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2007-2013: THIS IS WHAT THE INDICATOR TOLD US – EVALUATING THE PERFORMANCE OF REAL-TIME NOWCASTS FROM A DYNAMIC FACTOR MODEL

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2007-2013: This is What the Indicator told Us - Evaluating the Performance of Real-Time Nowcasts from a Dynamic Factor Model

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Abstract

In 2007, a new indicator of economic activity for Luxembourg was elaborated at the BcL. It was developed using a large database of about 100 economic and financial time series. The methodology was based on the generalized dynamic-factor models, and the model was estimated over the period from June 1995 to June 2007. Forecast performance was evaluated on several criteria (both in pseudo-real-time and using ex-post in-sample simulations) and results were satisfactory. They gave in particular clear evidence that the indicator provides better forecasts of GDP growth than a more standard approach that relies on past GDP values only. In this paper, we present results of the real-time use of the indicator from December 2007 onwards. Special attention is given to real-time forecasts of GDP growth and the real-time assessment of the economic situation that were made during the financial crisis. The root mean squared forecast errors of the indicator-based GDP growth forecasts have decreased during the 2009-2011 "recovery" period in comparison to the 2007-2009 period, which is an encouraging result. This paper also includes results based on an extended study period, which includes (real-time) forecasts that were produced until the end of April 2013. The mean squared errors appear to have on average decreased over the second half of this extended study period in comparison with the first half. Finally, the BcL indicator produced better forecasts on average than the benchmarks over this extended study period.

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Résumé non-technique

L'indicateur d'activité de la BcL pour l'économie luxembourgeoise repose sur un modèle à facteurs dynamiques généralisé, tel qu'introduit par Forni, Hallin, Lippi et Reichlin (2000, 2005). Cette modélisation permet de résumer, à des fins d'analyses conjoncturelles, l'information contenue dans un vaste ensemble de séries temporelles. Dans le cas présent, une base de données composée de plus de 100 séries économiques et financières a servi à l'élaboration de l'indicateur d'activité. Cet indicateur d'activité est ensuite utilisé pour prévoir le taux de croissance du PIB du Luxembourg.

Les résultats d'une évaluation préliminaire de l'indicateur d'activité, présentés en 2008 dans le Cahier d'étude numéro 31 de la BcL, sont apparus encourageants. Les simulations réalisées ex-post indiquaient que les performances prédictives de l'indicateur d'activité tendaient à surpasser celles obtenues à partir d'approches plus classiques, se basant exclusivement sur les valeurs passées du PIB. Ainsi, l'apport de l'indicateur d'activité apparaissait bénéfique, puisqu'il permettait de prévoir le taux de croissance du PIB à un horizon de 1, 2 ou 3 trimestres avec des erreurs en moyenne inférieures à celles obtenues à l'aide d'un processus autorégressif (AR) standard.

Ce cahier d'étude présente les résultats d'une évaluation en temps réel de l'indicateur d'activité, sur une période allant de décembre 2007 à avril 2013. Plus précisément, l'utilisation en temps réel de l'indicateur d'activité est évaluée au travers d'une part des prévisions du PIB (trimestres passés et courant) qu'il a permis de générer et d'autre part du diagnostic conjoncturel qui a été fait sur base de cet indicateur dans les publications de la BcL. Les résultats obtenus ont premièrement indiqué que les erreurs des prévisions - ou plus exactement la racine carrée de l'erreur de prévision moyenne portée au carré - ont été en moyenne plus faibles lors de la "reprise" économique de 2009-2011) que lors du creux conjoncturel (2007-2009). Deuxièmement, les erreurs de prévisions des taux de croissance des trimestres passé et courant du PIB qui se basent sur l'indicateur d'activité ont été en moyenne inférieures à celles obtenues à l'aide d'un modèle Auto Regressif (AR) ou basées sur l'estimation récursive de la moyenne. Ces résultats sont robustes suivant que l'on considère l'ensemble de la période d'étude ou seulement la période de creux. Troisièmement, l'utilisation de l'indicateur d'activité a permis de générer des prévisions du taux de croissance du PIB qui sont qualitativement meilleures que celles obtenues à l'aide d'un processus AR ou du calcul de la moyenne récursive, ces deux dernières approches conduisant à des prévisions relativement biaisées. Quatrièmement, ces résultats sont confirmés lorsque la période d'étude est étendue à 2013. Enfin, le diagnostic conjoncturel qui a été établi sur base de l'indicateur d'activité a permis de fournir à intervalle régulier une appréciation critique sur nos exercices de

projections macroéconomiques de moyen terme - ces dernières étant publiées deux fois par an, au mois de juin et décembre - et, le cas échéant, d'annoncer à l'avance certaines de leurs révisions.

A l'issue de cet exercice d'évaluation de l'indicateur d'activité, les travaux futurs devraient principalement s'orienter vers une direction. En vue d'amélio -rer les performances prédictives de l'indicateur d'activité, nous allons revoir sa composition afin d'y intégrer plus de séries représentatives, d'une part, de l'activité économique hors Luxembourg et d'autre part des marchés financiers européens. De plus, les séries individuelles faisant l'objet de révisions fréquentes ou ayant de longs délais de publications sont susceptibles d'être écartées de l'échantillon actuel.

1 Introduction

Monetary and economic policy decisions require an accurate assessment of the current state of the economy in real time. Tracking economic and financial time series helps to assess the present and future economic situation. It requires a focus on variables that can provide information on the current state of the economy.

Gross Domestic Product (GDP) is generally taken as the reference series to represent the state of the economy. However, it has several drawbacks: it is released at a quarterly frequency, with a certain delay and may be subject to significant revisions afterwards. Publication lags for GDP vary across countries. They are never negligible[1], which requires forecasting past GDP growth in a real-time context. We can distinguish forecasts of the current value of GDP that is not yet published (nowcasting), forecasts of past values (backcasting) and forecasts of future values (forecasting)[2].

On the other hand, there are many economic and financial time series with shorter publication delays and other notable advantages such as fluctuations in line with those of GDP, released at monthly frequency and with minor or no revision. This is mostly the case for monthly statistics related to employment, industrial production, interest rates or business surveys, which are published by national statistics institutes or central banks. Most of these data are nevertheless released with a certain delay and in a non-synchronized manner, which makes the real-time assessment of the present economic situation still delicate. *Real-time data* refers to the set of historical values for a variable that is available at a particular date. Note that the vintage of the real-time data will differ at different dates, as will the last available observation. Each new data vintage is likely to include revisions with respect to the preceding one. Taking into account these features is important to make the distinction between pseudo-real time forecasting and real-time forecasting. In the former case, one specific vintage dataset is used recursively to produce forecasts. In the latter case, forecasts are based on different vintage data and in genuine real-time conditions.

Nowcasting in a (pseudo) real-time data environment is the subject of many papers. For instance, Angelini et *alii* (2011) exploit timely releases of monthly data in order to construct early estimates and short-term forecasts of quarterly GDP growth for the euro area. Evans (2005) obtains high-frequency real-time estimates of (current and future) US GDP by means of (the state-space representation of) an econometric model that allows for variable reporting lags, temporal aggregation and mixed data frequency. Giannone, Reichlin and Small (2008) use the parametric dynamic factor

[1]The publication delay is about 45 days for the Eurostat first flash estimate of euro area GDP growth, while it is about 90 days for the Statec first release of Luxembourg GDP growth.

[2]Below, I shall use the term forecast(ing) to cover all three cases in a real-time context.

model of Doz, Giannone and Reichlin (2005) to exploit a large number of US monthly time series. They use intra-month releases of monthly time series to update estimates of GDP within the current quarter. In the same spirit, Nguiffo-Boyom (2008) used the non-parametric model of Forni *et alii* (2005) to exploit the information contained 99 times series for Luxembourg. The dataset is made up of 98 monthly series plus a quarterly one, Luxembourg GDP that has been linearly interpolated to obtain a monthly series. The common component of monthly GDP is extracted and used as the raw indicator of economic activity for Luxembourg. The BcL monthly indicator of economic activity for Luxembourg is then obtained by smoothing the raw indicator to remove its most volatile movements that tend to be reversed in the short run. Evaluation of the indicator is also performed through pseudo-real time nowcasts of GDP growth.

This paper reviews the business cycle analysis and the GDP growth forecasts made at the BcL over the period December 2007-April 2013 by means of its monthly indicator for the Luxembourg economy. The dataset is made up of about 100 economic and financial time series. Around five years of data vintages are available, which implies 22 vintages of GDP data and about 65 vintages of data for each monthly times series. The paper provides an assessment of the real-time forecasting performance. Economic analysis in a real-time environment is also discussed.

Results presented should be interpreted carefully, for at least two reasons. First, the time period is not sufficiently long for results to be considered statistically significant. Second, the real-time exercise includes the financial crisis, which was a challenging period in terms of forecasting by all standards. Nevertheless, results confirm previous pseudo-real time results that were discussed in Nguiffo-Boyom (2008), as the BcL indicator produced better results on average than benchmark approaches.

The paper is organized as follows. Section two describes the model. Section three presents the data and the main results of the estimation. Note that the composition of the dataset has been slightly modified compared with Nguiffo-Boyom (2008) as it includes four new series related to the Luxembourg financial and banking sector. Section four covers various aspects of the five-year period of GDP growth forecasts in real time. It first explains how we deal with the series end-of-sample issues by rebalancing data. It then describes how we calculate the BcL indicator and as a byproduct produce GDP growth forecasts on a monthly basis. Finally, the relative accuracy of both the real-time forecasts and the economic situation assessment of the Luxembourg economy are discussed. Section five concludes.

