HOUSE OF FINANCE
WORKING PAPER SERIES

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A Novel Ex-Ante Leading Indicator for the EU Industrial Production

SAFE Working Paper No. 118

SAFE | Sustainable Architecture for Finance in Europe
A cooperation of the Center for Financial Studies and Goethe University Frankfurt

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Non-Technical Summary

Understanding the future state of an economy is crucial for economic agents such as households, investors, policy makers, or economists. This need tends to be more urgent in times of uncertainty, like 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 transparent statistical selection procedure to identify the most relevant candidate variables for the LI's construction. Therefore, we do not rely on any subjective views on the constituent variables but let the different economic scenarios decide the best ones to be included.

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 embedded in the LIs proposed by previous studies.

A Novel Ex-Ante Leading Indicator for the EU Industrial Production

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Abstract

We build a novel leading indicator (LI) for the EU industrial production (IP). Differently from previous studies, the technique developed in this paper is able to produce an ex-ante LI that is immune to "overlapping information drawbacks". In addition, the set of variables composing the LI relies on a dynamic and systematic criterion. 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. The predictive power improves if the indicator is revised every five or ten years. In a forward-looking framework, via a general-to-specific procedure, we also show that our LI represents the most informative variable in approaching expectations on the EU IP growth.

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

JEL Codes: E32; C22; C52

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We thank Monica Billio, Saten Kumar and Federico Silvestri for helpful comments. We gratefully acknowledge research support from the Research Center SAFE, funded by the State of Hessen initiative for research LOEWE. All remaining errors are our own.

1. Introduction

The anticipation of the turning points of the real activity turns out to be crucial for all those agents dealing with real-time decisions (e.g., investors, policy makers, economists, households). While there have been many attempts to capture swings in the US economic activity,[1] the number of existing leading indicators (LIs) focusing directly and exclusively on the EU economy as a whole 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 though policymakers, practitioners, and statistical warehouses largely employ the aforementioned LIs, they embody a common drawback. Specifically, they do not use the actual set of information when needed. Loosely speaking, when it comes the time to update the LI they include the newest information (i.e., variables' updates) 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). This may make the index useless once one is willing to estimate a forward-looking model. For instance, the OECD LI and ALI embody data revisions of their constituent series. 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 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 LEI 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 an *ex-ante* LI, which is immune to the overlapping information drawback. In practice, it uses only the information available at that specific point in time (i.e., it is not subject to dynamic revisions or upgrades across the entire time series). In addition, our LI relies on a systematic data selection procedure implying that the set of variables composing the LI is updated, and thus improved every 10 or 5 years in an automatic way. This ensures that none of the variables depends on subjective views and they can thus be objectively selected for the construction of the LI. In other words, an *ex-ante* prior on the variables does not exist as emphasized by Baba and Kisinbay (2011). This implies that we let the current economic environment decide on the "best variables" to be included.

[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).

The LI constructed in this paper anticipates (on average) swings in the EU industrial production by 2 to 3 months. To compare the performance of our LI with that of the LIs proposed by the TCB and OECD, we estimate a hybrid version of a forward-looking IS equation (Fuhrer and Rudebusch, 2004; Goodhart and Hofmann, 2005; Paradiso et al., 2013). Following Banerjee and Marcellino (2006), we use the general-to-specific (GETS) approach (Krolzig and Hendry, 2001). This, in general, allows for the inclusion of statistically significant variables only. The GETS algorithm selects our LI and does not classify the other LIs as statistically relevant drivers (i.e., OECD and TCB LIs). This suggests that the LI proposed in this paper tends to give a better representation of the IS forward-looking model and, in general, of the dynamics of the EU IP.

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 the existing literature in fitting a hybrid IS forward-looking model. 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 EU IP growth (i.e. $\Delta_{12} ip_t = ip_t - ip_{t-12}$, where $ip_t = lnIP_t$ and ip_{t-12} is the level of the 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 a Granger causality – at 5% significance level – between all the 823 candidates and the EU IP growth.[2] 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

$$max\{|corr(y_{t-5}, \Delta_{12} ip_t)|, |corr(y_{t-6}, \Delta_{12} ip_t)|, \dots, |corr(y_{t-9}, \Delta_{12} ip_t)|\} \quad (1)$$

Notice that points (*i*) and (*ii*) are repeated any time 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 (see

[2] Specifically, we run a bivariate VAR(5) over a period of 10 years (i.e. 1990M1-2000M1, 2000M1-2010M1, etc.).

