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# *Table of contents*

**The Swedish business cycle, 1969-2013** . . . . . 7
*by* Louise Holm

**Reverse-engineering the business cycle with Petri nets** . . . . . 29
*by* Johnnie B. Linn III

**Frequency based co-movement of inflation in selected euro area countries** . . . . . 57
*by* Aviral Kumar Tiwari, Niyati Bhanja and Arif Billah Dar

**The role of data revisions and disagreement in professional forecasts** . . . . . 71
*by* Eva A. Arnold

**A comparison of economic indicator analysis and Markov switching methods concerning the cycle phase dynamics (Report)** . . . . . 111
*by* Pami Dua and Vineeta Sharma

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# *Note by the Chair of the Editorial Board*

This issue of the *Journal of Business Cycle Measurement and Analysis* (JBCMA) will be the last issue published under the joint responsibility of the OECD and the Centre for International Research on Economic Tendency Surveys (CIRET).

The co-operation between the two organisations started in 2004 and comprised the joint publication of 11 volumes of the JBCMA.

From 2004 to 2007, 9 issues, comprising 45 articles, were handled by CIRET. The cooperation with the OECD was deepened in 2008, when the JBCMA was integrated into the package of OECD Journals. Since then, 16 issues and 73 articles have been published on various important topics including economic activity and inflation forecasting, the construction of composite leading indicators, the information content of business tendency and consumer surveys, and the dating of turning points in economic activity. The Great Recession revived the interest for these topics in academic and policy circles, and the JBCMA played a significant role in helping applied economists and statisticians to confront their experiences since then.

From the next issue onwards, SPRINGER will publish the journal under the revised name of *Journal of Business Cycle Research*. In accordance with the OECD policy, all previous issues will remain available *via* OECD iLibrary (*www.oecd-ilibrary.org*) where all articles will be free to access. I would like to thank the CIRET for our fruitful co-operation in the last years and wish the best fortune to the *Journal of Business Cycle Research*.

Martine DURAND

Director of Statistics and Chief Statistician of the OECD
Chair of the JBCMA Editorial Board

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# The Swedish business cycle, 1969-2013

*by*
Louise Holm*

*The aim of this paper is to apply a non-stationary, non-parametric method to date the Swedish business cycle where no official dating method exists, defined as the common dynamic of some macroeconomic time series. The method draws on a paper where the business cycle for the euro area by Holm (2011) was found and the method worked well and closely matched the dates found by the Centre for Economic Policy Research, CEPR. In this paper five recessions were found for Sweden in the 1969-2013 period.*

*Keywords: Business cycle, non-parametric smoothing, non-stationarity*

*JEL: C14, C32, E32*

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## 1. Introduction

Business cycles are often defined as the ups and downs in real GDP but also as movements seen somewhat simultaneously in different macroeconomic series. To call them "cycles" is misleading, however, as they usually do not repeat at regular intervals. Nevertheless, many researchers and governments use the business cycle as a basis for describing and studying the state of the economy, so dating the business cycle has always been of interest in macroeconomic research. The dating might help find the cause of a recession and this understanding could in turn help prevent or limit the duration of recessions in the future. More precisely, business cycle dating refers to the ex post dating of the start and the end of a recession in an economy.

The purpose of the present paper is to date the business cycle for Sweden since 1969 using a non-parametric method. There exists no official dating of the business cycle in Sweden, and the method worked well in Holm (2011) for the euro area, as it closely matched the dates found by the Centre for Economic Policy Research, CEPR.[1] Previous relevant contributors on the Swedish business cycle are mentioned below.

Backus and Kehoe (1992) study the cyclical behaviour of national income, expenditure components, price levels and money stocks for Sweden and nine other countries and find that business cycles before World War II share many features with those of the post-war period. Hassler et al. (1992) try to establish a number of stylised facts for the Swedish business cycle using different band pass filters during a period of 130 years.

Englund et al. (1992) examine Swedish business cycle data for 1861-1988 and conclude that most cycles last 3-8 years. They too use a band pass filter on important macroeconomic variables to look at stylised facts of business cycles, and find that the post-war period is much less volatile than the inter-war period and slightly less volatile than the pre-war period. Skalin and Teräsvirta (1999) investigate the existence of a driving variable for the cycle using Granger causality on the same data used in Englund et al. (1992). They find that there is plenty of individual behaviour in the series, that there are plenty of temporal links between the variables and that industrial production is the closest candidate for a clear driving variable among the ones considered. More recent work includes Brinca (2013), who uses data from 1982-2010 for six macroeconomic variables and a method drawing on Sustek (2010). Among several results, Brinca attempts to explain two major recession episodes in Sweden: in the early 1990s and in 2008.

Regarding dating of the business cycle and the modelling of individual economic series, previous research can be divided into two groups: parametric and non-parametric methods. The parametric approach assumes that the dynamic of the macroeconomic series is described by a small number of parameters. The non-parametric approach differs from parametric models in that the model structure is not specified a priori but instead determined from data.

Beveridge and Nelson (1981), Nelson and Plosser (1982), and Campbell and Mankiw (1987) use ARIMA and ARMA models to analyse business cycles, while Harvey (1985), Watson (1986)

and Clark (1987) use linear unobserved components models. The dominant non-linear parametric approach originates from the work of Hamilton (1989). He assumes that the mean growth rate of the observed series evolves according to a two-state Markov-switching process. This means that the dynamics of expansions are qualitatively different from those of contractions (See also Chauvet [2001], Kaufmann [2000] and Artis et al. [2004]).

The co-movement of representative coincident series, i.e their common evolution along the cycle, was first used in the dating by Burns and Mitchell (1946). Geweke (1977), and Sargent and Sims (1977) used a parametric dynamic index model, a model that measures the co-movement of many time series, whereas more recently Quah and Sargent (1993), Stock and Watson (1998, 2002) used co-movements of variables along the cycle to extract a common factor. Diebold and Rudebush (1996) propose a mix of dynamic factor models and regime switching (see also Chauvet [1998], and Kim and Nelson [1998]). Forni et al. (2000), and Forni and Lippi (2001) propose a generalised dynamic factor model that allows for serial correlation within and across individual processes. Their model generalises the factor model of Geweke (1977), and Sargent and Sims (1977) by allowing for non-orthogonal idiosyncratic terms. All the approaches described so far are parametric. We will continue with an overview of the non-parametric methods in the literature.

The Bry and Broschan (1971) procedure is a non-parametric approach that identifies points as local maxima or minima based on some censoring rules. The Burns and Mitchell procedure was adopted by for example King and Plosser (1994), Watson (1994), Pedersen (1998) and Harding and Pagan (2002). For comparative work on the Bry-Broschan and Hamilton cycle dating methods, see Harding and Pagan (2003). In their comparison of two business cycle dating methods, one non-parametric, i.e. the Bry and Broschan algorithm, and one parametric, i.e. a Markov switching (MS) model, they argue that the non-parametric method is more robust than the MS model. Harding and Pagan suggest using techniques that are as non-parametric as possible and conclude that non-parametric methods are preferred.

The literature on business cycle dating for Nordic countries is not too rich. Among earlier research, Christoffersen (2000) dates economic peaks (starting points of recessions) and troughs (ending points of recessions) for the Nordic countries. Christoffersen (2000) finds the Swedish recessions 1970-2006 shown in Table 1 by applying the Bry and Broschan (1971) algorithms to industrial production.

Table 1. **Peaks and troughs in Sweden 1970-2000**

| Peak | Trough |
|---|---|
| 1971:1 | 1972:1 |
| 1974:6 | 1978:7 |
| 1979:12 | 1982:11 |
| 1985:8 | 1986:5 |
| 1989:1 | 1993:1 |

*Source:* Christoffersen, 2000.

According to another study, by Edvinsson (2005), Sweden experienced four recessions in the 1969-2001 period; in 1976-78 (depression), 1979-81 (mini-recession), 1990-93 (depression) and 2000-01 (mini-recession). A depression, i.e. a severe economic crisis, is defined as an event, where GDP in one year is beneath the level of GDP two years earlier.

Most business cycles since World War II lasted 4-5 years, yet this changed in the 1980s. The expansion in the 1980s was very long. The deregulations of the financial markets in the latter half of the decade created a situation of overheating in the economy, which in particular led to a real estate bubble. The burst of the bubble together with the bankruptcy of several big financial companies opened up for a depression in the early 1990s. This depression was particularly severe. In fact, at no other time since the Napoleonic war in 1806-09 has GDP fallen for three consecutive years.

In Sweden, the National Institute of Economic Research (NIER), an independent government agency, is responsible for the analysis and forecast of business cycles. The institute interview 7000 companies every month about their position, results and expectations and uses the information to publish a monthly and quarterly "business cycle barometer" utilising the growth cycle definition[2] of a business cycle. NIER, however, does not date the turning points of the business cycle.

We will think of the business cycle as in Hassler et al. (1992), believing the series, $y$, that define the business cycle is the sum of a trend component, a cyclical component, a seasonal component and a noise component.

$$y = trend + cycle + season + noise \tag{1}$$

We will seasonally adjust all series to get rid of the seasonal component, use first differences to get rid of the trend component, use a smoothing technique to get rid of the noise component and then be left with just the cycle.

We will furthermore use a non-stationary, non-parametric method previously used by Holm (2011) described in Section 3 and 4 using four macroeconomic series to date the Swedish business cycle *ex post* where no official dating method exists. We will use the classical definition[3] of the business cycle and follow the definition used by the National Bureau of Economic Research (NBER).[4] NBER defines the business cycle as "a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production and wholesale-retail sales". The decision to use the non-stationary, non-parametric method also used in Holm (2011) is motivated by the closeness of the dates compared with those found by the Centre for Economic Policy Research (CEPR) on the euro area. Moreover, a non-parametric approach can uncover structural features of the data that a parametric approach might not find. The non-parametric method will, in contrast to a parametric method, let the data speak for itself. We will use a very common non-parametric technique called kernel smoothing, to smooth the results from the data. A smoothed series is less noisy and shows the signal more clearly.

Section 2 describes the data set, and Sections 3 and 4 the estimation procedure; more exactly Section 3 gives a bird's eye view of non-parametric regression and Section 4 describes the approach used in this article in more depth. Section 5 presents the results and Section 6 concludes the paper.

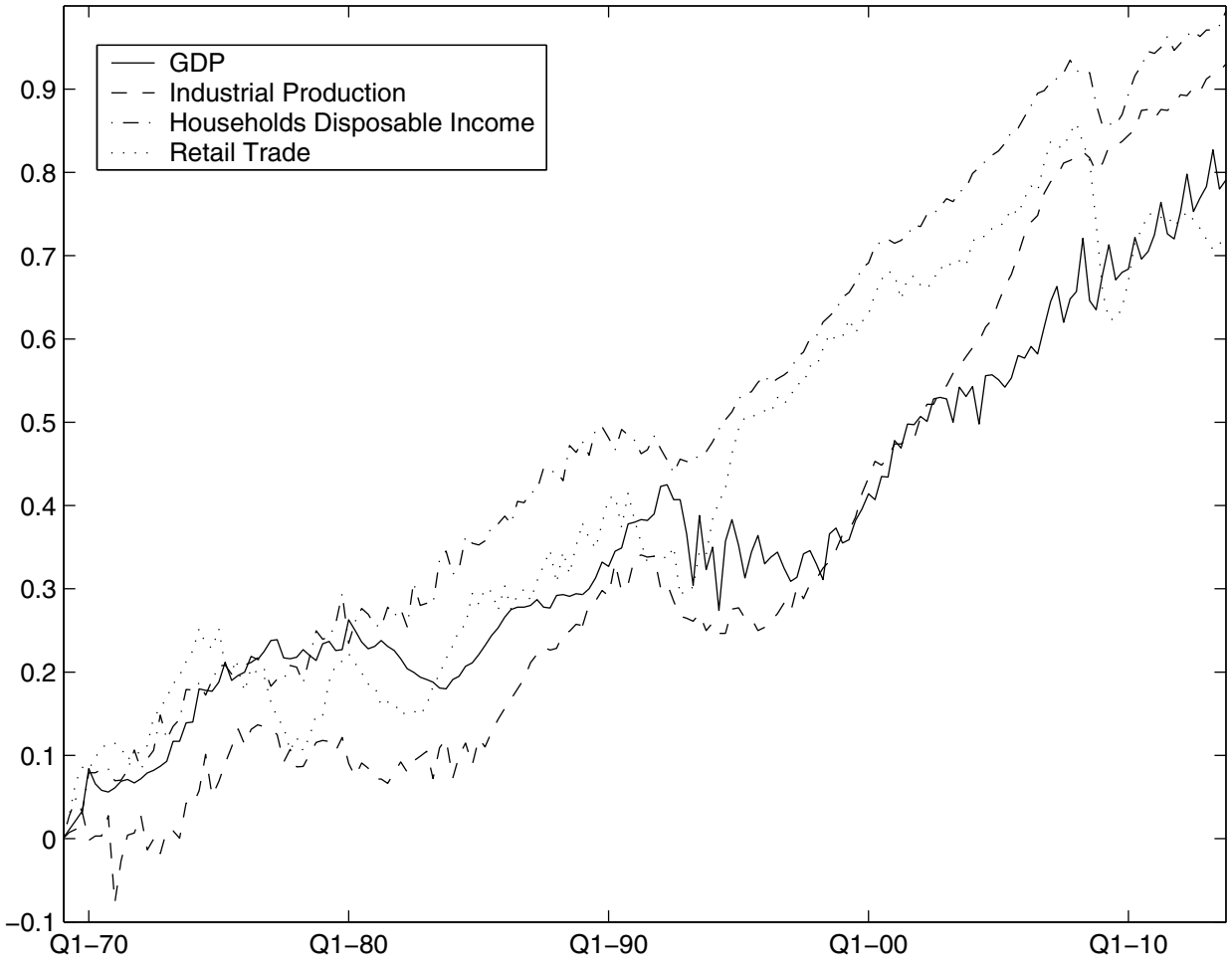
## 2. The data

In our dating we will use four of the five series used by NBER: retail trade,[5] industrial production,[6] households disposable income and GDP. All series are seasonally-adjusted real quarterly data in logarithms, taken from Datastream, ECB and NIER. The data covers the period from the first quarter of 1969 until the last quarter of 2013. Quarterly data prior to 1969:Q1 was not found. Employment is also used by NBER but was not included in the

final estimation here due to the different dynamic compared with the other series. The different dynamic is to some extent explained by the change in the measurement procedure during that period and perhaps a heavily regulated labour market. Using employment in this method would not give good results since it does not follow the rest of the series, which is a prerequisite for the approach to work.

Figure 1 plots the data minus their first values and Figure 2 the first-order differences. Looking at one series at a time, it is clear from Figure 2 that the series are too noisy to reveal any clear signals of peaks and troughs.

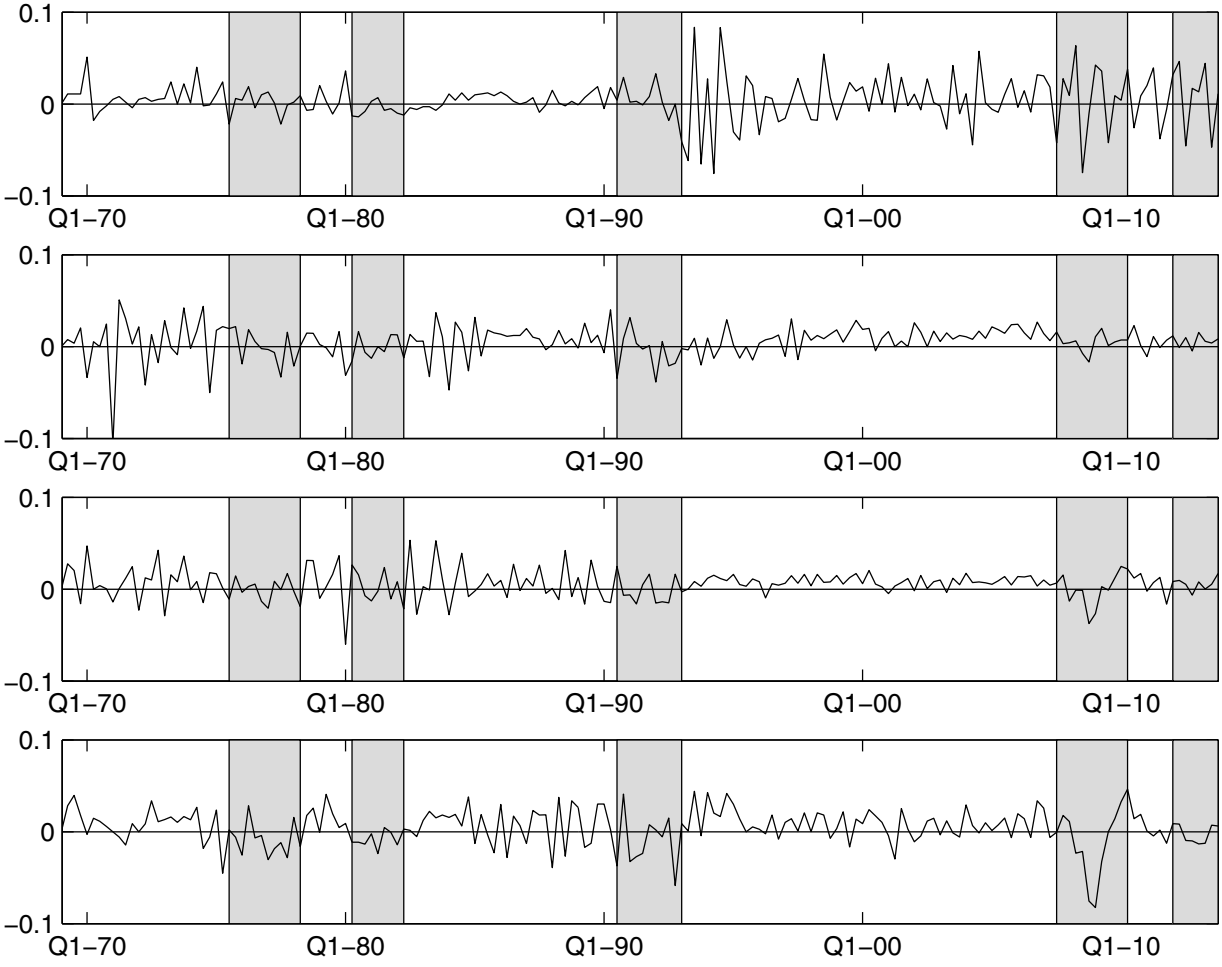
Figure 1. **The four logarithmic series minus their first values, Q1 in 1969**




## 3. Non-parametric regression: A bird's eye view

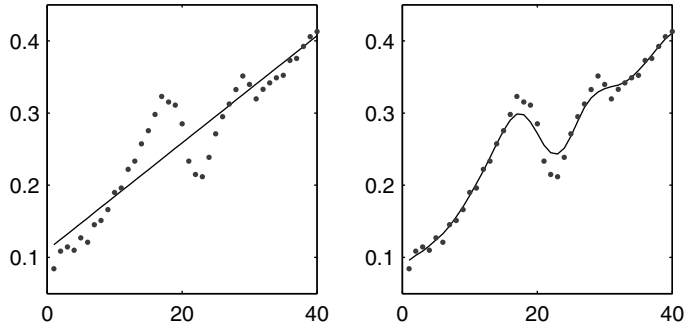
By letting the data speak for itself, a non-parametric approach can uncover structural features of the data that a parametric approach might not find. One of the most commonly used non-parametric techniques is kernel smoothing.[7] Figure 3 compares establishing a relationship between two variables using a parametric linear model and a non-parametric model. The latter approach seems to be more truthful to the empirical relationship between the variables.

