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DATING THE EURO AREA BUSINESS CYCLE: AN EVALUATION

by Claudia Pacella*

Abstract

In this paper we study the business cycle dating formulated by the CEPR committee for the euro area. We first compare recessions as defined by the CEPR to those obtained using alternative methodologies (e.g. Bry-Boschan algorithm) and we find that the CEPR dating is not fully in line with other dating rules that are based only on GDP dynamics, thus confirming that the committee considers a broader set of variables. We then evaluate the classification of economic activity in recessions and expansions; the underlying business cycle is either based on a single variable or estimated as a latent factor that captures the comovements of several macroeconomic series. We find that the CEPR chronology is more consistent with the estimated common factor than with what is implied by methods solely based on GDP. Finally, we analyze which real variables drive the classification of economic activity by the CEPR and we find that the properties of the CEPR chronology are mainly related to the dynamics of demand components, especially final consumption, and employment.

JEL Classification: E32, C38.
Keywords: business fluctuations, cycle, factor models.
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1 Introduction[1]

Since the Great financial crisis, the attention on business cycle analysis has strongly increased. Non-linear models such as regime-switching models have become popular tools to estimate the probability a variable to be in one of its possible states (Hamilton, 1989). The underlying idea is that macroeconomic variables behave according to different dynamics during expansionary and contractionary periods. In the last decade the literature on recession probabilities has further developed. The performance of non-linear models is usually tested vis-à-vis the recession periods. This exercise implicitly assumes that the target variable, which consists of a specific classification into recessions and expansions, is correctly identified.

In the euro area the chronology formulated by the CEPR is well-established, likewise the one for the US by the NBER. In this paper we evaluate the business cycle chronology of the euro area as identified by the CEPR. This analysis is relevant for both policymakers and academics interested in using the CEPR dating.

The aim of the paper is twofold. Firstly, we compare the turning points underlying the CEPR dating with those obtained using other possible alternatives, such as mechanical rules on one single variable or more sophisticated multivariate models. Secondly, we analyze which real variables drive the classification of economic activity by the CEPR.

We relate to the stream of literature studying the accuracy of business cycle chronologies. However, as not many official chronologies are available, to our knowledge the only paper evaluating a comparable consolidated dating is Berge and Jordà (2011) on the NBER dating for the US. They find that the NBER chronology is consistent with the dynamics of US business cycle. On the other hand, many methodologies to estimate turning points have been proposed and we compare those to the CEPR classification. Most methods rely on only one time series and they consist of non-parametric rules: the most popular are the Bry and Boschan (1971) algorithm and the 'rule of thumb' on GDP (Shiskin, 1974). A statistical model which was introduced to estimate the probability of transition between the two states of the business cycle is the regime-switching model (Goldfeld and Quandt, 1973; Hamilton, 1989; 1994). Chauvet and Piger (2008) and Hamilton (2011) find that both the Markov-switching model and the Bry-Boschan algorithm are very accurate in matching NBER dates. Other methodologies employed for turning points detection include factor models, which exploit the information common to many macroeconomic variables without

[1] I wish to thank Travis Berge, Fabio Busetti, Michele Caivano, Domenico Giannone, Adrian Pagan, Oscar Jorda, Stefano Neri, and Philippe Weil for their helpful comments and suggestions. I acknowledge the editor and two anonymous referees for their useful remarks.

just choosing one (Stock and Watson, 2002; 2014). Our paper complements the existing literature with evidence on the euro area business cycle, with a specific focus on the CEPR chronology.

With respect to the US, for the euro area the exercise is further challenging, because time series are relatively short and business cycles of different countries have not completely converged towards a common business cycle, especially after the Sovereign Debt Crisis. The CEPR euro area business cycle dating Committee defines the chronology of recessions and expansions of the euro area by identifying turning points since 2003. The committee considers the euro area as including the original eleven member countries for the period ranging from 1970 to 1999 and in its changing composition after 1999. The committee detects turning points looking at the dynamics of several macroeconomic aggregates. The issue arises because the classification of business cycle does not only depend mechanically on the quarterly growth of GDP or on a fixed threshold of a selected indicator. The classification of economic activity is very difficult, because it is even ex-post unobservable, and it does not rely on one single variable.

As in Burns and Mitchell (1946) the business cycle is defined as "*a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own.*"

In principle two approaches on business cycle exist. The growth or deviation cycle approach distinguishes four phases of the business cycle depending on the deviations from the long-term trend using the GDP as reference series. The phases of the deviation cycle are therefore defined according to the output gap and the actual-versus-trend growth as expansion, downturn, recession and recovery. An expansion or boom occurs when the output gap is positive and GDP growth is above potential growth. After that, economy faces downturn when activity is still above the trend, but deteriorating. A recession or slow-down happens when the output gap becomes negative and the real growth is below potential growth. Finally, when at last activity is below the trend but improving the economy is in recovery or upturn. The problem of this approach is that it requires the estimation of the unobservable long-term trend. The classical approach (Burns and Mitchell, 1946; Mintz, 1969) distinguishes two phases depending on the general economic situation. This is the approach followed by the NBER and CEPR for dating peaks and troughs in the US and the euro area respectively. The advantage of this approach is that it relies on observable hard data, entailing less uncertainty than in the growth cycle approach. Under this approach, the phases are recession and expansion. A recession or contraction is characterized by a sustained decline in economic activity (e.g. real GDP), while the rest of the time economy is in expansion.

Following Burns and Mitchell (1946), the so-called 'reference cycle' is described either by one single variable capturing the general state of the economy or by a latent factor obtained from a big dataset including many 'specific cycles'. Among the several approaches in the literature, the most predominant way to estimate the reference cycle using many variables are factor models (Forni et al., 2000; Stock and Watson, 2002). In the last two decades a lot of indicators have been constructed in order to track the business cycle of many countries, some of which are published by private institutions, such as the Conference Board[2] and ECRI.[3]

For the euro area the business cycle is well described by Eurocoin[4] (Altissimo et al., 2001; 2010). The OECD also publishes Composite Leading Indicators (CLIs[5]) for many countries.

From a statistical point of view, the issue the committee faces consists in a classification problem of the business cycle, which is itself represented as a mixture of two distributions, one for recessions and the other for expansions. Figure 1 shows the density distribution of the quarter-on-quarter growth rate of GDP in the two states of the economy obtained with gaussian kernel. The mode of the distribution of downturns is -1.1% with values ranging from -15.2% to 4.8% and a standard deviation of 3.1; the distribution of upturns is centered around 2.4% going from -3.8% to 9.5% and a standard deviation of 1.9. The figure illustrates that high magnitude of growth rates of GDP are categorized as expansion or recession if positive or negative respectively, while the classification of growth rates close to zero is not straightforward. As Berge and Jordà (2011) highlight, the issue graphically consists in the overlapping region.

[2]See https://www.conference-board.org/data/bci.cfm.

[3]See https://www.businesscycle.com/ecri-reports-indexes/all-indexes.

[4]See https://eurocoin.cepr.org.

[5]See https://data.oecd.org/leadind/composite-leading-indicator-cli.htm.

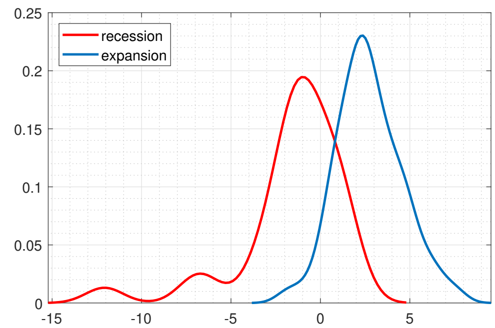


Figure 1: Density distribution of the growth rates of GDP in the two states of the economy (CEPR def.) obtained as gaussian kernel

Our analysis shows that the CEPR dating is not fully in line with other dating rules based only on GDP dynamics. One of the alternatives (the Markov-switching model) individuates only the sharpest recessionary episodes; the other mechanical rules (the Bry-Boschan algorithm and the rule of thumb), while reliable in replicating the CEPR turning points, detect shorter recessions with respect to the CEPR ones. These findings confirm that the committee considers more indicators. We then move to a multivariate framework and we find that the classification of economic activity appears to be mainly related to the dynamics of demand components, especially final consumption, and employment. Moreover, using the entire dataset we set up a model to compare with the CEPR dating and we find that the dating proposed by the CEPR committee consistently reflects the business cycle features common to most real macroeconomic time series.
The paper is structured as follows. Section 2 describes the different approaches to the business cycle with a focus on the business cycle dating committee. Section 3 illustrates the methodology and the evaluation criterion. Section 4 shows the main results.[6] Section 5 concludes.

[6]Unfortunately out-of-sample analyses cannot be conducted because of the very short sample size. Most time series are indeed available or recoverable from 1995Q1 or even 1999Q1, thus capturing only the two recent recession episodes. Moreover, we should have been able to split the sample in a training sample, on which estimating the parameters, and an evaluation sample, where comparing forecasts and actual endogenous variable. This would result in an even shorter sample.

2 Dating business cycles

2.1 CEPR Dating Committee for the euro area

The CEPR euro area business cycle dating Committee defines the chronology of recessions and expansions of the euro area by identifying turning points since 2003. The committee considers the euro area as including the original eleven member countries for the period ranging from 1970 to 1999 and in its changing composition after 1999.

The committee defines a recession as follows:[7]

"*a significant decline in the level of economic activity, spread across the economy of the euro area, usually visible in two or more consecutive quarters of negative growth in GDP, employment and other measures of aggregate economic activity for the euro area as a whole*".