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:

$$\widetilde{LI}_t = \left(\frac{v_1}{\lambda}\right) y_{1,t} + \cdots + \left(\frac{v_{15}}{\lambda}\right) y_{15,t} \qquad (2)$$

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 LI_1, LI_2, LI_3, LI_4.

3. Results

The three different versions of the LI are depicted in Figure 1. We stress that our LI anticipates – on average – the turning points of EU IP growth by 2 to 3 months. This holds across all versions. The update of the indicator (either every 10 years or 5 years) seems to largely improve the ability of the indicator 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. To be consistent with the OECD LI, we also filter our LI using a HP filter. Results suggest that version 1 of our LI tends to mimic rather well the dynamics of 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 is built considering only the information set available at a specific point in time 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, that is, the fact that the LI is estimated in 2015 using revised data that are not available at the time of the estimation. Notice that, as described in Appendix B, at maximum 2 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 IP and Spain IP for LI_1; JPN unemployment rate for LI_2; US money supply for LI_4). It is thus less likely that revisions undermine the forecasting performance of our LI. It is important to stress that the set of variables used for the construction of the LI does not change even if we use real-time data for the EU IP, taken from Real Time Database of European Central Bank. Figure 3 plots the LI_3 for the period 2005-2013 (i.e., pre- and post-crisis sample) using exclusively survey and financial variables (i.e., variables not subject to data providers' revisions). The ability of our LI_3 in anticipating EU IP swings is noteworthy.

4. Testing LIs

We estimate a hybrid version of forward-looking IS equation (Fuhrer and Rudebusch, 2004; Goodhart and Hofmann, 2005; Paradiso et al., 2013) specified in terms of EU IP growth, with the aim to investigate how our LI competes with the others:

$$\Delta_{12} ip_t = \alpha_0 + \sum_{j=1}^{n} \rho_{t-j} \Delta_{12} ip_{t-j} + \gamma' E_t x_{t+1} + \beta(i_t - E_t \pi_{t+1}) + \varepsilon_t, \quad (3)$$

where $E_t x_{t+1} = \begin{pmatrix} LI_{1,t} \\ LI_t^{OECD} \\ LI_t^{TCB} \end{pmatrix}$ is the vector of the leading indicators representing the proxy of IP growth expectations and inflation expectations – $E_t \pi_{t+1}$ – are obtained from consumer surveys of the EU commission.[3] A version of Eq. (3) imposing a different lag structure for IP growth expectations is also examined. This allows us to account for a scenario where the leading indicators represent expectations on longer horizons. Eq. (3) is estimated according to a General-to-Specific (GETS) approach with n = 13 and a maximum lag of 4 for the LIs. The GETS procedure implements the theory of reduction in an empirical context, thus facilitating the selection of the most plausible model once a more general model is identified (Krolzig and Hendry, 2001). Results are presented in Table 3 and suggest that only LI_1 is statistically relevant. As a consequence, all the other LIs are not considered by GETS.[4] Notice also that (*i*) the estimated coefficient exhibit the expected sign (i.e., $\gamma > 0$, $\beta < 0$) and (*ii*) standard diagnostic tests confirm the goodness of the model.

[3] 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. Since we use in Eq. (3) an estimated series, we calculate the standard deviations via bootstrapping procedure with 10,000 repetitions.

[4] GETS algorithm is implemented in *OxMetrics 7*.

5. Conclusions

This work introduces a novel LI for the EU IP. Four main aspects emerge from our study. First, the proposed LI – by construction – is immune to overlapping information bias. In other words, the past values of the indicator are not revised by adding future information (i.e., data revisions). Second, our LI relies on a systematic data selection procedure such that the set of variables composing the LI can be easily updated. This allows us picking up those variables with the highest information content. Third, the computed LI anticipates swings in the EU IP by 2 to 3 months and shows a higher predictive power than the one embedded in the *ex-post* LIs proposed by previous studies. Fourth, the performance of our LI is empirically supported. Precisely, the GETS procedure identifies our LI as the most informative variable in approaching the EU IP growth expectation within a forward-looking framework.