Figure 2. **Growth rates of the logarithmic series: GDP, industrial production, households disposable income and retail trade together with the recession periods found by our method**




*Note:* Shading indicates recession periods.

Figure 3. **Comparing a parametric (left) with a non-parametric (right) model**




Suppose we want to find a relationship between an explanatory variable $x$ and a response variable $y$. Assume that the relationship between $x$ and $y$ can be described with an unknown function $f$ and resid*uals* $\varepsilon$ *as*

$$y_i = f(x_i) + \varepsilon_i, \qquad i = 1, \ldots, n, \tag{2}$$

where E $[\varepsilon_i] = 0$ for each i. The idea is to estimate $f(x_0)$ by averaging over the y-values corresponding to xs close to $x_0$.

A non-parametric estimator can be described as

$$\hat{f}(x,h) = \sum_{i=1}^{n} W_i(x) y_i, \tag{3}$$

where the weights $W_i(x)$ indicate the importance of the contribution of the observation $y_i$ in the estimation of $f(x)$. Various weight schemes yield different estimates.

A common example is the Nadaraya-Watson estimator (first suggested by E.A. Nadaraya [1964] and G.S. Watson [1964]) with the weight function

$$W_i^{NW}(x) = \frac{K\left(\frac{x-x_i}{h}\right)}{\sum_{i=1}^{n} K\left(\frac{x-x_i}{h}\right)}, \tag{4}$$

where K is a kernel function with support in the interval [–1,1], and thus non-zero weights are associated only with observations $y_i$ such that $|x_i - x| < h$, where h is the bandwidth (window width or smoothing parameter).

Another weight function (see Gasser and Müller [1984]) is defined as

$$W_i^{GM}(x) = \frac{1}{h}\int_{s_{i-1}}^{s_i} K\left(\frac{x-u}{h}\right) du, \tag{5}$$

where $s_i = \frac{x_{i+1}+x_i}{2}, x_i = \frac{x}{n}$ and $x_i \in [0, 1]$.

Bandwidth determines how many observations should be averaged in estimating the y-value for x and how important they are in the estimation. Thus it determines the smoothness or roughness of the estimate. The kernel weighs observations closer to x more than those further away and then the contributions from each point are summed to create an overall estimate. For simplicity of presentation we will in what follows refer to the Nadaraya-Watson estimator. The Gasser and Müller estimator has similar properties.

One commonly used kernel function, K, is the Epanechnikov kernel:

$$K(u) = \frac{3}{4}\left(1-u^2\right) I_{\{|u|<1\}}. \tag{6}$$

The Epanechnikov kernel can be found in Figure 4. The weight function, which is proportionate to the distance, is

$$K\left(\frac{x-x_i}{h}\right) = \begin{cases} \frac{3}{4}\left(1-\left(\frac{x-x_i}{h}\right)^2\right) & \text{if } |x-x_i|<h \\ 0 & \text{if } |x-x_i|\geq h \end{cases}. \tag{7}$$

Figure 4. **The Epanechnikov kernel**

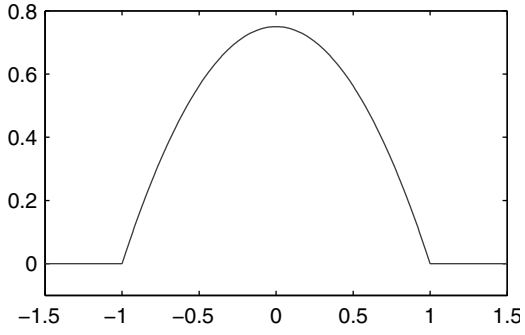
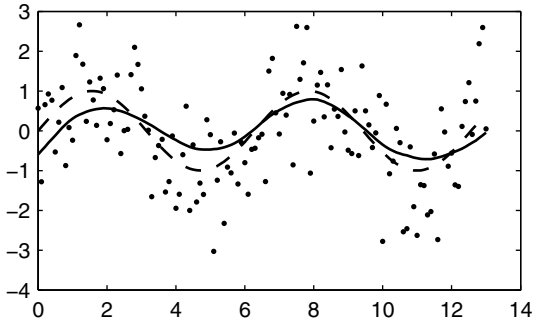


Figure 5 shows a smoothing obtained by the Nadaraya-Watson estimator with Epanechnikov kernel of data generated as $y = sin\,(x) + \varepsilon$.

Figure 5. **Nadaraya-Watson estimator of data points generated from y = sin (x) + ε**

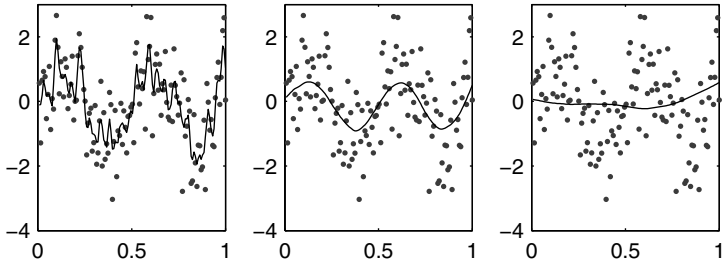



*Note:* The full line is the estimate and the dashed line is sin(x).

### *3.1. Bandwidth selection and cross-validation*

Non-parametric smoothing estimation faces the risk of under- or over-smoothing. A too small bandwidth will yield a too wiggly curve and a too large bandwidth will yield a too flat curve (see Figure 6).

Figure 6. **A Nadaraya-Watson estimator with (left) a very small bandwidth, (middle) an optimal bandwidth and (right) a very large bandwidth**




The bandwidth that minimises the mean squared error of the estimator (MSE), described in Gasser and Müller (1984), is the optimal bandwidth. Since MSE is an unknown theoretical quantity, we need to approximate it. To this end we define a function using one of the most popular methods, i.e. cross-validation (CV) (see Stone, 1974), as follows:

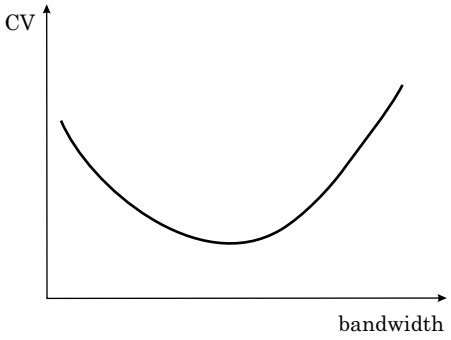
$$CV(h) = \sum_{i=1}^{n} \left( \hat{f}_i(x_i, h) - y_i \right)^2 \quad \text{where} \quad \hat{f}_i(x, h) = \frac{\sum_{j \neq i} K\left( \frac{x - x_j}{h} \right) y_j}{\sum_{j \neq i} K\left( \frac{x - x_j}{h} \right)}. \tag{8}$$

The CV method chooses the bandwidth $h$ that minimises the function $CV\,(h)$.

### *3.2. Overcoming edge effects*

Near the boundaries, the local averaging process gets asymmetric, that is, some of the weights are non-defined since we end up outside the boundary. Estimates close to the beginning and end of the study period must be based only on data within the period and are thus likely to be biased. For the Nadaraya-Watson estimator, this means that the usual optimal MSE of order $n - \frac{4}{5}$ is magnified to $n - \frac{2}{3}$ near the boundaries. These problems are referred to as edge effects.

Figure 7. **Cross-validation function**




Hall and Wehrly (1991) suggest an easy method for overcoming edge effects by reflecting the data set around the two values of *f* estimated at the end points of the design interval. This generates new data (called pseudodata) and the data set becomes three times as large. The technique is applicable to both regularly spaced and randomly spaced design points. For the remainder of the paper, the *x* variable will be time and will be regularly spaced.

## 4. Estimation procedures

In what follows we will extract the common dynamic from a number of macroeconomic series. The series have time-varying means and time-varying standard deviations and we assume that the former have a common dynamic and increase in an economic expansion and decrease in an economic contraction. The time-varying means are linear expressions of a "time-varying activity measure". We follow the non-parametric setup and estimate the common dynamic using the same method as in Holm (2001), where it performed well on euro area data and matched the recessions dated by the CEPR.

### *4.1. Non-parametric kernel smoothing*

We use the heteroscedastic model of Müller and Stadtmüller (1987) to describe the macroeconomic series as non-stationary independent random variables with varying unconditional means and varying standard deviations

$$y_k = \mu(t_k) + \sigma(t_k)\in_k, \qquad k = 1,\ldots,n, \tag{9}$$

where $t_k = \frac{k}{n}, t_k \in [0,1]$ and $y_k$ is the log of the macroeconomic variable at time *t*. The errors are assumed to be independent and identically distributed with zero mean and unit variance. The functions $\mu{:}[0,1] \to \mathbb{R}$ and $\sigma : [0,1] \to \mathbb{R}_+$ are assumed to be smooth.

#### *Estimating the mean*

Following Gasser and Müller (1984), the kernel estimator used to estimate the expected levels $\mu$ (*t*) is

$$\hat{\mu}(t) = \sum_{k=1}^{n} W_k(t) y_k. \tag{10}$$

$W_k$ (*t*) is the kernel- or weight-function, defined as

$$W_k(t) = \frac{1}{h}\int_{s_{k-1}}^{s_k} K\left(\frac{t-u}{h}\right)du, \tag{11}$$

where $s_k = \frac{t_{k+1}+t_k}{2}, t_k = \frac{k}{n}$ and $t_k \in [0, 1]$. The kernel itself (*K*) must be a continuous, bounded and symmetric real function that integrates to one $(\int K(u)du = -1)$.

We will use the Epanechnikov kernel here since it minimises the MSE. The kernel satisfies the Lipschitz condition[8], the regression function, $f(t, h)$, is at least twice continuously differentiable and bandwidth ($h$) must satisfy $h \to 0$ and $nh \to \infty$ as $n \to \infty$.

### *Estimating the standard deviation*

Local variances are assumed to be smooth and Lipschitz continuous of order $\gamma$, i.e. $\sigma^2(t) \in Lip\ _\gamma([0, 1])$, where $\gamma \in (0,1]$. In Equation (9), the standard deviation is estimated in two steps. First, the mean from Equation (9) is removed. A new series with mean zero and variance $\sigma\ (t_k)^2$ is then produced

$$\tilde{\sigma}^2(t_k) = \left( \sum_{j=-m_1}^{m_2} w_j y_{k+j} \right)^2, \tag{12}$$

where $w_j$ are weights that satisfy $\sum_{j=-m_1}^{m_2} w_j = 0$ and $\sum_{j=-m_1}^{m_2} w_j^2 = 1$ for some fixed $m_1, m_2 \geq 0$. In this case $m_1 = 1$ and $m_2 = 0$, so the weights are $\omega_{-1} = -\frac{1}{\sqrt{2}}$ and $w_0 = \frac{1}{\sqrt{2}}$. Second, the variance is estimated noting that

$$\tilde{\sigma}^2(t_k) = \sigma^2(t_k) + \tilde{\varepsilon}_k, \qquad 1 \leq k \leq n, \tag{13}$$

where the errors $\tilde{\varepsilon}_k$ form an $m_1 + m_2$-dependent sequence and $E[\hat{\varepsilon}_k] = 0$. Since Equation (13) has the form of Equation (9) the variance can be estimated as

$$\hat{\sigma}^2(t, h_{\sigma^2}) = \sum_{k=1}^{n} W_k(t) \tilde{\sigma}^2(t_k), \tag{14}$$

where $W_k\ (t)$ is given by Equation (11).

The estimated errors ($\varepsilon_k$) are defined as

$$\hat{\varepsilon}_k = \frac{y_k - \hat{\mu}(t)}{\hat{\sigma}^i(t)}. \tag{15}$$

### *Asymptotic properties of the estimated mean and the estimated variance*

The closeness of the estimator to its target is given in Müller and Stadtmüller (1987).

#### 4.1.1. *Confidence bands*

The 95 % confidence bands for the mean $\mu(t)$ will be calculated using the asymptotic formula of the variance described in Müller and Stadtmüller [32]:

$$\hat{\mu}(t) \pm 1.96 \hat{\sigma}(t) \sqrt{V / nh}, \tag{16}$$

where $V = \int_{-1}^{1} K(u)^2 du = 0.6$ for the Epanechnikov kernel and $\hat{\sigma}(t)$ is the standard deviation in Equation (9).

### *4.2. Modelling and estimating the common dynamic*

In what follows we will assume that the time-varying means of the macroeconomic series have a common dynamic: $\mu^{(i)}(t_k) = m^{(i)} + \alpha^{(i)} f(t_k)$. Let $y_t^{(i)}, (i = 1, \ldots, p)$, be the log of macroeconomic variable $i$ at time $t$. Then the hypothesis of a common dynamic yields the following model:

$$y_k^{(i)} = m^{(i)} + \alpha^{(i)} f(t_k) + \sigma^{(i)}(t_k) \varepsilon_k^{(i)}, \qquad k = 1, \ldots, n, \qquad i = 1, \ldots, p, \tag{17}$$

where $t_k = \frac{k}{n}, t_k \in [0,1], m$ and $\alpha$ are coefficients, the function $f(t_k)$ (the time-varying unconditional mean) is the state of the economy and $\sigma(t_k)$ is the varying standard deviation.

First the coefficients $m^{(i)}$ and $\alpha^{(i)}$ must be estimated. They are only identifiable up to a shift and scaling factor, so one of the $m$'s can arbitrarily be set to zero and the $\alpha$ set to unity.

One of the series will be taken as reference and be denoted $i_0$. Hence, $m^i{}_0 = 0$ and $\alpha^i{}_0 = 1$. Note that for $i \neq i_0$, Equation (17) can be rewritten as

$$y_s^{(i)} = m^{(i)} + \alpha^{(i)} y_s^{(i_0)} + \delta_s^{(i)}, \tag{18}$$

where the errors, $\delta^{(i)}$, are independent with zero mean and finite variance. The coefficients, $m$ and $\alpha$, can be estimated by OLS

$$\left(\hat{m}^{(i)}, \hat{\alpha}^{(i)}\right) = argmin_{(m,\alpha)} \sum_{t=1}^{n} \left(y_k^{(i)} - m^{(i)} - \alpha^{(i)} y_k^{(i_0)}\right)^2, \tag{19}$$

where $m$ and $\alpha$ minimise the sum of locally-weighted squared errors. If $m$ and $\alpha$ are allowed to be time dependent, the expression in Equation (19) is modified to read

$$\begin{aligned} &\left(\hat{m}^{(i)}(t), \hat{\alpha}^{(i)}(t)\right) = \\ &= argin f_{(m,\alpha)} \sum_{s=1}^{n} (y_s^{(i)} - m^{(i)} - \alpha^{(i)} y_s^{(i_0)})^2 W_s(t), \end{aligned} \tag{20}$$

where $W_s(t)$ are weights defined in Equation (11) that localise the estimation of $m$ and $\alpha$. In matrix notation, this is

$$\begin{pmatrix} m^{(i)}(t) \\ \hat{\alpha}^{(i)}(t) \end{pmatrix} = \begin{pmatrix} \Sigma_s W_s(t) & \Sigma_s y_s^{(i_0)} W_s(t) \\ \Sigma_s y_s^{(i_0)} W_s(t) & \Sigma_s |y_s^{(i_0)}|^2 W_s(t) \end{pmatrix}^{-1} \begin{pmatrix} \Sigma_s y_s^{(i)} W_s(t) \\ \Sigma_s y_s^{(i)} y_s^{(i_0)} | W_s(t) \end{pmatrix}$$

Next, the $y_k$'s are standardised by scaling them with the estimated $m$ and $\alpha$ to produce

$$z_k^{(i)} = \frac{y_k^{(i)} - m^{(i)}(t_k)}{\alpha^{(i)}(t_k)} + \frac{\sigma^{(i)}(t_k)}{\alpha^{(i)}(t_k)} \varepsilon_k^{(i)} = f(t_k) + \frac{\sigma^{(i)}(t_k)}{\alpha^{(i)}(t_k)} \varepsilon_k^{(i)}. \tag{21}$$

The z's have mean $f(t_k)$ and variance $\left(\frac{\sigma^{(i)}(t_k)}{\alpha^{(i)}(t_k)}\right)^2$. Next, we construct the linear combination, series $X(t)$, that has the smallest variance

$$X(t) = \beta(t)^T z_k, \tag{22}$$

where

$$\begin{aligned} \beta(t) &= \arg \min_{\beta \in \beta +} Var(\beta^T z_k) = \\ &= \arg \min_{\beta \in \beta +} \beta^T Var(z_k) \beta = \\ &= \arg \min_{\beta \in \beta +} \beta^T A^{-1}(t) \Sigma(t) A^{-1}(t) \beta \end{aligned} \tag{23}$$

and $\boldsymbol{\beta}$ must satisfy $\sum_{i=1}^{p} \beta^{(i)} = 1$, $\beta^{(i)} \geq 0$. $\Sigma(t)$ is the covariance matrix of the innovations in Equation (9) and $A(t)$ is the $\alpha$'s from Equation (17) organised as the diagonal matrix $A(t) = diag(\alpha^{(1)}(t), \ldots, \alpha^{(p)}(t))$. Solving the minimisation in Equation (23) yields

$$\beta(t) = \frac{1}{1^T A(t) \Sigma^{-1} A(t) 1} A(t) \Sigma^{-1} A(t) 1. \tag{24}$$

The $\beta$'s represent the contribution to $X(t)$ of each macroeconomic series. Note that $X(t)$ has the expectation $f(t_k)$.