2 The model

2.1 Introduction

The indicator of economic activity for Luxembourg is constructed using the generalized dynamic factor model (GDFM) of Forni *et alii* (2005). Let y_{nt}, $n = 1...N$ and $t = 1...T$, denote one of a set of N zero-mean first-order stationary times series. For convenience, we assume here that $y_{nt}, n = 1...N$ has unit variance. The GDFM assumes that each of these N times series may be represented as the sum of two mutually orthogonal unobservable components:

$$y_{nt} = c_{nt} + s_{nt}, n = 1...N \tag{1}$$

where c_{nt} and s_{nt} represent the common and idiosyncratic components of y_{nt}. For each n, these two components are zero-mean stationary processes. The model also assumes that the N common components are exclusively driven by past and present values of Q orthogonal common factors. These Q factors may be seen as the fundamental shocks shared by the N series. The factors, denoted $\{f_{qt}, q = 1...Q\}$, are supposed to be mutually-orthogonal white noise processes at all leads and lags and to be characterized by unit variance. They explain the common component of each individual series as follows:

$$c_{nt} = \sum_{q=1}^{Q} \phi_{nq}(L) f_{qt}, n = 1...N \tag{2}$$

where the lag-operator polynomial $\phi_{nq}(L)$ are one-sided in L and their coefficients are square summable. For each n and each q, the polynomial admits the following representation: $\phi_{nq}(L) = \phi_{nq0} + \phi_{nq1}L + \phi_{nq2}L^2 + ... + \phi_{nqs}L^s$. The terms $(\phi_{nq0}, ..., \phi_{nqs}L^s)$ at the right side of equation (2) are called the dynamic loadings. They determine the contribution of factor f_{qt} to series y_{nt} in terms of both duration and magnitude. There are two main assumptions that characterise the GDFM: (A1) the common factors and the idiosyncratic components of any series are uncorrelated at all leads and lags; and (A2) the idiosyncratic components are at the most weakly cross-correlated. Additional assumptions and conditions required for the identification of the model are discussed in Forni *et alii* (2000 and 2005).

2.2 Estimating the common components

The non-parametric approach proposed in Forni *et alii* (2005) allows identification of the common and idiosyncratic components of the GDFM defined by equations (1) and (2), as the cross-section (N) and the time (T) dimensions go to infinity. The advantage of their approach is that it provides consistent estimates of the components not only as both N and T go to infinity at some rate, but also when T is relatively small, possibly smaller than N. There are two steps to identify common components[3].

Step 1. Estimating the spectral density matrix of the common components. First, the spectral density matrix of the observed series $Y_t = (y_{1t}, ..., y_{Nt})'$ is estimated by applying a discrete Fourier transform to the sample auto-covariance matrices of Y_t over a set of frequencies θ_h:

$$\hat{\Sigma}_Y(\theta_h) = \frac{1}{2\pi} \sum_{k=-M}^{M} \omega_k \Gamma(k) e^{-i\theta_h}, h = 0, 1, ..., 2M \tag{3}$$

where $\Gamma(k)$ is the sample covariance matrix of Y_t and Y_{t-k}; integer M is the length of the Bartlett lag window; and $\omega_k = 1 - (|k|/M + 1)$ are the Bartlett lag window estimator weights. θ_h is the frequency at which spectral density matrix is evaluated. Note that the spectra are evaluated at $2M+1$ equally spaced frequencies in the interval $[-\pi, \pi]$.

Second, a decomposition in dynamic principal components of each spectral density matrix is performed. In other words, we compute the eigenvalues and eigenvectors of the estimated spectral density matrix at each frequency: for each θ_h, $\hat{\Sigma}_Y(\theta_h)$ is diagonalized, and then its (N) ordered-in-descending-order eigenvalues and associated eigenvectors are obtained. For $j = 1, ..., N$, let $\lambda_j(\theta_h)$ be $\hat{\Sigma}_Y(\theta_h)$'s j-th largest value and $p_j(\theta_h)$ the corresponding row eigenvector. By collecting the eigenvalues $\lambda_j(\theta_h)$ that correspond to different frequencies, eigenvalue and eigenvector functions of θ are obtained. These functions are respectively denoted $\lambda_j(\theta)$ and $p_j(\theta), j = 1, ..., N$. The dynamic eigenvectors $p_j(\theta)$ are then expanded in Fourier series:

$$p_j(\theta) = \frac{1}{2\pi} \sum_{k=-M}^{M} \left[\int_{-\pi}^{\pi} p_j(\theta) e^{ik\theta} d\theta \right] e^{-ik\theta} \tag{4}$$

and then transferred to the time domain by applying an inverse Fourier transform:

$$\underline{p}_j(L) = \frac{1}{2\pi} \sum_{k=-M}^{M} \left[\int_{-\pi}^{\pi} p_j(\theta) e^{ik\theta} d\theta \right] L^k \tag{5}$$

[3]Intuitively, this non-parametric approach is based on the frequency-domain representation of the series. Therefore, the spectral density of the series will be of interest in a first step and not their variance-covariance matrix. Thereafter, a principal component-analysis-type approach will be performed based on the spectral density matrices, and not on the variance-covariance matrix as in a classical principal component analysis.

The inverse Fourier transform of $p_j(\theta)$, $\underline{p}_j(L)$, allows us to get the j-th dynamic principal component of Y_t, which is defined

$$\underline{p}_j(L)\,Y_t = f_{jt} \tag{6}$$

The dynamic principal components are mutually orthogonal at any lead or lag. Also note that for each component, the ratio of its eigenvalue function to the sum of all eigenvalue functions, namely

$$\int_{-\pi}^{\pi} \lambda_j(\theta)\,d\theta / \sum_{j=1}^{N} \int_{-\pi}^{\pi} \lambda_j(\theta)\,d\theta, \tag{7}$$

naturally defines its contribution to the total variance in the system.

Third, one chooses a value Q, $Q \leq N$, for the number of dynamic factors using an eigenvalue-based criterion. For instance, the average over θ of the first Q empirical eigenvalues may diverge, while the average over the $(Q+1) - th$ one is relatively stable; or there may be a substantial gap between the variance explained by principal component Q and the variance explained by principal component $Q+1$[4].

Fourth, the spectral density matrix of the vector of the common components $C_t = (c_{1t}, ..., c_{Nt})'$ can be estimated as:

$$\hat{\Sigma}_C(\theta) = P(\theta)\,\Lambda(\theta)\,\tilde{P}(\theta) \tag{8}$$

where $\Lambda(\theta)$ is a $Q \times Q$ diagonal matrix having on the diagonal $\lambda_1(\theta)\ \lambda_2(\theta) ...$ $\lambda_Q(\theta)$, $P(\theta) = (p_1(\theta) ... p_Q(\theta))'$ is a $N \times Q$ matrix and $\tilde{P}(\theta)$ its conjugate transpose matrix. The estimated spectral density matrix of idiosyncratic components $S_t = (s_{1t}, ..., s_{Nt})'$ is obtained as the following difference: $\hat{\Sigma}_S(\theta) = \hat{\Sigma}_Y(\theta) - \hat{\Sigma}_C(\theta)$. Finally, the sample auto-covariance of C_t is obtained by applying the inverse discrete Fourier transform to the above estimated spectral density matrix:

$$\hat{\Gamma}_C(k) = \frac{2\pi}{2M+1} \sum_{h=-M}^{M} \hat{\Sigma}_C(\theta_h)\,e^{-ik\theta_h} \tag{9}$$

and

$$\hat{\Gamma}_S(k) = \frac{2\pi}{2M+1} \sum_{h=-M}^{M} \hat{\Sigma}_S(\theta_h)\,e^{-ik\theta_h} \tag{10}$$

Step 2. Estimating and forecasting the common components. This second step requires the estimation of static factors to approximate the Q

[4]These criteria are suggested in Forni *et alii* (2000 and 2005). More sophisticated methods for the identification of Q have recently been proposed in the literature, notably by Bai and Ng (2002 and 2007) and Hallin and Liska (2007).

dynamic factors (or shocks) of the model[5]. For that purpose, past values of the common factors are here treated as separate static factors. We therefore consider now that $r = Q(s+1)$ shocks affect the system, namely $(f_{1t}, f_{1,t-1}, ..., f_{1,t-s}, f_{2t}, f_{2,t-1}, ..., f_{2,t-s}, ..., f_{Q,t-s})$. These static factors are obtained by taking the r generalised principal components of $\hat{\Gamma}_C(0)$: computing the generalised eigenvalues μ_j, i.e. the N complex numbers solving $det\left(\hat{\Gamma}_C(0) - z\hat{\Gamma}_S(0)\right) = 0$; and the corresponding generalised eigenvectors $V_j, j = 1, ..., N$ satisfying

$$V_j \hat{\Gamma}_C(0) = \mu_j V_j \hat{\Gamma}_S(0) \tag{11}$$

and the normalizing condition

$$V_j \hat{\Gamma}_S(0) V_i' = \begin{cases} 1 for j=i \\ 0 for j\neq i \end{cases} \tag{12}$$

After ordering the eigenvalues μ_j in descending order and taking the eigenvectors corresponding to the r largest eigenvalues, the static factors are estimated by the r generalised principal components $v_j = V_j' Y_t, j = 1, ..., r$. These generalised principal components are the linear combination of the $y_{nt}, n = 1, ..., N$, having the smallest ratio of idiosyncratic to common variance (see Forni *et alii*, 2005). The generalised principal components together with the covariance matrices estimated in the first step provide both estimates and forecasts of C_t. Setting $V = (V_1 \cdots V_r)$ and $v_t = (v_{1t} \cdots v_{rt})'$, estimates of $C_{t+h}, h = 0, 1, .., s$ are given by

$$\hat{C}_{t+h} = \hat{\Gamma}_C(h) V \left(V'\hat{\Gamma}(0)V\right)^{-1} v_t = \hat{\Gamma}_C(h) V \left(V'\hat{\Gamma}(0)V\right)^{-1} V'Y_t \tag{13}$$

Forni *et alii* (2005) show that when both N and T go to infinity, $\hat{C}_t$ is a consistent estimate of C_t; and $\hat{C}_{t+h}$ converges to the theoretical projection of C_{t+h} on the past and present of $f_{1t}, ..., f_{Qt}$.