The recession begins after a peak (excluded) and ends with a trough (included); the remaining time the economy experiences an expansion. According to the statement there are no constraints on magnitude and sign of the growth rate of the reference variables, which can be very low in both phases. The members of the committee do not disclose the methodology they employ and it is fair to suppose that a certain degree of subjective judgement could play a role in the final decision.

Regarding the cross-country heterogeneity, until 2011 the committee required turning points to appear in the same periods for most countries of the euro area. Since 2012 the committee's sole objective is to characterize euro area economic business cycle by adopting a dating criterion that only refers to aggregate euro area economic activity. Balkan (2012) studies whether this 'new' definition would require a change of the turning points set until then: the analysis confirms that no revisions on the dating were needed. However, analysis of main euro area countries' key economic indicators keep on being released in the key finding meaning they are helpful for a deeper understanding.

In general, the issue of understanding how reliable the chronology established by the CEPR arises because the features of the recessions and the cycles are not stable over time (Table 1).

[7] See https://cepr.org/content/business-cycle-dating-committee-methodology

Table 1: Duration and amplitude of the cycles

Turning point		Duration in quarters				Amplitude
		Recession	Expansion	Cycle		
Peak (P)	Trough (T)	P to T	T to P	T to T	P to P	P to T
1974Q3	1975Q1	2	19	30	22	-2.5
1980Q1	1982Q3	10	20	44	48	0.4
1992Q1	1993Q3	6	38	63	64	-1.4
2008Q1	2009Q2	5	58	15	14	-5.7
2011Q3	2013Q1	6	9			-1.8
Average		*5.8*	*28.8*	*38.0*	*37.0*	*-2.3*

Note: Amplitude is computed as the loss in terms of real GDP between a peak and the following trough.

From 1970 to 2018 five recessions are identified lasting from 2 to 10 quarters, with an average duration of around 6 quarters; expansions last 7 years on average, varying from 9 to 58 quarters. The resulting cycles last almost 10 years, both when measured from peak to peak and from trough to trough. There is heterogeneity also in the amplitude of cycles, as measured by the loss in terms of real GDP during contractions: in the 1980Q2-1982Q3 recession GDP remained almost stable, while during the 2008Q2-2009Q2 one GDP fell of almost 6p.p.. On average in a recession GDP contracts for more than 2p.p..

2.2 Alternative dating rules

There are alternative methods to detect turning points.
The first method is a very popular rule of thumb often used by the media introduced by US Commissioner of Labor Statistics Shiskin (1974) in a New York Times article. The rule defines a recession when the economy experiences at least two consecutive negative quarters GDP growth or similarly six months for employment or industrial production. In the same article Shiskin actually describes other ways to detect a recession, not only depending on the duration: in terms of depth a recession occurs when real GDP declines by more than 1.5% or unemployment reaches 6%, while in terms of diffusion the contraction of economic activity should be widespread, namely a decline in employment in more than 75% of industries.
The second method was introduced by Bry and Boschan (1971) to identify the turning points of a monthly time series. Harding and Pagan (2002) adapted the algorithm for quarterly time series, that is the typical case for macroeconomic data. It works

as follows. Given a quarterly time series X_t (e.g. GDP) in levels we define x_t as a potential peak if x_t is a local maximum, that is:

$$x_t > x_{t-1}, \ldots, x_{t-w} \text{ and } x_t > x_{t+1}, \ldots, x_{t+w}$$

where w is the window size, usually set to $w = 2$ for quarterly data, $w = 5$ for monthly data and $w = 1$ for yearly data.
Prior to this a correction for outliers is applied. The optimization is subject to some constraints or censor rules:

- the distance between two consecutive peaks has to be at least w periods
- the distance between the peak and the next trough has to be at least w periods
- peaks and trough have to alternate

Correspondingly, the vice versa holds when it comes to troughs.
Once the turning points are found the sample period can be partitioned into periods (phases) of expansions (between troughs and peaks) and contractions (between peaks and troughs). The business cycle can therefore be represented as a state variable S_t, which takes value 0 in expansions and 1 in recessions, where a recession is defined as the time interval between a peak (excluded) and the trough (included).
The algorithm has advantages and disadvantages. On the one side, variables enter in levels without the need for any treatments to achieve stationarity. Canova (1998) studied how filters may alterate the properties of time series. On the other side, the choice of the parameter of the window size w can draw a slightly different picture of the state of the economy.
The third method to classify economic activity is the regime-switching (hidden Markov mixture) model (Goldfeld and Quandt, 1973; Hamilton, 1989; 1994). According to Pagan (2019) this should be considered an indirect dating rule, since it involves using a parametric model to produce a dating rule. A variable can assume two states which change according to a Markov chain, whose underlying probabilities are estimated with a iterative Kalman filter algorithm with starting values set to the unconditional probabilities. The model is estimated on annualized quarter-on-quarter GDP growth rates and it is defined as:

$$y_t = \phi_{0,S_t} + \phi_1 y_{t-1} + \epsilon_t, \; \epsilon_t \sim N(0, \sigma)$$

The estimated transition probabilities are equal to $\text{Prob}(S_t = 0|S_{t-1} = 0) = 0.98$ and $\text{Prob}(S_t = 1|S_{t-1} = 1) = 0.25$, where the two states can easily be interpreted as expansion ($S_t = 0$) and recession ($S_t = 1$) given the corresponding intercepts ($\phi_{0,0} = -7.1$, $\phi_{0,1} = 1.4$). States are therefore estimated as periods when $\hat{y}_t > 0.5$.

Figure 2 reports the turning points as detected according to each of the criteria: the CEPR dating, the Bry-Boschan (BB) algorithm on GDP, the rule of thumb on GDP, and the Markov-switching model (MS) on GDP. Some considerations follow. First, the BB algorithm and the rule of thumb individuate five recessions each like the CEPR, while the MS model identifies only the three sharpest recessionary episodes. Second, the turning points detected by both BB algorithm and the rule of thumb are very close to the CEPR ones, whereas the MS model finds that recessions are much shorter. Third, by and large the two mechanical rules can replicate most of the features of the euro area business cycle as recognized by the CEPR dating committee. However, some exceptions stand out. In two cases, for the recessions which are completely disregarded by the MS model the two rules detect the turning point with a two and one quarter lag respectively. The largest difference is for the cycle starting with the 1980Q1 peak: the mechanical rules detect it in 1980Q3, while the CEPR finds that the corresponding trough is in 1982Q3 confirming that the committee looks at many variables than only GDP.

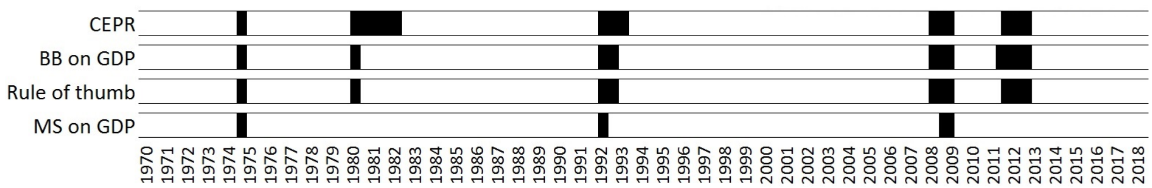


Figure 2: Alternative turning points definition

3 Methodology

We estimate a generalized linear model, where S_t is the state variable representing the dating, which takes value 0 in expansions and 1 in recessions and x_t is a business cycle indicator.
Let S_t be the binary response variable, that is distributed as a Bernoulli variable with parameter π_t, $S_t \sim \text{Bin}(1, \pi_t)$:

$$\mu_t = \mathbb{E}[S_t] = \text{Prob}(S_t = 1) = \pi_t$$

and $\mathbf{x}_t$ a vector of independent explanatory variables. Define the linear projector $\eta_t = \phi' \mathbf{x}_t$ and the link function $g(\cdot)$, such that $g(\mu_t) = \eta_t$. We choose the logit link (i.e. the log-odds):

$$\eta_t = \text{logit}(\pi_t) = \log\left(\frac{\pi_t}{1-\pi_t}\right) = \log\left(\frac{\text{Prob}(S_t = 1)}{\text{Prob}(S_t = 0)}\right)$$

because it is the canonical link such that $\eta_t = \theta_t$, where θ_t is the canonical parameter obtained from the exponential family representation.[8] We then get the implicit recession probabilities $\hat{\pi}_t = \frac{e^{\hat{\phi}'\mathbf{x}_t}}{1+e^{\hat{\phi}'\mathbf{x}_t}}$.

The fitted probabilities obtained through the logit model can be mapped into fitted recession periods on a 0-or-1 scale ($\hat{\pi}_t \mapsto \hat{y}_t$) depending on the cutoff τ in $[0, 1]$, such that:

$$\hat{S}_t(\tau) = \begin{cases} 1 & \text{if } \hat{\pi}_t \geq \tau \\ 0 & \text{if } \hat{\pi}_t < \tau \end{cases}$$

The instinctive choice is the unconditional probability (i.e. the mean or the median probability) or $\tau = 0.5$, because it is the value such that $\text{Prob}(S_t = 1) > \text{Prob}(S_t = 0)$. In general, for each value of τ we can construct a 2-by-2 confusion matrix by comparing the observed values S_t and the fitted values $\hat{S}_t$ (Table 2).