The series $X(t)$ has a time-varying mean and the noise added to it has the smallest variance possible. When estimating the mean of the first difference of the $X(t)$ series (denoted $\Delta X(t)$), we use Equation (9) with $y_k = \Delta X(t)$.

$$\Delta X(t) = g(t_k) + \sigma_{\Delta X}(t_k) \eta_k, \quad k = 1, \ldots, n, \tag{25}$$

where $g(t_k)$ is the mean and the errors $\eta_k$ are assumed to be independent and identically distributed with zero mean and unit variance.

We estimate $g(t_k)$ using

$$g(t_k)\sum_{k=1}^{n} W_k(t)\Delta X(t). \tag{26}$$

A positive mean, $g(t_k) > 0$, will be interpreted as an expansion period and a negative mean, $g(t_k) < 0$, as a recession. Furthermore, if a recession is followed by a period with a mean very close to zero (a stagnation), that period is also part of the recession.

## 5. Results

### *The macroeconomic series*

We computed the autocorrelation of the growth rates to investigate the relationship between the observations within the series. The autocorrelations, with 95% confidence bands, are shown in Figure 8. We can see that we have some autocorrelation in the first series, the GDP, and since the plot shows high values at fixed intervals we probably have some seasonality left in the series. Figure 9 displays the cross-validation function of the four series. Bandwidths $h_1 = 6$, $h_2 = 3$, $h_3 = 2$and $h_4 = 3$ were used when estimating the means of the individual series and bandwidth $h$ =10 when estimating standard deviations. Figure 10 shows the first difference of the estimated means for the series together with 95% confidence bands. From this, compared with Figure 2, we now see a much clearer signal of the series since the noise is reduced. We see that some series show negative values in the late 1970s and the early 1980s. Furthermore, all series have a negative growth rate in the early 1990s and two of them in the late 2000s.

Figure 11 shows autocorrelations of the estimated residuals and of their absolute values from the estimation using Equation (9) with 15 lags and 95% confidence bands. The first lag autocorrelations are quite small (compared with the autocorrelation of the first lags in Figure 8), indicating that Equation (9) seems to fit well, representing valid assumptions.

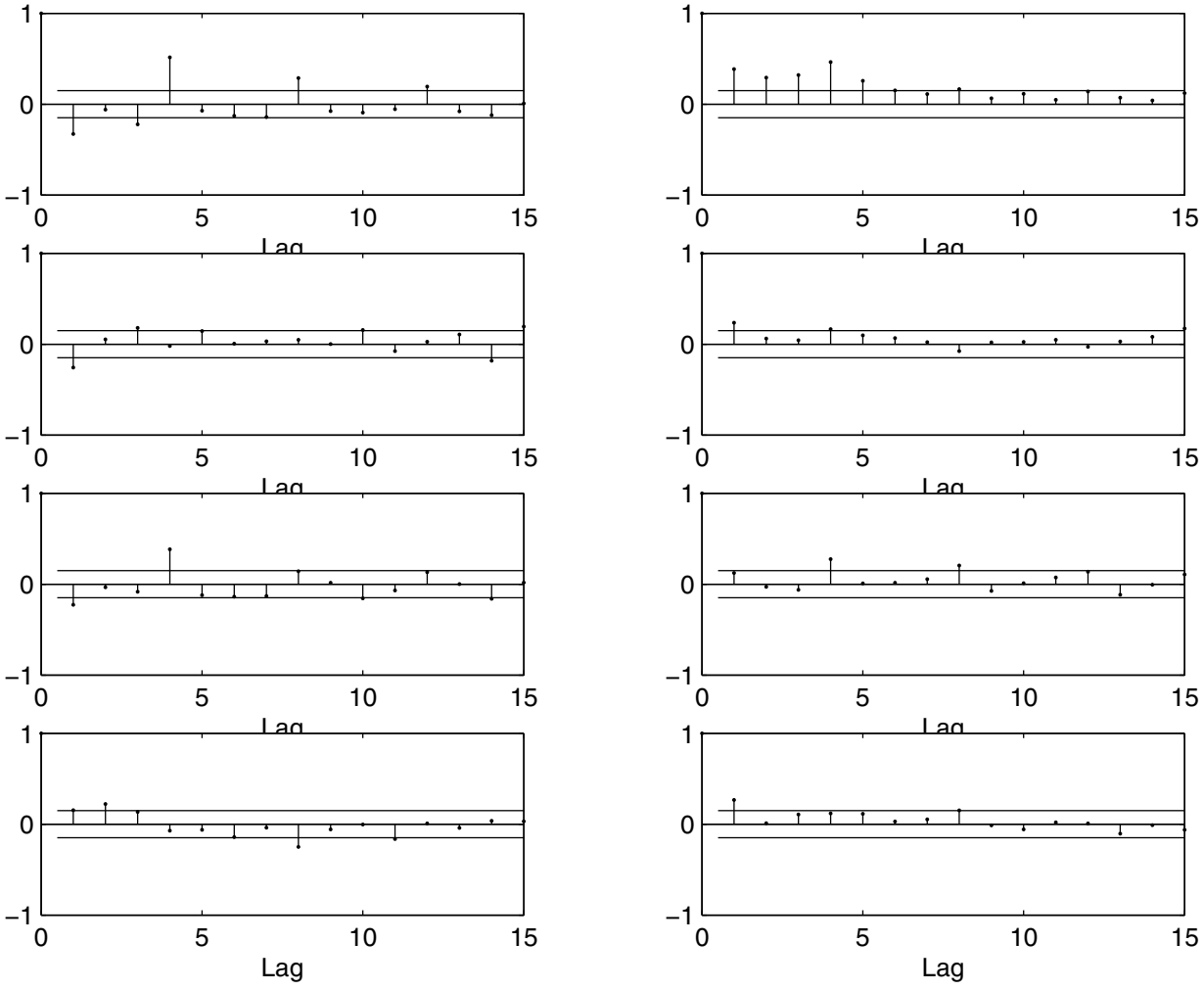
### *The common dynamic*

Retail trade was designated $i_0$, yet the final results are practically the same if we choose any of the other series. The rest of the $\hat{m}(t)$ and $\hat{\alpha}(t)$ coefficients were estimated with Equation (20), using bandwidth 30. A bandwidth of 20 or 35 did not make a major difference in the results. The logarithmic series minus their first value are shown in (a) in Figure 12, (b) shows the estimated coefficients $\hat{\beta}(t)$, which indicate how much each series was contributing when building $\hat{X}(t)$, (c) coefficients $\hat{\alpha}(t)$ and (d) coefficients $\hat{m}(t)$. The method used here for finding the common dynamic of the four series clearly works, as indicated by the $\hat{m}$'s and $\hat{\alpha}$'s, which changed over time, albeit slowly.

The estimated coefficients $\hat{\beta}(t)$, from Equation (24), indicate that the contributions of each series varied over the study period. In the beginning of the period, three of the series follow each other. In this period the $\hat{\beta}$ value for these series is around 0.3. The series that does not follow the others is industrial production, therefore $\hat{\beta}(t)$ is small during this period and the other three series will alone contribute to building $\hat{X}(t)$. The top graph in Figure 13 shows standardised standard deviations of the four series and the bottom shows the standard deviation of $\hat{X}(t)$. From this we can see that the standard deviation is kept small for $\hat{X}(t)$.

Looking at the series in Figure 1 or Figure 2, it is hard to see any common dynamic. However, after the standardisation, as we will show below, it is simpler to reveal the ups and downs and that they move together during some periods.

Figure 8. **The autocorrelation of the growth rates (left) and their absolute values (right) together with 95% confidence bands: GDP, industrial production, households disposable income and retail trade**

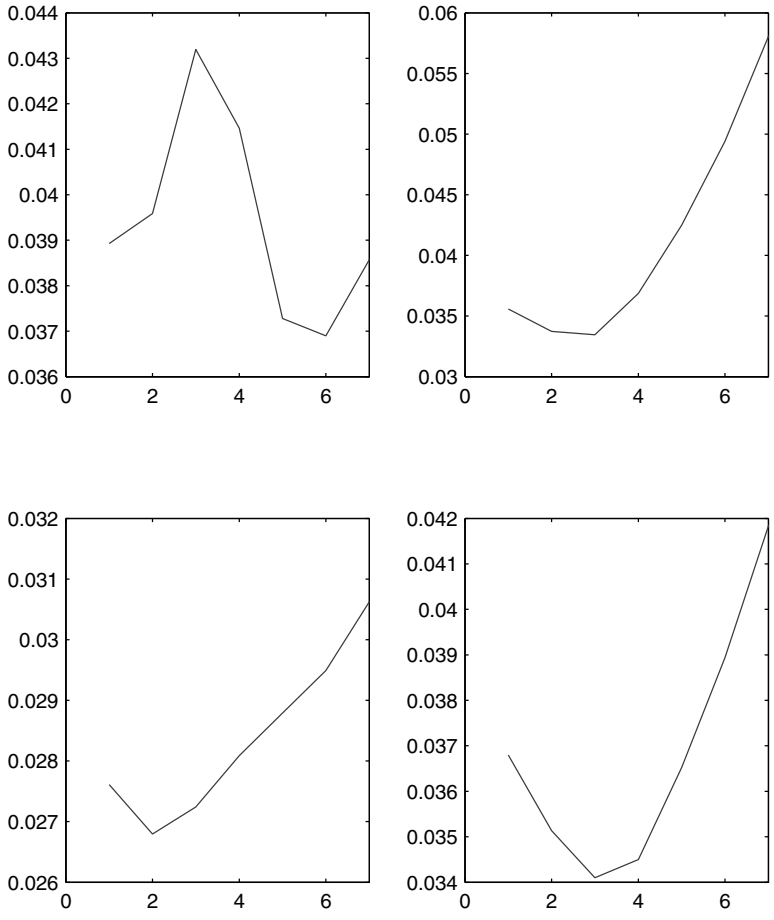



*The business cycle*

Figure 14 shows the autocorrelation, with 95 % confidence bands, of the residuals and their absolute values when estimating Equation (25). We find no evidence of autocorrelation. The $\hat{X}(t)$ series and the first difference, $\Delta\hat{X}(t)$, are shown in the top and middle graph in Figure 15. A positive slope of the common dynamic indicates an upswing in the economic activity and a negative a downturn. The bottom graph in Figure 15 shows the estimated business cycle, $\hat{g}(t)$, from Equation (25), with 95 % confidence bands, using bandwidth $h = 6$. It indicates five recessions between 1969:Q1 and 2013:Q4. If we compare the middle graph in Figure 15 with the bottom graph in the same figure, it is easy to see the effect of our smoothing technique, i.e. it reduces irregularities and provides a clearer view.

Had we only used GDP to date the business cycle, the result would have been different. Figure 10 (top) shows the series that would have indicated our business cycle. As can be seen, GDP would have indicated a recession in the early 1980s and in the early and mid 1990s. However, the confidence bands are never below zero, except for two quarters in the early 1980s, so it would have been difficult to claim a recession at all using only GDP. Using

Figure 9. **The cross-validation functions for four series: GDP and industrial production (top row); households disposable income and retail trade (bottom row)**




only GDP, one could also say that since the confidence bands are so wide, it all looks like stagnation. Table 2 shows the results using all four series with the peaks and the troughs. These dates are also the shaded areas in Figure 2, 10 and 15.

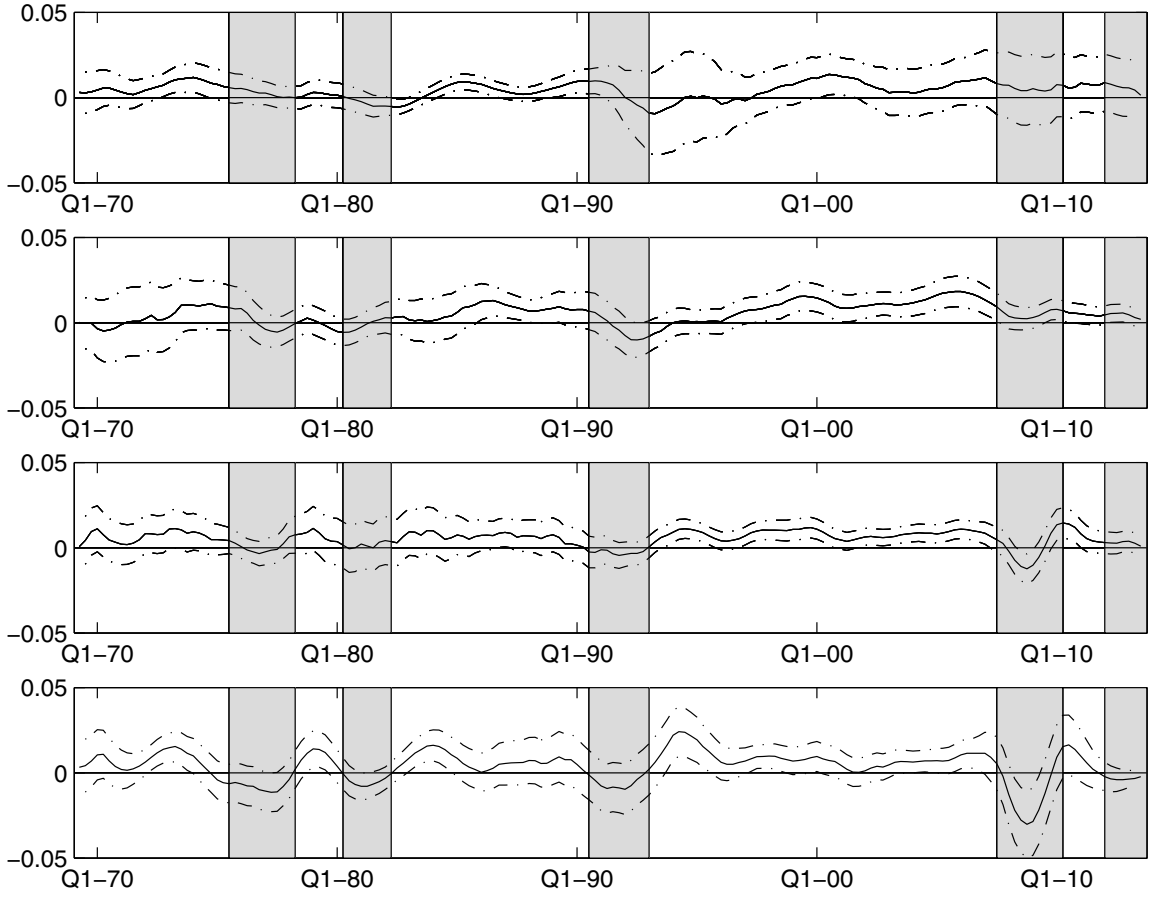
Note that the time series stops in 2013:Q4, so we can not tell when the 2012 recession ended.

Comparing the dates in Table 2 with those found by Christoffersen in Table 1, we see that he also found recessions in the mid 1970s, early 1980s and early 1990s. Unlike us, Christoffersen found a recession in 1971-72 and 1985-86. However, he used a different definition and only looked at industrial production. Figure 2 shows that the growth rate of industrial production was negative in these periods and the smoothed series in Figure 10 is negative or near zero, which may explain his results.

Comparing our dates with those found by Edvinsson (2005), we see that he also found recessions in the mid 1970s, early 1980s and 1990s. Similar to the recession periods discussed in Brinca (2013), we find the same recessions in the early 1990s and from 2008 as shown in Table 2.

In the top graph in Figure 13, the standard deviation of the series is plotted. We can see that it is larger for *GDP* than for $\Delta\hat{X}(t)$ in the mid 1990s. This is why the confidence bands

Figure 10. **The first difference of the mean $\hat{\mu}(t)$ estimated using Equation 9: GDP, industrial production, households disposable income and retail trade**




*Note:* Shading indicates recession periods.