3 The data and main results

The data set is made up of 103 series. It includes real GDP and 102 other series. More precisely, 100 monthly series and two quarterly series that have been each linearly interpolated to obtain a monthly series. The composition of the dataset used to construct the BcL indicator has therefore been slightly

[5]It appears indeed that dynamic factors are theoretically explained by both lagged and future values of observable series since the filters $\underline{p}_j(L), J = 1, ..., N$ are two-sided, as it appears in equation (6). The estimation of common components at the end and beginning of the sample is therefore not feasible if series are not available for $t < 0$ and $t > T$. For that reason, Forni *et alii* (2000 and 2005) propose an approximate of the common components, which is a one-sided filter of the observations.

modified compared with Nguiffo-Boyom (2008). The real-time dataset used here includes four more series related to the Luxembourg financial and banking sector. Two of them are the quarterly series that have been linearly interpolated to obtain a monthly series, namely the gross income and results before provisions from interim aggregated profit-and-loss accounts of credit institutions. The other two series, which come from the global situation of undertakings for collective investment, are the net capital investment and net asset value. The 102 series can be categorised in nine subgroups: industrial production; prices; turnover; wages and salary costs; new orders; financial series; external trade, and miscellaneous series (essentially car registrations and building permits). The complete list of 102 monthly series is reported in tables 9 to 11 of appendix 1. For the 102 monthly series, the data treatment consists of three steps. First, Tramo/Seats is used to clean the data of both possible outliers and seasonality. Second, all series are transformed by taking the first difference. All variables are in logs except interest and exchange rates and business surveys. Third, the data are standardized, that is expressed as deviations from mean and divided by their standard deviation. The quarter-on-quarter (qoq) growth of real (seasonally-adjusted) GDP is linearly interpolated to obtain a monthly series, and also standardized.

As discussed previously in section 2, several parameters need to be chosen, namely the number of dynamic factors (Q) and the size of the Bartlett window (M) which also determines the number $(2M+1)$ of frequencies at which the spectral density is evaluated in the interval $[-\pi, \pi]$. At this stage, there are no agreed criteria to determine the value of M. On the one hand, Forni *et alii* (2000) suggest that M should be a function of T. According to the results of their simulations, $M{=}round\left(\frac{2}{3}T^{\frac{2}{3}}\right)$performs relatively well. Schneider and Spitzer (2004) and Van Nieuwenhuyze (2006) choose the rule $M{=}round\left(\frac{1}{4}T^{\frac{1}{2}}\right)$. On the other hand, Altissimo *et alii* (2001) and Altissimo *et alii* (2006) use a Bartlett lag-window respectively of size 18 and 24 and evaluate the spectral density at respectively 101 and 121 frequencies. These authors justify their choices - for Q, M and the number of static factors r - by the results of a "pseudo real-time analysis".

In the present case, we set M=18. The spectra is therefore evaluated at 37 equally spaced frequencies in the interval $[-\pi, +\pi]$ by using a Bartlett window of size 18 and the 18 lead/lag covariance matrix of observed data. We use the criteria suggested by Forni *et alii* (2000) to determine the number of common factors: Q is set by requiring a minimum amount of explained variance for each dynamic component on average across all frequencies. We set the minimum contribution at 10 percent, implying $Q = 3$ dynamic factors as the remaining factors contribute less. The average contribution across all frequencies θ of the first dynamic factor is about 26 percent. For the second and third dynamic factors, these percentages are respectively about 16 and

13 percent. Overall, the first three dynamic factors explain more than 55 percent of the total variance over the interval $[0, \pi]$.

4 Assessing five years of real-time forecasts

This section introduces the framework used to assess five years of real-time forecasts, and it evaluates the real-time forecasting performance using the root mean squared forecast errors. First, it is explained how we calculate the indicator and produce the forecasts. Second, we consider the set of forecasts produced for each of the quarters between 2007Q3 and 2011Q1. we assume the first release of quarterly national accounts is the target of the forecast, and we evaluate the accuracy of the set of forecasts relatively to two benchmark approaches. Third, we extend the study period to include the set of forecasts produced for quarters between 2011Q2 and 2012Q4 for checking the robustness of results on a longer study period. Fourth, we review the assessment of the economic situation in Luxembourg - based on the indicator - we expressed at the BcL between December 2007 and June 2013. In this section, τ denotes the running month.

4.1 The framework

Our objective is twofold. First, providing a monthly indicator of economic activity and second, nowcasting and backcasting GDP growth. We aim to provide the indicator for the month τ at the end of month τ or at the beginning of month $\tau + 1$. We proceed as follows:

Step 1. Updating the database. The monthly series of the dataset are downloaded between the last days of month τ and the first days of month $\tau + 1$, so that both financial and business survey data for the month τ are available. GDP is also downloaded when the quarterly national accounts are published, that is four times a year usually around the beginning of January, April, July and October. The GDP quarter-on-quarter growth rate is converted to monthly frequency by a linear interpolation, which matches the growth rate between the last month of the given quarter and the last month of the preceding quarter to the quarter-on quarter (qoq) of the quarterly series. In our dataset GDP is usually published with the largest delay. It will therefore determine the date at which the sample data is balanced[6] because all series are available; and after which the sample data is unbalanced because publication lags differ from one series to another. Suppose GDP is the first series in our sample, so that y_1 represents the monthly GDP quarter-on-quarter growth rate and c_{1t} its common component.

Step 2. Rebalancing the data to compute common components. We adopt the strategy proposed by Altissimo *et alii* (2006), re-aligning the

[6]Series published with longer lag than GDP were dropped from the sample.

103 series before estimating their variance-covariance matrice to extract their common component. The principle is simply to shift the variables forward in time to eliminate missing observations in the most recent periods.

Let k_n be the release delay (in months) for variable y_{nt}. At the end of month τ, the last available observation of y_{nt} will therefore be $y_{n,\tau-k_n}$. We set $y^*_{nt} = y_{n,t-k_n}$ for $n = 1, ..., N$, so that the last available observation of y^*_{nt} is τ for all n. This means of course that for some variables we have to drop observations at the beginning of the sample to get the new matrix of re-aligned data. This matrix, which we denote Y^*_t, is such that the last row contains the last available observation of each series $(y_{1,\tau-k_1} y_{2,\tau-k_2} \cdots y_{N,\tau-k_N})$. Thus, we obtain a re-balanced[7] sample of data at the end of each month τ. Note that the release delay is zero for both financial and business surveys series, which are available at the end of the reference month. As for GDP, the release delay typically varies according to the position of the month τ in the quarter. More precisely, its release delay equals four if τ corresponds to the first month of the quarter, as GDP is published with a delay of around four months in Luxembourg. The delay increases to 5 or 6 when GDP is published in the second or third monyh of the quarter. Because we aim at nowcasting GDP growth at the end of each month τ, we need an estimate of c_{1t} until date τ [8]. Therefore we set $k_{GDP} = k_1$, where $k_1 = 4, 5$ or 6.

Generalized principal components are computed for Y^*_t to get C^*_t; and formula (13) is used to obtain the $(k_1 - 1) \times N$ remaining values of the matrix of the common component: $\hat{C}^*_{t+h} = \hat{\Gamma}^*_C(h) V^* \left(V^{*\prime}\hat{\Gamma}^*(0)V^*\right)^{-1} V^{*\prime}Y^*_t$, for $h = 1, 2...k_1$, k_1 being set according to the position of month τ. In this way, the values of the indicator for the period $[1, \tau]$ may be available at the end of month τ, even if GDP and all other monthly series are not available until τ. This approach exploits the dynamic covariance structure of the common components. Finally, the estimated common component of GDP $\left(\hat{c}^*_{1,t}, t = 1...\tau\right)$, is provided by the first column of the $(\tau \times N)$ matrix denoted $\hat{C}^*$,

$$\hat{C}^* = \begin{bmatrix} \hat{C}^*_t \\ ------ \\ \hat{C}^*_{t+h} \end{bmatrix}.$$

Step 3. Forecasting GDP QoQ growth. We forecast using a simple quarterly-frequency regression linking GDP qoq growth (ΔGDP) to a constant plus the quarterly GDP common component. Equations are re-estimated each month. We denote $\overline{c}^*_{1t}$ the quarterly common component of

[7]This re-alignment implies of course cutting some $max(k_1, ..., k_N)$ observations at the beginning of the sample for some variables.

[8]Then, the realignment implies cutting some k_1 or less observations at the beginning of the sample.

GDP constructed using the last available month of the quarter as the value for the quarter as a whole and estimate the following equation:

$$\Delta GDP_t = c + \psi \bar{c}^*_{1t} + e_t, e_t \sim N(0, \sigma^2) \qquad (14)$$

where c represents the constant term. The common component of GDP, which has been calculated for $t = \tau - k_1 + 3$ - the third month of the *past* quarter in a real-time context - and for τ - the current month of the *current* quarter in a real-time context[9]- according to equation (13), are used for respectively backcasting and nowcasting GDP growth using the parameters of the bridge equation (14).

Step 4. Calculation of the indicator. The indicator for the Luxembourg economy is obtained by removing the most volatile movements of the estimated common component $\hat{c}^*_{1,t}, t = 1...\tau$, which we call the "raw indicator". We use the Christiano and Fitzgerald (2003) full-sample asymmetric version of Baxter-King band-pass filter to eliminate high frequency variations which last 18 months or less. By construction, the indicator is centered on zero. For communication reasons, it is standardized to have an average and a variance comparable with those of GDP year-on-year (yoy) growth.

The five-year (December 2007 - April 2013) experience with real-time forecasting warrants several comments. First, unbalanced end-of-sample issues were in practice more dramatic than anticipated. Even if we expected release dates might significantly differ from one series to another[10], we faced additional problems over these five years updating our database: the calendar release was very irregular for some monthly data, whose new figures were often published late - simultaneously releasing together for three consecutive months; while GDP was released on a quarterly basis, the delay was time-varying; some individual series were sometimes published with a larger delay than GDP itself. Second, the approach based on dynamic factor models implied a certain revision in the estimated common component of the series and, as a consequence, the forecasts, which might be strongly revised from one month to another. In fact, the indicator was also subject to revisions. Revisions were partly anticipated, as discussed in Nguiffo-Boyom (2008). Nevertheless, the real-time exercise demonstrated that their scope had been somewhat minimized. Third, communication was complicated by revisions. Fourth, forecasting were challenging as most of the real-time exercise took place during the financial crisis and the recession that followed.

