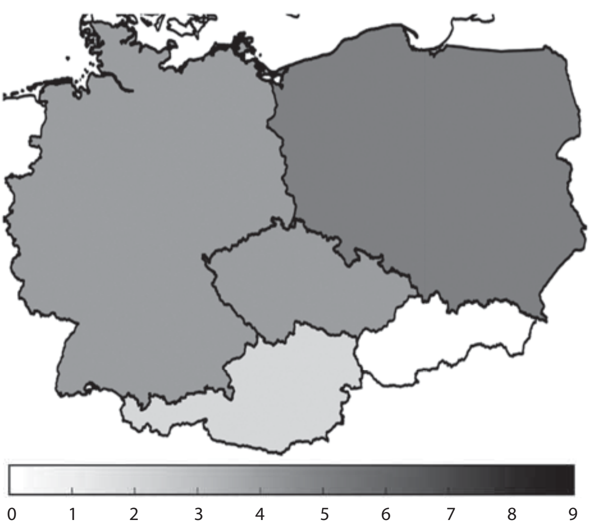
Table 4 Summary of international CLIs structures

		reference country					
		AUT	CZE	DEU	POL	SVK	Total
input data	AUT	3	2	1	2	4	12
	CZE	0	4	1	1	1	7
	DEU	9	4	6	4	5	28
	POL	3	5	6	6	5	25
	SVK	0	0	1	2	0	3
	Total	15	15	15	15	15	x

Source: Data from OECD (2017), processed by CIF

Data from Table 4 are visualized as choropleth maps to ease the interpretation of the results. Figure 6 shows the choropleth map of leading influences of the selected countries on the Czech business cycle. The darker the shade of area in the map, the higher number of its economic indicators appeared in the constructed CLI. For the maps of the rest of the analyzed countries, see Figure 7.

Figure 6 Visualization of the leading influences of neighboring countries on the Czech Republic business cycle. The darker the shade, the greater the influence measured by the number of individual economic series included in the international CLI.