Table 2: Comparison of fitted and actual data

		fitted $\hat{S}_t$	
		0	**1**
observed S_t	**0**	True Negative TN	False Positive FP
	1	False Negative FN	True Positive TP

Two errors can occur: either recession is called but it does not materialize (FP), or the recession hits the economy unexpectedly (FN). Therefore we are interested in two ratios:

- sensitivity, or power of the test, $1 - \beta = \text{Prob}(\text{reject } H_0 | H_0 \text{ false}) = \frac{TP}{TP+FN}$ where β is the Type II error
- 1 - specificity, or Type I error, $\alpha = \text{Prob}(\text{reject } H_0 | H_0 \text{ true}) = \frac{FP}{FP+TN}$

The Receiver Operating Characteristic (ROC) curve is a curve in $[0, 1]^2$ that represents the sensitivity ($1-\beta(\tau)$) and 1-specificity ($\alpha(\tau)$) on the two axes, since both are monotone non decreasing functions of τ. The Area under the ROC curve ($AUROC$)

[8] Another possible choice is the probit link $\eta_t = \text{probit}(\pi_t) = \Phi^{-1}(\pi_t)$, where $\Phi(\cdot)$ is the cumulative density function of the standard normal distribution. Results using this function are overall consistent with those presented here.

is used to evaluate whether an indicator is able to discriminate between recession and expansion (Peterson and Birdsall, 1953):

$$AUROC = \int_0^1 ROC(z)dz$$

whose sample equivalent can be estimated as:

$$A\hat{UROC} = \frac{1}{n_0 n_1}\sum_{i=1}^{n_0}\sum_{j=1}^{n_1}\left[I(X_i^0 > X_j^1) + \frac{1}{2}I(X_i^0 = X_j^1)\right]$$

where n_k is the number of times $S_t = k$ for $k = 0, 1$, X^k the distribution of X conditioned on $S_t = k$ and $I(\cdot)$ is the indicator function. The estimator is asymptotically normally distributed (Greiner et al., 2000; Hanley and McNeil, 1982; Obuchowski, 1994) with variance equal to:

$$\sigma^2 = \frac{1}{n_0 n_1}\left[AUROC(1 - AUROC) + (n_1 - 1)(Q_1 - AUROC^2) + (n_0 - 1)(Q_2 - AUROC^2)\right]$$

$$Q_1 = \frac{AUROC}{2 - AUROC}, \qquad Q_2 = \frac{2AUROC^2}{1 + AUROC}$$

It is a measure bounded in $[0.5, 1]$ where the higher the AUROC the better the fit. The two extreme cases are:

- *perfect classification* ($\alpha, \beta \to 0$): the ROC generates the line from (0,1) to (1,1) ($AUROC = 1$)
- *perfect randomization* between 0 and 1 ($\alpha = \beta = \tau$): the ROC is represented by the angle bisector from (0,0) to (1,1) ($AUROC = 0.5$).

The optimal cutoff value for τ is then found as the Youden's statistic (Youden, 1950):

$$\tau^* = \arg\max_{\tau\in[0,1]} 1 - \beta(\tau) - \alpha(\tau)$$

For an univariate model, where $\phi'\mathbf{x}_t = \phi_0 + \phi_1 x_t$, the corresponding cut-off value in the x-scale is:

$$x^* = \frac{1}{\phi_1}\left(\log\left(\frac{\tau^*}{1 - \tau^*}\right) - \phi_0\right)$$

In practice, looking back at Figure 1, the more separated the probability density functions the higher the AUROC. Berge and Jordà (2011) review the properties of this measure extensively.[9]

Alternative measures of the goodness of fit for models with a dichotomous response variable are available in the literature (see Berge (2015) for a review).

The pseudo R^2 firstly introduced by McFadden and Zarembka (1974) and later modified by Estrella (1998) is defined as:

$$\text{pseudo}R^2 = 1 - \left(\frac{\log L_u}{\log L_c}\right)^{-\frac{2}{T}\log L_c}$$

where L_c is the likelihood of the (constrained) model of interest and L_u is the likelihood of the unconstrained model where all the coefficients are zero but the only constant. It always holds that $\log L_u \leq \log L_c$. The values 0 and 1 correspond to *no fit* and *perfect fit* respectively, and intermediate values have roughly the same interpretations as their analogues in the linear case.

The quadratic probability score (Brier, 1950) is expressed in terms of squared residuals obtained as the difference between the actual values and the fitted probabilities:

$$QPS = \frac{1}{T}\sum_{t=1}^{T}(S_t - \hat{\pi}_t)^2$$

The better the model the lower the score, where $QPS = 0$ indicates *perfect fit*. The problem with this metrics is that two models can have different QPS, while leading to the same classification (Hand and Vinciotti, 2003).

3.1 Data

GDP data are retrieved in levels from Eurostat. Data before 1995Q1 are backcasted using the AWM database (Fagan et al., 2005). In the following analysis GDP appears transformed in:

- year-on-year growth rate (*GDP-Y*)
- quarter-on-quarter growth rate (annualized, *GDP-Q*)

[9]As Berge and Jordà (2011) notice the ROC can be drawn and the AUROC computed even without estimating a generalized linear model. The ROC is the same for any monotone transformation applied to the data. In order to compute the two ratios the fitted values are obtained on the basis of a threshold $\tau \in \mathbb{R}$, while we consider $\tau \in [0, 1]$ to be consistent with the domain of the fitted recession probabilities.

- Hodrick and Prescott (1997) filter (HP filter) with $\lambda = 1600$ as suggested for quarterly data (*GDP-HP*)
- band pass filter (Baxter and King, 1999) for frequencies corresponding to cycles lasting between 2 and 8 years (*GDP-BP*)

More data are used in the paper. An extensive description of their source, starting date and transformation applied for making the variable stationary for the factor model are in Table A.1 in Appendix A.

4 Results

The persistence of the two states of the economy is represented using the autoclassification function (ACF) introduced by Berge and Jordà (2011) to be the counterpart of the autocorrelation function for binary data. $ACF(h)$ equals the AUROC of a model where the current dating is explained by the past dating:

$$ACF(h) = AUROC(S_{t+h}, S_t)$$

As for the autocorrelation function, the ACF reaches its maximum for $h = 0$ ($ACF(0) = 1$) and then decreases. From Figure 3 we notice that the state of the economy at time $t-h$ is informative about the current state of the economy for $h \leq 4$, while for horizons longer than one year the ACF is very close to its lower bound (0.5, analogous to 0 in the correlogram), which is comparable to the performance of a cointoss.

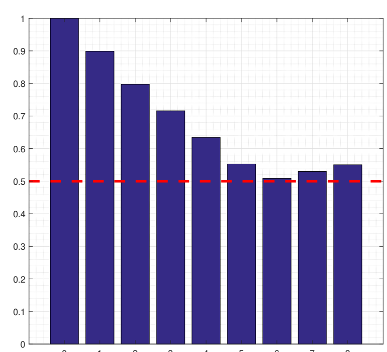
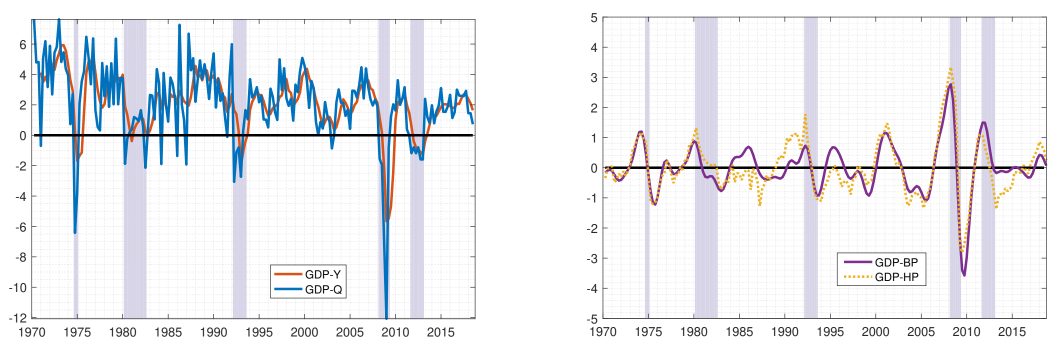


Figure 3: Persistence of CEPR dating

4.1 Results based on a single variable

We start from analyzing how much the CEPR dating is related to GDP. As anticipated in Section 3.1, GDP is transformed in multiple ways to extract the cycle: q-o-q growth rate, y-o-y growth rate, band pass filter, and HP filter. A stream of literature has focused on how detrending methods can influence business cycle evidence and detection of turning points (Canova, 1994; 1998; 1999; Harvey and Jaeger, 1993). In Figure 4 we show the time series together with the shaded areas for the recessions as identified by the CEPR dating committee: we report in the left panel the y-o-y and the annualized q-o-q growth rates which relate to the classical approach of business cycle and in the right panel we display the two other filters (HP and band pass) for completeness, since they describe the growth cycle.

Some findings arise. First, some features of the filters are noticed: the q-o-q growth rate is more volatile than the other series capturing short-run fluctuation and the y-o-y growth rate appears more smoother. Second, while the two growth rates show the same number of turning points, it is however true that the phase shift could interfere in the "correct" turning point detection; the band pass and HP filter detect much shorter cycles (around 5-year duration). In particular, all measures contract during the global financial crisis, but the peak appears in a different quarter and the resulting recession lasts a different number of quarters.



(a) Growth rates

(b) Hodrick-Prescott and band pass filters

Figure 4: GDP and CEPR recessions

Table 3 illustrates the average value of the four transformations of GDP for each episode of recession and expansion. The underlying guess is that recessions are characterized by negative values of growth, while expansions by positive values. In particular, the q-o-q growth rates are on average of -1.5% during recessions ranging between -5.1% for the 1974Q3-1975Q1 recession and 0.2% for the 1980Q1-1982Q3 one, while it is 2.7% during expansions with not much variability across the different episodes. The y-o-y growth rates are on average -0.3% and 2.4% during recessions and expansions respectively: the most severe recession appears the 2008Q1-2009Q2 (-2.4%) and the mildest one is the 1980Q1-1982Q3 (0.8%). The cycle extracted with the HP filter is on average -0.1% during recessions and 0 during expansions, with some unexpected values. The BP filtered series has an average value of -0.2% during recessions and 0 during expansions.