[9]The first, second and third months of the current quarter, the common component of GDP for the current quarter is calculated for respectively month τ; months τ and $\tau - 1$; and months τ, $\tau - 1$ and $\tau - 2$

[10]Monthly data are published with different delays with respect to their reference period as, for instance, financial variables and business surveys are released right at the end of the month while production indices are available with a delay of about six weeks.

The next section discusses our forecasts.

4.2 The real-time exercise: 2007Q3 - 2011Q1

The exercise began in December 2007. We produced for the first time forecasts for both third and fourth quarters of 2007. End of January 2008, we updated our forecasts on the basis of the additional information available at this time: we calculated forecasts for 2007Q4 (which was a backcast) and for 2008Q1 (which was a nowcast). The exercise was repeated on a monthly basis until July 2011, i.e. forecasts were updated on a monthly basis given newly available information until July 2011. In all, we produced 44 nowcasts of GDP growth and 38 backcasts of GDP growth between December 2007 and July 2011. There are various criteria for evaluating forecast accuracy. We proceed as follows: First, some indicator-based root mean squared forecast errors (RMSFE) results are considered measures of its predictive accuracy *per se*. Second, the indicator accuracy needs to be compared against benchmark time-series models[11]. Thus, the RMSFE of these real-time forecasts are compared to those obtained in real-time using a naive approach. Two alternative naive approaches are considered for calculating relative RMSFEs: naive 1 uses the recursive mean of GDP growth to produce forecasts; and naive 2 uses a real-time estimates of an AR(1) model with constant. Finally, we perform an analysis of the mean squared forecast errors decomposition for checking whether the indicator-based forecast errors were biased.

The RMSFE of our forecasts is a quadratic scoring rule which measures the average magnitude of the errors as

$$\sqrt{\sum_{q=1}^{Q}\sum_{p=1}^{P}(y_q - y_q^p)^2} \tag{15}$$

and relative RMSFEs were calculated using

$$RR^v = \frac{\sqrt{\sum_{q=1}^{Q}\sum_{p=1}^{P}(y_q - y_q^p)^2}}{\sqrt{\sum_{q=1}^{Q}\sum_{p=1}^{P}(y_q - y_q^{p,naive})^2}}, \tag{16}$$

where v represents a particular release (first release or latest vintage for instance) of GDP growth data, q denotes the quarter for which forecasts are made, y_q^p denotes the $p-th$ forecasts for quarter q, $y_q^{p,naive}$ denotes the naive forecast for quarter q we have obtained in real-time using a naive approach, P represents the number of forecasts made for quarter q, and y_q

[11] Note the results presented in this section refer to the period 2007-2011, and may not provide evidence of forecasting performance in other periods.

the observed value of GDP growth for quarter q according to a particular data vintage. For example, the first quarter $q = 1$ represents 2007Q3, $q = 2$ represents 2007Q4, ..., and $q = 16$ represents 2011Q1. $p = 1$ represents the first forecast of a given quarter, $p = 2$ the second, ... and P the last one we made for quarter q.

The MSFEs of our forecasts and of the benchmarks are respectively defined by

$$\sum_{q=1}^{Q}\sum_{p=1}^{P}(y_q - y_q^p)^2 \tag{17}$$

and

$$\sum_{q=1}^{Q}\sum_{p=1}^{P}(y_q - y_q^{p,naive})^2. \tag{18}$$

Since the errors are squared before they are averaged, both the RMSFE and MSFE give a relatively high weight to large errors and are therefore useful - compared to alternative accuracy measures - when large forecast errors are particularly undesirable.

Finally, we will also evaluate the forecast accuracy of our forecasts and the benchmarks by considering the Mean Forecast Error (MFE) in section 4.3. The MFE is a signed measure of error which indicates whether the forecasts are biased - i.e., whether they tend to be disproportionately positive or negative. The MFE of our forecasts and of the benchmarks are respectively defined by

$$\sum_{q=1}^{Q}\sum_{p=1}^{P}(y_q - y_q^p) \tag{19}$$

and

$$\sum_{q=1}^{Q}\sum_{p=1}^{P}(y_q - y_q^{p,naive}). \tag{20}$$

Note that in theory, P should equal 6 since three nowcasts and three backcasts should be produced for each quarter q. Unfortunately, in practice the GDP data release pattern is irregular in Luxembourg and therefore P may slightly vary from one quarter to another. We will focus on results obtained (i) using first release data of GDP as the observed value of y_q; (ii) applying naive 1 or naive 2 approach as a benchmark; and (iii) distinguishing between first half and second half of the sample (study period) by splitting the study period in two and then considering on the one hand results for the 2007Q3 - 2009Q3 period and, on the other hand, results for the 2009Q4 - 2011Q1 period. Note that splitting the sample in this way implies that the first period encompasses the 2008 recession whereas the second one includes the recovery. Before introducing and discussing the value of the relative RMSFEs, we track the developments of the individual errors. For that purpose, we calculate the individual squared forecast errors over the study period - i.e. $\left\{(y_q - y_q^p)^2\right\}$ across quarters $q = 1, ...16$ and for $p = 1...P$ -. Figures 1 and 2 display the evolution of the individual squared forecast errors over the study period respectively when the first release of qoq GDP growth for quarters 2007Q3 to 2011Q1 are the target, and when the first releases of yoy GDP growth are the target. Looking at the figures, it appears that there has been some variability in the forecast errors. The magnitude of the forecast errors was relatively strong when nowcasting GDP growth for quarters 2008Q4 and 2009Q1. Finally, these figures clearly indicate that the individual forecast errors we made were on average greater on the first part of the study period (2007Q3 - 2009Q3) than on the second one (2009Q4 - 2011Q1).

Table 1 displays the RMSFEs of our forecasts together with those of the benchmarks. First, we consider RMSFEs that were obtained over (subsamples of) the period 2007-2011 when forecasts for quarters 2008:4 and 2009:1 are included (lines 1-3) and excluded (lines 4-6). Second, we consider RMSFES that are related to nowcasts and backcasts produced over the whole period (lines 7-8) and excluding quarters 2008:4 and 2009:1 (lines 9-10). The RMSFEs actually decreased during the second part of the study period. This decrease was not simply the artifact of the huge forecast errors we made when forecasting GDP growth in 2008Q4 and 2009Q1, as can be seen in the table (lines 4-6). RMSFEs did not appear to be smaller for backcasts than for nowcasts, which is against the intuition. In the case of indicator-based forecasts for instance, RMSFEs did not look smaller for backcast than for nowcast even when excluding forecasting errors made for quarters 2008Q4 and 2009Q1. Anyway, the indicator allowed outperforming the benchmarks when forecasting the first release of qoq GDP growth rate.

Table 2 displays the RMFSEs when yoy GDP growth (first release) is the target. The RMSFEs decreased during the second part of the study period and they were smaller for backcasts than for nowcasts. Both naive approaches were outperformed by our indicator over 2007Q3 - 2011Q1.

The relative RMSFEs are presented in table 3. The ratios RRs are always less than one over 2007Q3 - 2011Q1 as both naive approaches were outperformed over the study period. The null hypothesis *equal predictive accuracy* underlying the Diebold-Mariano (DM) test is clearly rejected over the whole study period. Splitting the study period in two reveals that although our forecast errors were larger in the first part, performance of the benchmarks was even worse. The overall relative forecasting performances of our indicator did not lessen during the 2009Q4 - 2011Q1 recovery period in comparison to the 2007Q3 - 2009Q3 period when forecasting qoq GDP

Figure 1: Individual squared forecast errors - Based on real-time backcasts and nowcasts of qoq GDP growth (first release)

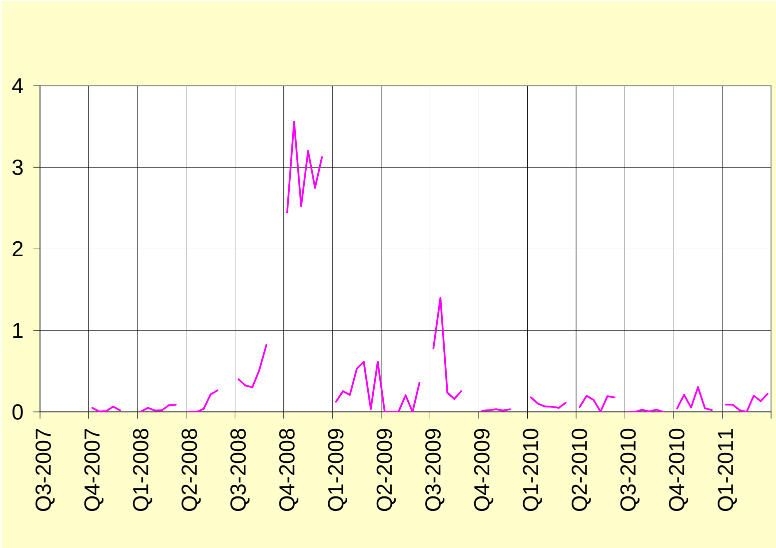
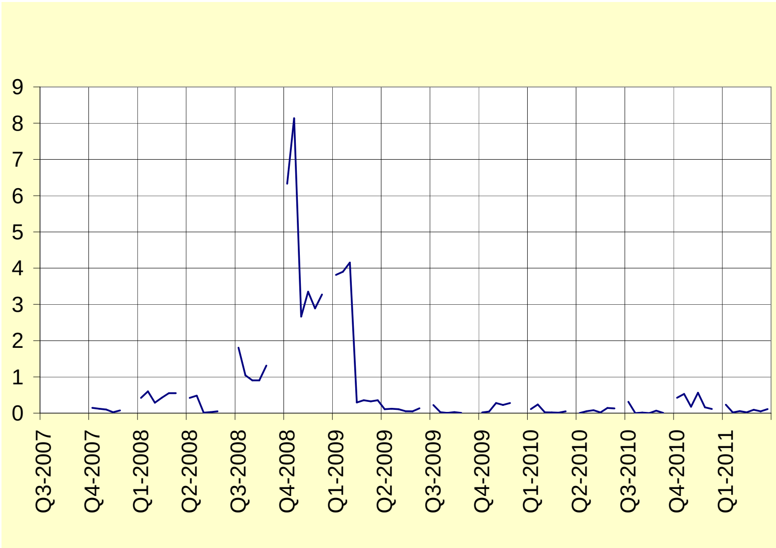


Figure 2: Individual squared forecast errors - Based on real-time backcasts and nowcasts of yoy GDP growth (first release)



growth. However, our relative forecast performances deteriorated somewhat on average during the second (recovery) period when forecasting yoy GDP growth. Our indicator still continued to outperform the benchmarks when forecasting yoy GDP growth but the DM test results did not provide any evidence against the null at the 1 percent level. Indeed, the null hypothesis was rejected only at the 5 percent (15 percent) level when comparing our yoy forecasts to those of the recursive mean (AR(1)) benchmark.