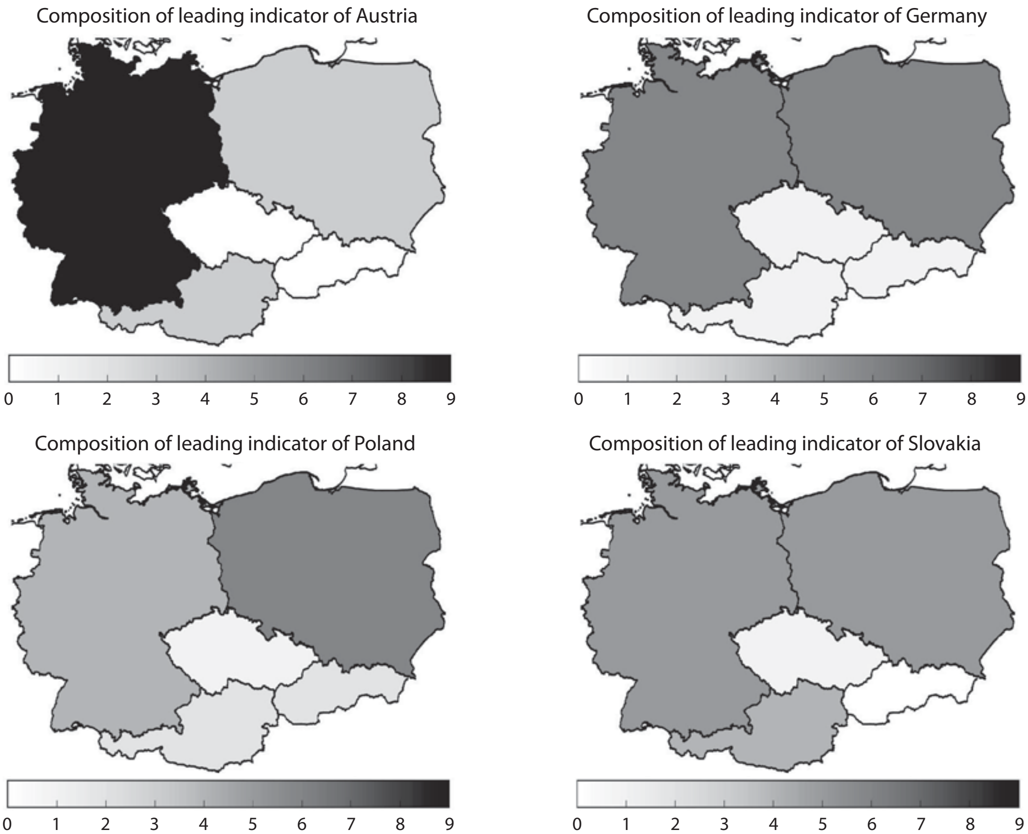


Source: Data from OECD (2017), processed by CIF

Germany and Poland are the most leading economies according to the appearance of their economic indicators in CLIs (28 and 25 times, respectively). The CLIs of these two countries also contain the highest ratio of their own national indicators (6 out of 15). The other extreme is Slovakia, whose CLI contains only foreign indicators (almost exclusively German, Polish and Austria ones).

The leading role of Poland could explain, why the Polish international CLI does not show up any improvement when compared with OECD CLI (as described in section 4.2). This is, however, in contradiction with the German CLI, which tends to perform better when international data are incorporated.

Figure 7 Visualizations of the leading influences between the business cycles of selected countries. The darker the shade, the greater the leading influence measured by the number of individual economic series included in the international CLI.



Source: Data from OECD (2017), processed by CIF

The influence of Germany on the Czech economy is not surprising as it is the key business partner of the Czech Republic. Tables 5 and 6 show values of Czech imports and exports in 2016 and Germany is number one in both. The role of Poland, which provides most of the leading individual indicators, is more surprising: Poland is of course in the top positions among the Czech import and export countries, but its values are only a fraction of the German ones. On the other hand, Slovakia occurs on the top ranks of Czech imports and exports as well, but not even one of its economic indicators appeared in Czech CLI.

Table 5 Neighboring countries by imports into the Czech Republic in 2016

country	rank	import value (thousands of CZK)	import ratio (%)
DEU	1	924 082 513	26.40
POL	3	288 884 681	8.30
SVK	4	177 637 683	5.10
AUT	7	101 370 620	2.90

Source: Czech Statistical Office (2017)

Table 6 Neighboring countries by exports from the Czech Republic in 2016

country	rank	export value (thousands of CZK)	export ratio (%)
DEU	1	1 286 717 667	32.40
SVK	2	331 354 077	8.30
POL	3	229 138 114	5.80
AUT	7	168 445 174	4.20

Source: Czech Statistical Office (2017)

Austria business cycle is led mainly by German indicators, which form more than half of its CLI. It displays no signs of the influence of Czech or Slovak economies.

CONCLUSION

This paper presented the OECD methodology of composite indicators construction and how to modify it by considering international input data. Three objectives were defined: (1) to assess whether the international data would change the structure of OECD CLIs, (2) whether the international CLIs could be used to analyze the relationships between business cycles of several countries and (3) how could these relationships be interpreted and visualized.

The OECD methodology was described in section 3 and followed during the rest of this paper with two modifications: the preselection phase included data from multiple countries and the number of selected component series was fixed to enable the comparison of international influences.

Section 4.2 presented the newly constructed international CLIs of Austria, the Czech Republic, Germany, Poland and Slovakia. Their performances were compared to the national CLIs published by OECD. All the CLIs, except the Polish one, tended to improve their leading performance after the international data were added. This confirmed, that the individual economic series from one country can contribute to predicting the business cycle movements of another country. The first of the three objectives of this paper was therefore met.

Section 4.3 discussed the structure of the international CLIs and analyzed the leading or lagging behavior of each country's business cycle. Germany and Poland were recognized as the most leading economies, Slovakia as the most lagging one. The choropleth maps were designed to visualize and easily interpret the leading influences between the analyzed countries. This section therefore gave the answers to the other two research questions. This was also the first time, to the best of my knowledge, when the structure of international CLI was visualized on maps and used to interpret the relationships between the countries.

Moreover, it was shown, on the example of the Czech Republic, that the leading influences revealed by this analysis were not driven solely by the country's international trade. Therefore, the modified CLI could serve as another indicator of international relationships.

The described approach could be extended to analyze the available data from countries all around the world and it could for example help to create clusters of regions with similar business cycle movements.

None of these analyses would be possible in any of the publicly available software programs. Therefore, a new computational framework was proposed and introduced for the very first time in section 2 of this paper. This framework is now available as an open-source project on GitHub platform and it will soon be available as Python library installable via pip command. Researchers from now on will not have to waste their time on deploying basic tasks, e.g., how to detect the turning points or evaluate and aggregate the series. They will be allowed (and encouraged) to download the new framework and start to collaborate on its future development.