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Tables and Figures

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

	Our LI	OECD LI	TCB LEI	ALI
Reference time series	IP Index	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;	LI_1 → 2000M1-2009M12
		2000M1-2010M1	LI_2 → 2010M1-2015M7*
3	Yes: every 5 years	1990M1-2000M1;	LI_1 → 2000M1-2004M12
		1995M1-2005M1;	LI_3 → 2005M1-2009M12
		2000M1-2010M1;	LI_2 → 2010M1-2014M12
		2005M1-2015M1	LI_4 → 2015M1-2015M7*

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

Table 3: Estimates of the IS Eq. (3), 2000M1-2015M7

Coefficients	**Estimations**
α_0	-3.916 (0.45)***
γ_{LI_1}	0.754 (0.08)***
β	-0.297 (0.06)***
ρ_{t-1}	0.538 (0.07)***
ρ_{t-2}	0.340 (0.07)***
ρ_{t-4}	-0.122 (0.05)**
ρ_{t-12}	-0.418 (0.06)***
ρ_{t-13}	0.306 (0.06)***
Diagnostic statistics	**Probability/Test value**
R^2 adj.	0.966
$LM(1)$	0.833
$LM(2)$	0.609
$LM(6)$	0.613
$LM(15)$	0.106
JB	0.414
BPG	0.903

Note: Standard errors are in parenthesis. LM(*k*) is the Lagrange Multiplier test for *k*-order serial correlations of the residuals; JB is the Jarque-Bera normality test of residuals; BPG is the is the Breusch-Pagan-Godfrey heteroskedasticity test. *p*-values are reported for LM, JB, BPG test. OLS is used to estimate Eq. (3). Standard errors are bootstrapped with 10,000 repetitions. ***, **, * denote significance at the 1, 5, 10% levels, respectively.