Table 1: RMSFEs for real-time QoQ growth rate

	Indicator	Recursive mean	AR(1)
2007:3 - 2011:1	1.90	2.13	2.28
2007:3 - 2009:3	2.41	2.70	2.89
2009:4 - 2011:1	0.90	1.03	1.10
2007:3 - 2011:1*	1.18	1.40	1.40
2007:3 - 2009:3*	1.43	1.72	1.67
2009:4 - 2011:1	0.90	1.03	1.10
Nowcasts	1.83	2.15	2.16
Backcasts	1.98	2.11	2.42
Nowcasts*	1.18	1.46	1.49
Backcasts*	1.19	1.33	1.29

* indicates exclusion of all backcasts and nowcasts for quarters 2008:4 and 2009:1.

Table 2: RMSFEs for real-time YoY growth rate

	Indicator	Recursive mean	AR(1)
2007:3 - 2011:1	2.60	5.45	3.81
2007:3 - 2009:3	3.33	7.18	4.96
2009:4 - 2011:1	1.14	1.36	1.28
2007:3 - 2011:1*	1.51	3.97	2.37
2007:3 - 2009:3*	1.84	6.01	3.31
2009:4 - 2011:1	1.14	1.36	1.28
Nowcasts	2.98	5.70	4.46
Backcasts	2.09	5.15	2.88
Nowcasts*	1.63	4.32	2.76
Backcasts*	1.37	3.52	1.81

* indicates exclusion of all backcasts and nowcasts for quarters 2008:4 and 2009:1.

We now use the following Mean Squared Forecast Error (MSFE) decomposition for evaluating the accuracy of forecasts:

$$MSFE = (\bar{y} - \bar{\hat{y}})^2 + (\sigma_y - \sigma_{\hat{y}})^2 + 2(1 - \hat{\rho})\sigma_y\sigma_{\hat{y}}, \tag{21}$$

where $MSFE = E\left(y_q - y_q^p\right)^2$, $\bar{y}$ and $\bar{\hat{y}}$ are the sample means of the actual (y_q) and forecast values (y_q^p) respectively, σ_y and $\sigma_{\hat{y}}$ are the sample standard

Table 3: Relative RMSFEs for real-time QoQ and YoY GDP growth rate

	QoQ		YoY	
Benchmark	Recursive mean	AR(1)	Recursive mean	AR(1)
2007:3 - 2011:1	0.8925**	0.8333**	0.4779**	0.6840**
2007:3 - 2009:3	0.8940**	0.8341**	0.4638**	0.6717**
2009:4 - 2011:1	0.8794**	0.8259**	0.8346*	0.8872

*(**) indicates rejection of the DM test of the null hypothesis of equal forecasting accuracy at 5 percent(1 percent) level.

Table 4: MSFEs decomposition in percentage (Actual: qoq GDP growth rate - 1st release)

	Bias prop.	Variance prop.	Covariance prop.
Indicator	13.3	32.7	54.0
Recursive mean	18.5	72.7	8.8
AR(1)	20.2	43.7	36.1
Indicator*	2.3	19.2	78.5
Recursive mean*	5.7	80.9	13.4
AR(1)*	7.2	56.4	36.4

* indicates exclusion of all backcasts and nowcasts for quarters 2008:4 and 2009:1.

Table 5: MSFEs decomposition in percentage (Actual: yoy GDP growth rate - 1st release)

	Bias prop.	Variance prop.	Covariance prop.
Indicator	17.8	8.2	74.0
Recursive mean	42.7	43.1	14.2
AR(1)	26.0	20.4	53.6
Indicator*	5.8	0.1	94.1
Recursive mean*	34.1	46.4	19.5
AR(1)*	14.4	14.4	71.2

* indicates exclusion of all backcasts and nowcasts for quarters 2008:4 and 2009:1.

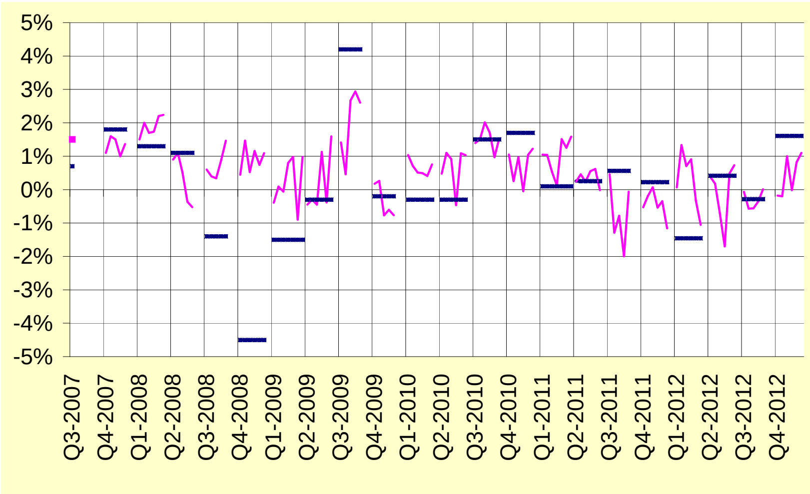
deviations of actual and forecast values respectively and $\hat{\rho}$ is the sample correlation between actual and forecast values. The proportion are of course defined by $(\bar{y}-\bar{\hat{y}})^2/(MSFE)$, $(\sigma_y-\sigma_{\hat{y}})^2/(MSFE)$ and $2(1-\hat{\rho})\sigma_y\sigma_{\hat{y}}/(MSFE)$. The first element is the bias proportion, the second one is the variance proportion and the third one is the covariance proportion. The bias proportion is an indication of the systematic error as it indicates how far the mean of the forecast is from the mean of the actual series; the variance proportion indicates the extent to which the variability of forecast and actual differ, and the covariance proportion measures the remaining unsystematic forecast errors. In a *good* forecast, the bias and the variance proportions should be small so that most of the MSE is concentrated on the unsystematic forecast errors. Table 4 shows the mean squared forecast error decomposition for the qoq GDP growth for forecasts obtained with the indicator, the recursive mean approach and the AR(1) approach. The results indicate that forecasts produced with the indicator could be considered better than those of the benchmarks, as the bias and variance proportions are relatively smaller than those of the benchmarks. The remaining unsystematic forecasting errors represent more than 50 percent of the MSFE, which is not the case with both alternative benchmark models. These last findings are borne out by MSFE decomposition results excluding forecasts for both quarters 2008Q4 and 2009Q1. Finally, Table 5 shows that yoy GDP growth for forecasts obtained with the indicator was still less biased that the ones produced by means of the benchmarks, and thus could be considered by far the better according to the MSFE decomposition criterion.

4.3 The real-time exercise extended to April 2013

In this section, we replicate the evaluation exercise of the previous section by extending the study period until April 2013. We can therefore check the robustness of results that were discussed in section 4.2 and perform some sensitivity analyses. Figure 3 displays the sequences of our forecasts together with the first release of qoq GDP growth for each quarter going from 2007Q3 to 2012Q4. It clearly shows that our forecasts have a strong variability from month to month. A natural outcome is that our forecast errors do not decrease along the forecast cycle[12] monotonically. As the amount of information related to the GDP growth for the specific quarter increases along the forecast cycle, we intuitively expect the forecast accuracy should on average increase. Lack of such pattern implies some non-monotonically decrease of the RMSFEs along the forecast cycle. Angelini, Bańbura and R*ü*nstler (2010) argue that while such absence of any gains may reflect a lack of forecastability of the series per se, it also may be a consequence of

[12]By forecast cycle, we mean the sequence of the following forecasts for a given quarter Q: the three nowcasts made during months 1, 2 and 3 of the quarter Q followed by the backcasts made during months 1, 2 and 3 of quarters $Q+1$.

Figure 3: Evolution of the forecasts (pink) versus first release of qoq GDP growth (blue)



a lack of appropriate monthly indicators in the dataset. More specifically, they observe that their dynamic factor model forecast performances for both (euro area) private and public consumption growth rates are not increasing monotonically over the forecast cycle. In my opinion, we should look into a particular direction for explanations. My intuition is that we underestimate the fact that some of the monthly data are very noisy, and this may be a factor of strong variability in month-to-month forecasts. Figure 4 displays the evolution of the individual squared forecast errors over the extended study period when the first releases of qoq GDP growth for quarters 2007Q3 to 2012Q4 are the target. The individual forecast errors we made seem on average greater on the latest part of the study period (2011Q2 - 2012Q4) than on the second one (2009Q4 - 2011Q1).