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APPENDIX

Table A1 Structure of international CLIs (indicators are sorted according to the strength of their relationship with the reference series)

	country	indicator code	indicator full name	note
AUT	DEU	BRBUFT02	Business tendency surveys (retail trade) > Business situation - Activity > Future tendency > National indicator	
	DEU	BCOBLV02	Business tendency surveys (construction) > Order books > Level > National indicator	
	AUT	PIEAFD01	Producer Prices Index > Economic activities > Manufacture of food products > Total	inverted
	DEU	BREMFT02	Business tendency surveys (retail trade) > Employment > Future tendency > National indicator	
	DEU	BCSPFT02	Business tendency surveys (construction) > Selling prices > Future tendency > National indicator	
	POL	BVCICP02	Business tendency surveys (services) > Confidence Indicators > Composite Indicators > National indicator	
	DEU	BVEMFT02	Business tendency surveys (services) > Employment > Future tendency > National indicator	
	DEU	BRCICP02	Business tendency surveys (retail trade) > Confidence indicators > Composite indicators > National indicator	
	DEU	PITGCD01	Producer Prices Index > Type of goods > Durable consumer goods > Total	inverted
	DEU	BRBUTE02	Business tendency surveys (retail trade) > Business situation - Activity > Tendency > National indicator	
	POL	BSPRTE02	Business tendency surveys (manufacturing) > Production > Tendency > National indicator	
	POL	SPASTT01	Share Prices > All shares/broad > Total > Total	
	AUT	PITGCG01	Producer Prices Index > Type of goods > Consumer goods > Total	inverted
	DEU	BVDETE02	Business tendency surveys (services) > Demand evolution > Tendency > National indicator	
	AUT	PITGND01	Producer Prices Index > Type of goods > Non durable consumer goods > Total	inverted

Source: Own construction

Table A2 Structure of international CLIs (indicators are sorted according to the strength of their relationship with the reference series)

	country	indicator code	indicator full name	note
CZE	POL	SPASTT01	Share Prices > All shares/broad > Total > Total	
	CZE	SPASTT01	Share Prices > All shares/broad > Total > Total	
	POL	BVCICP02	Business tendency surveys (services) > Confidence Indicators > Composite Indicators > National indicator	
	CZE	BSPRTE02	Business tendency surveys (manufacturing) > Production > Tendency > National indicator	
	CZE	BSPRFT02	Business tendency surveys (manufacturing) > Production > Future Tendency > National indicator	
	DEU	SPASTT01	Share Prices > All shares/broad > Total > Total	
	POL	BRCICP02	Business tendency surveys (retail trade) > Confidence indicators > Composite indicators > National indicator	
	CZE	XTIMVA01	International Trade > Imports > Value (goods) > Total	
	DEU	BRCICP02	Business tendency surveys (retail trade) > Confidence indicators > Composite indicators > National indicator	
	DEU	PRMNCG03	Production > Manufacturing > Consumer goods > Non durable goods	
	AUT	BRBUFT02	Business tendency surveys (retail trade) > Business situation - Activity > Future tendency > National indicator	
	DEU	SLMNCN01	Sales > Manufacturing > Consumer goods non durable > Volume	
	AUT	PRMNIG01	Production > Manufacturing > Intermediate goods > Total	
	POL	CSCICP02	Consumer opinion surveys > Confidence indicators > Composite indicators > National indicator	
	POL	BVDEFT02	Business tendency surveys (services) > Demand evolution > Future tendency > National indicator	

Source: Own construction

Table A3 Structure of international CLIs (indicators are sorted according to the strength of their relationship with the reference series)