Table 3: Average value of the transformations of GDP during the phases of the cycle

Turning point		GDP-Q		GDP-Y		GDP-HP		GDP-BP	
Peak	Trough	rec.	exp.	rec.	exp.	rec.	exp.	rec.	exp.
1974Q3	1975Q1	-5.1	3.5	-0.7	3.0	-0.7	0.0	-0.5	0.0
1980Q1	1982Q3	0.2	2.8	0.8	2.7	0.2	0.1	-0.2	0.0
1992Q1	1993Q3	-1.0	2.3	0.0	2.3	-0.3	0.1	-0.3	0.1
2008Q1	2009Q2	-4.7	1.8	-2.4	0.8	0.0	-0.4	-0.6	-0.6
2011Q3	2013Q1	-1.2		-0.7		-0.2		0.6	
Average		*-1.5*	*2.7*	*-0.3*	*2.4*	*-0.1*	*0.0*	*-0.2*	*0.0*

In Table 4 we report the measures of goodness of fit of the different transformations of GDP with respect to the four dating criteria to see whether there are material differences among criteria and whether CEPR dating is based on GDP and, if this is the case, which transformation better expresses the underlying state of the business cycle and at which lag h^*. The model is:

$$\mathbb{E}[\mathrm{S}_{t+h}] = \beta_0 + \beta_1 x_t$$

The results confirm that the three measures of goodness of fit are consistent: the ranking among the business cycle indicators at $h = 0$ and the lag corresponding to the highest predictive accuracy h^* are the same across criteria. Moreover, the different metrics agree on the fact that the q-o-q growth rate captures the change of the state of the business cycle with no lags: on the contrary, the y-o-y growth rate lags 2 quarters and the filtered series need at least 2 quarters. Furthermore, when looking at the four dating criteria, we notice that, although there is a very strong correlation among the rankings of the indicators, the goodness of fit of the CEPR

dating is slightly different from what we obtain from the BB and the rule of thumb in terms of magnitude. This corroborates the evidence that the CEPR committee not only relies on GDP dynamics.
Despite the two filters reveal weak performances, it is quite hard to notice material differences among the performances of the models on q-o-q and y-o-y growth rates. Regarding the classification procedures, all seem to be equally adequate in discriminating the two phases of the business cycle as described by these GDP transformations.

Table 4: Goodness of fit of dynamic logit with transformations of GDP

	CEPR dating			BB algorithm on GDP			two quarters of negative GDP			Markov-Switching on GDP		
AUROC												
	$h=0$	h^*		$h=0$	h^*		$h=0$	h^*		$h=0$	h^*	
GDP-Q	0.94	0.94	*(0)*	0.98	0.98	*(0)*	0.98	0.98	*(0)*	0.98	0.98	*(0)*
GDP-Y	0.93	0.97	*(-2)*	0.91	0.99	*(-2)*	0.91	0.99	*(-2)*	0.90	0.98	*(-2)*
GDP-HP	0.67	0.91	*(3)*	0.73	0.91	*(2)*	0.72	0.93	*(3)*	0.68	0.95	*(-4)*
GDP-BP	0.58	0.85	*(3)*	0.74	0.95	*(2)*	0.73	0.95	*(2)*	0.44	0.97	*(-4)*
QPS												
	$h=0$	h^*		$h=0$	h^*		$h=0$	h^*		$h=0$	h^*	
GDP-Q	0.06	0.06	*(0)*	0.03	0.03	*(0)*	0.03	0.03	*(0)*	0.01	0.01	*(0)*
GDP-Y	0.08	0.05	*(-2)*	0.07	0.02	*(-2)*	0.06	0.02	*(-2)*	0.03	0.02	*(-1)*
GDP-HP	0.12	0.09	*(3)*	0.08	0.06	*(-4)*	0.08	0.06	*(-4)*	0.03	0.02	*(-2)*
GDP-BP	0.12	0.09	*(3)*	0.08	0.05	*(3)*	0.08	0.05	*(3)*	0.03	0.02	*(-3)*
pseudo R^2												
	$h=0$	h^*		$h=0$	h^*		$h=0$	h^*		$h=0$	h^*	
GDP-Q	0.52	0.52	*(0)*	0.68	0.68	*(0)*	0.70	0.70	*(0)*	0.68	0.68	*(0)*
GDP-Y	0.37	0.63	*(-2)*	0.32	0.77	*(-2)*	0.33	0.75	*(-2)*	0.34	0.50	*(-1)*
GDP-HP	0.05	0.34	*(3)*	0.10	0.37	*(2)*	0.09	0.40	*(3)*	0.03	0.41	*(4)*
GDP-BP	0.02	0.31	*(3)*	0.10	0.47	*(2)*	0.09	0.49	*(2)*	0.00	0.45	*(-3)*

Note: Positive (negative) values of h^* indicate that the variable in row leads (lags) the CEPR chronology.

In Figure 5 we illustrate how the ROC curve generated by the model at $h = 0$ looks like, focusing of the different GDP transformations. The curves corresponding to the growth rates perform very well for every threshold value τ, leading to AUROCs of almost 0.95. Concerning the filtered series, we notice that the HP filter produces a curve that is dominated by those generated by the q-o-q growth rates and the y-o-y growth rate for every value of τ ($AUROC = 0.67$) and the band pass filter is less informative ($AUROC = 0.58$), even crossing the bisector for some values of τ. Figure 6 shows that for the filtered series the goodness of fit improves as h increases, while for the growth rates the evidence is opposite, because the maximum fit is reached at $h^* \leq 0$.
All in all the CEPR seems to do very well. There is however a difference between the peak/trough approach and the above/below trend approach.

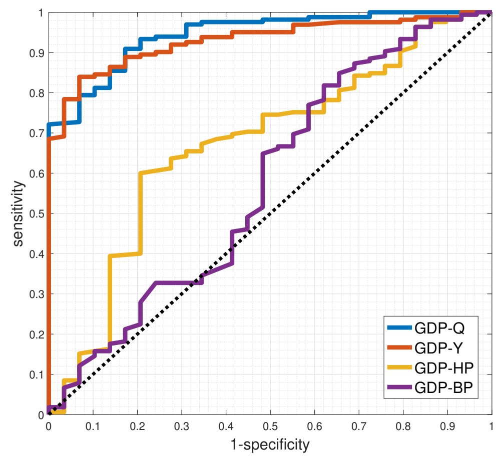
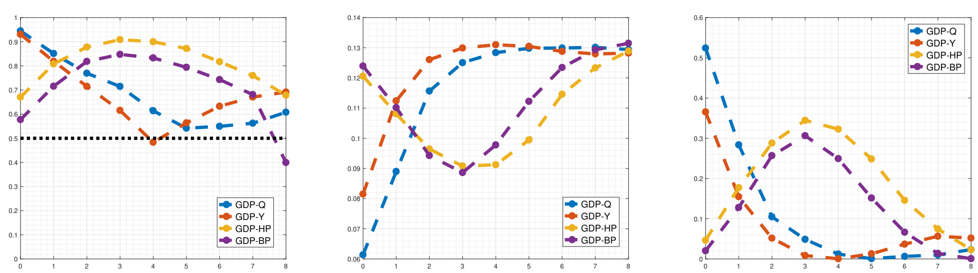


Figure 5: ROC curve for $h = 0$



(a) AUROC (b) QPS (c) pseudo R^2

Figure 6: Goodness of fit at different horizons

4.2 Results based on a multivariate approach

Since the pioneering work by Burns and Mitchell (1946), the idea that the business cycle could be better described by the comovement of many macroeconomic time series than only one (e.g. GDP or unemployment) has become predominant in the modern macroeconomic literature. Therefore we consider more than 100 indicators of economic activity, such as consumption, labor market data, industrial production.[10]

[10] See Appendix A for details.

Some methods can be applied to take into account the richness of information available in a big dataset. Concerning the problem of classification of economic activity we can distinguish the *date-then-average* approach from the *average-then-date* approach (Stock and Watson, 2010; 2014).