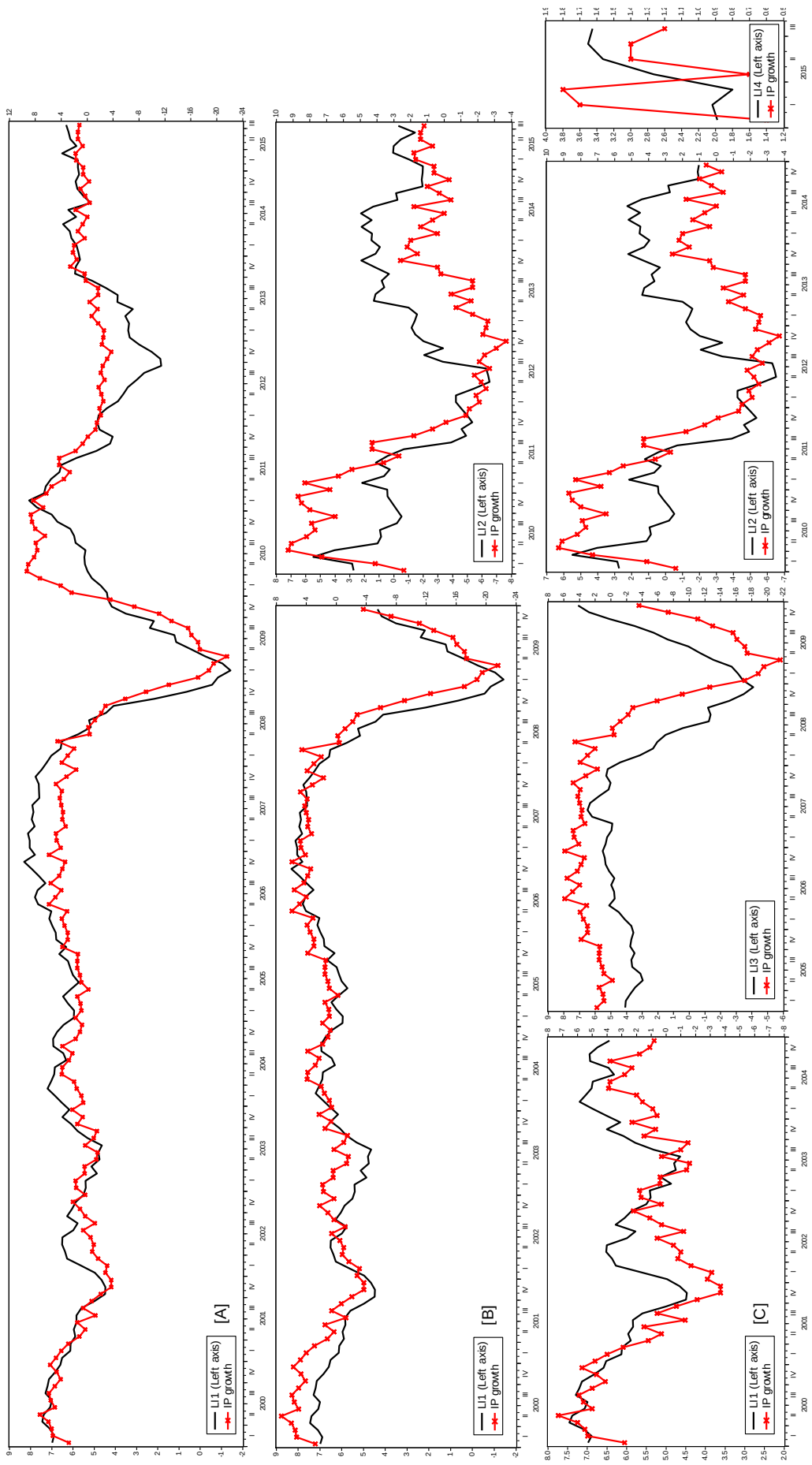
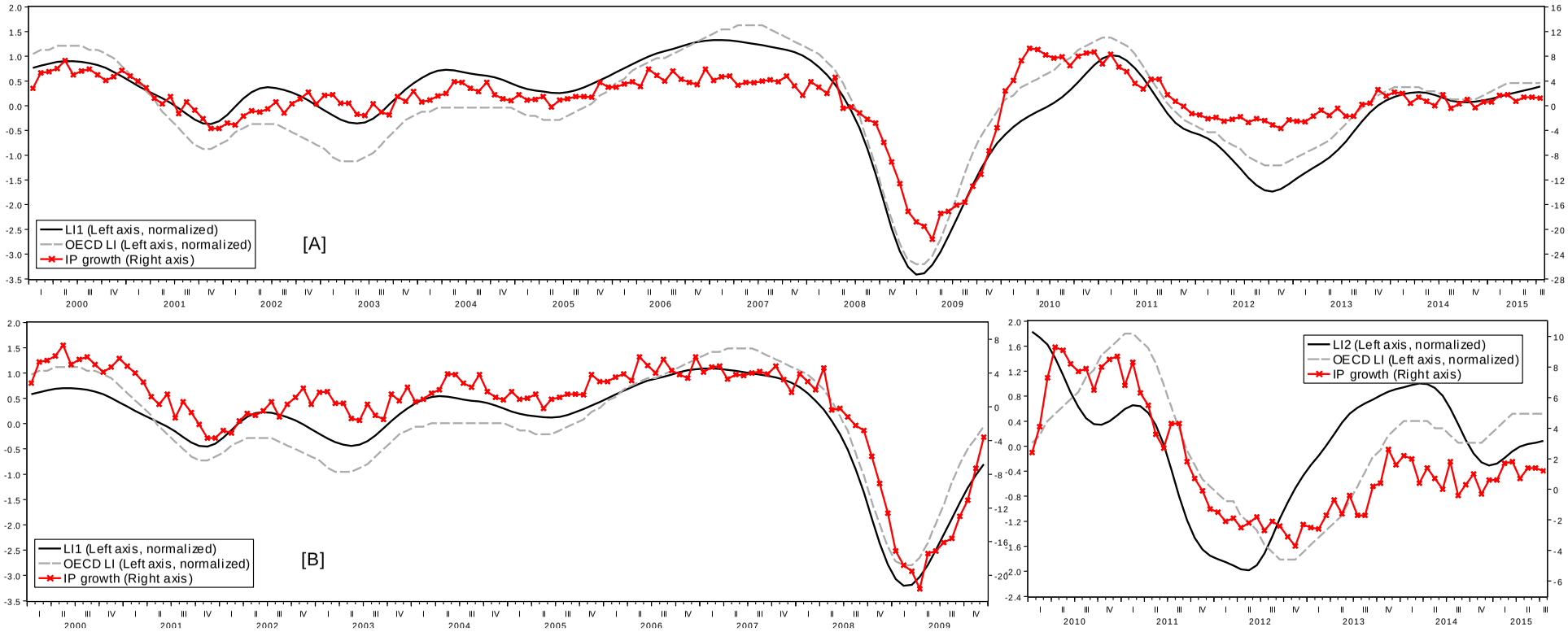