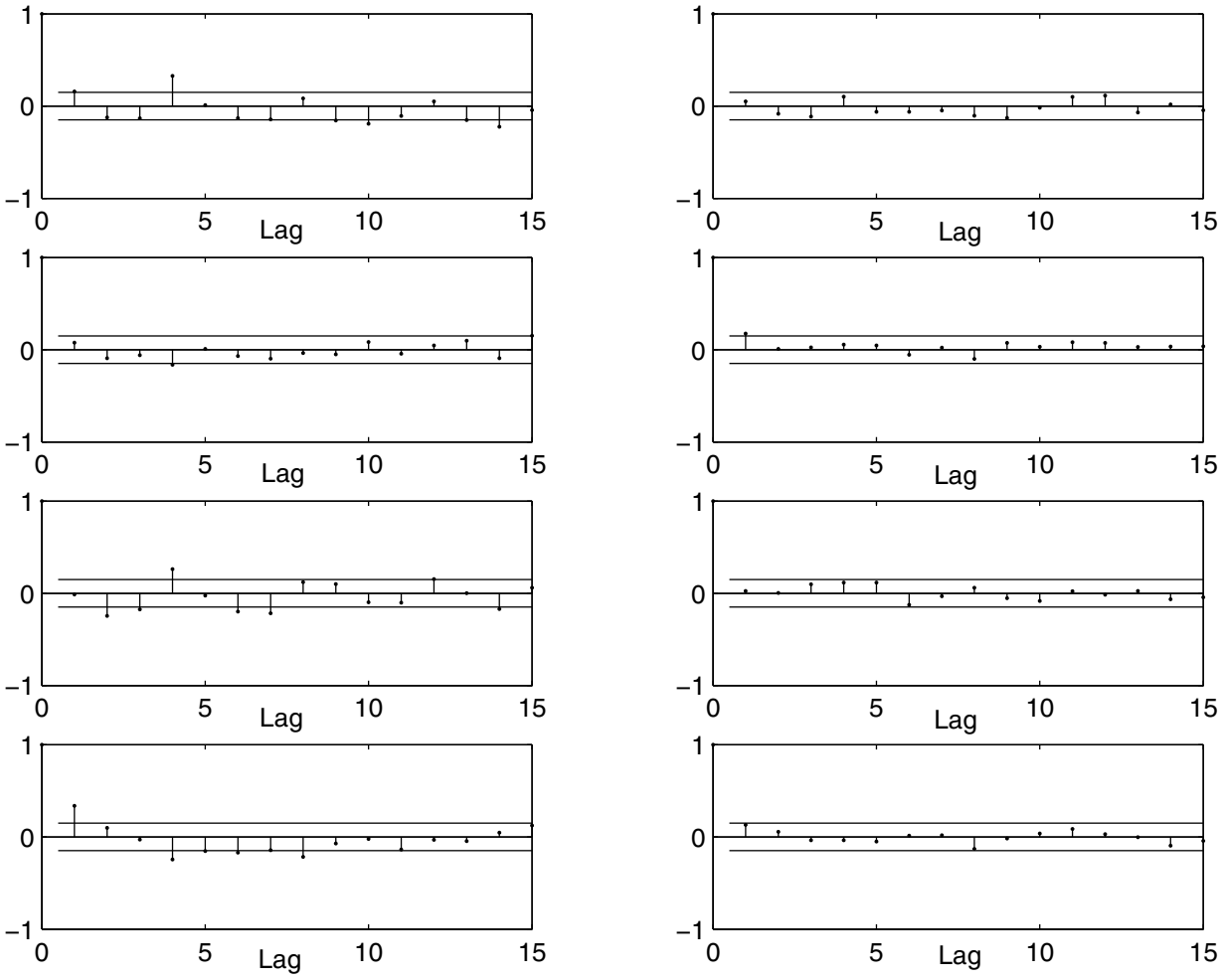
are so wide for GDP in Figure 10 during this period. In the bottom of Figure 13 we find the standard deviation for $\Delta\hat{X}(t)$. Retail sales took a deep dive during the deep recession in 2008-10, affecting the standard deviation during this period. Comparing this with the same period in Figure 15, we see the wide confidence bands during these years.

## 6. Conclusions

Activity in industrialised economies alternates between periods of economic growth and economic contraction, the so-called business cycle. The business cycle is a representation of what is going on in an economy and is therefore an important state of a region. Government policies and investment decisions require acceptable knowledge of the state of the economy. A model that can forecast recessions can be a valuable instrument for policy makers, and dating the business cycle is the first step in creating models to predict the business cycle.

Business cycle dating refers to the ex-post dating of the start and the end of a recession in an economy. The aim of this paper was to apply a non-stationary, non-parametric business cycle dating method on Swedish data where no official dating exists. We used data from 1969:Q1 to 2013:Q4 and found recession dates from the common dynamic of four macroeconomic time series: GDP, industrial production, households

Figure 11. **Autocorrelation of estimated residuals of the four series in Equation 9 $\hat{\varepsilon}_k$, (left column); autocorrelation of the absolute values of the estimated residuals together with 95% confidence bands (right column): GDP, industrial production, households disposable income and retail trade**




disposable income and retail trade. This dating is useful in economic cyclical analysis as it can reveal when a recession happened and what caused it. Knowledge that in turn may help prevent or limit the duration of future recessions. The dates obtained could be used in forecasting methods for an upcoming recession in Sweden. Knowing in advance the future movements in economic activity could be very important from a policy perspective. If recessions can be predicted, monetary policy can respond and avoid an output gap or fall in inflation.

Five recessions in the study period were found. Had we only used GDP in this approach, we would have found only two recessions and would furthermore have got the impression that the economy was stagnant throughout the study period since the confidence bands are so wide. Using a non-parametric smoothing technique, we revealed more from the data than would have been possible by merely studying the ups and downs of the individual series.

Figure 12. **(a) The series; (b) the time-varying coefficient $\hat{\beta}(t)$; (c) the time-varying coefficient $\hat{\alpha}(t)$; (d) the time-varying coefficient $\hat{m}(t)$**

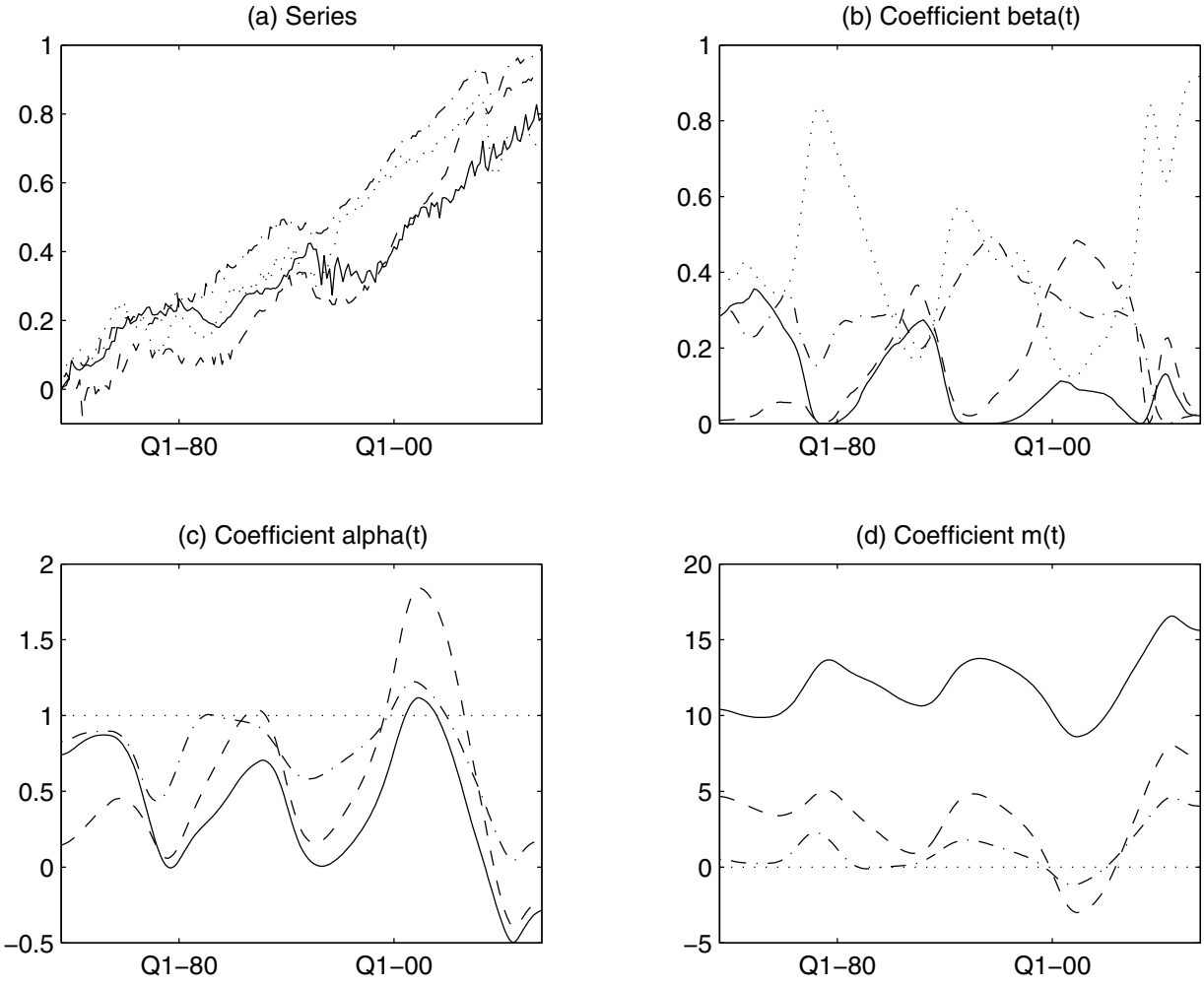


Figure 13. **Estimated standard deviations ($\hat{\Sigma}(t)$) of the four series in Equation 9 (top), and the standard deviations, from estimating Equation 25 $\Delta(t)$](bottom)**

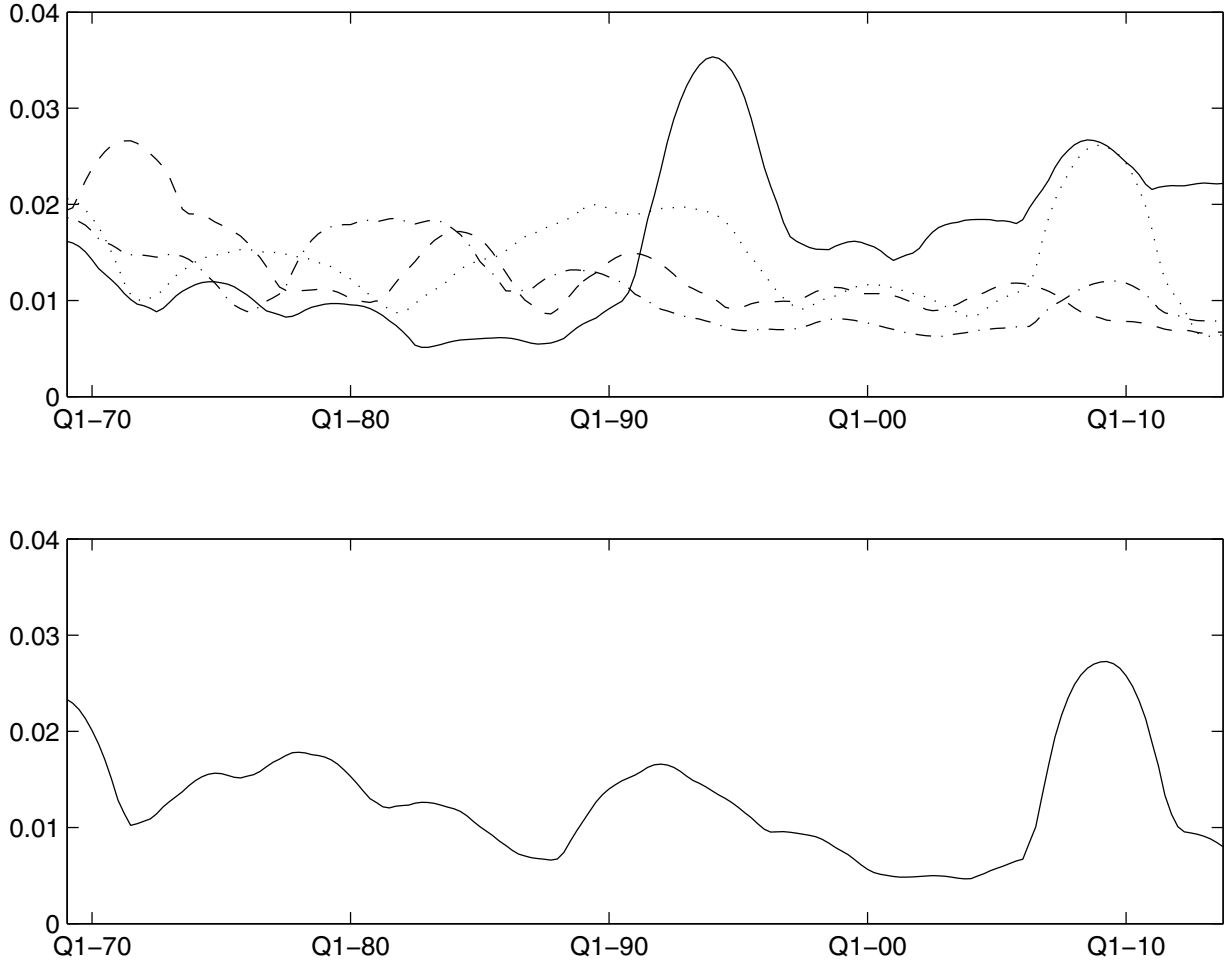



Table 2. **The peaks and troughs identified by the procedure with all four series**

| Estimated business cycle using all four series | |
|---|---|
| Peak | Trough |
| 1976:Q1 | 1978:Q2 |
| 1980:Q4 | 1982:Q4 |
| 1991:Q1 | 1993:Q1 |
| 2008:Q1 | 2010:Q2 |
| 2012:Q3 | - |

Figure 14. **Autocorrelations of the residuals from estimating Equation 25 (top) and their absolute values (bottom)**

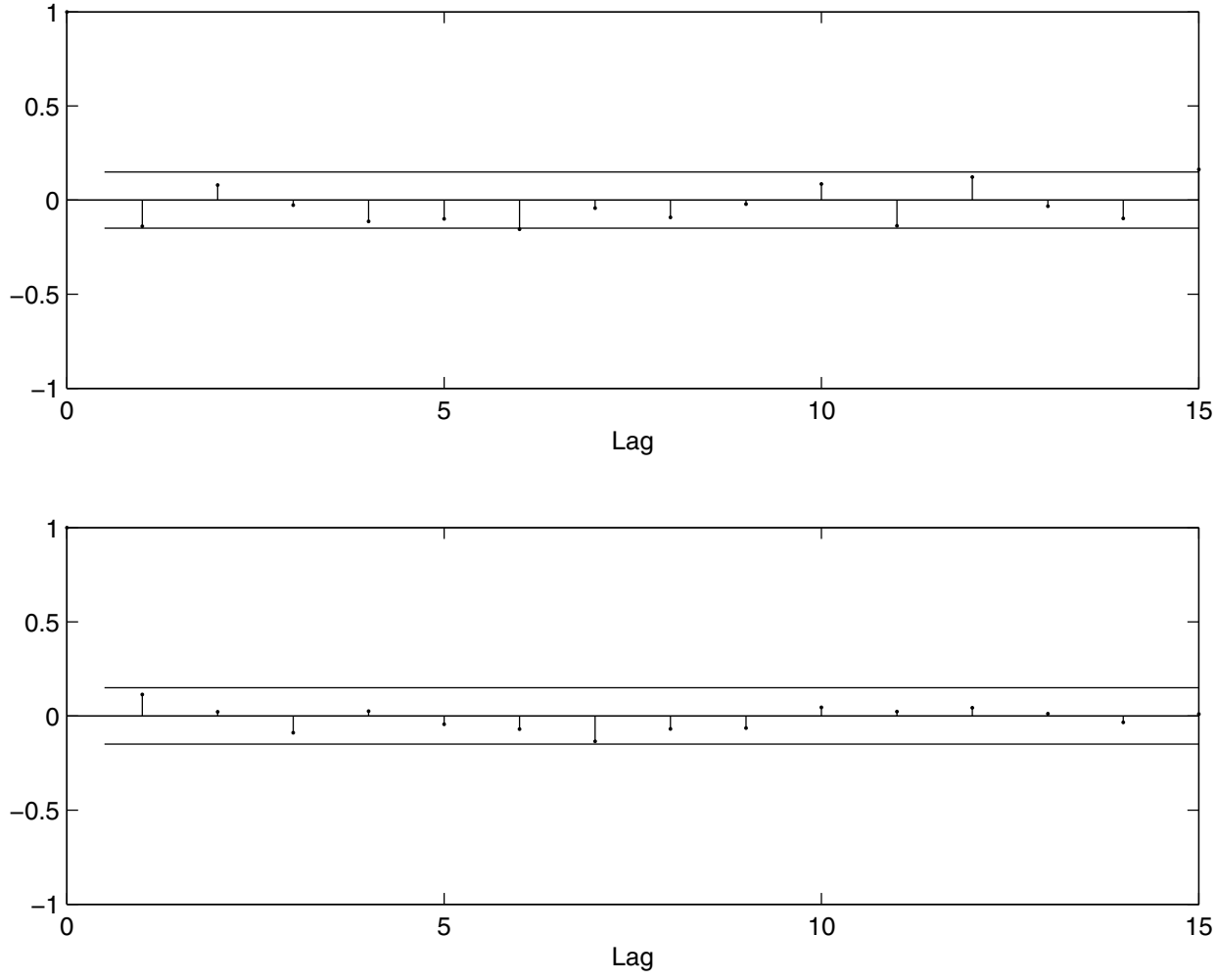
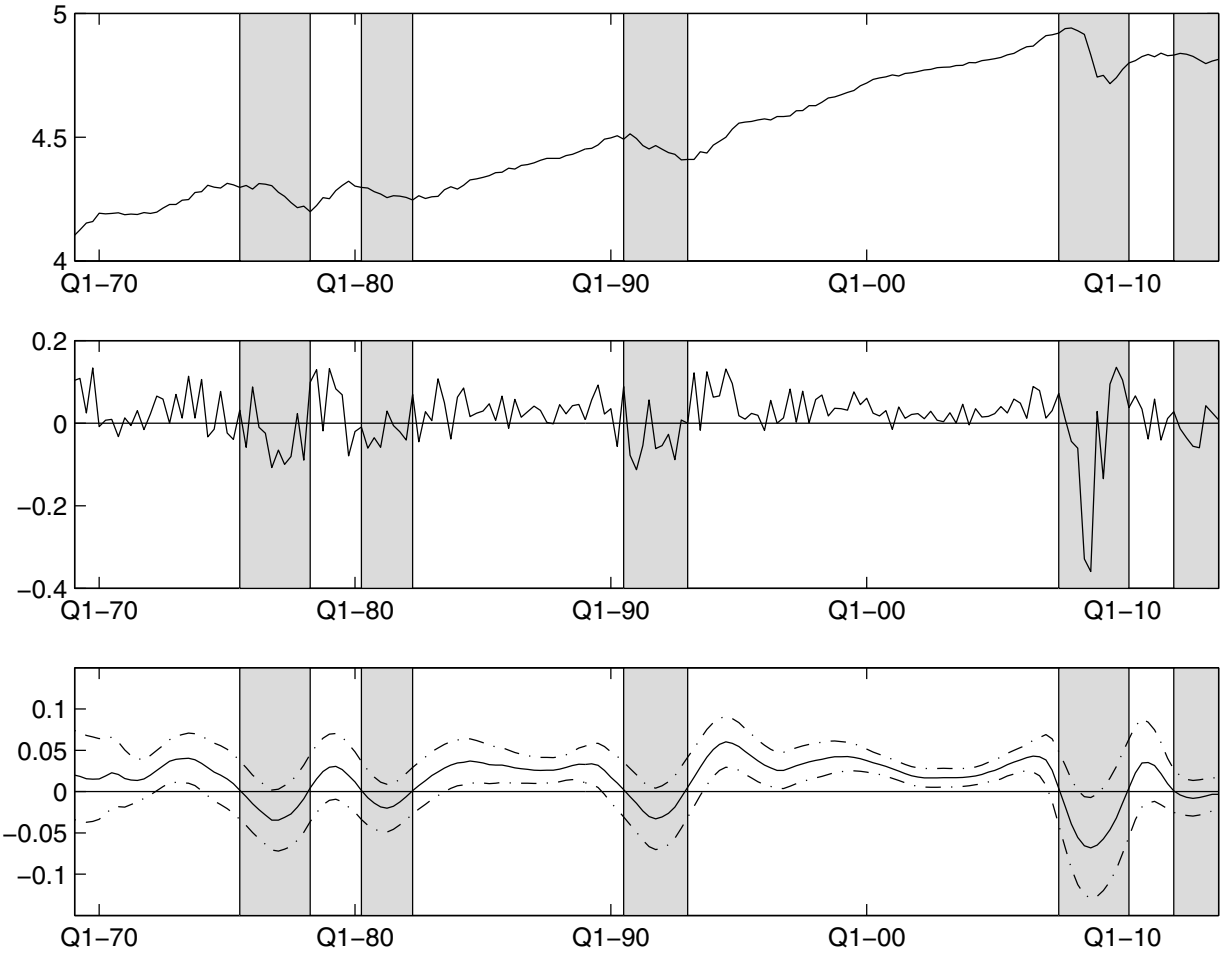