The date-then-average approach consists in studying the indicators separately and then making an assessment on the business cycle itself. We therefore apply the BB algorithm on each of the variables.[11] In Figure 7 periods between peaks and troughs (recessions) are in red, while periods between troughs and peaks (expansions) are in green. We notice that the variables strongly comove: for instance, the depression of economic activity during the great financial crisis was widespread to the entire economy. Similar evidence emerge when we analyse soft data.[12]

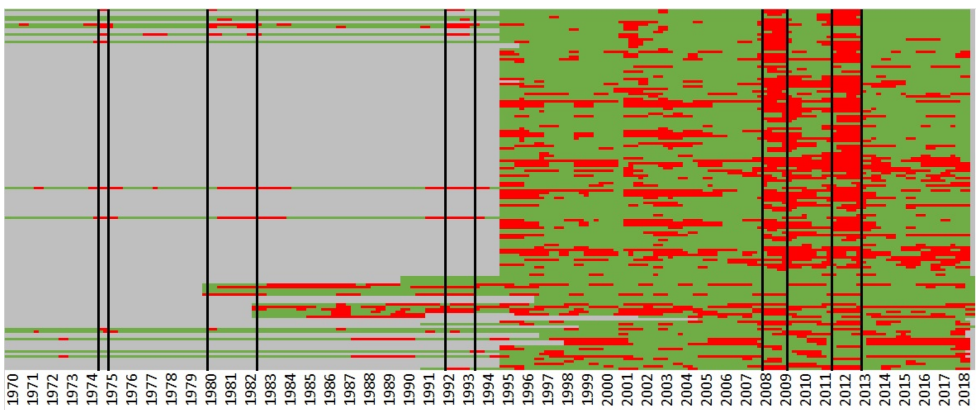


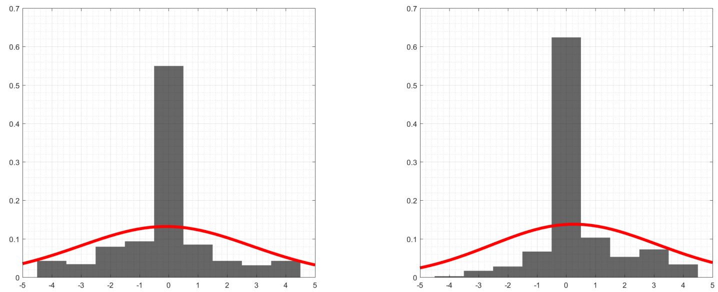
Figure 7: Classification of peaks and troughs as detected through the Bry-Boschan algorithm

In the chart periods between peaks and troughs (recessions) are in **red**, while periods between troughs and peaks (expansions) are in **green**. **Gray** cells identify missing data. **Black** vertical lines individuate CEPR turning points.

In Figure 8 we report the histogram representing the distribution of turning points together with the corresponding kernel function for peaks or troughs. In general the turning points seem to be fairly synchronized around those individuated by the CEPR committee.

[11] As in Burns and Mitchell (1946), time series representing aggregates which increase during recession periods (e.g. unemployment rate) are 'inverted', i.e. transformed in order to decrease during recession.

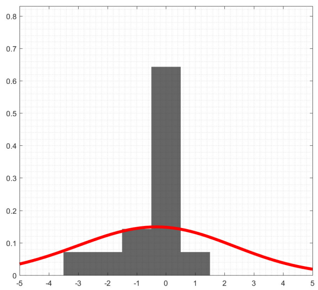
[12] See Appendix B for details.



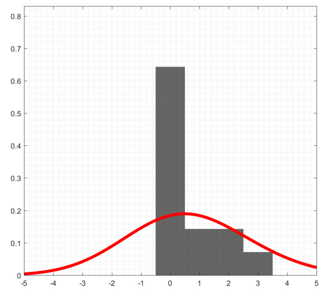
(a) Peaks (b) Troughs

Figure 8: Distribution around CEPR turning points

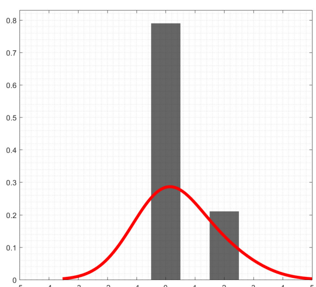
We study each single recession episode, because aggregate evidence could hide heterogeneity across the different episodes (Figure 9). Concerning the recession episodes prior to 1999 we clarify that not many series where available from 1970. Specifically, we reconstructed only 14 time series using the AWM database (Fagan et al., 2005). Starting with the first recession episode we observe that most series individuate the peak one to three quarters earlier than the CEPR (1974Q3) and the following trough one to three quarters later than the CEPR (1975Q1), thus resulting in a longer recession. The 1980Q1 peak is common to most time series and the same happens for the corresponding trough (1982Q3). The 1992Q1 peak has a probability of almost 0.6 and the distribution is quite concentrated around the turning point, while the one relative to the following trough (1993Q3) shows a higher variance. The last two recessions in the sample occurred when the euro area was already established. For what concerns the great recession, both the peak (2008Q1) and the trough (2009Q2) appear in more than half of the indicators although some of the remaining time series identify the turning points in a window of one year around the CEPR ones. The same applies to the sovereign debt crisis, defined as the period from the 2011Q3 peak to the 2013Q3 trough: most indicators individuate the peak contemporaneously or earlier than the CEPR, while only a 10% show a later peak; most troughs coincide with the one identified by the CEPR signalling a wide spread recovery from the 2013Q4.



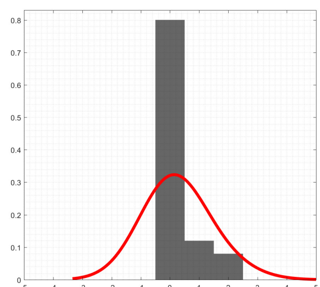
(a) 1974Q3 Peak



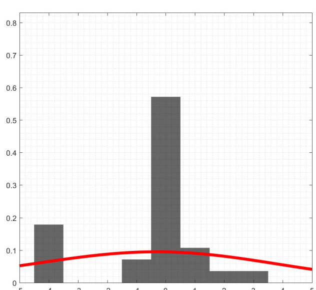
(b) 1975Q1 Trough



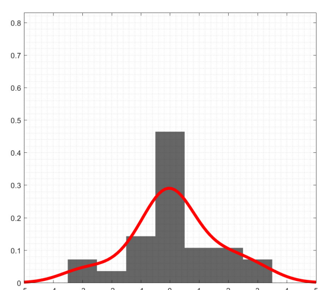
(c) 1980Q1 Peak



(d) 1982Q3 Trough

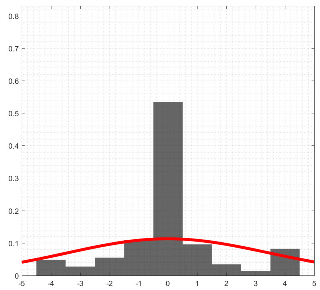


(e) 1992Q1 Peak

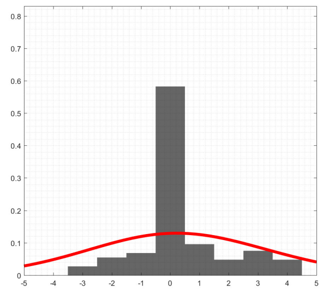


(f) 1993Q3 Trough

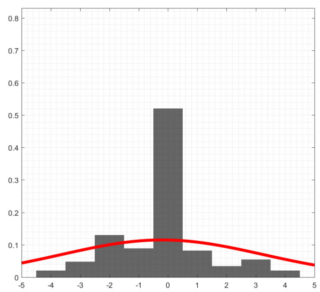
Figure 9: Distribution around each CEPR turning point *(cont.)*



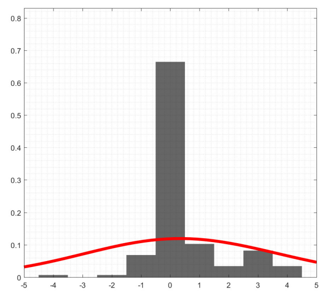
(g) 2008Q1 Peak



(h) 2009Q2 Trough



(i) 2011Q3 Peak



(j) 2013Q3 Trough

Figure 9: *(continued)* Distribution around each CEPR turning point

We validate the CEPR dating with respect to the macroeconomic variables [13]. The goodness of fit of the models is generally very high and maximum for $h^* = 0$ (for around almost half of the indicators) pointing at how important these variables are for the assessment of the state of the business cycle formulated by the committee. Some variables reflects however the dynamics of a specific subsector of economic activity which is not really procyclical. Figure 10 shows the distribution of contemporaneous ROCs with different colors identifying levels of goodness of fit: half of the indicators have $AUROC(0)$ greater than 0.8 (light and dark blue lines) and only 15% show a fit lower than 0.6.

[13]See Appendix C for details.

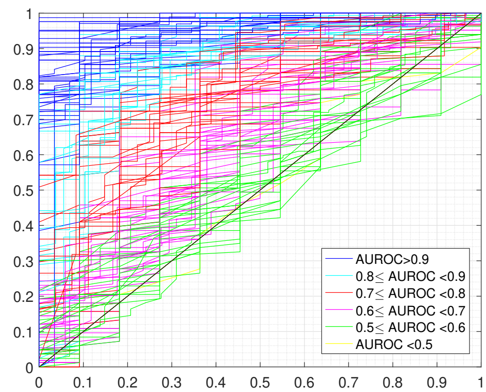


Figure 10: ROC curve at $h = 0$ for the different indicators

On the other hand, according to the average-then-date approach there is an effective way to summarize the information of the dataset before classifying economic activity in recessions and expansions. Stock and Watson (2014) suggest to compute a weighted average of the indicators across the cross sectional dimension.
The first method is the static factor model (Stock and Watson, 2002). In a factor model every time series x_{it} is expressed as the sum of the common component χ_{it} and the idiosyncratic component ϵ_{it}:

$$x_{it} = \chi_{it} + \epsilon_{it} = \lambda_i \mathbf{F}_t + \epsilon_{it}$$

where $\mathbf{F}_t$ is the $(r \times 1)$ vector of unobservable common factors with $r << N$ and λ_i is the $(r \times 1)$ vector of the corresponding factor loadings. The factors are estimated through principal component analysis on the entire dataset.
From the scree analysis we find that two factors are enough to capture the common state underlying the economy as represented by the $N = 123$ variables in the dataset. The first two factors explain more than the 30% of the total variance (17.3% and 13.8% respectively). Specifically, the first factor is highly correlated with GDP (35.8%), value added (47.8%), industrial production (54.0%), while the second one is more correlated with labor market indicator such as employment (66.2%), employees (70.1%), and unemployment rate (48.5%). The two factors explain almost the 50% of the variance of GDP.
The second method to aggregate consists in weighting the observations with the inverse of the standard deviation normalized by the sum of the standard deviations.