Table 6: RMSFEs for real-time QoQ growth rate

	Indicator	Recursive mean	AR(1)
2007:3 - 2012:4	1.70	1.87	2.00
2011:2 - 2012:4	1.17	1.15	1.22
2007:3 - 2010:2	2.13	2.42	2.60
2010:3 - 2012:4	1.09	1.05	1.10

Figure 4: Individual squared forecast errors (2007Q3-2012Q4)- Based on real-time backcasts and nowcasts of qoq GDP growth (first release)

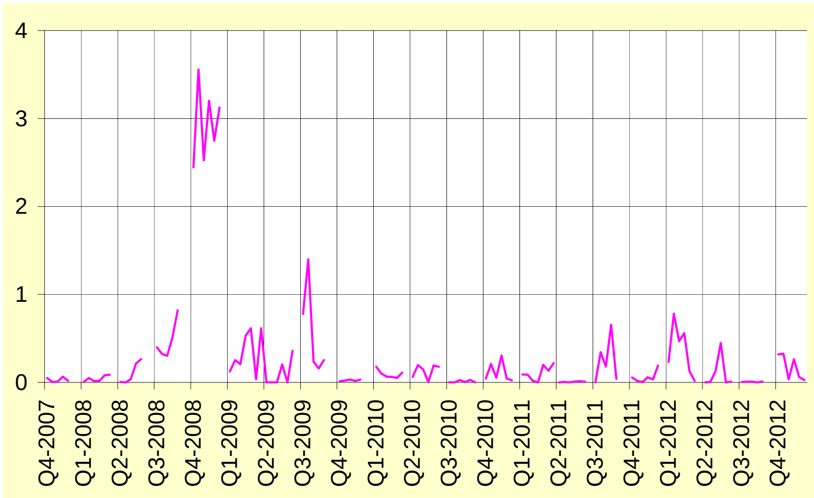


Table 7: MFEs for real-time QoQ growth rate

	Indicator	Recursive mean	AR(1)
2007:3 - 2012:4	-0.38	-0.86	-0.97
2011:2 - 2012:4	0.13	-0.51	-0.59
2007:3 - 2010:2	-0.69	-0.92	-1.02
2010:3 - 2012:4	0.25	-0.75	-0.86

Table 8: MSFEs decomposition in percentage (Actual: qoq GDP growth rate - 1st release) 2007Q3 - 2012Q4

	Bias prop.	Variance prop.	Covariance prop.
Indicator	5.1	19.1	75.8
Recursive mean	23.4	42.3	34.3
AR(1)	21.1	68.1	10.8
Indicator*	0.04	6.51	93.45
Recursive mean*	24.1	54.7	21.2
AR(1)*	21.2	69.8	9.0

* indicates exclusion of all backcasts and nowcasts for quarters 2008:4 and 2009:1.

Table 6 displays the RMSFEs of our forecasts together with those of the benchmarks. The target is the first release of qoq GDP growth, and we consider RMSFEs that were obtained for the entire study period going from 2007Q3 to 2012Q4 (line 1); over the most recent period from 2011Q2 onwards (line 2); over the first half of the study period (line 3); and over the second half of the study period (line 4). Our forecasts have outperformed the benchmarks over the entire study period and the DM tests have given strong evidence against the null (at the 5 percent level). However, looking into the most recent period, the DM tests are unable to provide any evidence against the null at the 5 percent level. We can finally conclude that our forecasts have outperformed both benchmarks in the first half of the study period (at the 1 percent level), whereas the assumption of equal accuracy of our forecasts and those of benchmarks cannot be rejected over the second half of the study period. Table 7 displays the Mean Forecast Errors (MFEs[13]). The forecast errors have been on average negative for our forecasts and the benchmarks pointing to a systematic overestimation - positive bias - over the entire study period (line 1). The bias have been clearly higher for the benchmarks than for our forecasts. Note that over the most recent period from 2011Q2 onwards (line 2) or over the second half of the study period (line 4), our forecast errors were on average positive pointing to a systematic underestimation - negative bias - contrary to the benchmarks. Finally, the results of the MSFE decomposition for the whole study period are displayed on table 8. They unambiguously indicate that our forecasts produced with the indicator may be qualified better than those of the benchmarks as the bias and variance proportions are relatively smaller than those of the benchmarks (i.e. the forecast errors tend to be less systematic with our indicator).

The results of this section have shown the limitations of forecasting (evaluation exercises) in special time. Forecasting performances may be strongly altered by extreme events like the ongoing financial crisis. The succession of events such as the great recession (2008-2009) and the failed recovery (2010-mid-2011) and the high degree of uncertainty thereafter (from mid-2011 onwards) has made the forecast exercises hazardous.

4.4 Real-time assessment of the economic situation and the financial crisis period

This section is based on the BcL publications and communications between December 2007 and July 2013. It focuses more specifically on the real-time assessment of the economic situation in Luxembourg during this period based on our indicator. Note that in this section the term *GDP growth* refers

[13] The MFE is defined as the average of the differences between the first releases of qoq GDP growth and the forecasts.

to year-on-year growth rate when related to a specific quarter, as this is the measure of interest.

- In December 2007, the Bcl presented its Winter 2007 (BMPE[14]) projections (see BcL Bulletin 2007/2). It was expecting real GDP growth to increase by between 4.7 percent and 5.3 in 2007, and by between 3.8 percent and 4.8 percent in 2008, and by between 4 percent and 5 percent in 2009 (see BcL 2006 Annual Report). These projections were produced only a few months after the beginning of the financial turmoil. The economic fundamentals of the euro area were still considered sound. However, risks surrounding growth in the euro area were oriented downward as the reappraisal of risk in financial markets was still evolving and was accompanied by continued uncertainty about the potential impact of the financial turmoil on the real economy. First attempts at nowcasting GDP yoy growth were communicated through the press conference accompanying the December 2007 Bulletin. On the basis of the information available up to 4 December 2007, our indicator anticipated GDP growth to lie between 4.9 and 6.6 percent in 2007Q3 and between 4.0 and 5.8 in 2007Q4. Average annual GDP growth was then expected between 4.7 and 5.6 percent in 2007. Note that our indicator was used to estimate a point forecast but this was reported as a range based on the observed average revision of the indicator[15]. A few weeks later, Statec released its first estimate of the quarterly national accounts for the third quarter of 2007. GDP growth was estimated as +5.6 percent in 2007Q3, within the range anticipated by our indicator. The first estimate of GDP growth for 2007Q4 was released on May 2008 at +3.7 percent, i.e slightly below our interval. The average growth of GDP for 2007 was therefore estimated at +4.5 percent in May 2008.

- Updated projections for 2008 and 2009 were published in the **Bcl 2007 Annual Report**, which was released in June 2008. GDP was expected to increase between 2.9 and 3.5 percent in 2008 and between 3.5 and 4.5 in 2009 (after +4.5 percent in 2007). These projections were made in a particular context, marked on the one hand by the positive surprise of the first estimate of quarterly national accounts for Luxembourg for the first quarter of 2008 in May 2008. First estimates for 2008 had appeared stronger than expected in the US and the euro area too. On the other hand, the international scenario and world demand addressed to Luxembourg were revised downward com-

[14]The Broad Macroeconomic Projection Exercise (BMPE) is conducted by the staff of National central banks and the ECB twice a year, for the June and December Governing Council meetings. For these exercises we use conventional macroeconometric tools (macroeconomic models and bridge equations), augmented by judgment to produce projections of inflation and economic activity for the coming two to three years. Projections for the euro area are published as ranges on the day they are discussed by the Governing Council and appear subsequently in the ECB Monthly Bulletin. Luxembourg projections are published as ranges in the BcL Annual Report (June) or in the December Bulletin

[15]See Nguiffo-Boyom (2008) for detailed discussion on quantifying revisions of the indicator.

pared to December 2007. Indeed, dollar oil prices reached historical peaks, and the exchange rate of the euro against the dollar reached record levels. Moreover, the uncertainty related to the vulnerability of European and Luxembourg financial sectors to the US subprime crisis was difficult to assess. In this BcL 2007 Annual Report, we also provided an assessment of the risks surrounding these forecasts, which was based on the indicator. Despite the global slowdown, the indicator suggested that economic growth had been buoyant during the first half of 2008 (after +3.7 percent in 2007Q4). According to the first estimate of GDP growth for 2008Q1 and 2008Q2 released a few months later, this last statement appeared too optimistic.

- In **the September issue of our Bulletin** (see BcL Bulletin 2008/2), we reviewed our summer 2008 macroeconomic projections for Luxembourg. Cut-off date for publication was the first week of September, just a few days before the bankruptcy of Lehman Brothers. New information since June 2008 was in general negative. Business surveys and stockmarkets were already down. The indicator was decreasing, and suggested a moderation of GDP growth in 2008. Therefore, our short-term economic outlook for Luxembourg was more cautious than in June. We began to anticipate GDP growth to be below the lower bound of our June 2008 forecast.

Around mid-September 2008, the financial turmoil turned into a financial and banking crisis affecting most developed countries. The Lehman Brothers bankruptcy underlined not only the interdependence of the global financial system but also some fragilities. Several other financial institutions filed for bankruptcy, and stock prices in both the non-financial and the financial sectors declined strongly. Moreover, this financial crisis rapidly spilled over into the non-financial sector of the economy, namely industry and non-financial services.

- In **the December 2008 issue of our Bulletin** (see BcL Bulletin 2008/3), we discussed our new macroeconomic projections for Luxembourg. The international environment was very unfavorable in comparison to earlier, and real GDP growth was expected to grow between -0.5 and +0.5 percent in 2009, after a range between +1.8 and +2.4 percent in 2008. The indicator anticipated a resilient yoy growth in 2008Q3 followed by a decreasing yoy growth during 2008Q4 (after +2.8 percent in 2008Q2). This message appears qualitatively accurate *a posteriori*, but still optimistic from a quantitative point of view. First estimates of GDP yoy growth were 0.0 and -5.4 percent for 2008Q3 and 2008Q4 respectively.

-In **the March 2009 issue of our Bulletin** (see BcL Bulletin 2009/1), we discussed latest developments since December 2008. Globally, the financial crisis was clearly spreading to both the industrial sector and the emerging economies. Latest statistics led to a downwards revision of the macroeconomic short-term outlook for Luxembourg. Starting in January 2009, GDP growth forecasts for 2008Q4 were anticipated to be negative - after 0.0 in 2008Q3 -. Note that given the vintage of data that was available at this time, the situation was exceptional as yoy GDP growth had never been negative in any data vintages released before 8 January 2009. The December 2008 projections were judged too optimistic and our indicator preannounced their downward revision in June 2009.