Figure 15. **The $\hat{X}(t)$ series calculated with Equation 22 (Top); the first difference of the $\hat{X}(t)$ series (middle); the estimated business cycle (bottom) for Sweden during 1969:Q1-2013:Q4 with 95 % confidence bands using all four series**




*Note:* Shading indicates recession periods.

### *Notes*

1. *www.cepr.org*.
2. The definition of a growth cycle is the deviation of the reference series to the trend.
3. The definition of a classical cycle is a series in level. A peak is represented by a maximum in the level of the series and a trough is indicated when the series has reached its lowest value and is increasing again.
4. *www.nber.org*.
5. Retail trade includes all merchandise sold for personal or household consumption and incidental services.
6. Industrial production includes total output from factories and mines.
7. See Härdle (1990) and Wand and Jones (1995) on smoothing techniques for curve estimation.
8. Lipschitz continuity, named after Rudolf Lipschitz, is a smoothness condition for functions that are stronger than regular continuity.

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# Reverse-engineering the business cycle with Petri nets

*by*
Johnnie B. Linn III*, **

*Petri nets are used to extract information from the complex and negative eigenvalues of a von Neumann model employing the US sector-level use tables from 1997 to 2013. The complex eigenvalues show a cyclical component having a period of about 10 years. Sectors that contribute most to the cyclical component are agriculture, mining, retail trade, construction, and utilities. Negative eigenvalues indicate the instability in the economy from 1997 to 2009. In 2010 a Neimark-Sacker bifurcation boundary is crossed, beyond which the economy exhibits damping. The point of critical damping is approached in 2012. In 2013 the economy exhibits over-damping.*

*Keywords: Petri net, von Neumann growth model, Leontief model, eigenvalue, business cycle, use table, Neimark-Sacker bifurcation, over-damping*

*JEL classification: C65, C67, E32*

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** This research would not have been possible except for the availability of the Bluebit Online Matrix Calculator, which can handle matrices of up to 32 rows and 32 columns, precisely the size needed for this model.

## 1. Introduction

This paper offers a decomposition of the business cycle at the sector level for the United States from 1997 to 2013, on a year-to-year basis, using the von Neumann growth model. The unique contribution of this paper is not to find the long term growth path, but to identify what causes evolution of the economy from one year to the next.

Von Neumann (1937, 1945) showed that if all possible production technologies are known, and there is a proportional growth rate in production of all commodities, and the rate of return, or profit, is the same in all industries, and all profits are reinvested, there exists a solution set of quantities produced where the rate of growth and the return on capital is the same. To assure the proportional growth rate, he assumed that all production technology coefficients were positive (meaning that all inputs made a contribution to each output) and that all quantities produced were nonnegative.

In matrix form, the vector of total output by commodity and the vector of rate of return by industry are the right and left eigenvectors, respectively, of the matrix product of the input coefficient matrix and the inverse of the output coefficient matrix employed in the Leontief input-output model (van Schaik, 2002). If this product has all positive elements, the Perron-Frobenius theorem holds that the matrix has only one eigenvalue that has all positive elements, that it is the largest, and that it is unique. This eigenvalue, the Frobenius eigenvalue, expresses the growth rate to which the von Neumann problem converges.

The second eigenvalue has been shown to control the speed of convergence to the long-term growth path (Bródy, 1997).

As the computation cost of eigenvalues decreases, authors have shown more interest in the complete eigenvalue solution sets, or spectra. Bródy offered a conjecture that the speed of convergence to the long term growth path increased as the square root of the dimension of the input-output matrix, based on properties of randomly-generated input-output matrices. A desire to test the conjecture led to analysis of observed input-output matrices. Mariolis and Tsoulfidis (2014) computed complete spectra for the benchmark years 1997 and 2002 for the United States, for which years input-output matrices of several sizes were available. Their results did not support Bródy's conjecture. Steenge (1990) computed and examined spectra of the characteristic matrix for forward looking or backward-looking Leontief models to account for instabilities in these models. He computed complete eigenvalue sets for the earlier work done by Leontief (1953) for the United States, Tsukui (1968) for Japan, and Meyer and Schumann (1977) for Germany.

This paper takes a different approach. The von Neumann process is a self-replicating machine. One year's production and consumption contains the information necessary to bring the machine to the start of the next year's production. In a one-year period, none of the eigenvalues are to be discarded, for there is not sufficient time for them to die out. If there are cyclical components in the von Neumann process, here meaning those that are not an integer multiple of years in duration, each year's production should show a phase angle that indicates the machine's advancement in its course, or precession, in the

one-year period. To find this change of angle we look for complex eigenvalues. Also, if there is instability in the system, some evidence of that instability should manifest itself in a one-year period.

Since we do not need to find the long term growth path, we do not require the eigenvectors to be strictly positive nor do we require the characteristic matrix to be semi-positive or decomposable. Thus we can use the raw use tables, some of whose elements are negative, without further modification.

Petri nets are used to model the creative and destructive processes implied in the use tables. For each year the complex eigenvalues and their associated eigenvectors are found. The sectors that account for the largest eigenvector components drive the cyclical variations.

### *1.1. Outline of the paper*

Petri nets are introduced, and a Petri net model for cyclical models is set up. A worked example for a cyclical IS-LM model is given. The Petri net model for the von Neumann process is developed. Results are generated for 1997-2013 from input-output data. A test of significance for the results is made. Accommodation is made for systematic error having generated negative eigenvalues in the results.

A decomposition of systematic error and cyclical variation is made by use of the centre manifold theorem. A Neimark-Sacker bifurcation boundary appears to have been crossed in 2010. Analysis is made of resonances that manifest themselves near this boundary.

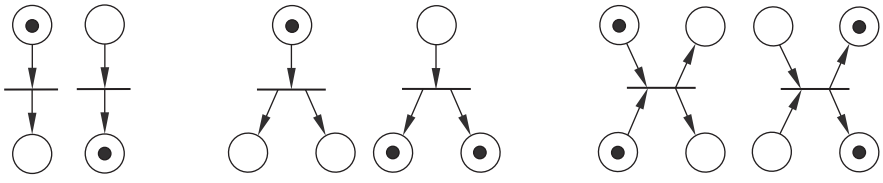
The paper ends with concluding remarks and notes for future work.

## 2. Petri nets

Petri nets are represented among forms of business process modelling (BPM) notations along with Integrated Definition (IDEF), United Modeling Language (UML) activity diagrams, role activity diagrams, and event-driven processing chains (Letsholo et al., 2014). Utama (no date given, TPQ 2013) places Petri nets in a group among operational models including system dynamics/stock flow diagrams, state diagrams, and workflow. His paper shows various macroeconomic models expressed as causal loop diagrams and stock-flow diagrams.

An overview of Petri nets is given in Murata (1989). Petri nets are bipartite directed graphs, having two kinds of nodes: places and transitions, represented by circles and bars respectively, and directed arcs, represented by arrows. Each arc links a place to a transition or a transition to a place. Places can hold tokens, represented by dots, and all the tokens in the net constitute the marking, or state, of the net. A transition cannot be fired if it has input places not occupied by tokens. When a transition is fired, tokens are removed from places that are linked by an incoming arc to that transition and are added to places to which are linked with an outgoing arc. In Figure 1, the left transition in each pair is enabled to fire and the right transition in each pair shows that transition after firing.

Figure 1. **Petri nets before and after firing.**



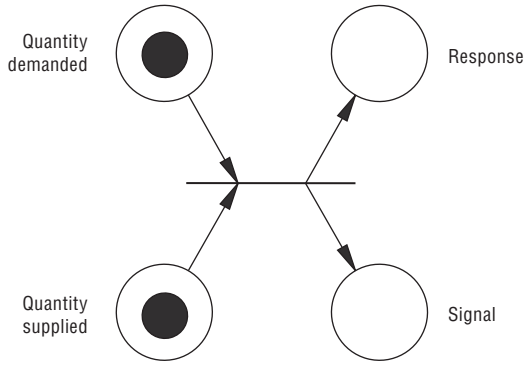
Arcs can exist in multiples. For a transition with a multiple in an incoming arc, the corresponding multiple of tokens must be available in its input place for the transition to be enabled. Multiple output arcs deliver the corresponding number of tokens to their output places.

A transition is represented as a row in an adjacency matrix whose columns represent places and whose rows represent transitions. The number of arcs from an input place is designated by the appropriate negative integer and the number of arcs to an output place is designated by the appropriate positive integer. The adjacency matrices for the three transitions in Figure 1, ordering the places from left to right in successive rows downward, are [-1 +1], [-1+1+1], and [-1+1-1+1].

### *2.1. An example of an agent-based model component expressed as a Petri net*

A Petri net for a market is shown in Figure 2. In this example, when a token leaves a place, the quantity or signal represented by that place is made use of by agents involved in the transition, but we, as onlookers, do not necessarily know what that quantity or signal is. When a place receives a token, a new quantity or signal appropriate to that place is generated, and what that quantity or signal is we do not necessarily know.

Figure 2. **Petri net for a market with agents**




The transition is enabled when quantity demanded and quantity supplied are specified. When the transition is fired, a response variable is generated, which is a quantity sold during the movement of the market toward the clearing price. The response variable does not necessarily clear the market. Also, a signal is generated whose sign depends on whether the market condition when fired is a surplus or shortage. The transition models the behaviour of the market but imposes no specific forms for the demand function or supply function. The transition also places no constraint on what agents may be involved. In a surplus market the signal might be given by sellers and in a shortage the signal might be given by buyers, or the signaller may be a third party who is recording and transmitting information about the transactions.

### *2.2. Algebraic representation of Petri nets*

The marking of a Petri net can be represented by a vector and a sequence of firings of the net can be represented by the equation

$$M_t = M_0 + A' \sum_{i=1}^{t} U_i \qquad (1)$$

where $M_0$ is the initial marking, $M_t$ is the marking after the $t^{th}$ set of firings, $U_i$ is the set of transitions fired in the $i^{th}$ set of firings, and A is a real adjacency matrix whose rows represent transitions and whose columns represent places. When a transition is fired, the number of tokens taken from each of its input places and delivered to each of its output places is determined from the magnitudes and signs of the elements for that transition's row in A.

### *2.3. Decomposition of the Adjacency Matrix*

For the purposes of this paper, the adjacency matrix will be expressed as a sum,

$$A = N + B \tag{2}$$

where N is A with its entries for output places suppressed, and B is A with its entries for input places suppressed. We will specify the initial marking as

$$M_0 = -N' \sum_{i=1}^{t} U \tag{3}$$

This marking seeds the input places of each transition with the precise set of tokens needed to enable that transition. Thus, all the transitions in the net are fireable.

### *2.4. Modification of the firing rule*

The firing $U_i$ of each transition will be here represented by a complex number, rather than an integer, and each input token will have a "denomination" – a modulus and phase angle – that matches the complex number. The output tokens will have the same denomination as the input tokens. The firings themselves are instantaneous, but duration of a process will be imputed by assigning separate transitions to its beginning and ending and ascertaining the intervening change of phase angle. The phase angle for a firing represents a "time" stamp for the firing, falling somewhere on the arc spanned by $[-\pi, \pi]$.

A petri net that uses this firing rule is a kind of coloured Petri net. A "colour" in a coloured Petri net is information, such as a time of firing, carried on tokens or other components of the net (Jenson, 1981). Because visible light encompasses an almost complete "octave" of colour (Westland et al., 2012), the phase angle of a firing can be visualized as having a particular hue on a colour circle. The modulus can be visualized as the degree of saturation of the hue. The visualization of a firing is then the disappearance of tokens of a particular colour from the input places and appearance of tokens of the same colour in the output places.

Tokens involved in a particular firing are not reused. The initial marking will contain tokens of all the denominations required for the complete round of firings. Technically, then, the initial marking and subsequent markings are no longer vectors but collection of multisets, but since we do not observe a marking in isolation but always involved with a transition from another marking, we will see their differences represented only as vectors. Equation (3) will guarantee that each transition has the correct "change" in its input places necessary for a firing at the time called for in the solution of the model. The denominations, or saturations and hues, of the firings are the unknowns that will be solved for in the model.

### *2.5. Reverse-engineering a sequence of firings*

Equation (1) shows how a final set of variables, $M_t$, arises from an initial set, $M_0$. We seek to find the corresponding dual relation that shows how a final set of events, $U_t$, can arise from the initial set, $U_1$. An event is associated with a firing. In each firing, at least one

token is delivered to an output place. We keep a tally of firings by counting the new tokens created by each. The difference in the markings after and before each firing, pre-multiplied by B, gives us a count of tokens created. When adjusted for instances where more than one output place receives tokens in a firing, or when there are multiple output arcs, the count of tokens gives us a count of the firings.

Starting with the last set of firings,

$$U_t = \rho B(M_t - M_{t-1}) - C_t \tag{4}$$

where $U_t$ is the set of firings for time t, $\rho$ is a real normalizing factor whose purpose is described below, and $C_t$ is a vector of constants that ensure that no changes are made by the firings to any other elements of U other than $U_t$. The function of $C_t$ is like that of a constant of integration, except that here it is a vector. The magnitude of $C_t$ is a function of the number of output places of transition t, that is, the degree of connectivity of transition t to the other transitions in the net. As other transitions will have varying degrees of connectivity, their respective elements of C will likewise have varying magnitudes. As we intend to match the magnitudes of the elements of U to their corresponding elements of C, the elements of U will have varying magnitudes. What $\rho$ represents is the degree of connectivity of the entire set of firings, and it is used to normalize the combined elements of C to match the magnitude of U.

Working backward,

$$\begin{aligned} &U_{t-1} = \rho B(M_{t-1} - M_{t-2}) - C_{t-1} \\ &\ldots \\ &U_1 = \rho B(M_1 - M_0) - C_1 \end{aligned} \tag{5}$$

Then summing over all elements of U,

$$\sum_{i=1}^{t} U_i = \rho B(M_t - M_0) - C \tag{6}$$

Now, making use of Equation (1), we have

$$\sum_{i=1}^{t} U_i = \rho BA' \sum_{i=1}^{t} U_i - C \tag{7}$$

or

$$(I - \rho BA') \sum_{i=1}^{t} U_i = -C \tag{8}$$

This equation is similar in form to the Leontief generalized production model where U is a set of commodities produced to meet a final consumption vector C, but here, since we are looking backward in time, we have a set of events U that arise from an initial condition set C.

### *2.6. When the Sequence of Events is a Cycle*

We are looking for cyclical solutions, so we limit ourselves to solutions for U that are replications of themselves, subject only to the possibility of a change of phase angle, so we set

$$C = \nu \sum_{i=1}^{t} U_i \tag{9}$$

where $\nu$ is a complex number whose modulus is unity. When equation (9) is substituted into the right hand side of Equation (8), we obtain

$$(I - \rho BA') \sum_{i=1}^{t} U_i = -\nu \sum_{i=1}^{t} U_i \tag{10}$$

which indicates that the negative of ν is the eigenvalue of the matrix in parentheses on the left hand side. Rearranging, we obtain

$$[(1+\nu)\mathrm{I}-\rho\mathrm{BA}']\sum_{i=1}^{t}\mathrm{U}_i = 0 \tag{11}$$

or

$$(\lambda\mathrm{I}-\rho\mathrm{BA}')\sum_{i=1}^{t}\mathrm{U}_i = 0 \tag{12}$$

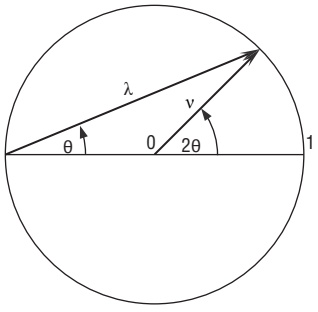
where

$$\lambda = 1+\nu \tag{13}$$

and λ is itself an eigenvalue, of the matrix ρBA′. The modulus of λ varies in proportion to the value of ρ, but changing ρ does not change the angle of λ. So the angle for λ can be found with any convenient assumed value for ρ.