	country	indicator code	indicator full name	note
DEU	POL	SPASTT01	Share Prices > All shares/broad > Total > Total	
	DEU	PRMNCG03	Production > Manufacturing > Consumer goods > Non durable goods	
	DEU	LRHUADMA	Labour Force Survey - quarterly rates > Harmonised unemployment - monthly rates > Aged 25 and over > Males	
	POL	BVCICP02	Business tendency surveys (services) > Confidence Indicators > Composite Indicators > National indicator	
	POL	CSCICP02	Consumer opinion surveys > Confidence indicators > Composite indicators > National indicator	
	SVK	BRVSLV02	Business tendency surveys (retail trade) > Volume of stocks > Level > National indicator	inverted
	POL	BVDEFT02	Business tendency surveys (services) > Demand evolution > Future tendency > National indicator	
	CZE	SPASTT01	Share Prices > All shares/broad > Total > Total	
	DEU	LFHUADTT	Labour Force Survey - quarterly levels > Harmonised unemployment - monthly levels > Aged 25 and over > All persons	
	DEU	LRHUADFE	Labour Force Survey - quarterly rates > Harmonised unemployment - monthly rates > Aged 25 and over > Females	
	DEU	BRCICP02	Business tendency surveys (retail trade) > Confidence indicators > Composite indicators > National indicator	
	POL	PITGND02	Producer Prices Index > Type of goods > Non durable consumer goods > Domestic	inverted
	DEU	BRBUFT02	Business tendency surveys (retail trade) > Business situation - Activity > Future tendency > National indicator	
	AUT	PIEAFD01	Producer Prices Index > Economic activities > Manufacture of food products > Total	inverted
	POL	BSPRTE02	Business tendency surveys (manufacturing) > Production > Tendency > National indicator	

Source: Own construction

Table A4 Structure of international CLIs (indicators are sorted according to the strength of their relationship with the reference series)

	country	indicator code	indicator full name	note
POL	POL	BCBUTE02	Business tendency surveys (construction) > Business situation - Activity > Tendency > National indicator	
	POL	SPASTT01	Share Prices > All shares/broad > Total > Total	
	SVK	CPGDFD02	Consumer Price Index > Goods > Food > Food (excl restaurants)	inverted
	DEU	BVDETE02	Business tendency surveys (services) > Demand evolution > Tendency > National indicator	
	POL	BSPRTE02	Business tendency surveys (manufacturing) > Production > Tendency > National indicator	
	SVK	PIEAFD02	Producer Prices Index > Economic activities > Manufacture of food products > Domestic	inverted
	AUT	PITGCD02	Producer Prices Index > Type of goods > Durable consumer goods > Domestic	inverted
	DEU	BRBUFT02	Business tendency surveys (retail trade) > Business situation - Activity > Future tendency > National indicator	
	DEU	BRCICP02	Business tendency surveys (retail trade) > Confidence indicators > Composite indicators > National indicator	
	POL	XTIMVA01	International Trade > Imports > Value (goods) > Total	
	CZE	BVCICP02	Business tendency surveys (services) > Confidence Indicators > Composite Indicators > National indicator	
	DEU	BREMFT02	Business tendency surveys (retail trade) > Employment > Future tendency > National indicator	
	POL	BVBUTE02	Business tendency surveys (services) > Business situation - Activity > Tendency > National indicator	
	POL	BVCICP02	Business tendency surveys (services) > Confidence Indicators > Composite Indicators > National indicator	
	AUT	CPALTT01	Consumer Price Index > All items > Total > Total	inverted

Source: Own construction

Table A5 Structure of international CLIs (indicators are sorted according to the strength of their relationship with the reference series)

	country	indicator code	indicator full name	note
SVK	POL	BSEMFT02	Business tendency surveys (manufacturing) > Employment > Future Tendency > National indicator	
	DEU	CSCICP02	Consumer opinion surveys > Confidence indicators > Composite indicators > National indicator	
	POL	BRBUTE02	Business tendency surveys (retail trade) > Business situation - Activity > Tendency > National indicator	
	POL	BSPRFT02	Business tendency surveys (manufacturing) > Production > Future Tendency > National indicator	
	AUT	BSPRFT02	Business tendency surveys (manufacturing) > Production > Future Tendency > National indicator	
	DEU	BSPRTE02	Business tendency surveys (manufacturing) > Production > Tendency > National indicator	
	AUT	BSEMFT02	Business tendency surveys (manufacturing) > Employment > Future Tendency > National indicator	
	DEU	BSBUCT02	Business tendency surveys (manufacturing) > Business situation > Current > National indicator	
	POL	BRBUFT02	Business tendency surveys (retail trade) > Business situation - Activity > Future tendency > National indicator	
	AUT	PRMNCG01	Production > Manufacturing > Consumer goods > Total	
	POL	BVCICP02	Business tendency surveys (services) > Confidence Indicators > Composite Indicators > National indicator	
	DEU	BSFGLV02	Business tendency surveys (manufacturing) > Finished goods stocks > Level > National indicator	inverted
	AUT	XTNTVA01	International Trade > Net trade > Value (goods) > Total	
	DEU	BSOBLV02	Business tendency surveys (manufacturing) > Order books > Level > National indicator	
	CZE	PRINTO01	Production > Industry > Total industry > Total industry excluding construction	

Source: Own construction