The resulting time series (ISD) is thus:

$$x_t^{ISD} = \sum_{i=1}^{N} x_{it} \frac{\text{std}(\mathbf{x_i})}{\sum_i \text{std}(\mathbf{x_i})}$$

The third aggregation we consider, Eurocoin, is also obtained through a (dynamic) factor model (Altissimo et al., 2001; 2010). Eurocoin is a coincident indicator that summarizes the state of the euro area economy in a single common factor and is released monthly by the CEPR-Bank of Italy. We obtain the quarterly version by simple average of the values of the three months.

The fourth weighted average is the Composite Leading Indicator (CLI) released monthly by the OECD.[14] The indicator is obtained as a chain-linked Laspeyres index with country-specific weights for the indicators of single countries. In the first place, among many financial and macroeconomic variables the components series are selected according to some criteria: they need to be timely, not materially revised and they should lead the reference series. In the second place the component series are HP-filterd to get the cycles. Finally, the indicator is given as the weighted average of the component series using equal weights.

We then validate the CEPR classification of economic activity with respect to the aggregate indicators. Table 5 reports the goodness of fit of the model for the factors and ISD average: the first factor exhibits the highest contemporaneous AUROC, while the vice versa holds for the pseudo R^2 with the second factor showing a value higher than the first one; the dynamic model with the ISD series shows a very high goodness of fit. The first factor and the ISD aggregated time series turn out to have the highest in-sample dynamic power at $h^* = 0$ too. This generally confirms the guess that the committee has in mind a broad definition of economic activity. These conclusions appear even stronger, since Eurocoin is obtained from a dynamic factor model, therefore comparable to the aggregated series. Eurocoin shows the highest goodness of fit according to the three criteria and the maximum concordance with the dating for $h^* = -1$, thus pointing to the fact that it is a slightly leading indicator of economic activity. At last, CLI confirms the good capacity to discriminate between recession and expansion.

[14]The indicator actually tracks the growth cycle, but it is included for completeness, as in Berge and Jordà (2013) who provide a chronology of turning points for the Spanish business cycle.

Table 5: Goodness of fit of dynamic logit with factors

factors	AUROC			QPS			pseudo R^2		
	$h=0$	h^*		$h=0$	h^*		$h=0$	h^*	
1	0.95	0.95	*(0)*	0.08	0.08	*(0)*	0.24	0.24	*(0)*
2	0.92	0.95	*(-1)*	0.08	0.06	*(-2)*	0.34	0.52	*(-2)*
ISD	0.96	0.96	*(0)*	0.05	0.05	*(0)*	0.61	0.61	*(0)*
Eurocoin	0.98	1.00	*(-1)*	0.04	0.02	*(-1)*	0.71	0.84	*(-1)*
CLI	0.89	0.95	*(-1)*	0.08	0.06	*(-1)*	0.37	0.51	*(-1)*

Note: Positive (negative) values of h^* indicate that the variable in row leads (lags) the CEPR chronology.

5 Conclusions

In this paper we study the classification of the business cycle in recessions and expansions formulated by the CEPR committee for the euro area.
Firstly, we notice that the CEPR dating is not completely in line with alternative dating rules based only on GDP dynamics, thus revealing that the committee considers more indicators. Moreover, when looking individually at each of the variables the classification of economic activity appear to be mainly driven by final consumption and employment. Furthermore, using a big dataset including more than 100 macroeconomic variables we find that the dating proposed by the CEPR committee reflects the business cycle features common to most real macroeconomic time series.

An extension of this framework to country-specific chronologies is left for future research. It would be interesting to define recessions for each single country (see Berge and Jordà (2013) for the Spanish economy) and to study which of the existing macroeconomic variables and indexes better track the business cycles.

A Data description

Table A.1: Data description *(cont.)*

	Variable	Start date	Source	Trans.
1	Real GDP	1970Q1	Eurostat	1
2	Value added	1995Q1	Eurostat	1
3	Final consumption expenditure	1995Q1	Eurostat	1
4	Final consumption expenditure of general government	1970Q1	Eurostat	1
5	Household and NPISH final consumption expenditure	1970Q1	Eurostat	1
6	Gross capital formation	1995Q1	Eurostat	1
7	Gross fixed capital formation	1970Q1	Eurostat	1
8	Exports of goods and serv.	1970Q1	Eurostat	1
9	Exports of goods	1995Q1	Eurostat	1
10	Exports of serv.	1995Q1	Eurostat	1
11	Imports of goods and serv.	1970Q1	Eurostat	1
12	Imports of goods	1995Q1	Eurostat	1
13	Imports of serv.	1995Q1	Eurostat	1
14	Taxes less subsidies on products	1970Q1	Eurostat	1
15	Final consumption expenditure and gross capital formation	1996Q1	Eurostat	1
16	Final consumption expenditure, gross capital formation and exports of goods and serv.	1996Q1	Eurostat	1
17	Value added	1995Q1	Eurostat	1
18	Value added Agriculture, forestry and fishing	1995Q1	Eurostat	1
19	Value added Industry (except construction)	1995Q1	Eurostat	1
20	Value added Manufacturing	1995Q1	Eurostat	1
21	Value added Construction	1995Q1	Eurostat	1
22	Value added Wholesale and retail trade, transport, accomodation and food serv. act.	1995Q1	Eurostat	1
23	Value added Information and communication	1995Q1	Eurostat	1
24	Value added Financial and insurance act.	1995Q1	Eurostat	1
25	Value added Real estate act.	1995Q1	Eurostat	1
26	Value added Professional, scientific and technical act.; administrative and support serv. act.	1995Q1	Eurostat	1
27	Value added Public administration, defence, education, human health and social work act.	1995Q1	Eurostat	1
28	Value added Arts, entertainment and recreation; other serv. act.	1995Q1	Eurostat	1
29	Total fixed assets	1995Q1	Eurostat	1
30	Total Construction	1995Q1	Eurostat	1
31	Dwellings	1995Q1	Eurostat	1
32	Other buildings and structures	1995Q1	Eurostat	1
33	Machinery and equipment and weapons systems	1995Q1	Eurostat	1
34	Transport equipment	1995Q1	Eurostat	1
35	Cultivated biological resources	1995Q1	Eurostat	1
36	Intellectual property products	1995Q1	Eurostat	1
37	Total employment Hours Total - all NACE act.	1995Q1	Eurostat	1
38	Total employment Hours Agriculture, forestry and fishing	1995Q1	Eurostat	1
39	Total employment Hours Industry (except construction)	1995Q1	Eurostat	1
40	Total employment Hours Manufacturing	1995Q1	Eurostat	1
41	Total employment Hours Construction	1995Q1	Eurostat	1
42	Total employment Hours Wholesale and retail trade, transport, accomodation and food serv. act.	1995Q1	Eurostat	1
43	Total employment Hours Information and communication	1995Q1	Eurostat	1
44	Total employment Hours Financial and insurance act.	1995Q1	Eurostat	1
45	Total employment Hours Real estate act.	1995Q1	Eurostat	1
46	Total employment Hours Professional, scientific and technical act.; administrative and support serv. act.	1995Q1	Eurostat	1
47	Total employment Hours Public administration, defence, education, human health and social work act.	1995Q1	Eurostat	1
48	Total employment Hours Arts, entertainment and recreation; other serv. act.	1995Q1	Eurostat	1
49	Employees Hours Total - all NACE act.	1995Q1	Eurostat	1
50	Employees Hours Agriculture, forestry and fishing	1995Q1	Eurostat	1
51	Employees Hours Industry (except construction)	1995Q1	Eurostat	1
52	Employees Hours Manufacturing	1995Q1	Eurostat	1
53	Employees Hours Construction	1995Q1	Eurostat	1
54	Employees Hours Wholesale and retail trade, transport, accomodation and food serv. act.	1995Q1	Eurostat	1
55	Employees Hours Information and communication	1995Q1	Eurostat	1
56	Employees Hours Financial and insurance act.	1995Q1	Eurostat	1
57	Employees Hours Real estate act.	1995Q1	Eurostat	1
58	Employees Hours Professional, scientific and technical act.; administrative and support serv. act.	1995Q1	Eurostat	1
59	Employees Hours Public administration, defence, education, human health and social work act.	1995Q1	Eurostat	1
60	Employees Hours Arts, entertainment and recreation; other serv. act.	1995Q1	Eurostat	1
61	Self-employed Hours Total - all NACE act.	1995Q1	Eurostat	1
62	Self-employed Hours Agriculture, forestry and fishing	1995Q1	Eurostat	1

Legend for transformation: (1) $\Delta \ln$; (2) Δ; (3) none; (4) seasonally adjusted with TRAMO-SEATS.