Figure 3 shows how the angle of precession, or alibi, for ν can be deduced from the angle for λ.

Figure 3. **The ν and λ vectors and their phase angles**




From Equation (13), ν originates from the origin and λ originates from (-1, 0). By the inscribed angle theorem, angle θ, the alibi for λ, generates an alibi of twice that value for ν. The modulus of λ starts at a value of 2 but diminishes to zero, and in the process pulls ν around the upper half of the unit circle. The imaginary components of ν and λ are the same, so for a given unscaled non-zero λ of modulus *E*, the magnitude of its scaling factor is the ratio of the imaginary components of ν and λ or

$$\rho = \frac{2\cos\theta}{E},\ \theta < \frac{\pi}{2} \tag{14}$$

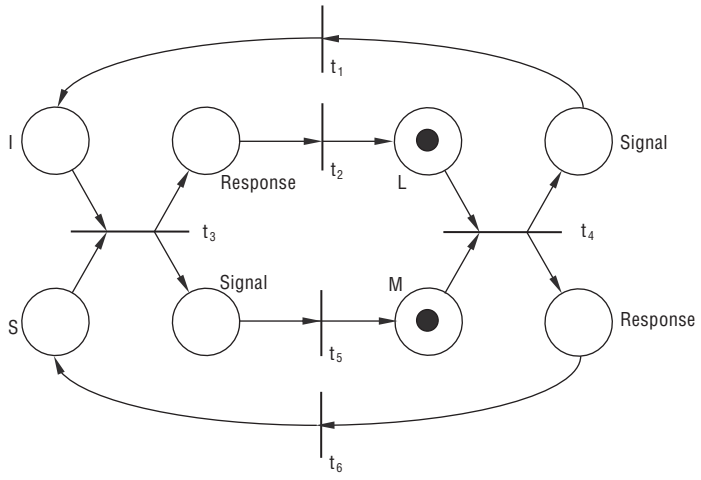
From Equation (12), the adjacency matrix A is never of full rank, so BA′ will never be of full rank, so there will always be at least one zero value of λ or negative unit value of ν. If λ is zero, a phase angle is not defined for it.

## 3. Worked example: An agent-based IS-LM model

In the following, we define a "round" as one set of firings, each transition fired once, and a "cycle" as the time interval between a round and the next round of the same set of firings. An IS-LM model with six sets of agents is shown in Figure 4.

On the left side of the net, the interaction of savers and investors in the bond market ($t_3$) generates a flow of investment funds that, through the investment multiplier, will affect the demand for liquidity in the market for money balances on the right side of the

Figure 4. **An agent-based IS-LM model**




net ($t_2$). Also, producers send an inventory adjustment signal to the controllers of the money supply ($t_5$). On the right side, a difference between liquidity demand and money supply in the market for money balances ($t_4$) will cause households to adjust their bond holdings, changing the quantity of bonds demanded in the bond market ($t_6$). Also, an interest rate signal will be sent to the supply side of the bond market ($t_1$). The net is marked to enable the set of firings associated with the first complex eigenvalue. All the transitions are enabled but the markings that enable the others are not shown.

This model has six eigenvalues of $\lambda$ for BA′. The numbers shown here are generated by the bluebit.gr eigenvalue algorithm. The eigenvalues are 3, 1.5 + *i*1.322876, 1.5 – *i*1.322876, 0, 1, and 1. The imaginary parts are the square roots of -1.75. The largest eigenvalue is associated with simultaneous firings of transitions $t_3$ and $t_4$ followed half a cycle later by simultaneous firings of transitions $t_1$, $t_2$, $t_5$, and $t_6$. The next two eigenvalues are associated with $t_3$ and $t_4$ firing in alternation, with intervening simultaneous firings of $t_1$ and $t_6$ and $t_2$ and $t_5$. With the fourth eigenvalue – the zero eigenvalue – phase angles for the firings are not defined. Since all the firings are enabled, they can occur in any sequence. With the last two eigenvalues, the algorithm could not find solutions in which all transitions were fired and returned values of unity for $\lambda$, meaning that the corresponding values of $\nu$ were zero and made no contribution to the solution.

Of each pair of complex eigenvalues, the first is consistent with the counter clockwise convention for a positive rotation, so it will be used in all representations of the solutions. The other is regarded as also having a positive rotation (though exhibited as clockwise), and it will have the same time stamp as the first. The two eigenvalues move like the two lever arms of a cork extractor when the corkscrew is being inserted – each mirrors the other but the movements of both arise from the same operation.

We select the first of the two complex eigenvalues. Its modulus is 2. Its alibi is 41.40963 degrees, so the corresponding alibi for $\nu$ is 82.81926 degrees. The coordinates of $\nu$ are therefore 0.125000 + *i*0.992157. From Equation (13), the value of $\lambda$ is then 1.125000 +*i*0.992157 and has a modulus of 1.5. The scaling factor $\rho$ must then have been 0.75, which is not unexpected as the net has eight output places but only six transitions.

What does this value of $\nu$ tell us? In a round of six firings, the model processes approximately, but not exactly, 90 degrees. In four cycles, the model will be in approximately,

but not exactly, the same state that it was at the start. We consider a scenario that begins with the central bank launching the first round by generating a signal in the money market but not repeating the signal thereafter. The first round closes with the money market receiving a response and a signal from the bond market. The second round differs from the first in that the signal from the money market is initiated by the holders of money balances rather than the central bank. In the third round the holders of money balances will have given a second signal based on feedback received from the effects of their first signal. At the end of the fourth round, the agents are not in exactly the same situation they were in at the start, for there is unprocessed information in the money balance holders' last signal.

Table 1 shows the six components of the eigenvector that is associated with our selected eigenvalue. The algorithm performs a Householder transform on the eigenvector such that the component with the greatest modulus ($t_3$ or $t_4$) is made to have no imaginary part. The complex components are not conjugates of each other but of the corresponding components of the other complex eigenvector.

Table 1. **Eigenvector for the first complex eigenvalue of the IS-LM model**

| Transition | Component | Modulus | Phase angle (Degrees) |
|---|---|---|---|
| $t_3$ | -0.500000 | 0.500000 | -180 (or 180) |
| $t_1$ | 0.125000 –*i*0.330719 | 0.353553 | -69.295194 |
| $t_6$ | 0.125000 –*i*0.330719 | 0.353553 | -69.295194 |
| $t_4$ | 0.500000 | 0.500000 | 0 |
| $t_2$ | -0.125000 +*i*0.330719 | 0.353553 | 110.704806 |
| $t_5$ | -0.125000 +*i*0.330719 | 0.353553 | 110.704806 |

The major transitions, $t_3$ and $t_4$, are 180 degrees apart. The minor transitions, $t_1$, $t_2$, $t_5$, and $t_6$, are not oriented midway between the major transitions but are lagged an additional 20.704806 degrees beyond a right angle from each, suggesting that the major transitions are more "massive" and the model "takes longer" to absorb their impact before the next transitions are fired.

With an alibi of 82.81926 degrees, the precession period is 4.346 cycles.

## 4. Constructing a Petri net for the von Neumann process

Figure 5 is a Petri net that shows, qualitatively, the creative and destructive processes and the variables for the von Neumann process.

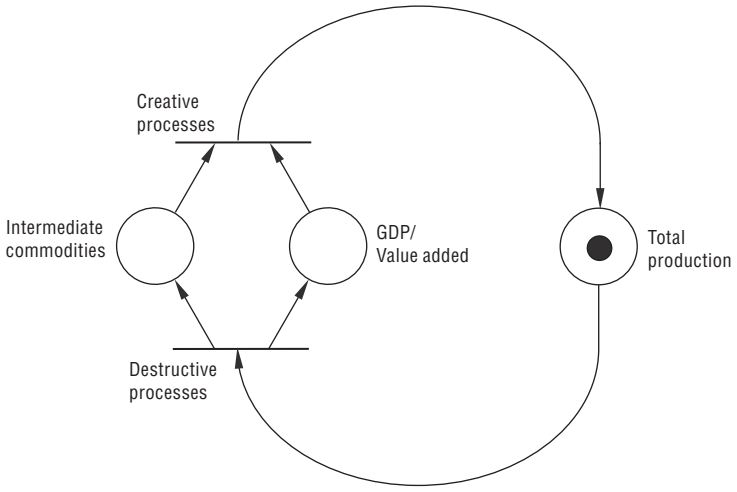
The adjacency matrix for this net is

$$A = \begin{pmatrix} -1 & -1 & +1 \\ +1 & +1 & -1 \end{pmatrix} \tag{15}$$

where the top row is the creative, or assembly, process and the bottom row is the destructive, or allocative, process, and the columns, from left to right, represent intermediate commodities, final goods or value added, and total production. The next step we take is to adapt the net to a particular set of production data for a particular year, as is this example in Equation (16) with NIPA consolidated data for use of commodities at producer prices, in 2010.

$$A = \begin{pmatrix} -11.284836 & -14.526547 & +25.811383 \\ +11.284836 & +14.526547 & -25.811383 \end{pmatrix} \tag{16}$$

Figure 5. **Initial concept for the von Neumann process**




This technique of using multiple arcs to represent elements in input-output tables has been employed by Settanni and Heijungs (2008), who combine standard input-output processes with waste treatment and recycling processes in a Petri net format.

The upper left element of A has become the dollar volume, in trillions, of all intermediate goods used in the year. The next element in the top row is value added contributed by labour. The last element in the top row is the value of total commodity output created for the year. In the bottom row, the left element is the dollar volume of all intermediate goods produced in the year. The middle element is final goods and services, or gross domestic product. The last element in the bottom row is the dollar volume of commodity uses.

### *4.1. Disaggregation to the sector level*

Our final step is the disaggregation of the creative and destructive processes among the 17 commodities and 15 industries measured in the sector level use tables. Figure 6 shows a sector level use table for the United States with detail broken out for only three commodities for the sake of compactness of the figure.

Figure 6. **The Use of Commodities by Industries, before Redefinitions (Producers' Prices)**

Millions of dollars

| Commodities/Industries | | 11 | 21 | 22 | | | | |
|---|---|---|---|---|---|---|---|---|
| IOCode | Name | Agriculture, forestry, fishing, and hunting | Mining | Utilities | Intermediate not selected | Total intermediate | Total final uses (GDP) | Total commodity output |
| 11 | Agriculture, forestry, fishing, and hunting | 103 993 | 105 | 0 | 299 575 | 403 673 | 87 173 | 490 846 |
| 21 | Mining | 2 520 | 58 402 | 43 079 | 598 180 | 702 181 | -82 992 | 619 189 |
| 22 | Utilities | 4 955 | 4 430 | 3 076 | 247 456 | 259 917 | 268 829 | 528 746 |
| | **Intermediate not selected** | 161 939 | 149 847 | 90 813 | ... | ... | ... | ... |
| | **Total intermediate** | 273 407 | 212 784 | 136 968 | ... | 13 622 962 | ... | ... |
| | **Total value added** | 215 416 | 453 756 | 280 809 | ... | ... | 17 348 071 | ... |
| | **Total industry output** | 488 824 | 666 540 | 417 777 | ... | ... | ... | 30 971 033 |

Bureau of Economic Analysis (2014).

Reading down a column identifies contributions of each row's commodity to the creation process of that column's industry. We see, for example, that utilities contributed

USD 43 079 million to the production process of the mining industry. Value added also makes a contribution to each column's creative process.

Reading across a row identifies allocations to each column's industries in the destructive process of that row's commodity. For example, USD 4 430 million of the output of the mining sector was converted into output of the utilities sector. Final uses are also a destination of commodities in each row's destructive process. A negative value for total final uses in mining is indicative of the impact of oil imports.

The total industry outputs at the bottoms of the columns do not necessarily match the total commodity outputs at the right ends of the rows because the total commodity outputs also include production from industries in which that commodity is a secondary output. For example, a substantial amount of the production of utilities comes from government enterprises and is shown in the column for government rather than in the column for utilities.

"Redefinitions" refers to whether commodities have been reassigned to other industries than those that actually produced them. Redefinitions will be discussed in more detail when the data are introduced.

The fully expanded use table has rows for 17 commodities including one row for scrap, used, and second-hand goods and one row for non-comparable imports and rest-of-the-world adjustments. These last two sets of commodities are not goals of creation processes so they do not have corresponding industries in the columns. The number of columns for industries in the table is 15 and the number of rows for commodities is 17.

The fully expanded use table also breaks out three rows for subcategories of value added and six columns for subcategories of final use.

### *4.2. Substituting the use table transpose for the make table*

The von Neumann model employs the make tables to aggregate total production by industry in the upper part of the loop in Figure 5 and it employs the use tables to break out the intermediate commodities and final uses in the lower part of the loop. Here, in the upper part, we will use the transpose of the use table instead of the make table. The make table integrates value added into its entries while here we intend to show value added in a distinct column, so that their aggregate can be matched with the aggregate of total final uses. Also, in using the use tables, we track the behaviour of economic agents, each agent or class of agents in charge of an element in the table, rather than marshalling all output of a particular commodity and marshalling all buyers of that commodity in a single market. Each agent's job is to deliver packets of its input to its various users and receives packets of outputs from suppliers from which it constructs a new packet to start the process again. A particular agent receives a commodity from one or more industries and transforms it into a product with one or more uses. A visualization of agents delivering packets is found in Weyns and Holvoet (2002).

In the fully disaggregated system, the left part of Figure 5 will have 18 places, one for each commodity and one for final use/value added. The 18 places are shared by all the creative and destructive processes. The figure is like a plan of one floor of a factory with 17 floors, all of which look the same, though two (scrap and non-comparable imports) are partly unused. The 17 places are like freight elevators used by agents transferring packets from their suppliers to the creators who will transform them into their new forms. The place for final use/value added is like a refectory where agents are "fed" and restored for

their role in the next round of creative processes. The place on the right is the receiving point for all of industry production. It reconciles production by industry with production by commodity and enables the next cycle.

### 4.3. *Constructing the adjacency matrix*

The magnitude of each element in A is the volume of a corresponding cell in the use table. In this way the production technologies, value added totals, and final uses for the year are "hard wired" into the model but the agents otherwise have full freedom of action. The adjacency matrix has 17 columns for the 17 commodities, plus column 18 for total value added/total final uses, and column 19 for total commodity/total industry value. The three subcategories of value added and six subcategories of final use are not broken out in the matrix because the input places for the three do not have individual links to the output places for the six.

There are 32 processes represented in the adjacency matrix. The first 15 rows are the creative processes, and are formed from the transpose of the first 15 columns of the use table with total value added inserted in column 18 and total input values in column 19. All these entries are multiplied by -1 after the transpose except the total input values in column 19. The remaining 17 rows are the destructive processes, and are the untransposed rows of the use table, with zeroes in columns 16 and 17 for scrap and non-comparable imports, total final uses in column 18, and total output value in column 19. The last column is multiplied by -1. Scrap and non-comparable imports have some negative entries in the use table. Since the BEA denotes these as negative uses, rather than positive values of some other quantity, the negative values will be kept. In the creative transitions in A, these appear as positive numbers and are reckoned as input arcs with reversed flow. They are suppressed in B. In the destructive transitions in A, negative numbers for scrap and non-comparable imports are reckoned as output arcs with negative flow, and are retained as negative elements in B. The entry for final uses in mining is negative in the use table and is retained as a negative element in B.

The matrix B has the form

$$B = \begin{pmatrix} & & & a_{1;19} \\ & 0 & & \vdots \\ & & & a_{15;19} \\ a_{16;1} & \cdots & a_{16;18} & \\ \vdots & \ddots & \vdots & 0 \\ a_{32;1} & \cdots & a_{32;18} & \end{pmatrix} \tag{17}$$

Only a single column of non-zero elements appears in the top part of B, so when B is post-multiplied by A′, the top 15 rows of BA′ will be multiples of each other. In a model where detail for value added and final use is broken out, more columns will be added to B and the top 15 rows will no longer be multiples of each other.

### 4.4. *The characteristic matrix*

The BA′ matrix has 32 rows and 32 columns. The maximum rank of A is 18, but columns 17 and 18 are completely suppressed in B, so the maximum rank of the characteristic matrix is 16 and there will be 16 zero eigenvalues for λ. The upper left block of BA' is the outer product of total production by industry. The upper right block is the outer product of

production by industry and production by commodity. It contains information about commodities that are produced by industries other than their primary producers. The lower left block is the Hadamard product of the intermediate production coefficients in the use table with themselves, plus the outer product of final use by commodity and valued added by industry. The outer product contains information about the nonalignment of final uses for commodities and their primary producers' values added. The lower right block is the product of the use table – with its column 19 suppressed – and its transpose.

### 4.5. *The trace, industry block trace and commodity block trace*

The trace of BA′ is the sum of the unscaled eigenvalues. The sum of the 15 upper elements of the diagonal, hereafter referred to as the industry block trace, comprises the squares of total production of each industry at producer prices, and serves as a Herfindahl-like index of concentration of production across industries. Only the sums on industry outputs in column 19 of the adjacency matrix contribute to the industry block trace. The remaining 17 elements of the diagonal are the sums of the squares of intermediate and final uses at producer prices for each commodity. Their sum is the commodity block trace. No elements of column 19 contribute to the commodity block trace. A change in the industry block trace indicates an inter-industry composition change in production or prices, and a change in the commodity block trace indicates an intra-commodity composition change in production or prices.

