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A Quasi Real-Time Leading Indicator for the EU Industrial Production

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Non-Technical Summary

Understanding the future state of an economy is crucial for economic agents (e.g. households, investors and policymakers). Usually this need is more urgent in times of uncertainty such as in the aftermath of a deep recession or in the presence of a sluggish recovery. We aim to facilitate decision makers' assessment of future movements in economic performance by constructing a comprehensive leading indicator (LI) for the EU Industrial Production (IP).

Differently from the LIs proposed in recent studies, our indicator is not updated once new information is available (i.e. due to data revisions). This eliminates an "overlapping information bias" and thus makes our LI suitable for retrospective economic analyses. In addition, we employ a two-steps statistical selection procedure to identify the variables to be used for the LI's construction. Therefore, we do not rely on any subjective views on the LI components. Differently, the choice of the set of variables used to construct the LI is driven by the state of the economy.

The LI constructed in this study anticipates swings in the EU IP by 2 to 3 months and its predictive power is higher than that one of the LIs proposed by previous studies. In addition, it captures the pattern of the EU interest rate policy rather well.

A Quasi Real-Time Leading Indicator for the EU Industrial Production

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Abstract

We build a quasi real-time leading indicator (LI) for the EU industrial production (IP). Differently from previous studies, the technique developed in this paper gives rise to an ex-ante LI that is immune to "overlapping information drawbacks". In addition, the set of variables composing the LI relies on a two-steps dynamic and systematic procedure. This ensures that the choice of the variables is not driven by subjective views. Our LI anticipates swings (including the 2007-2008 crisis) in the EU industrial production – on average – by 2 to 3 months. If revised, its predictive power largely improves. Via a couple of standard empirical exercises we show that the proposed LI (*i*) forecasts crises' phases better than the ex-post LIs proposed by the OECD and the Conference Board and (*ii*) captures the interest rate policy pattern rather well.

Keywords: Leading indicator; EU industrial production; Granger causality; Turning points; Forward-looking Taylor rule.

JEL Codes: E32; C22; C52

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1. Introduction

The anticipation of the turning points of the real economic activity turns out to be crucial for all those agents dealing with real-time decisions (e.g. investors, policymakers, economists, households). While there have been many attempts to capture swings in the US real economic activity,[1] the number of existing leading indicators (LIs) focusing directly and exclusively on the EU economy is rather small. Examples are (*i*) the EU LI released by the OECD (Gyomai and Guidetti, 2012); (*ii*) the Conference Board LI for EU Area (TCB, 2001; Ozyildirim et al., 2010) and (*iii*) the Aggregate EU Leading Indicator (ALI) developed by de Bondt and Hahn (2014).

Even if the aforementioned LIs are still widely used by policymakers, practitioners and statistical warehouses, they embody a common drawback. Specifically, these LIs do not use the authentic set of information when needed. Loosely speaking, when it comes the time to update the LI the newest information (i.e. variables' updates) are used even for the calculation of past LI values. This results in an *ex-post* measure. But, "*what good is a leading index whose history continues to be re-calculated*?" (see Hansen's blog, 2015). An index of this type may be useless once one is willing to estimate a forward-looking model. For instance, the OECD LI and ALI embody data revisions of their components. Of course, this information is not available in the past (i.e. in the last revision of the LI). Moreover, these LIs employ revisions even in the presence of smoothed series, exacerbating thus the overlapping information issue. Needless to mention, at any revision a change in the dynamics of the LI is observed (see de Bondt and Hahn, 2014, Figure 3). Instead, TCB LI uses standardized factors as components weights in the construction of the index that are updated "*to incorporate any data revisions that occurred in the preceding twelve months*" (TCB, 2001).

Differently, we propose a novel LI, which is immune to the "overlapping information drawback". In practice, it is not subject to dynamic revisions or upgrades across the entire time series as new information become available (i.e. no "backward-looking" revision). We label the proposed LI as a "quasi real-time indicator". On the one side, since the vintage series of the EU IP growth is used as targeting series, it can be interpreted as a real-time indicator. On the other side, the proposed LI relies on few ex-post time series and thus it cannot be classified as a fully real-time indicator.[2] We stress that, at most, two out of 15 variables employed to build the LI are subject to revisions (i.e. ex-post time series). In this respect, the term "quasi real-time" seems appropriate.

[1] See, among many others, the following LIs: the Conference Board LI (Levanon et al., 2011); the OECD composite index (Gyomai and Guidetti, 2012); the Federal Reserve Bank of Philadelphia leading index (Crone, 2000); the Economic Cycle Research Institute weekly index; the Chemical Activity Barometer index (Swift, 2015); the Purchasing Managers' Index (Koening, 2002).

[2] Notice that this is due to the fact that vintage series are not available for all the variables employed in this study.

In addition, our LI relies on a two-steps dynamic and systematic data selection procedure implying that the set of variables composing the LI can be easily updated every five or 10 years. This ensures that the choice of the LI components does not depend on subjective views. Differently, they are objectively selected by using a two-steps statistical procedure. In other words, an *ex-ante* prior on the variables does not exist as emphasized by Baba and Kisinbay (2011). Loosely speaking, we let the current economic environment choose the “best variables” to be included in the construction of the LI.

The LI constructed in this paper anticipates - on average - swings in the EU industrial production by 2 to 3 months. For robustness purposes, we test the ability of our LI and the LIs proposed by the TCB and OECD in (*i*) forecasting the EU IP growth and (*ii*) explaining empirical regularities relying on established theoretical contents.