-In **the BcL 2008 Annual Report** (see BcL 2008 Annual Report), our GDP growth forecasts were revised down to between -5.4 and 4.4 percent in 2009 and between -0.5 and +0.5 percent in 2010 (after -0.9 percent in 2008). According to the first estimate of national accounts for 2008Q4, GDP decreased by -5.4 percent yoy and by -4.5 percent qoq, which were both historical declines by all standards. In our risk assessment of GDP growth projections for 2009, we wrote that our indicator suggested that the economic deterioration should be less dramatic for the first two quarters of 2009 than what had been already observed in 2008Q4. In other words, we conjectured that the trough was probably behind us. We also warned that this didn't mean that GDP growth would turn positive. Future GDP growth would probably stay negative for a while, but the decline would be less marked than over the last quarters. This was implied by the latest positive developments in the individual economic and financial series observed during the second quarter of 2009.

- **The September 2009 Bulletin** (see BcL Bulletin 2009/2) provided an *ex post* discussion of our last projections. The first estimate of GDP growth for 2009 Q1 was a negative surprise (-5.4 percent yoy) and revisions to past GDP values had not been correctly anticipated. The main economic indicators for both industry and construction available for the second and third quarters of 2009 suggested that the deterioration was less dramatic than what was observed at the turn of 2008/2009. Financial services appeared to have grown during the second quarter because of a more favourable environment. External demand showed increasing signs of improvement. Several industrial countries experienced positive GDP qoq growth in the second quarter of 2009. The first estimate of GDP for both France and Germany was a positive surprise as the decline halted. GDP qoq growth was estimated at +0.3 percent for both countries. Stronger-than-expected growth was also recorded in the US and in Japan. Thus, the international environment appeared more favourable than the one that prevailed in June 2009. Our indicator, based on information available until end of August 2009, was oriented upward. However, it suggested that yoy GDP growth would remain negative during the second and third quarter of 2009, respectively between -6.8 and -5.2 percent and between -5.7 and -2.5 percent. It also suggested that our June 2009 projections would be revised upward.

- In **the December 2009 BcL Bulletin** (see BcL Bulletin 2009/3), we published our new projections. According to our December 2009 projections, GDP was expected to decline in 2009, falling between -4.0 and -3.4 percent. Our projections for 2010 were also revised up in comparison with the June 2009 projections, as GDP growth was expected to be between +1.4 and +2.4

percent in 2010. According to the indicator, yoy GDP growth was expected between -3.4 and -1.3 percent during the third quarter of 2009 and between -1.4 and +2.9 percent during the fourth quarter of 2009. The indicator anticipated then GDP growth around -3.3 percent in 2009 focussing on the top of the range of our December 2009 projections. A few weeks later, Statec released the first estimate of the quarterly national accounts for the third quarter of 2009. GDP growth was reported at -2.6 percent which was just below the mid-point of the range (-3.4 -1.3) we published in December 2009.

- In **the March 2010 BcL Bulletin** (see BcL Bulletin 2010/3),we argued we expected GDP to expand by between -1.3 and +0.8 percent yoy in the fourth quarter of 2009, so that the overall GDP decrease should stand around -4.2 percent in 2009. This last result was found to be somewhat more pessimistic than the December 2009 projections. We also expected economic growth to be more buoyant during the first quarter of 2010 as we anticipated GDP yoy growth to be between -0.8 and +3.5 percent. The first estimate of the national accounts for the year 2009 was released a few weeks later. According to it, economic growth for the year 2009 was set at -3.4 percent and GDP yoy growth stood at +1.4 percent for 2009Q4.

- **The BcL 2009 Annual Report** presented updated projections for 2010. They were revised up after the global economic recovery had been stronger than expected owing to the revival of the international trade, in a general context of notable improvements in economic activities in the euro area and Luxembourg since the second half of 2009. According to our June 2010 projections, Luxembourg GDP growth was expected to be in a range between 2.6 and 3.2 percent in 2010, so well-below its historical average. In our risk assessment, we warned of the high degree of uncertainty that surrounded our macroeconomic projections, given the multiplicity of shocks (adjustments in the labor market, high volatility in the bond market, the financial crisis, the need for balance sheet rebuilding in the banking industry, fiscal consolidation needs, etc) that was hurting the Luxembourg and global economy. On the other hand, our indicator of economic activity indicated that economic growth was buoyant during 2010 Q1 and Q2; so that as of the second quarter of 2010, the carryover on annual average real GDP growth in 2010 was estimated to be around 3 percent. Therefore and in retrospect, our June 2010 GDP growth estimate for 2010 to be between 2.6 and 3.2 percent could appear quite careful.

- **In the September 2010 issue of our Bulletin** (see BcL Bulletin 2010/2), the assessment of the June 2010 projections emphasized the latest economic developments. Data showed the international environment (euro area) had significantly improved since the summer beginning, but we nevertheless stayed cautions about the remainder of the year as we were anticipated the end of the exceptional fiscal support measures and the slowdown of the global trade. At the Luxembourg level, the GDP yoy growth had exhibited a marked increase in 2010Q1 according to the Statec first estimate, which had been accurately anticipated by our indicator. The indicator suggested yoy GDP growth for the second quarter of the year 2010 to stand between +4.0 and 5.9 percent and to decelerate thereafter in the third quarter. The national account statistics that were published later in the year corroborated this short-term diagnostic for economic growth.

- **The December 2010 Bulletin** (see BcL Bulletin 2010/3) presented our December 2010 projections. The international environment was rather more favourable for 2011 than the one that prevailed in June 2010 and the projected GDP growth were revised up for 2010, as it ranged between +3.5 and +4.1 percent in 2010. On the other hand, the indicator pointed out that GDP should increase by between +2.5 and +4.2 percent yoy in 2010Q3 and by between +0.6 and +4.0 percent yoy in 2010Q4, so that GDP growth should stand between +2.8 and +4.1 percent in 2010. This latter was judged to be in line with the December 2010 projections for the year 2010.

- The assessment of the December 2010 projections based on the indicator we made in **the March 2011 issue of our Bulletin** (see BcL Bulletin 2011/1) emphasized that the first estimate of GDP growth for the third quarter of 2010, which was released in the beginning of 2011, had been quite well anticipated by our indicator. The latter was anticipating that yoy GDP growth should stand between +2.4 and +4.3 percent in 2010Q4 (after +3.5 percent in 2010 Q3) and therefore GDP should increase by between +3.2 and +3.7 percent in 2010. This result was judged to be in accordance with the December 2010 projections. Finally, the expected yoy GDP growth for 2011Q1 was anticipated by the indicator to be between +2.6 and +6.4 percent, which was considered to fit into the December 2010 projections for 2011 - which ranged between +2.4 and +3.4 percent in 2011 -.

- We presented our June 2011 projections in **the BcL 2010 Annual Report** (see BcL 2010 Annual Report). Our GDP growth forecast were revised up - to be around +4.0 percent in 2011 - in a context of apparent evidence of overall economic recovery. It appeared the global economic recovery had been stronger than expected in 2010 and the recovery in the global economy had continued in the first quarter of 2011, whereas growth was set to decelerate in the second. In the same vein, it turned out that first estimate of GDP growth for 2010 had been estimated at 3.5 percent in Luxembourg by the Statec, which was slightly over our December projections. The favourable business cycle dynamics observed in Luxembourg towards the end of 2010 seemed to have extended into the beginning of 2011. The more favourable growth momentum towards the end of 2010 and its extension into 2011 yielded a more favourable scenario than previously envisaged in the December 2010 projection exercise. Real GDP growth in 2011 was expected to be between +3.7 and +4.3 percent in our June 2011 projections. This outlook for the Luxembourg economy was somewhat less favourable than the one based on the indicator. According to the BCL indicator, Luxembourg GDP yoy growth was estimated to be between +4.7 percent and

+6.5 percent in the first quarter of 2011 (after +4.6 percent in the fourth quarter of 2010). The indicator indicated that the GDP growth should loose some momentum in the second quarter of 2011, by standing between +2.8 percent and +6.5 percent yoy, so that the carry-over for the year 2011 reached +3.8 percent. This last result suggested that GDP growth in 2011 could be somewhat higher than the June 2011 macroeconomic projections for the year 2011.

- **The September 2011 issue of our Bulletin** (see BcL Bulletin 2011/2) was published in a context of high uncertainty given the ongoing tensions in a number of euro area sovereign debt markets and the financial market instability. The international environment was getting worse since June 2011 and the indicator told us that GDP should increase by between +0.3 and +4.0 percent yoy in 2011Q3, which lead us to anticipate a downward revision of our June 2011 macroeconomic projections for the year 2011.

- **The December 2011 Bulletin** (see BcL Bulletin 2011/3) presented our December 2011 projections, which were unsurprisingly less favourable than than those of June. Real GDP growth in 2011 was now expected to be between +1.4 and +2.0 percent in our December 2011 projections. According to the indicator, yoy GDP growth should be between +0.6 percent and +2.3 percent in 2011Q3 and between -1.5 percent and +2.0 percent in 2011Q4 and the economic growth should therefore average +1.6 percent in 2011. A few weeks later, Statec released the first estimate of the quarterly national accounts for the third quarter of 2011. GDP growth was reported at +1.1 percent, which was below the mid-point of the forecast range we published in the December 2011 Bulletin.

- In **the March 2012 Bulletin** (see BcL Bulletin 2012/1), we expected GDP growth to be between between -1.3 percent and +0.4 percent in 2011Q4. We therefore expected real GDP growth should average +1.0 percent in 2011, i.e. less than expected in the December macroeconomic projections for 2011. According to the first estimate of the national accounts that was released a few weeks later, the indicator-based expectations were too pessimistic. Indeed, the Statec estimated economic growth at +1.6 percent for the year 2011 and GDP yoy growth at +0.8 percent for 2011Q4.