Table A.1: *(continued)* Data description

	Variable	Start date	Source	Trans.
63	Self-employed Hours Industry (except construction)	1995Q1	Eurostat	1
64	Self-employed Hours Manufacturing	1995Q1	Eurostat	1
65	Self-employed Hours Construction	1995Q1	Eurostat	1
66	Self-employed Hours Wholesale and retail trade, transport, accomodation and food serv. act.	1995Q1	Eurostat	1
67	Self-employed Hours Information and communication	1995Q1	Eurostat	1
68	Self-employed Hours Financial and insurance act.	1995Q1	Eurostat	1
69	Self-employed Hours Real estate act.	1995Q1	Eurostat	1
70	Self-employed Hours Professional, scientific and technical act.; administrative and support serv. act.	1995Q1	Eurostat	1
71	Self-employed Hours Public administration, defence, education, human health and social work act.	1995Q1	Eurostat	1
72	Self-employed Hours Arts, entertainment and recreation; other serv. act.	1995Q1	Eurostat	1
73	Total employment Persons Total - all NACE act.	1970Q1	Eurostat	1
74	Total employment Persons Agriculture, forestry and fishing	1995Q1	Eurostat	1
75	Total employment Persons Industry (except construction)	1995Q1	Eurostat	1
76	Total employment Persons Manufacturing	1995Q1	Eurostat	1
77	Total employment Persons Construction	1995Q1	Eurostat	1
78	Total employment Persons Wholesale and retail trade, transport, accomodation and food serv. act.	1995Q1	Eurostat	1
79	Total employment Persons Information and communication	1995Q1	Eurostat	1
80	Total employment Persons Financial and insurance act.	1995Q1	Eurostat	1
81	Total employment Persons Real estate act.	1995Q1	Eurostat	1
82	Total employment Persons Professional, scientific and technical act.; administrative and support serv. act.	1995Q1	Eurostat	1
83	Total employment Persons Public administration, defence, education, human health and social work act.	1995Q1	Eurostat	1
84	Total employment Persons Arts, entertainment and recreation; other serv. act.	1995Q1	Eurostat	1
85	Employees Persons Total - all NACE act.	1970Q1	Eurostat	1
86	Employees Persons Agriculture, forestry and fishing	1995Q1	Eurostat	1
87	Employees Persons Industry (except construction)	1995Q1	Eurostat	1
88	Employees Persons Manufacturing	1995Q1	Eurostat	1
89	Employees Persons Construction	1995Q1	Eurostat	1
90	Employees Persons Wholesale and retail trade, transport, accomodation and food serv. act.	1995Q1	Eurostat	1
91	Employees Persons Information and communication	1995Q1	Eurostat	1
92	Employees Persons Financial and insurance act.	1995Q1	Eurostat	1
93	Employees Persons Real estate act.	1995Q1	Eurostat	1
94	Employees Persons Professional, scientific and technical act.; administrative and support serv. act.	1995Q1	Eurostat	1
95	Employees Persons Public administration, defence, education, human health and social work act.	1995Q1	Eurostat	1
96	Employees Persons Arts, entertainment and recreation; other serv. act.	1995Q1	Eurostat	1
97	Self-employed Persons Total - all NACE act.	1995Q1	Eurostat	1
98	Self-employed Persons Agriculture, forestry and fishing	1995Q1	Eurostat	1
99	Self-employed Persons Industry (except construction)	1995Q1	Eurostat	1
100	Self-employed Persons Manufacturing	1995Q1	Eurostat	1
101	Self-employed Persons Construction	1995Q1	Eurostat	1
102	Self-employed Persons Wholesale and retail trade, transport, accomodation and food serv. act.	1995Q1	Eurostat	1
103	Self-employed Persons Information and communication	1995Q1	Eurostat	1
104	Self-employed Persons Financial and insurance act.	1995Q1	Eurostat	1
105	Self-employed Persons Real estate act.	1995Q1	Eurostat	1
106	Self-employed Persons Professional, scientific and technical act.; administrative and support serv. act.	1995Q1	Eurostat	1
107	Self-employed Persons Public administration, defence, education, human health and social work act.	1995Q1	Eurostat	1
108	Self-employed Persons Arts, entertainment and recreation; other serv. act.	1995Q1	Eurostat	1
109	House Prices	2005Q1	Eurostat	1
110	Industrial Production (Construction)	1995Q1	ECB-SDW	1,4
111	Industrial Production (Total Industry)	1991Q1	ECB-SDW	1,4
112	Labor Productivity	1970Q1	Eurostat	1
113	Active pop Total	1970Q1	Eurostat	1
114	Active pop Males	1997Q1	Eurostat	1
115	Active pop Females	1997Q1	Eurostat	1
116	Unemployed Total	1970Q1	Eurostat	1
117	Unemployed Males	1998Q2	Eurostat	1
118	Unemployed Females	1998Q2	Eurostat	1
119	Real labour productivity per person	1995Q1	Eurostat	1,4
120	Real labour productivity per hour worked	1995Q1	Eurostat	1,4
121	Nominal unit labour cost based on persons	1970Q1	OECD	1
122	Nominal unit labour cost based on hours worked	1995Q1	Eurostat	1,4
123	Unemployment rate	1970Q1	Eurostat	2
124	EUROCOIN	1999Q1	CEPR-BoI	3
125	CLI	1970Q1	OECD	3

Legend for transformation: (1) $\Delta \ln$; (2) Δ; (3) none; (4) seasonally adjusted with TRAMO-SEATS.

B Survey data

Modern business cycle analysis also relies on survey data (Table B.1). Even if they are soft data, which do not correspond to quantitative outcomes, they have many advantages: they are indeed very timely and they can capture the dynamics of the business cycle (Figure B.1).
Survey data are usually available as balance statistics and therefore the interpretation depends on a certain threshold, which can depend on how the balance is computed: quarters are classified as recessions or expansions if they are below or above the threshold respectively. For instance, if the balance is computed as the difference between the positive and negative responses the resulting threshold is '0'.

Table B.1: Survey data description

	Variable	Start date	Source	Threshold
1	Industrial confidence indicator	1985Q1	EU Commission	0
2	Services confidence indicator	1985Q1	EU Commission	0
3	Consumer confidence indicator	1985Q1	EU Commission	0
4	Retail trade confidence indicator	1985Q1	EU Commission	0
5	Construction confidence indicator	1985Q1	EU Commission	0
6	Economic sentiment indicator	1985Q1	EU Commission	100
7	Employment expectations indicator	1985Q1	EU Commission	100
8	Confidence Indicator (*)	1985Q1	EU Commission	0
9	Production trend observed in recent months	1985Q1	EU Commission	0
10	Assessment of order-book levels	1985Q1	EU Commission	0
11	Assessment of export order-book levels	1985Q1	EU Commission	0
12	Assessment of stocks of finished products	1985Q1	EU Commission	0
13	Production expectations for the months ahead	1985Q1	EU Commission	0
14	Selling price expectations for the months ahead	1985Q1	EU Commission	0
15	Employment expectations for the months ahead	1985Q1	EU Commission	0
16	Business Climate Indicator	1985Q1	EU Commission	0
17	Business Activity Index - services	1998Q1	MarkitEcon - PMI	50
18	Backlog orders - manufacturing	2003Q1	MarkitEcon - PMI	50
19	Employment index - composite	1998Q3	MarkitEcon - PMI	50
20	Employment index - manufacturing	1997Q3	MarkitEcon - PMI	50
21	Employment index - services	1998Q3	MarkitEcon - PMI	50
22	Stocks of Finished Goods Index - manufacturing	1997Q3	MarkitEcon - PMI	50
23	Incoming new business index - composite	1998Q3	MarkitEcon - PMI	50
24	Incoming new business index - services	1998Q3	MarkitEcon - PMI	50
25	New Orders Index - manufacturing	1997Q3	MarkitEcon - PMI	50
26	Outstanding Business Index - services	1998Q3	MarkitEcon - PMI	50
27	New export orders index - manufacturing	1997Q3	MarkitEcon - PMI	50
28	Output Index - composite	1998Q3	MarkitEcon - PMI	50
29	Output Index - manufacturing	1997Q3	MarkitEcon - PMI	50
30	Output Prices - manufacturing	2003Q1	MarkitEcon - PMI	50
31	Quantity of Purchases Index - manufacturing	1997Q3	MarkitEcon - PMI	50

Note: All variables are obtained as balance statistics. Thresholds are: '**0**': *positive* minus *negative* responses; '**50**': *improvement*, *no change* and *deterioration* responses are weighted with 1, 0.5, 0 respectively; '**100**': two composite indicators are rescaled in order to have mean equal to 100. (*) It is obtained as $(Q2 - Q4 + Q5)/3$.

Figure B.1 shows the classification of economic activity as obtained by each of the survey variables. The upper panel refers to the survey produced by the European

Commission, which are available since 1985, while the lower one regards those produced by Markit Economics from the late 90s. Most of the times periods classified as recession correspond indeed to CEPR recessions, especially in more recent years. The only exception is the period of early 2000s, which the CEPR committee does not define recession, while many survey indicators report a level that is compatible with a deterioration of economic activity.

Figure B.1: Classification of peaks and troughs for survey variables

In the chart periods between peaks and troughs (recessions) are in **red**, while periods between troughs and peaks (expansions) are in **green**. **Gray** cells identify missing data. **Black** vertical lines individuate CEPR turning points. The classification is obtained by using the thresholds in Table B.1.