To evaluate the forecasting performance of the LIs we use traditional statistical metrics: the root mean square error (RMSE) and the mean absolute error (MAE). We evaluate the forecasting power of each LI at different horizons (i.e. 1-month ahead, 3-month ahead, 6-month ahead) using as benchmark a simple autoregressive equation for EU IP growth. Focusing on the pre- and post-crisis periods (i.e. 2007m1-2012m12), we observe that the quasi real-time LI proposed in this study does a better job than the TCB and OECD indicators in predicting EU IP growth at both short and long horizons. We stress that this performance is achieved by developing a LI that is not ex-post revised.

We then focus on the ability of the different LIs in mimicking the interest rate pattern of the ECB. To do so, we rely on the forward-looking Taylor rule with a smoothing parameter.[3] Even if the monetary policy is, in general, more complicated than what is suggested by the simple Taylor rule, over the last two decades this rule captured the pattern of the interest policy rate in numerous countries rather well (Clarida et al., 1998). Some studies use as proxies of expectations of inflation and business cycle conditions the surveys of consumers or professional forecasters (Sauer and Sturm, 2007; Gorter et al., 2008). In our revised empirical exercise, the inflation expectations derived from the EU Commission consumer surveys and the LIs (i.e., EU IP growth proxies) capture policymakers’ expectations on future business cycle conditions. We find that our LI, differently from the LIs proposed by the OECD and TCB, gives rise to a statistical significance coefficient for business cycle conditions and satisfies the “Taylor principle” (i.e. the condition for

[3] Standard policy rules, such as the Taylor type-rule, are derived from models that often posit forward-looking pricing behavior and sticky price and usually comprise an intertemporal IS relation and a structural Phillips curve (see Svensson, 1997, 2003; Clarida et al., 1999; Gorter et al., 2008). Conventional wisdom suggests that Central Banks have historically implemented a smooth monetary policy rate. This motivates the minimization of interest rate volatility as an additional goal of stabilization policies (the so-called interest rate smoothing effect). Such policy inertia is rationalized in different ways. See, among others, Mishkin (1999), Goodfriend (1991), Woodford (1999, 2001), Orphanides (2003A).

having a stable policy rule). Furthermore, in line with the inflation objective of the European Central Bank, the proposed LI reproduces estimates of the inflation target almost perfectly.

The rest of the paper is organized as follows. Section 2 describes the empirical strategy carried out to develop our LI. Section 3 presents and discusses the results. Section 4 tests the ability of our LI and the LIs proposed by previous studies in forecasting the EU IP growth and in explaining the interest rate policy via a forward-looking Taylor rule. Section 5 concludes.

2. Methodology and empirical strategy

In Table 1, we report a detailed description of the LI methodology employed in this paper along with the main differences between our LI and the existing ones (i.e. OECD, TCB, ALI). The ultimate goal of our strategy is to predict/anticipate the turning points of the vintage series of EU IP (IP^v) growth (i.e. $\Delta_{12} ip_t^v = ip_t^v - ip_{t-12}^v$, where $ip_t^v = lnIP_t^v$ and ip_{t-12}^v is the level of the vintage series of industrial production in the same month of the previous year). Our LI is based on a large and heterogeneous dataset, which consists of real economic data, expectations data (i.e. surveys) and financial data. Overall, we make use of 823 time series. See appendix A for a detailed data description.

The construction of the LI relies on two main steps: (*i*) the selection of the "best variables" and (*ii*) the construction of the indicator. Our selection procedure requires two distinct empirical exercises. First, we test whether there exists Granger causality – at 5% significance level – between each of the 823 candidates and the EU IP growth.[4] In other words, we estimate the following model for each of the potential *LI* component, *y*:

$$\Delta_{12} ip_t^v = a_0 + a_1 \Delta_{12} ip_{t-1}^v + \cdots + a_5 \Delta_{12} ip_{t-5}^v + b_1 y_{t-1} + \cdots + b_5 y_{t-5} + u_t \quad (1)$$

We use HAC standard error (i.e. Newey-West adjustment with automatic lag length selection) to test H_0: $b_1 = b_2 = \cdots = b_5 = 0$ against H_A: "Not H_0".

Second, among the variables that Granger cause the EU IP growth, we select those 15 displaying the highest absolute lagged correlation (lag 5 to 9) with the EU IP growth over a period of 10 years. Therefore, for each lagged variable y_{t-j}, we compute the following correlations

$$max\{|corr(y_{t-5}, \Delta_{12} ip_t^v)|, |corr(y_{t-6}, \Delta_{12} ip_t^v)|, \ldots, |corr(y_{t-9}, \Delta_{12} ip_t^v)|\} \quad (2)$$

Notice that these two steps can be easily replicated once one desires to update the set of variables needed for the construction of the LI. In this respect, we develop three different versions of the LI

[4] A one-year change with monthly data overlaps observations for 12 months. The overlapping of the observations generates a MA term in the residuals. As a consequence, OLS estimates would be inefficient and hypotheses tests biased (see Hansen and Hodrick, 1980). A simply way to overcome this issue is to use HAC estimators.

(see Table 2 for details). Given that the relations among variables tend to change over time, the idea here is to upgrade the information set periodically in order to pick up the set of variables with the highest information content. Appendix B reports the lists of the 15 variables used to compute the three different versions of the LI.

The construction of our LI follows the procedure described in Hakkio and Keeton (2009). This approach requires the use of rolling windows. We decide to employ 10-year window to make sure that a whole business cycle is captured. First, within each rolling window we estimate the correlation matrix of the 15 variables that were selected via the aforementioned two-steps procedure and perform an "eigendecomposition" of the matrix. Second, we retain the highest eigenvalue λ and the corresponding eigenvector v and compute the so-called first-stage LI. This indicator is a linear combination of constituent variables weighted by their respective eigenvector components that are normalized by the first eigenvalue:

$$\widetilde{LI}_t = \left(\frac{v_1}{\lambda}\right) y_{1,t} + \cdots + \left(\frac{v_{15}}{\lambda}\right) y_{15,t} \tag{3}$$

Finally, from each rolling window the last value of the first-stage $\widetilde{LI}$ is retained and used as the value composing our LI. Additional details are reported in appendix C. Notice that this procedure applies for the construction of all the indicators (i.e. LI_1, LI_2, LI_3 and LI_4).