- In **the June 2012 Bulletin** (see BcL Bulletin 2012/2), we presented a GDP macroeconomic projection unchanged for the year 2012 as the economic situation appraisal was mostly unchanged since the December 2011 projection exercise. Real GDP growth was expected to stand between 0.7 and 1.3 percent in 2012, which was judged compatible with the short-term developments anticipated by the indicator in 2012Q1 and Q2.

- In **the September 2012 issue of our Bulletin** (see BcL Bulletin 2012/3), we noted economic and financial data that had been released since June indicated a strong deterioration of the economic climate. The indicator led us to anticipate that economic growth in 2012 would therefore be much lower than indicated in the June 2012 Bulletin.

- **The December 2012 Bulletin** (see BcL Bulletin 2012/4) presented our last macroeconomic projections. GDP growth expectation for 2012 was revised downward in comparison with that of June 2012, to be between 0.2 and 0.8 percent in 2012. It was judged to be compatible with the short-term developments anticipated by the indicator in 2012Q3 and Q4 that led to expect GDP to increase by 0.6 percent on average in 2012.

- In **the March 2013 issue of our Bulletin** (see BcL Bulletin 2013/1), the economic environment was still judged very uncertain and the indicator-based forecast for 2012Q4 implied GDP growth in 2012 should stand around the lower bound of our December 2012 macroeconomic projection (0.2 - 0.8), namely around 0.3. The first estimate of the national accounts for the year 2012 was set at +0.3 a few weeks later by the Statec.

- Finally, in **the June 2013 issue of our Bulletin** (see BcL Bulletin 2013/2), the indicator was reported to indicate yoy GDP growth should be between 0.5 and 1.7 percent in 2013Q1, which implied also a negative qoq growth in 2013Q1. The first week of July, the Statec released its first estimate of the quarterly national accounts for the first quarter of 2013. It estimated yoy GDP growth to be 1.0 percent in 2013Q1 and qoq GDP growth was estimated at -1.6.

Overall, these five years of real-time assessment of the economic situation in Luxembourg provide a challenging period to evaluate our econometric tool. First, 2007-2013 was exceptional from an economic point of view, given the extent of the recession we faced. It required the intervention of monetary and fiscal authorities with policies sufficiently comprehensive enough to contain both the financial crisis and its spillover effects on the real economy. Second, the volatility of revisions to Luxembourg GDP were especially marked during this period and this made nowcasting even more difficult. Third, our indicator failed to anticipate the beginning of the Luxembourg recession in real-time[16]. Fourth, nowcasting GDP growth for the first two quarters of 2009 was rather difficult. Informal discussion with other national experts suggests that this was even difficult in larger euro area countries and for the euro area as a whole. Indeed, in most countries several individual economic and financial series reached levels near their historical minimum (in particular industrial production, business and consumer surveys), but mechanical tools used to produce forecasts missed the scale of the GDP declines for 2009 Q1 and Q2 (see for instance the real-time evolution of Eurocoin, which had difficulty forecasting euro area medium term growth at this time). One explanation may be that tools based on the factor representation of times series data may be too linear to forecast

[16]Using the July 2013 vintage of Luxembourg quarterly national accounts and applying a BBQ-type procedure to date the business cycle, the beginning of the last recession falls in the second quarter of 2008.

extreme events.

5 Concluding remarks

The BcL developed a monthly indicator of economic activity for Luxembourg based on a variety of economic and financial data in addition to GDP. It was constructed using a statistical approach to summarize the information contained in a large dataset, the generalized dynamic factor model introduced by Forni *et alii* (2005).

The performance of the indicator for Luxembourg has been assessed in real time over the period December 2007-April 2013. The results could be qualified as satisfactory, given that the real-time exercise covers the economic and financial crisis - namely a period marked by a high level of uncertainty and a severe recession. First, we evaluated its real-time forecasting performance by calculating (relative) root mean squared forecast errors. We found that on average, the indicator for the Luxembourg economy produced better forecasts than the benchmark approaches over the entire study period. Second, we reviewed and discussed the real-time assessment of the Luxembourg economic situation we conducted for the period December 2007 to July 2013. We found *inter alia* that the indicator has been helpful in anticipating and preannouncing revisions between our two annual (June and December) macroeconomic projection exercises.

We look forward for some changes in the dataset composition of our indicator. In order to improve our indicator forecasting performances, we should use more time series related to economic activity outside Luxembourg and to European financial markets. Moreover, monthly series that have been frequently revised or that have been released with relatively long delays should be excluded from the current database.

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A Appendix 3: List of individual series

Table 9: Data set

PERSPE	Business survey, industry: Employment expectations
CET	Business survey, industry: Export order-books
CTX	Business survey, industry: Total order-books
STO	Business survey, industry: Stocks of finished products
PERSP	Business survey, industry: Production expectations
TPPA	Business survey, industry: Production trend observed in recent months
PERSPX	Business survey, industry: Selling-prices expectations
ACPAS	Business survey, building: Trend of activity
CCOM	Business survey, building: Order books
EXPEM	Business survey, building: Employment expectations
EXPX	Business survey, building: Prices expectations
PJO-M	Production per working day: Manufacturing
PJO-K	Production per working day: Equipment goods
PJO-J	Production per working day: Energy
PJO-B	Production per working day: Building
PJO-TP	Production per working day: Civil engineering
PJO	Production per working day: Total industry excluding construction
PJO-I	Production per working day: Intermediate goods
IP	Industrial production index: Total industry excluding construction
IP-I	Industrial Production index, Intermediate goods Industry
YEMP-MA	Output per employee: Manufacturing
YEMP	Production per employee: Total industry excluding construction
YHR	Production per man hour: Manufacturing
YHRL	Production per man-hour: Total industry excluding construction
NICP	National index of consumer prices
OIL	Price of crude oil Europe (DTD BRENT)
PPI-DO	Industrial producer prices: Total industry on domestic market
PPI-X	Industrial producer prices: Total industry on exported goods
PPI-IX	Industrial producer prices: Total industry on exports outside EU
PPI	Industrial producer prices: Total industry excluding construction
PPI-I	Industrial producer prices: Intermediate goods
PPI-K	Industrial producer prices: Capital goods
PPI-C	Industrial producer prices: Consumer goods
PPI-BTP	Industrial producer prices: Construction input prices

Table 10: Data set *(continued)*

CA-B	Turnover: Building
CA-TP	Turnover: Civil engineering
CA-I	Turnover: Total industry excluding construction
CA-DET	Turnover: Retail trade
CA-OTO	Turnover: Sale, maintenance and repair of motor vehicles and motorcycles
CA-GRO	Turnover: Wholesale trade and commission trade
CA-HR	Turnover: Hotels and restaurants
CA-TT	Turnover: Land transport
CA-TA	Turnover: Air transport
CA-TS	Turnover: Auxiliary services to transport
CA-PTT	Turnover: Post office and telecommunications network
CA-INF	Turnover: Computing activity
CA-SE	Turnover: Services for enterprises
CA-DMET1	Turnover: Basic metals and fabricated metal products, domestic market
CA-XMET1	Turnover: Basic metals and fabricated metal products, non-domestic market
SAL	Wages and salaries: Total industry excluding construction
SAL-BTP	Wages and salaries: Building and Civil engineering
CSU-m	Unit labour costs: Manufacturing
RSU-M	Labour price index: Manufacturing
RMO-M	Average earnings per employee: Manufacturing
GMO-M	Average hourly earnings of wage earners: Manufacturing
SAL-I	Gross wages and salaries: Intermediate Goods Industry
SAL-MET1	Gross wages and salaries: Basic metals and fabricated metal products
SAL-MET2	Gross wages and salaries: Fabricated metal products, except machinery
EMPSAL	Employment: civilian domestic employees
NSAL-BTP	Number of employees : Civil engineering and building
NSAL	Number of employees: Total industry excluding construction
RESIDE	Employees resident in Luxembourg
TRPR-BTP	Hours worked : Civil engineering and building
TRAPRES	Hours worked: Total industry excluding construction
CHILO	Number of unemployed (thousand)
OENS	Registered vacancies
L-I	Employment: Intermediate Goods Industry
L-MET1	Employment: Basic metals and fabricated metal products
L-MET2	Employment: Fabricated metal products, except machinery
HW-I	Hours worked: Intermediate Goods Industry
HW-MET1	Hours worked: Basic metals and fabricated metal products
HW-MET2	Hours worked: Fabricated metal products, except machinery
UNEMP	Unemployment rate

Table 11: Dataset *(continued)*

COM	New orders: Total industry excluding construction
$\text{NCOM}_X I$	-: Non-domestic market, Intermediate Goods Industry
NCOM_I	-: Total, Intermediate Goods Industry
NCOM-XMET1	-: Non-domestic market, Basic metals and fabricated metal products
NCOM-MET1	-: Total, Basic metals and fabricated metal products
NCOM-XMET2	-: Non-domestic market, Fabricated metal products, except machinery
NCOM-MET2	-: Total, Fabricated metal products, except machinery
PER-TNB	Number of building permits issued: Total
PER-TNL	Number of building permits issued: Residential
PER-INB	Number of building permits issued: Individual housing
PER-ANB	Number of building permits issued: Collective housing
PER-ANL	Number of building permits issued: Collective housing, number of flat
PER-IVB	Building permits issued: Volume, Individual housing
PER-AV	Building permits issued: Volume, collective housing
IMAC	Car registrations: Commercial cars
IMATP	Car registrations: Private cars
OCCASO	Imported cars
LUXX	Luxembourg Stock Price Index - LUXX
EXR	Exchange rate: Euro / US Dollar
STI	Three-month Euribor rate
SOTOBI	Aggregated balance sheet of the Luxembourg banks
CPP-PB	Interim aggregated profit and loss account of credit institutions, Gross income
CPP-RE	Interim aggregated profit and loss account of credit institutions, Results before provisions
OPC-INC	Global situation of undertakings for collective investment, Net capital investment
OPC-AN	Global situation of undertakings for collective investment, Net assets
X	Merchandise trade: Total exports
M	Merchandise trade: Total imports
X-OUT	Merchandise trade: Exports to non-EU countries(EU-25)
X-IN	Merchandise imports, CIF, From non-EU countries(EU-25)

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