C Results using many macroeconomic variables

Table C.1: Goodness of fit of dynamic logit with many variables *(cont.)*

	Variables	AUROC($h = 0$)	AUROC(h^*)	
1	Real GDP	0.94	0.94	*(0)*
2	Value added	0.98	0.98	*(0)*
3	Final consumption expenditure	0.96	0.96	*(0)*
4	Final consumption expenditure of general government	0.57	0.70	*(-4)*
5	Household and NPISH final consumption expenditure	0.87	0.87	*(0)*
6	Gross capital formation	0.97	0.97	*(0)*
7	Gross fixed capital formation	0.92	0.92	*(0)*
8	Exports of goods and serv.	0.81	0.81	*(0)*
9	Exports of goods	0.87	0.87	*(0)*
10	Exports of serv.	0.78	0.80	*(-1)*
11	Imports of goods and serv.	0.90	0.90	*(0)*
12	Imports of goods	0.96	0.96	*(0)*
13	Imports of serv.	0.75	0.78	*(1)*
14	Taxes less subsidies on products	0.67	0.67	*(0)*
15	Final consumption expenditure and gross capital formation	1.00	1.00	*(0)*
16	Final consumption expenditure, gross capital formation and exports of goods and serv.	0.99	0.99	*(0)*
17	Value added	0.98	0.98	*(0)*
18	Value added Agriculture, forestry and fishing	0.62	0.64	*(-6)*
19	Value added Industry (except construction)	0.94	0.94	*(0)*
20	Value added Manufacturing	0.94	0.94	*(0)*
21	Value added Construction	0.90	0.90	*(0)*
22	Value added Wholesale and retail trade, transport, accomodation and food serv. act.	0.95	0.95	*(0)*
23	Value added Information and communication	0.89	0.89	*(0)*
24	Value added Financial and insurance act.	0.77	0.77	*(0)*
25	Value added Real estate act.	0.66	0.73	*(-6)*
26	Value added Professional, scientific and technical act.; administrative and support serv. act.	0.92	0.92	*(0)*
27	Value added Public administration, defence, education, human health and social work act.	0.70	0.71	*(-6)*
28	Value added Arts, entertainment and recreation; other serv. act.	0.85	0.87	*(-1)*
29	Total fixed assets	0.96	0.96	*(0)*
30	Total Construction	0.95	0.95	*(0)*
31	Dwellings	0.92	0.92	*(0)*
32	Other buildings and structures	0.89	0.89	*(0)*
33	Machinery and equipment and weapons systems	0.96	0.96	*(0)*
34	Transport equipment	0.83	0.83	*(0)*
35	Cultivated biological resources	0.63	0.63	*(0)*
36	Intellectual property products	0.70	0.71	*(-1)*
37	Total employment Hours Total - all NACE act.	0.96	0.96	*(0)*
38	Total employment Hours Agriculture, forestry and fishing	0.60	0.70	*(-7)*
39	Total employment Hours Industry (except construction)	0.90	0.90	*(0)*
40	Total employment Hours Manufacturing	0.91	0.91	*(0)*
41	Total employment Hours Construction	0.97	0.97	*(0)*
42	Total employment Hours Wholesale and retail trade, transport, accomodation and food serv. act.	0.91	0.91	*(0)*
43	Total employment Hours Information and communication	0.64	0.79	*(-5)*
44	Total employment Hours Financial and insurance act.	0.57	0.77	*(-5)*
45	Total employment Hours Real estate act.	0.85	0.96	*(-1)*
46	Total employment Hours Professional, scientific and technical act.; administrative and support serv. act.	0.97	0.99	*(-1)*
47	Total employment Hours Public administration, defence, education, human health and social work act.	0.75	0.75	*(0)*
48	Total employment Hours Arts, entertainment and recreation; other serv. act.	0.59	0.71	*(-1)*
49	Employees Hours Total - all NACE act.	0.95	0.95	*(0)*
50	Employees Hours Agriculture, forestry and fishing	0.64	0.69	*(-7)*
51	Employees Hours Industry (except construction)	0.90	0.90	*(0)*
52	Employees Hours Manufacturing	0.91	0.91	*(0)*
53	Employees Hours Construction	0.97	0.97	*(0)*
54	Employees Hours Wholesale and retail trade, transport, accomodation and food serv. act.	0.88	0.90	*(-1)*
55	Employees Hours Information and communication	0.61	0.77	*(-5)*
56	Employees Hours Financial and insurance act.	0.55	0.75	*(-5)*
57	Employees Hours Real estate act.	0.85	0.92	*(-1)*
58	Employees Hours Professional, scientific and technical act.; administrative and support serv. act.	0.96	0.98	*(-1)*
59	Employees Hours Public administration, defence, education, human health and social work act.	0.74	0.74	*(0)*
60	Employees Hours Arts, entertainment and recreation; other serv. act.	0.60	0.72	*(-4)*
61	Self-employed Hours Total - all NACE act.	0.78	0.78	*(0)*
62	Self-employed Hours Agriculture, forestry and fishing	0.56	0.59	*(2)*

Table C.1: *(continued)* Goodness of fit of dynamic logit with many variables

	Variables	AUROC($h=0$)	AUROC(h^*)	
63	Self-employed Hours Industry (except construction)	0.65	0.67	*(-1)*
64	Self-employed Hours Manufacturing	0.66	0.67	*(-1)*
65	Self-employed Hours Construction	0.84	0.85	*(2)*
66	Self-employed Hours Wholesale and retail trade, transport, accomodation and food serv. act.	0.70	0.70	*(0)*
67	Self-employed Hours Information and communication	0.75	0.78	*(-1)*
68	Self-employed Hours Financial and insurance act.	0.69	0.73	*(2)*
69	Self-employed Hours Real estate act.	0.71	0.81	*(-1)*
70	Self-employed Hours Professional, scientific and technical act.; administrative and support serv. act.	0.73	0.77	*(-1)*
71	Self-employed Hours Public administration, defence, education, human health and social work act.	0.64	0.64	*(0)*
72	Self-employed Hours Arts, entertainment and recreation; other serv. act.	0.50	0.60	*(7)*
73	Total employment Persons Total - all NACE act.	0.89	0.92	*(-1)*
74	Total employment Persons Agriculture, forestry and fishing	0.61	0.70	*(-6)*
75	Total employment Persons Industry (except construction)	0.77	0.83	*(-1)*
76	Total employment Persons Manufacturing	0.77	0.83	*(-1)*
77	Total employment Persons Construction	0.95	0.95	*(0)*
78	Total employment Persons Wholesale and retail trade, transport, accomodation and food serv. act.	0.88	0.89	*(-2)*
79	Total employment Persons Information and communication	0.63	0.82	*(-5)*
80	Total employment Persons Financial and insurance act.	0.54	0.79	*(-5)*
81	Total employment Persons Real estate act.	0.86	0.96	*(-1)*
82	Total employment Persons Professional, scientific and technical act.; administrative and support serv. act.	0.96	0.98	*(-1)*
83	Total employment Persons Public administration, defence, education, human health and social work act.	0.67	0.77	*(4)*
84	Total employment Persons Arts, entertainment and recreation; other serv. act.	0.54	0.71	*(-5)*
85	Employees Persons Total - all NACE act.	0.91	0.93	*(-1)*
86	Employees Persons Agriculture, forestry and fishing	0.62	0.67	*(4)*
87	Employees Persons Industry (except construction)	0.75	0.82	*(-2)*
88	Employees Persons Manufacturing	0.75	0.82	*(-2)*
89	Employees Persons Construction	0.97	0.97	*(0)*
90	Employees Persons Wholesale and retail trade, transport, accomodation and food serv. act.	0.88	0.90	*(-2)*
91	Employees Persons Information and communication	0.59	0.80	*(-5)*
92	Employees Persons Financial and insurance act.	0.53	0.79	*(-6)*
93	Employees Persons Real estate act.	0.83	0.90	*(-1)*
94	Employees Persons Professional, scientific and technical act.; administrative and support serv. act.	0.95	0.97	*(-1)*
95	Employees Persons Public administration, defence, education, human health and social work act.	0.66	0.75	*(4)*
96	Employees Persons Arts, entertainment and recreation; other serv. act.	0.54	0.70	*(-4)*
97	Self-employed Persons Total - all NACE act.	0.72	0.72	*(0)*
98	Self-employed Persons Agriculture, forestry and fishing	0.54	0.61	*(6)*
99	Self-employed Persons Industry (except construction)	0.57	0.65	*(-1)*
100	Self-employed Persons Manufacturing	0.57	0.67	*(-6)*
101	Self-employed Persons Construction	0.69	0.79	*(2)*
102	Self-employed Persons Wholesale and retail trade, transport, accomodation and food serv. act.	0.67	0.68	*(-1)*
103	Self-employed Persons Information and communication	0.65	0.74	*(-1)*
104	Self-employed Persons Financial and insurance act.	0.67	0.68	*(2)*
105	Self-employed Persons Real estate act.	0.72	0.81	*(-1)*
106	Self-employed Persons Professional, scientific and technical act.; administrative and support serv. act.	0.72	0.75	*(-1)*
107	Self-employed Persons Public administration, defence, education, human health and social work act.	0.55	0.59	*(5)*
108	Self-employed Persons Arts, entertainment and recreation; other serv. act.	0.50	0.59	*(7)*
109	House Prices	0.93	0.93	*(0)*
110	Industrial Production (Construction)	0.88	0.88	*(0)*
111	Industrial Production (Total Industry)	0.96	0.96	*(0)*
112	Labor Productivity	0.77	0.77	*(0)*
113	Active pop Total	0.59	0.78	*(-7)*
114	Active pop Males	0.61	0.87	*(-5)*
115	Active pop Females	0.50	0.84	*(-5)*
116	Unemployed Total	0.92	0.92	*(0)*
117	Unemployed Males	0.98	0.98	*(0)*
118	Unemployed Females	0.95	0.95	*(0)*
119	Real labour productivity per person	0.76	0.77	*(1)*
120	Real labour productivity per hour worked	0.60	0.69	*(8)*
121	Nominal unit labour cost based on persons	0.73	0.77	*(-6)*
122	Nominal unit labour cost based on hours worked	0.57	0.58	*(2)*
123	Unemployment rate	0.96	0.96	*(0)*

Note: Positive (negative) values of h^* indicate that the variable in row leads (lags) the CEPR chronology.

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