3. Results

The different versions of the LI are depicted in Figure 1. In line with the OECD and TCB versions, we observe that the LI_1 anticipates – on average – the turning points of EU IP growth by 2 to 3 months over the entire sample. An update of the indicator (either every 10 years or 5 years) seems to largely improve its ability in anticipating EU IP swings (see Figure 1, Panels A and B). For comparison purposes, in Figure 2 we plot version 1 (Panel A) and version 2 (Panel B) of our indicator along with the LI produced by the OECD and TCB. To be consistent with the OECD LI, we also filter our LI using a HP filter for $\widetilde{LI}_t$ in each window. In doing so, we avoid the "backward-looking" revision effect. Results suggest that version 1 of our LI tends to mimic rather well the dynamics of the EU IP growth, at least until 2010 (see Figure 2, Panel A). By updating our procedure as of 2010 we observe an improvement in the ability of the LI in anticipating turning points. It turns out that our LI has much more predictive power than the OECD LI over the period 2010-2015 (see Figure 2, Panel B).

We stress once again that our LI has been constructed by using only the information set available at a specific point in time for EU IP growth (i.e. the available vintage series of EU IP) and it is not regularly "backward-looking" revised. One possible concern about the performance of the LI presented in this paper refers to the "look-ahead" bias, i.e. the fact that the LI is estimated in 2015 using revised data that are not available at the time of the estimation. Notice that, at most, two out of 15 of the series included in the different versions of the LI are subject to revisions from the data provider (i.e. G7 and Spain IP for LI_1; Spain IP for LI_2; US and G7 IP for LI_3). It is thus less likely that these revisions undermine the real-time characteristics of our LI.

4. Testing LIs: Empirical and theoretical checks

4.1 Forecasting the EU IP growth

To assess the performance of our quasi real-time LI, we construct a series of recursive forecasts running from 2007m2 through 2012m12 (i.e. a period comprising the beginning of the decline in the EU IP growth and the latest EU economic crisis) to predict the *actual* (i.e. ex-post) EU IP growth. Needless to mention, this period represents a very difficult sample for predicting the EU IP growth via a LI that is constructed using real-time information on EU economic growth. This is due to the fact that economic crisis' signals became evident only after the beginning of the turmoil (see Ghysels et al., 2014). We implement a forecast exercise along the lines of Diebold and Rudebusch (1991), McGuckin et al. (2007) and Ozyildirim et al. (2010). In practice, our LI_1 is compared with predictions of a simple autoregressive model of EU IP growth – labeled as "Naive model" – and with those of the two ex-post LIs measure (i.e. OECD and TCB LIs).

The Naive model is represented by a simple autoregression model with specified lags. Formally,

$$\Delta_{12} ip_t = \sum_{i=1}^{k} \theta_{1,i} \Delta_{12} ip_{t-1} + \varepsilon_{1,t} \qquad (4)$$

The optimal number of lags (with a maximum of k = 13) are chosen using the general-to-specific procedure. Starting from a general model that passes all the diagnostic tests (i.e. a model with all k lags), the algorithm *Autometrics* implemented in *Oxmetrics 7* allows us to select the most significant lags and preserves the robustness of the diagnostic tests (see Doornik and Hendry, 2013).

The alternative models use lags of LIs in addition to the lags of the Naive model. For each LI (i.e. LI_1, OECD LI, and TCB LI), we estimate the following equation:

$$\Delta_{12} ip_t = \sum_{i=1}^{k} \theta_{1,i} \Delta_{12} ip_{t-1} + \sum_{i=1}^{k} \theta_{2,i} LI_{t-i} + \varepsilon_{2,t} \qquad (5)$$

As for Eq. (4), the optimal number of lags, starting from a maximum of k =13, is selected according with the general-to-specific procedure. The models presented in Eqs. (4) and (5) are used to generate forecasts at three different horizons: 1-month ahead, 3-month ahead, and 6-month ahead of ex-post EU IP growth (i.e. $\Delta_{12} ip_t$). Results from these recursive forecasting exercises are displayed in Table 3 and Figure 3.

We find that RMSE and MAE statistics are lower over the entire out-of-sample forecasts for our LI_1 in the case of short horizons (1-month ahead), whereas on medium horizons (3-month ahead) are in line with OECD LI. For all horizons, our LI_1 performs better than the TCB LI and Naive model. In addition, we find that our LI on average does a better job in signaling the beginning and the trough phase of the crisis at all horizons (i.e. the period 2007m2-2009m12) than all the other models (see Table 3). Moreover, Figure 3 suggests that that at longer horizons the ability of our LI_1 in predicting and signaling the beginning of the crisis improves with respect to the other LIs and Naive model. This is an inspiring result since our LI_1 is the only one built using real-time information of EU IP growth.