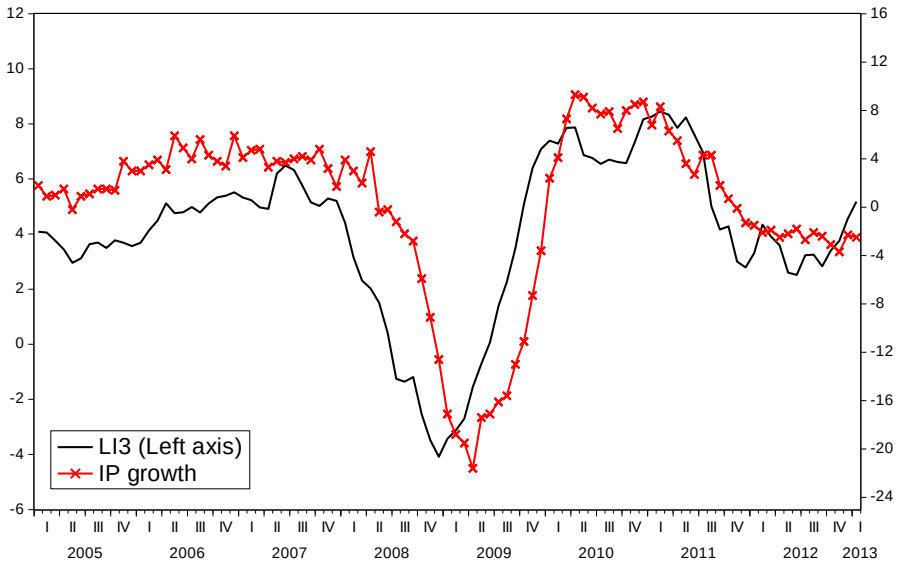
Figure 1: Plot of version 1 [A], version 2 [B] and version 3 [C] of the LI against the observed EU IP growth

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



Note: LI is filtered using HP with a smoothing parameter of 12.

Figure 3: LI_3 against the EU IP growth



Appendix A: Data

Table A: Data description: sample, sources and transformation

	Base Year	*Country*	*N° of Series*	*Transform.*	*Source*
Target variable					
Industrial production (SA)	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 earning (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; EU; EA	30	NO	European Commission

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; FI; LV; LT; LU; MT; IR; IT; NE;	30	NO	European Commission

		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; FI; LV; LT; LU; MT; IR; IT; NE;	30	NO	European Commission

		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 (M3) index (SA)	1990	JP; KO; UK; US; EU	5	YES	OECD Stat

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

***LI₁*:** Belgium OECD business confidence; EU production expectations for the months ahead; EA production expectations for the months ahead; Belgium industry confidence indicator; Belgium assessment of stocks of finished products; Belgium production expectations for the months ahead; Germany production expectations for the months ahead; Netherlands production expectations for the months ahead; Greece OECD consumer confidence; Greece consumer confidence indicator; Greece financial situation over last 12 months; Greece financial situation over next 12 months; Greece savings at present; Spain industrial production; G7 industrial production.

***LI₂*:** EA production expectations for the months ahead; Germany production trend observed in the recent months; Germany production expectations for the months ahead; Finland industry confidence indicator; Japan OECD consumer confidence; Estonia unemployment expectations over next 12 months; UK major purchases over next 12 months; UK retail trade; France share price returns; Germany share price returns; Netherlands share price returns; Portugal share price returns; Spain share price returns; UK share price returns; Japan unemployment rate.

***LI₃*:** Belgium OECD business confidence; Belgium industry confidence indicator; Belgium production expectations for the months ahead; France production expectations for the months ahead; Finland industry confidence indicator; UK OECD consumer confidence; US OECD consumer confidence; Czech R. consumer confidence indicator; Czech R. general economic situation over last 12 months; Czech R. general economic situation over next 12 months; UK

consumer confidence indicator; UK general economic situation over last 12 months; France government bond spread; Portugal government bond spread; Spain share price returns.

***LI₄*:** Romania selling price expectations for the months ahead; EU price trends over last 12 months; Czech R. price trends over last 12 months; Denmark price trends over last 12 months; Denmark price trends over next 12 months; Germany price trends over last 12 months; Estonia price trends over last 12 months; Italy price trends over next 12 months; Lithuania price trends over last 12 months; Austria price trends over last 12 months; Slovak R. price trends over last 12 months; Finland general economic situation over next 12 months; Finland price trends over last 12 months; Finland major purchases at present; US broad money (M3).

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 $\text{LI} = [\widetilde{LI}_{1,m}, \dots, \widetilde{LI}_{N,m}]$. Thus, our final LI is actually composed of the latest values of the first-stage $\widetilde{\text{LI}}$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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