### 4.6. *The solution*

For non-zero values of $\lambda$, the first 15 eigenvector components – the 15 creative processes – will all have the same phase angle. The phase angles for the remaining 17 components – the destructive processes – will be all different. We cannot compare the time stamps of two commodities' destructive processes directly, but we can compare each of them, except scrap and non-comparable imports, with the time stamps of their corresponding primary industries' input processes to impute a creation-destruction lead time for each sector. These lead times generate precession in the model.

## 5. Data, results and test for significance

### 5.1. *The data*

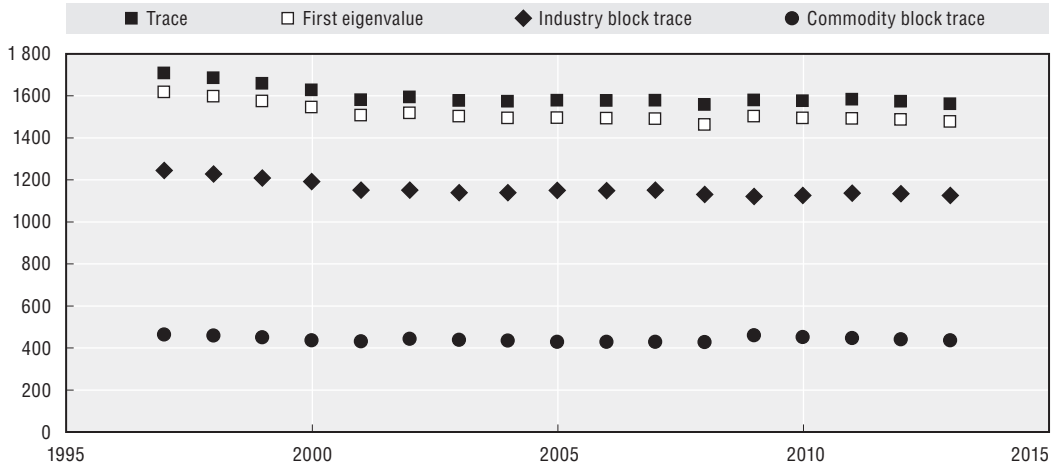
The newly revised annual North American Industry Classification System (NAICS)-classified input-output tables, at the sector level, before redefinition, for the years 1997 to 2013 are used (BEA, 2014a). The corresponding input-output tables after redefinition (BEA, 2014b), whose entries differ slightly, are used as a test for the "butterfly effect". A commodity before redefinition is counted in the industry that produced it (for example, construction done by a firm's workforce would be counted in that firm's industry's production) while after redefinition it would be counted in the industry whose primary output it matches (all construction would be counted as construction industry production). The results for industries after redefinition are expected to have larger systematic errors in them, as redefinition is not a part of the actual creative and destructive processes.

The elements of BA′ for each year are normalized to the square of total industry output at producer prices. They are then multiplied by a factor of $10^5$ to yield magnitudes on the order of unity for the complex eigenvalues.

### 5.2. *The trace, industry block trace and commodity block trace*

Figure 7 shows the trace, the first eigenvalue, and the decomposition of the trace into the industry block trace and commodity block trace.

Figure 7. **Trace, first eigenvalue, industry block trace, and commodity block trace**




The trace shows perturbations in the trough years of 2001 and 2008. Systematic changes in the value of the trace are attributable to the industries or commodities that show changes in the values of their respective elements of the diagonal. The decline in the trace from 1997 to 2001 arises from a decrease in manufacturing's share of total industry output. This decline in manufacturing is carried over to the industry block trace.

The commodity block trace shows an increase in 2009, attributable to an increase in the interaction of government with other sectors.

The five sectors making the largest contributions to the industry block trace are manufacturing; finance, insurance, and real estate (FIRE); government; professional and business services (PROF); and educational services and health care, etc.

In 1997, the five sectors making the largest contributions to the commodity block trace are manufacturing, FIRE, government, educational services, etc., and retail trade. Construction displaces retail trade for fifth place in 1998. In 2002, FIRE displaces manufacturing for first place and retains it thereafter. In 2008, PROF replaces construction for fifth place. In 2008 and 2009, government surges to second place before receding again.

### 5.3. *The first eigenvalue*

Figure 7 shows that the first eigenvalue accounts for the bulk of economic activity, and follows the trace closely. For all years, the first eigenvalue exhibits eigenvector components of opposite signs for the creative and destructive processes in all sectors except mining. So, for all sectors except mining, creative transitions are fired, each followed half a cycle later (or earlier) by the firing of the destructive transitions. The firings for different sectors could be staggered during the cycle but there is no way of ascertaining the stagger of firings because the computation of BA'forces all creative transitions to have the same phase angle.

Mining shows opposite signs for its creative and destructive transitions from 1997 to 1999 but the same sign afterwards until 2013, which it exhibits the opposite sign again.

Mining makes a net negative contribution to gross domestic product in all years, but after 1999 its impact is more. It becomes large enough to "flip" the sign for the destructive transition's component.

The five largest creative components of the first eigenvector are manufacturing; FIRE, government; PROF, and educational services, etc. The five largest destructive components are manufacturing, FIRE, government, educational services, etc., and PROF.

### 5.4. *The second and third eigenvalues*

The second eigenvalue is about one and a half orders of magnitude smaller than the trace. Many of its destructive eigenvector components carry the same sign as their corresponding creative components, but that for mining carries the opposite sign. The five largest creative processes are the same as those for the first eigenvalue. The five largest destructive processes are FIRE, government, educational services, retail trade, and construction. The last two of these likely account for lack of synchronization of all the destructive processes, because retail trade is an additional intermediate stage in the process of making goods available for final use, and construction in progress is measured as value put in place rather than as receipts for the finished structure.

The third eigenvalue is about two orders of magnitude smaller than the trace. All of its creative and destructive processes carry the same sign. The five largest creative processes are the same as for the first eigenvalue, and the five largest destructive processes are manufacturing, government, educational services, etc., FIRE, and retail trade.

As the magnitudes of the eigenvalues go as the square of total industry production, their square roots yield their relative proportion to total industry production. Thus the second eigenvalue accounts for about 18% of production and the third eigenvalue accounts for about 10%.

### 5.5. *The negative eigenvalue and the complex eigenvalues*

Table 2 shows the complex eigenvalue moduli and alibis for commodities before redefinitions. Also shown is the negative eigenvalue, which for most years is fourth in rank.

The modulus for the complex eigenvalue is posted in the appropriate column according to whether the first member of its pair ranks fifth, seventh, eighth, or ninth.

The algorithm failed to return a complex eigenvalue for 1999, though it does return an alibi of 5.2 degrees for 1999 from the data in a year-earlier (2013) revision. As will be seen below, an alibi of 5.1 degrees is returned in this year's revision for commodities after redefinitions.

The model does not permit negative eigenvalues for $\lambda$, so their presence must be accounted for. Also, the sudden drop-off in the magnitude of the negative eigenvalue after 2007, its vanishing in 2011 and 2012, and reappearance as a pair of negative eigenvalues in 2013 must be explained. An accommodation for negative eigenvalues in the model is introduced below.

The last two columns in the table show the alibis for $\lambda$, before and after accommodation is made for negative eigenvalues. Given that the alibi for $\nu$ is twice that for $\lambda$, the economy goes through one complete "orbit" in the period 1997 to 2006, but after that, behaviour of the system changes as it approaches a bifurcation boundary, which is crossed in 2010. In 2013 the complex eigenvalues vanished.

Table 2. **Eigenvalues and alibis for commodities before redefinitions**

| Year | Negative Eigenvalue | $E_5$ | $E_7$ | $E_8$ | $E_9$ | Alibi for λ (Degrees) | Corrected Alibi for λ (Degrees) |
|---|---|---|---|---|---|---|---|
| 1997 | -2.841 | | | | 0.0621 | 7.8 | 6.7 |
| 1998 | -3.889 | | | 0.0766 | | 9.6 | 7.9 |
| 1999 | -4.008 | | | | | | |
| 2000 | -4.018 | | | | 0.0617 | 14.5 | 11.9 |
| 2001 | -4.318 | | | | 0.0718 | 14.2 | 11.5 |
| 2002 | -3.666 | | | 0.0769 | | 23.5 | 19.2 |
| 2003 | -3.705 | | | 0.0899 | | 24.3 | 19.8 |
| 2004 | -3.358 | | | 0.1010 | | 27.5 | 22.9 |
| 2005 | -3.506 | | | 0.1027 | | 25.5 | 21.2 |
| 2006 | -3.170 | | | 0.1228 | | 43.1 | 36.0 |
| 2007 | -3.039 | | | 0.1156 | | 52.3 | 43.6 |
| 2008 | -1.236 | | 0.1559 | | | 77.9 | 44.4 |
| 2009 | -0.968 | | 0.1527 | | | 97.9 | 59.5 |
| 2010 | -0.095 | | 0.4680 | | | 119.6 | 86.1 |
| 2011 | | 0.8891 | | | | 106.03 | 80.3* |
| 2012 | | 0.8434 | | | | 138.36 | 82.7* |
| 2013 | -1.031**<br>-0.467** | | | | | | |

* Calculated with error estimate from Eq. (22).
** Two negative eigenvalues.

Table 3 is the equivalent of Table 2 for commodities after redefinitions. As has been mentioned previously, redefinitions introduce further systematic error into the model; their effect is reflected in the larger magnitudes of the negative eigenvalues.

Table 3. **Eigenvalues and alibis for commodities after redefinitions**

| Year | Negative Eigenvalue | $E_5$ | $E_7$ | $E_8$ | $E_9$ | Alibi for λ (Degrees) | Corrected Alibi for λ (Degrees) |
|---|---|---|---|---|---|---|---|
| 1997 | -2.898 | | | 0.0782 | | 9.1 | 7.9 |
| 1998 | -3.916 | | | 0.0819 | | 10.8 | 9.0 |
| 1999 | -4.086 | | | 0.0760 | | 5.1 | 4.2 |
| 2000 | -4.098 | | | | 0.0645 | 13.7 | 11.3 |
| 2001 | -4.292 | | | | 0.0744 | 13.7 | 11.1 |
| 2002 | -4.024 | | | 0.0789 | | 22.8 | 18.6 |
| 2003 | -4.136 | | | 0.0913 | | 23.6 | 19.2 |
| 2004 | -3.821 | | | 0.1005 | | 27.0 | 22.3 |
| 2005 | -4.001 | | | 0.1052 | | 23.7 | 19.6 |
| 2006 | -3.770 | | | 0.1218 | | 39.7 | 32.8 |
| 2007 | -3.695 | | | 0.1132 | | 48.4 | 39.9 |
| 2008 | -1.902 | | | 0.1361 | | 69.1 | 59.5 |
| 2009 | -1.767 | | 0.1220 | | | 79.0 | 66.0 |
| 2010 | -1.189 | | 0.1415 | | | 107.2 | 81.7 |
| 2011 | | 0.8337 | | | | 132.2 | 87.7* |
| 2012 | -1.463**<br>-0.424** | | | | 0.1091 | 2.2 | 1.2<br>1.8 |
| 2013 | -1.935**<br>-0.201** | | | | | | |

* Calculated with error estimate from Eq. (22).
** Two negative eigenvalues.

In 2012 the pair of large complex eigenvalues vanished and a tiny new pair emerged. In 2012 and 2013, negative eigenvalues appeared in pairs.

The results suggest that the complex eigenvalues and the negative eigenvalue interact when their moduli are of similar size. The pairs of negative eigenvalues that emerge in 2013 for commodities before redefinition and in 2012 for commodities after redefinition appear to result from the splitting of the previously-existing pair of complex eigenvalues with negative real parts when they encounter the real axis.

### 5.6. *Test of significance for the complex eigenvalues*

If results for the complex eigenvalues are significant, we should not expect to see a uniform random distribution of the phase angles of the eigenvectors for the various commodities, and the phase angles we see should be compatible with observations of the commodities' lead times reported in other sources. A simple visual test, based on Wendel (1962), is available for points in a uniform random distribution on a circle. The likelihood that all such points will be found on one side of a line intersecting the circle's centre is

$$p(N) = \frac{2N}{2^N} \tag{18}$$

where $N$ is the number of points on the circle. For points not on a circle, the equivalent of the test is that the convex hull of the points not enclose the origin. Figure 8 shows the eigenvector scatterplots for each commodity, with non-comparable imports included to make use of available extra space in the figure. Black represents commodities before redefinitions and white represents commodities after redefinitions. The spans of all horizontal and vertical axes are from -0.6 to +0.6, except for the horizontal axis for agriculture, which extends from -0.2 to +1.0.

For commodities before redefinitions, all sectors except FIRE meet the Wendel test for all 15 years of observations, for a level of significance of 0.0009 in each of these sectors. For commodities after redefinitions, the Wendel test is met for all 16 years of for all sectors except FIRE, transportation and warehousing, and arts, entertainment, etc. with a single outlier for each of the latter two.

### 5.7. *Calibrating the Zero Datum for Lead Times*

Sectors that carry no fixed investment or inventory in their own commodities, such as utilities, education and health care, and other services except government, are expected to have zero lead times. In Figure 9, these three commodities exhibit negative lead times of about one month. The zero datum is the angle assigned by the algorithm to all the productive processes, but some of these, such as construction and transportation and warehousing, are not reported using receipts, and their negative lead times contribute to the phase angle calculated by the algorithm. To calibrate utilities, education and health care, and other services except government to zero, all of the scatterplots should be rotated counter clockwise about 30 degrees.

Figure 8. **Eigenvector scatterplots for commodities**

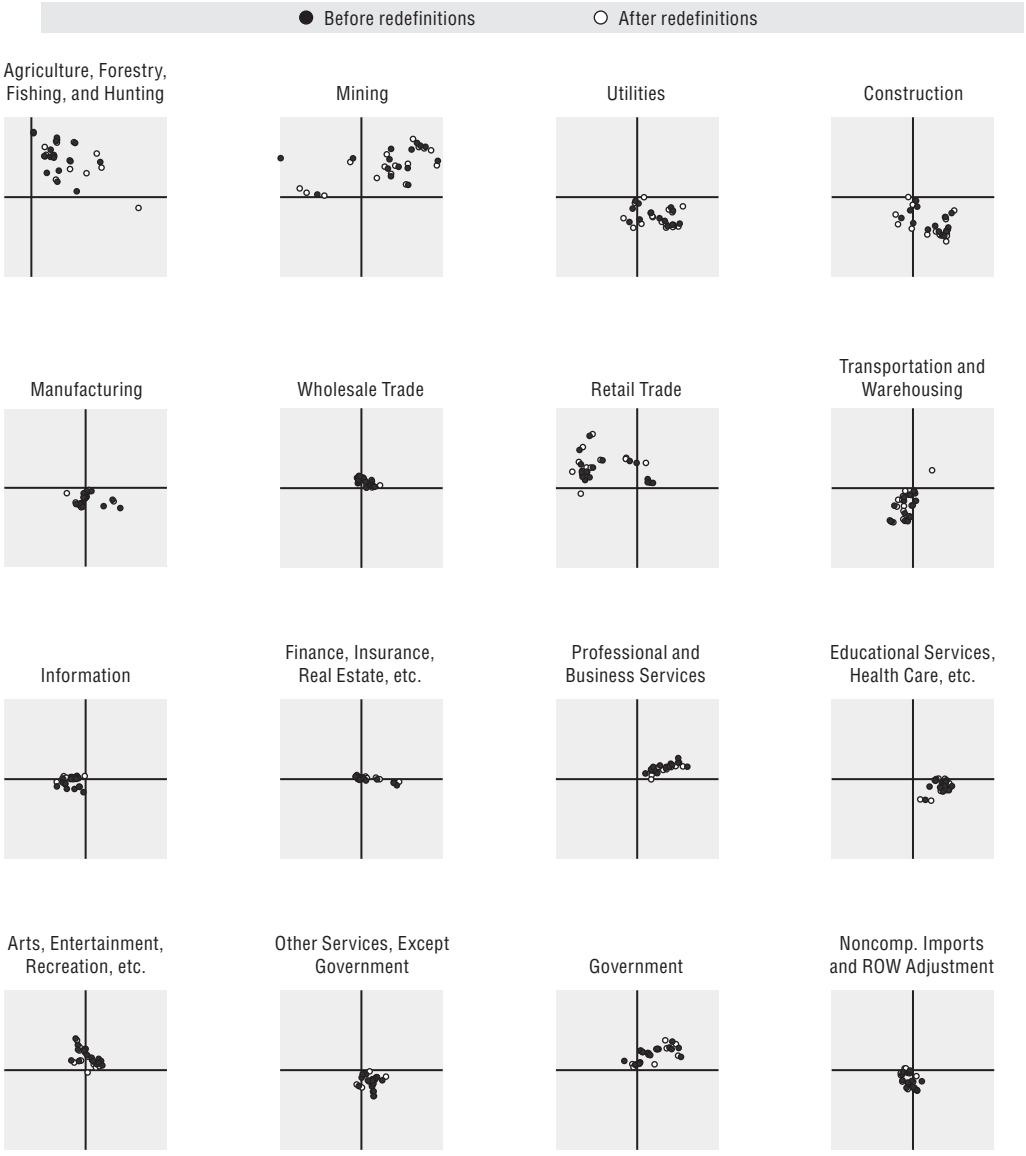
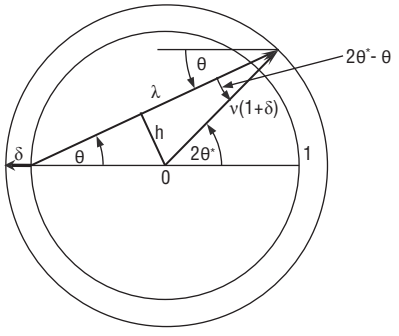



Figure 9. **Accommodating a negative eigenvalue**



## 6. Corroboration of results with sector data

Comments are made for selected sectors.