4.2 Estimating a forward-looking Taylor rule

In the spirit of Clarida et al. (2000), we estimate the following forward-looking Taylor rule with a smoothing parameter:

$$i_t = (1-\rho)\alpha + (1-\rho)\beta E(\pi_{t+n}) + (1-\rho)\gamma E\left(y_{t+q}\right) + \rho i_{t-1} + \varepsilon_t \qquad (6)$$

where i_t is the policy rate of the Central Bank, the constant α captures the term $(i^* - \beta\pi^*)$,[5] $E(\pi_{t+n})$ represents the expected inflation rate between *t* and *t* + *n*, $E\left(y_{t+q}\right)$ indicates the expected output gap between *t* and *t* + *q*, and ρ is the smoothing parameter. In line with the economic theory and existing studies (see, among others, Fourcans and Vranceanu, 2004; Sauer and Sturm, 2007; Fendel and Frenkel, 2006), the interbank rate for the Euro Area is used as proxy for the policy rate. We then use the series "*price trends over the next 12 months*" - taken from the consumer surveys of the European Commission - as proxies for inflation expectations.[6] Following Fourcans and Vranceanu (2004, 2007) and Blattner and Margaritov (2010), we use the industrial production growth as a proxy measure of the business cycle for the Euro Area.[7] Specifically, we use three different LIs: the OECD LI, the TCB LI and our quasi real-time LI_1 measure. Results are presented in Table 4.[8]

An important empirical question relates to the estimated coefficients of inflation and economic conditions (i.e. β and γ). Clarida et al. (2000) show that $\beta > 1$ and $\gamma > 0$ are required to satisfy the

[5] The terms are the equilibrium levels of the nominal interest rate and the inflation target, respectively.

[6] Since inflation expectations in the consumer surveys are expressed as balance (i.e. the difference between positive and negative answers in percentage points of total answers), we have to connect them with the inflation. To do this, we run a regression between inflation and inflation expectation to express expectations in the same measure of inflation.

[7] In addition, this modification is in line with McCallum (2001), Orphanides (2003B), Leitemo and Lonning (2006), Williams (2006), among others, who have argued in favor of interest rate rules based on output growth rates as they suffer from fewer measurement problems.

[8] All the time series involved in the estimation of the monetary policy rule are stationary. The short-term interest rate for EU exhibits a stationary pattern after the second half of 1990s as argued by Gorter et al. (2008).

stability condition of the interest rule. Entries in Table 4 suggest that only the LI_1 presented in this paper produces realistic results. The regression based on the OECD LI seems to indicate that the ECB has followed a destabilizing policy (i.e., $\beta < 1$) whereas the β is not statistically significant once the TCB LI is used. In contrast, the coefficient of inflation estimated using our LI_1 is significant and higher than one implying that the Taylor rule holds. Moreover, the coefficient γ for the OECD and TCB LIs is not statistically significant.

As a further robustness check, it is possible to calculate the inflation target π^* implied by our LI_1. Given that the equilibrium real interest rate is given by $r^* = i^* - \pi^*$ and that $\alpha = i^* - \beta\pi^*$, the implicit inflation target can be extracted from the regression according to this formula: $\pi^* = (r^* - \alpha)/(\beta - 1)$. Recent studies aimed at estimating the real natural interest rate for the Euro Area find a value close to 1% (see Messonier and Renne, 2007; Wintr et al., 2005; Belke and Klose, 2013). Given our estimates and using $r^* = 1\%$ (as suggested by existing studies), we end up with an implicit inflation target slightly below 2%. Needless to mention, this value reflects the ECB mandate.

5. Conclusions

This work introduces a novel LI for the EU IP. Our LI differs from previously introduced indicators in three main aspects. First, the proposed LI – by construction – is immune to "overlapping information drawbacks". In other words, the past values of the indicator are not revised by adding future information (i.e. data revisions). Second, it relies on a dynamic and systematic data selection procedure, which allows updating the LI easily. This allows us picking up those variables with the highest information content. Third, it can be considered as a "quasi real-time" measure because it is constructed by using a very small number of ex-post components.

We show that the computed LI (*i*) anticipates swings in the EU IP by 2 to 3 months and (*ii*) has a higher predictive than the *ex-post* LIs proposed by previous studies, in particular during crisis periods. Moreover, it explains empirical regularities that rely on well-known theoretical contents. In a forward-looking Taylor rule framework, we show that our quasi real-time LI – as opposed to the OECD and TCB LIs - captures the pattern of the EU interest rate policy relatively well.

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Tables and Figures

Table 1: Our LI and existing indicators: main characteristics.

	Our LI	OECD LI	TCB LI	ALI
Reference time series	IP Index (vintage series)	IP Index	Composite index of coincident economic indicators: IP, employment, manufacturing turnover, retail trade	IP (no construction)
Filter for extraction of the reference time series' cyclical component	12 month growth rate	Double HP filter (one for low and one for high frequency)	The component contributions are seasonally adjusted and deflated, standardized by the inverse of the reference time series' standard deviations	Christiano and Fitzgerald (2003) random walk filter
Data sources	Real data, opinions/expectations data, financial data	Real data, opinions/expectations data, financial data	Real data, opinions/expectations data, financial data	Real data, opinions/expectations data, financial data
Pre-selection	12 month growth rate (if needed)	Linear interpolation of quarterly series, seasonal adjustment, outlier detection, de-trending, smoothing, normalization	Economic and practical relevance. The variables are seasonally adjusted and deflated where necessary	Christiano and Fitzgerald (2003) random walk filter, outlier detection, de-trending, normalization, turning point detection
Selection	*Step 1*: test for Granger causality of lagged (t=-5) variables with contemporaneous IP growth. *Step 2*: compute average absolute correlation	Economic and practical relevance. Turning point detection using simplified Bry-Boschan routine	Turning point detection using Bry-Boschan routine	Five month lead, lagged cross correlation, broad-based economic mixture of different kinds of candidates
Aggregation	Hakkio and Keeton (2009)	Equal weighting	Weighting by inverse of components' standard deviation	Equal weighting
Presentation of LI	Normalized (double axis)	(i) Amplitude adjusted, (ii) trend restored, (iii) 12-month rate of change	Index value (2010=100), percent change	Normalized, in double axis
Comprehensive revisions	Component revision every 5/10 years	Periodical (but not specified) revision	NA for Euro Area	NA

Table 2: Description of the three versions of the LI

Version	Update of the indicator	Variable selection period	Leading indicator produced
1	No update	1990M1-2000M1	LI_1 → 2000M1-2015M7
2	Yes: every 10 years	1990M1-2000M1; 2000M1-2010M1	LI_1 → 2000M1-2009M12 LI_2 → 2010M1-2015M7*
3	Yes: every 5 years	1990M1-2000M1; 1995M1-2005M1; 2000M1-2010M1; 2005M1-2015M1	LI_1 → 2000M1-2004M12 LI_3 → 2005M1-2009M12 LI_2 → 2010M1-2014M12 LI_4 → 2015M1-2015M7*

Note: * The next update is scheduled for 2020M1.

Table 3: Statistics for recursive forecasting exercise, 2007m2-2012m12

Number of out-of-sample forecasts (n)	Naïve		OECD LI		TCB LI		Our LI_1	
	MSE	MAE	MSE	MAE	MSE	MAE	MSE	MAE
Sample: 2007m2-2012m12								
$n = 1$	1.24	1.24	1.03	1.03	1.11	1.11	1.04	1.04
$n = 3$	2.11	1.92	1.60	1.44	1.77	1.58	1.64	1.47
$n = 6$	3.57	3.13	2.36	2.08	2.68	2.33	2.54	2.21
Sample: 2007m2-2009m12								
$n = 1$	1.43	1.43	1.09	1.09	1.18	1.18	1.02	1.02
$n = 3$	2.50	2.25	1.79	1.62	2.07	1.85	1.60	1.42
$n = 6$	4.28	3.76	2.81	2.48	3.51	3.05	2.61	2.21

Notes: RMSE is defined as $\sqrt{\sum_{t=1}^{n} e_t^2/n}$, where n is the number of out-of-sample forecasts and e_t refers to the out-of-sample forecast errors. MAE is defined as $\sum_{i=1}^{n}|e_t|/n$. When n =1 the two measures are equal.

Table 4: Estimated forward-looking Taylor rule with smoothing parameter, 2000m1-2013m12

Coefficients	**Estimations**		
	$E(y_{t+q})$ = OECD LI	$E(y_{t+q})$ = TCB LI	$E(y_{t+q})$ = LI_1
α	-7.044 (1.355)***	-0.021 (0.044)	-0.142 (0.048)***
ρ	0.985 (0.008)***	0.983 (0.011)***	0.954 (0.010)***
β	-0.270 (1.229)	1.775 (2.678)	1.583 (0.563)***
γ	5.177 (2.817)*	0.649 (0.514)	1.304 (0.215)***
R^2 adj.	0.993	0.991	0.994

Notes: The equations are estimated by non-linear GMM with Newey-West (1987) standard errors in parenthesis to correct for heteroskedasticity and autocorrelation. Instruments used are: $i_{t-1}, i_{t-2}, E(\pi_{t+n})_{-1}, E(\pi_{t+n})_{-2}, E(y_{t+q})_{-1}, E(y_{t+q})_{-2}, E(y_{t+q})_{-3}$. *J*-statistics, not reported for brevity, indicate that the chosen set of instruments are valid. *, **, *** denote significance at 10%, 5%, and 1% level, respectively.

Figure 1: Plot of version 1 [A], version 2 [B] and version 3 [C] of the LI against the observed EU IP growth

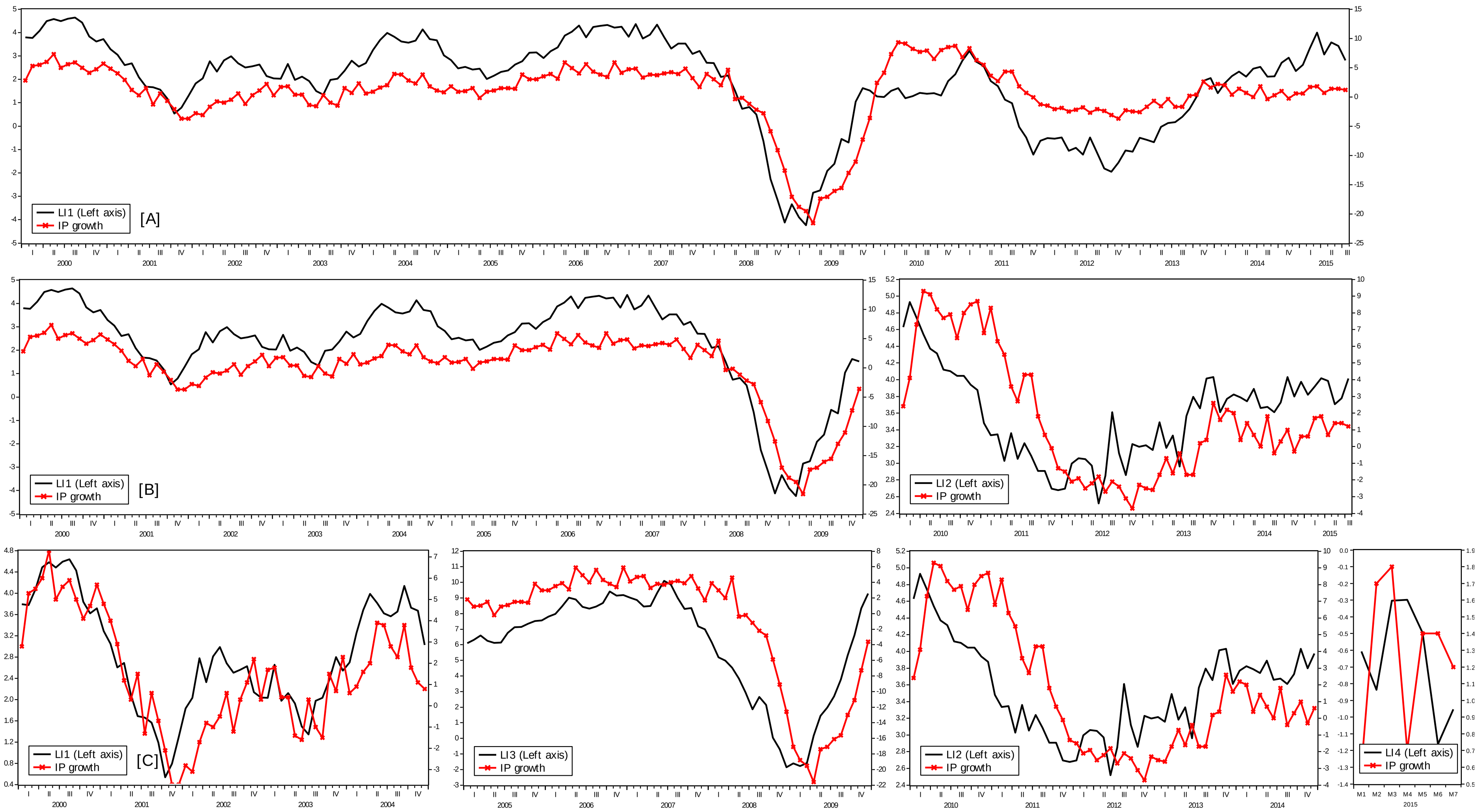
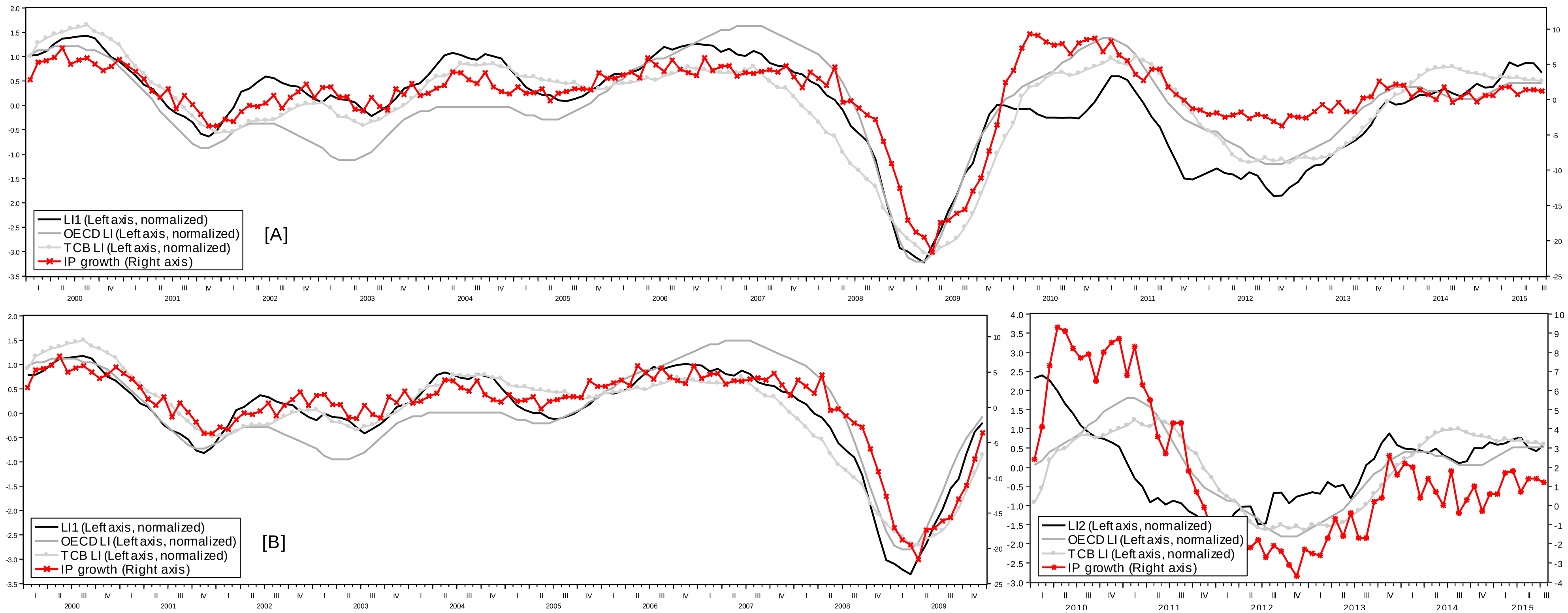
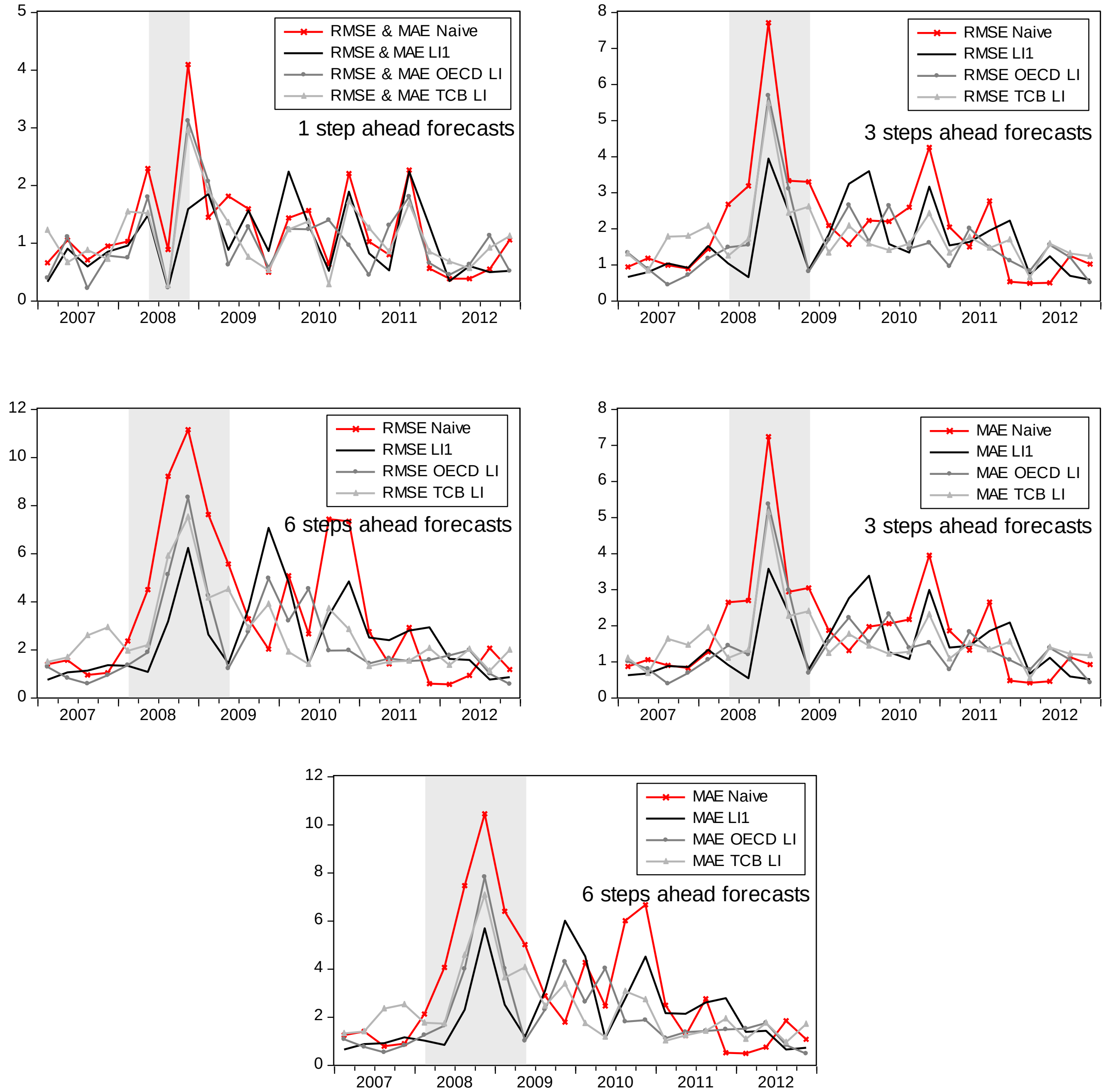


Figure 2: Plot of version 1 [A], version 2 [B] of the LI against the observed EU IP growth, OECD and TCB LI



Note: LI is smoothed applying the HP filter (with a smoothing parameter of 12) filtered using HP with a smoothing parameter for $\widetilde{LI}_t$ in each window.

Figure 3: RMSE and MAE, forecast period: 2007m2-2012m12



Notes: RMSE is defined as $\sqrt{\sum_{t=1}^{n} e_t^2 / n}$, where n is the number of out-of-sample forecasts and e_t refers to the out-of-sample forecast errors. MAE is defined as $\sum_{i=1}^{n} |e_t| / n$. When n =1 the two measures are equal. To get a better understanding of the LIs' performance monthly figures are transformed in quarterly statistics taking the average of 3 monthly obs. The grey area denotes the crisis period. Within this period our LI_1 predicts better than the LIs proposed by the OECD and TCB LI.

Appendix A: Data

Table A: Data description: sample, sources and transformation

	Base Year	*Country*	*N° of Series*	*Transform.*	*Source*
Target variable					
Industrial production (SA); vintage series	1990	EU	1	YES	OECD Stat
Real data					
Industrial production (SA)	1990	BE; FR; DE; IR; IT; JP; KO; NE; PT; ES; UK; US; G7	13	YES	OECD Stat
USA Manufacturing, New order (SA)	1990	US	1	YES	FRED
Retail trade volume (SA)	1990	BE; FR; DE; IR; IT; JP; KO; NE; PT; ES; UK; US; EU	13	YES	OECD Stat
Passenger cars volume (SA)	1990	BE; JP; KO; NE; PT; ES; UK; US; EU	9	YES	OECD Stat
Permitted issued for dwellings (SA)	1990	BE; FR; DE; KO; NE; PT; ES; EU	8	YES	OECD Stat
Hourly earnings (SA)	1990	IT; JP; NE; PT; UK; US	6	YES	OECD Stat
Total consumer credit owned (SA)	1990	US	1	YES	FRED
Export in goods (SA)	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; US; G7	12	YES	OECD Stat
Import in goods (SA)	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; US; G7	12	YES	OECD Stat
Unemployment rate (SA)	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; US; EU; G7	13	NO	OECD Stat
Oil price (US$ per barrel)	1990	US	1	YES	FRED
Opinions/Expectations data					

Consumer surveys					
OECD Consumer confidence indicator (SA)	1990	BE; FR; DE; IR; IT; JP; KO; NE; PT; ES; UK; US; EU; G7	14	NO	OECD Stat
Confidence indicator (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Financial situation over last 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Financial situation over next 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
General economic situation over last 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
General economic situation over next 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK;	30	NO	European Commission

		EU; EA			
Price trends over last 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Price trends over next 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Unemployment expectations over next 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Major purchases at present	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Major purchases over next 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Saving at present	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY;	30	NO	European Commission

		FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA			
Saving over next 12 months	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Statement on financial situation of households	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Industry surveys					
OECD business confidence indicator (SA)	1990	BE; FR; DE; IR; IT; JP; KO; NE; PT; ES; UK; US; EU; G7	14	NO	OECD Stat
Capacity Utilization (SA)	1990	US	1	NO	FRED
Confidence indicator (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Production trend observed in recent months (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Assessment of order-book levels (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY;	30	NO	European Commission

		FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA			
Assessment of export order-book levels (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Assessment of stocks of finished products (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Production expectations for the months ahead (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Selling price expectations for the months ahead (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Employment expectations for the months ahead (SA)	1990	AT; BE; BG; CZ; DK; FR; DE; EE; EL; HR; HU; CY; FI; LV; LT; LU; MT; IR; IT; NE; PL; PT; ES; RO; SE; SI; SK; UK; EU; EA	30	NO	European Commission
Financial data					
Broad Money	1990	JP; KO; UK;	5	YES	OECD Stat

(M3) index (SA)		US; EU			
Overnight interbank rate	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; US; EU	12	NO	OECD Stat
3-months interest rate	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; US; EU	12	NO	OECD Stat
Long-term interest rate	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; US; EU	12	NO	OECD Stat
Share prices	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; US	11	NO	OECD Stat
Exchange rates (National currency per US$)	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; EU	11	NO	OECD Stat
Government bond spread	1990	BE; FR; DE; IT; JP; KO; NE; PT; ES; UK; US; EU	12	NO	OECD Stat

Notes: SA = Seasonally Adjusted series. YES indicates that data are expressed as growth on the same period of previous year, whereas NOT indicates that data are not transformed because stationary. AT = Austria; BE = Belgium; BG = Bulgaria; CZ = Czech Republic; DK = Denmark; FR = France; DE = Germany; EE = Estonia; EL = Greece; HR = Croatia; HU = Hungary; CY = Cyprus; FI = Finland; LV = Latvia; LT = Lithuania; LU = Luxembourg; MT = Malta; IR = Ireland; JP = Japan; KO = South Korea; NE = Netherlands; PL = Poland; PT = Portugal; ES = Spain; RO = Romania; SE = Sweden; SI = Slovenia; SK = Slovak Republic; UK = United Kingdom; US = United States of America; EA = Euro countries; EU = Euro group of 19 countries; G7 = G7 group of countries.

Appendix B: The "best 15 variables" selected for the construction of our LIs

LI_1**:** Belgium OECD business confidence; EU production expectations for the months ahead; EA production expectations for the months ahead; Belgium production expectations for the months ahead; Spain production expectations for the months ahead; Spain assessment of order-book levels; Greece financial situation over last 12 months; Greece financial situation over next 12 months; Finland general economic situation over last 12 months; Finland savings at present; UK unemployment expectations over next 12 months; Portugal exchange rate; France government bond spread; Spain industrial production; G7 industrial production.

LI_2**:** Spain OECD business confidence; Spain production expectations for the months ahead; Spain assessment of stocks of finished products; UK OECD business confidence; G7 OECD business confidence; Denmark price trends over last 12 months; Spain unemployment expectations over next 12 months; Finland financial situation over next 12 months; Finland major purchases over next 12 months; Sweden price trends over last 12 months; Sweden major purchases at present; Sweden major purchases over next 12 months; UK price trend over last 12 months; UK financial situation over next 12 months; Spain industrial production.

LI_3**:** Belgium OECD business confidence; G7 OECD business confidence; Belgium industry confidence indicator; Belgium production expectations for the months ahead; Czech R. employment expectations for the months ahead; UC OECD consumer confidence; G7 OECD consumer confidence; Czech R. general economic situation over next 12 months; Netherlands general economic situation over next 12 months; Finland general economic situation over next 12 months; US industrial production; G7 industrial production; France share price returns; Germany share price returns; Netherlands share price returns.

***LI_4*:** US OECD business confidence; EU price trends over last 12 months; Denmark general economic situation over next 12 months; Denmark major purchases at present; Germany price trends over last 12 months; Austria financial situation over next 12 months; Austria price trends over last 12 months; Slovenia price trends over last 12 months; Finland price trends over last 12 months; US manufacturing new orders; Belgium share price returns; Germany share price returns; Netherlands share price returns; UK share price returns; US share price returns.

Note: For each LI the "best 15 variables" have been selected via the procedure described in Section 2.

Appendix C: Description of leading indicator computation

The following guideline is a technical step-by-step instruction for computing the Leading Indicator (LI) in the spirit of Hakkio and Keeton (2009), Kansas City FED.

Assuming an overall sample size of length T, choose a rolling window of size m such that the entire data set has $N = T - m + 1$ partitioned subsamples. Then, for each rolling window $w \in \{1, \dots, N\}$ repeat the following steps

1. Calculate correlation matrix ρ_w between the 15 candidate variables $y = [y_1, \dots, y_{15}]$:

$$\rho_w(y) = \begin{bmatrix} 1 & \cdots & \rho_{1,15} \\ \vdots & \ddots & \vdots \\ \rho_{15,1} & \cdots & 1 \end{bmatrix}$$

2. Perform an eigendecomposition of ρ_w and retain the largest eigenvalue λ and the corresponding eigenvector $v = [v_1, \dots, v_{15}]$.
3. Calculate the first-stage Leading Indicator $\widetilde{LI}$ as a linear combination of constituent variables y weighted by their respective eigenvector components that are normalized by the largest eigenvalue:

$$\widetilde{LI}_{w,t} = \left(\frac{v_1}{\lambda}\right) y_{1,t} + \cdots + \left(\frac{v_{15}}{\lambda}\right) y_{15,t},$$

   where $t = 1, \dots, m$.

4. Retain the last component of $\widetilde{LI}_w = [\widetilde{LI}_{w,1}, \dots, \widetilde{LI}_{w,m}]$ and use it as input variable for our final Leading Indicator LI.

Iterating the above steps yields the resulting Leading Indicator LI = $[\widetilde{LI}_{1,m}, \dots, \widetilde{LI}_{N,m}]$. Thus, our final LI is actually composed of the latest values of the first-stage $\widetilde{LI}$s that were computed for each rolling window. This procedure guarantees that subsequent data revisions of variables y do not affect the LI in hindsight.

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