### *6.1. Agriculture, forestry, fishing and hunting*

The high degree of scatter may be due to volatility in prices of crops such as corn. The average lead-time of three months is compatible with crop data. The time from planting to harvest for field crops range from three to six months (US Department of Agriculture, 2010) Hay is generally cut three times per year and some crops, such as winter wheat, are planted in the fall for harvest the following summer. Hogs and cattle have breeding cycles longer than one year. Ezekiel (1929) attributed long cycles in hog and cattle prices in terms of corn prices to cobweb interactions. Peak to peak cycle lengths for cattle averaged 15 years and for hogs averaged about four years. In the annual NIPA data used here, hogs and cattle sold for slaughter in a given year are not the same animals that had been conceived in that year. The cattle and hog cycles manifest themselves in the annual data by changes in inventory or fixed investment.

### *6.2. Mining*

The high degree of scatter is likely due to volatility in oil prices. There is a high degree of travel in the scatterplot. The points toward the right hand side of the plot are in the latter years of the study.

### *6.3. Construction*

Construction of structures is measured by value put in place (VPIP) rather than by receipts for the finished structure (Bureau of Economic Analysis, 2009, chapter 10, p. 4). The negative phase angle suggested by the scatterplot is likely attributable to incompatibility of VPIP timing to the timing of receipts.

### *6.4. Retail trade*

The points toward the right in the plot are for the latter years of measurement. The reduced lead-time may be attributable to increasing automation.

### *6.5. Transportation and warehousing*

The negative lead-time of approximately three months may arise from the "unbundling" of transportation costs and their being shifted forward to the final users of the transported goods (Bureau of Economic Analysis, 2009, chapter 5, p. 5).

### *6.6. Non-comparable imports and ROW adjustment*

The phase angle shown is as if non-comparable imports were an industry with its own creative processes. If it had been so considered in the use table, the algorithm would have assigned it the same phase angle for creative processes as it did for the other commodities. Imports in general are valued in the use tables not by receipts but at domestic port value plus domestic freight (Bureau of Economic Analysis, 2006, chapter 7, pp. 8-9). So, as in the case of construction, the negative phase angle we see is likely due to incompatibility with the timing of receipts.

## 7. Corroboration of the results with observed spectra

Complete spectra are found in Steenge (1990). Mariolis and Tsoufidis (2014), Iliadi, Mariolis, et al., (2012), and Mariolis and Tsoufidis (2010) for the United States, Japan, Germany, Denmark, Finland, Sweden, China, Korea, and Greece. All of these spectra exhibited at least one pair of complex eigenvalues. When only the moduli of the spectra were shown, the complex eigenvalues could still be spotted because their moduli were identical pairs. The phase angles associated with these eigenvalues tended to be small. The largest one for the Greek economy was about 48 degrees (Mariolis and Tsoufidis 2010, p. 30). In the spectra compiled by Steenge, the phase angle for the United States was about 13 degrees and for Germany, for its largest complex eigenvalue pair, about 21 degrees. Japan exhibited two adjacent pairs, the larger with a phase angle of 106 degrees and the smaller with a phase angle of 20 degrees. In their analysis of the United States benchmark data, Mariolis and Tsoufidis (2010) found three pairs of complex eigenvalues at the sector level for 12 and 15 commodities for 1997 and 2002, respectively. For the tables of 129 and 133 commodities for 1997 and 2002 respectively, at least 30 distinct pairs can be identified from the scatterplots in the complex plane. For the tables of 488 and 426 commodities for 1997 and 2002 respectively, about 30 pairs of complex eigenvalues can be resolved, but a much larger number form a continuous mass whose shape vaguely resembles a Mandelbrot set aligned on the real axis. Negative real eigenvalues are also found.

The matrices from which these eigenvalues have been extracted are different than the one used here, but the economies they measure are the same, so the results derived here are not out of alignment with those found elsewhere.

## 8. What does the negative eigenvalue signify?

Round-off error can account for a small negative eigenvalue, but from 1997 to 2008 we have a large negative eigenvalue exhibiting eigenvector components all of the same sign, indicating the presence of systematic error.

The two likely causes of systematic error are errors in the way that the values in the use table are measured and reported, or violations of the assumptions underlying the use tables – that the input-output relationships are unique and invariant for the year for each commodity and have constant returns to scale (Bureau of Economic Analysis, 2009, Chapter 1, pp. 2-3). Also, for a sector, a change in relative composition of commodity output or a change of relative prices of commodities in a year can lead to systematic error.

In January 2014, the Bureau of Economic Analysis issued complete new sets of input-output tables based on the 2007 NAICS standards, spanning the years 1997 to 2012 These new tables cured the incompatibilities in the tables available earlier, which had revisions for 1998-2002 and 2003-07. In November of 2014, the input-output tables for 1997 to 2012 were revised again, the 2103 account was added, and a first-time ever revision was made of a benchmark input-output account, that for 2007 (Howells and Morgan, 2014). Systemic error is therefore not likely due to how the new data are measured and reported. We look to changes in relative prices or technology instead.

### *8.1. Accommodating a negative eigenvalue*

We modify Equation (10) to introduce a positive coefficient of systematic error $\delta$ as follows:

$$(\mathrm{I}-\rho\mathrm{BA}')\sum_{i=1}^{t}\mathrm{U}_i=-\nu(1+\delta)\sum_{i=1}^{t}\mathrm{U}_i \tag{19}$$

This parameter results in all of the ν eigenvalue initially on the unit circle being mapped upon a circle of radius 1 + δ in a set of firings. Figure 3 is modified in Figure 9 as follows:

The value of the scaled negative eigenvalue for λ is –δ. The angle of precession for ν is now somewhat less than, rather than exactly, twice that of λ. The value of the corrected angle θ* is

$$\sin\theta = (1+\delta)\sin(2\theta^{*}-\theta) \tag{20}$$

and the magnitude of each side of the equation is the length of the perpendicular member h in the figure. The corrected angle can never be more than 90 degrees, so twice that angle, which is the alibi for ν, cannot be more than 180 degrees.

Equation (14) is modified as follows:

$$\rho = \frac{(1+\delta)\sin 2\theta^{*}}{E\sin\theta}, 0 < \theta < \pi \tag{21}$$

Against what attribute of the set of eigenvalues should δ be scaled? The trace – the sum of all the eigenvalues – could be used, but the trace and first eigenvalue embody attributes which remain as the economy converges to its long term growth path, while we expect systematic error to fade as transient attributes die out. The systematic error is of the same order of magnitude or one order of magnitude higher than the complex eigenvalues. If we apportion systematic error equally to the fourteen transient eigenvalues, a one-fourteenth share of the systematic error is of the same order of magnitude or one order of magnitude smaller than the complex eigenvalues. We obtain a rough estimate of δ by scaling it to the next larger real eigenvalue. The next larger eigenvalue, when scaled, has a magnitude of 2 + δ. Then, from the ratio of the two eigenvalues,

$$\delta \cong \frac{2E_{\delta}}{E_{\delta+1}-E_{\delta}} \tag{22}$$

where $E_{\delta}$ is the magnitude of the negative eigenvalue and $E_{\delta+1}$ is the magnitude of the next larger real eigenvalue. With a root-finding algorithm, we combine Equations (20) and (22) to find θ*. It is not necessary that a precise value be found for θ*; it is sufficient to know that the roots exist, and that equation (19) is adequate in accommodating negative eigenvalues.

### *8.2. No negative eigenvalue, but complex eigenvalues with negative real parts*

Even if a negative eigenvalue is absent or does not show systematic error, but complex eigenvalues exist with negative real parts, we still can have systematic error. The estimate of δ then requires an additional step, as we have to estimate a value for $E_{\delta}$.

In Figure 10 we make an estimate of δ from complex eigenvalues with negative real parts.

A lower limit for the magnitude for δ can be found by dropping a perpendicular from the arrow for λ to the real axis. The upper limit for the magnitude of δ is the modulus of λ itself. These two limits are in scale with λ. Let $\lambda_{\delta}$ denote the complex eigenvalue being used to find δ. An approximation of $E_{\delta}$ to be used in Equation (22) is the arithmetic average of the two limits of δ scaled to $\lambda_{\delta}$, or

$$E_{\delta} = \frac{\mathrm{Re}(\lambda)+\lambda}{2} \tag{23}$$

### *8.3. What accounts for the negative eigenvalue?*

In a manner analogous to that for the complex eigenvalues, we look for the sector components that make the largest contribution to the negative eigenvalue's eigenvector.

Figure 10. **Error estimation when negative eigenvalue is absent**

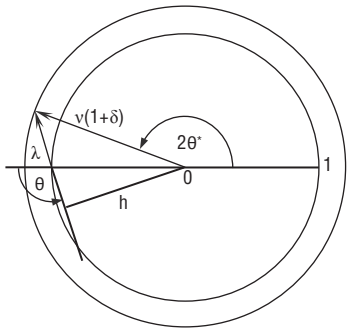
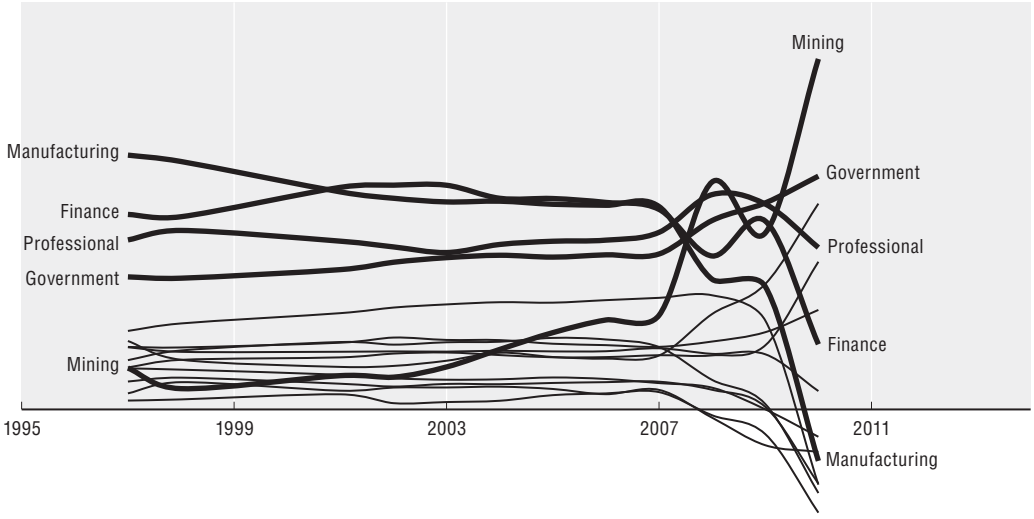



Figure 11 shows the negative eigenvalue's eigenvector components for the creative processes for the 15 commodities, each given a sign reflecting polarity with the signs of the appropriate year's destructive processes. The five commodities that make the biggest contribution to the eigenvalue have bolded curves and are labelled; the remainder are unlabelled.

Figure 11. **Eigenvector components for the negative eigenvalue, 1997-2010**




From 1997 to 2007, all the components exhibit a coherence to be expected of systematic error. Manufacturing and finance are the largest contributors to the eigenvector in this period. In 2008 the coherence unravels. Mining and government take prominence thereafter as the leading components. Mining, finance, and manufacturing display a perturbation in the trough year of 2008. Results do not exist after 2010 because of the absence of a negative eigenvalue or sole negative eigenvalue.

Employment data (Federal Reserve Bank of St. Louis, 2015) support what we see for the top five components in Figure 11, except for finance. Manufacturing reverses polarity in 2010; this is also the year that manufacturing employment, designated in the Federal Reserve Economic Database (FRED) as *MANEMP*, ends its precipitous decline that began at the end of 2000. Mining (*USMINE*) shows an increase of percentage of total nonfarm employment (*PAYEMS*) from 2004 to 2008 and again from 2010 to 2012. Professional services

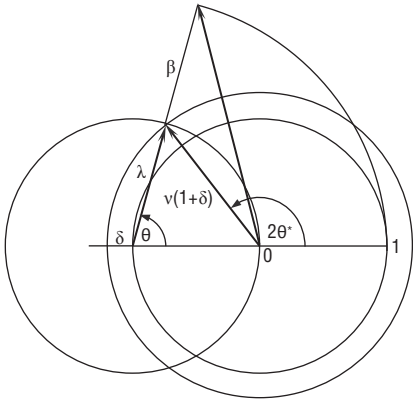
(*USPBS*) shows an increase of its percentage of total employment from 11.5% in 1997 to 13.5% in 2013. Government (*USGOVT*) showed a sharp increase of its share of employment in 2009. Finance (*USFIRE*) showed an increase in its share of employment from 1997 to 2003 and a decline thereafter, but the range of variation, from 5.8% to 6.2%, seems too small to account for finance's large impact on the eigenvector. Corroboration of the results for finance awaits further evidence, perhaps changes in leverage of employees with regard to real assets or real profits.

## 9. What happens at the bifurcation boundary?

In Equation (19), a cycle of firings with systematic error forces the $\nu$ eigenvectors outward off the unit circle as we would see near a subcritical, Neimark-Sacker bifurcation. What happens inside the unit circle we cannot ascertain with the $\nu$ eigenvectors, since we repeatedly reset them on, not inside, the unit circle, but we can ascertain what happens inside the unit circle for the $\lambda$ eigenvectors, since they do cross their unit circle.

Figure 12 shows that a change in $\delta$ causes the $\lambda$ eigenvectors to cross their eigenvalue's unit circle at non-zero speed.

Figure 12. **Eigenvectors for $\lambda$ crossing their unit circle at speed**




An increase in $\delta$ forces $\lambda$ outside its unit circle. The unit circle for $\lambda$ is not its eigenvectors' limit cycle, though; that is the circle of radius 2, part of which is shown in the figure. The modulus for $\lambda$ is initially set at 2. In each iteration, $\lambda$ spirals inward unless $\delta$ is sufficiently large. For the eigenvector of $\lambda$ to maintain a constant length, the line segment $\beta$ will indicate the amount of offset beyond its unit length needed for $\lambda$. If the offset is less than $\beta$, the eigenvector is spiralling inward; if the offset is greater than $\beta$, the eigenvector would spiral outward; thus the circle of radius 2 is a subcritical Neimark-Sacker bifurcation boundary for $\lambda$. Since the vector solution sets for $\nu$ and $\lambda$ are the same, we have proven the existence of a subcritical Neirmark-Sacker bifurcation boundary for $\nu$.

### *9.1. Interaction of the negative and complex eigenvalues on the centre manifold*

When a discrete-time dynamical system with more than two dimensions has complex eigenvalues that have a unit modulus, they lie on a centre manifold. By the centre manifold theorem (Kuznetsov, p. 152), if all eigenvectors corresponding to the eigenvalues off the centre manifold remain in the same neighbourhood for iterations going forward in time or backward in time, the eigenvectors will converge to the "critical", or solution, points on the

manifold. Then the attributes of the manifold completely describe the behaviour of the bifurcation.

We first demonstrate that the centre manifold theorem holds for the ν eigenvectors. In one set of firings in Equation (19), all the real non-zero ν eigenvectors are of opposite sign and have a larger modulus than before. Thus in two sets of firings, all the real non-zero ν eigenvectors are of the same sign and have a larger modulus than before. Thus, when an iteration is two sets of firings, all the real eigenvalues will converge to zero going backward in time, which is the location of the critical point.

The eigenvector solution set for λ is the same as that for ν, so the centre manifold theorem holds for both.

### *9.2. Incorporating systematic error into a two-dimensional manifold*

We assume the existence of a pair of complex roots of the characteristic equation for λ and a sole negative real root. At a point not on the origin for λ, let all the roots be factored out of the characteristic equation except the three aforementioned roots. What remains is a cubic polynomial. Let the three roots be designated as $a + ib$, $a - ib$, and $d$. The depressed characteristic equation is

$$(x-d)\left[(x-a)^2+b^2\right]=0 \tag{24}$$

or

$$x^3-(2a+d)x^2+\left(a^2+b^2+2ad\right)x-d\left(a^2+b^2\right)=0 \tag{25}$$

The coefficients of the quadratic term and constant term are the negative trace and negative determinant, respectively, of a 3 x 3 characteristic matrix to which the equation conforms. These are hereafter designated as $T_3$ and $D_3$. If $d$ is zero, an additional factorization of $x$ can be made, resulting in an equation identical to the characteristic equation of an oscillating system where the first term – now a quadratic – has a unit inertial coefficient, the second term the damping coefficient, and the third term the stiffness – or resistance to deformation – coefficient. The natural frequency, at which the system oscillates if there is no damping, is $b$.

We have assumed that $d$ is non-zero, so we make a transformation of coordinates to centre the horizontal axis on it, thus:

$$x=z+d \tag{26}$$

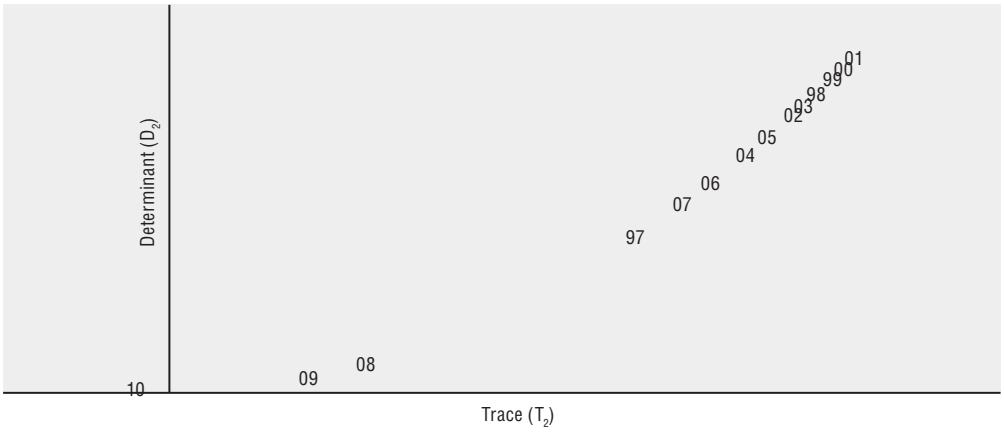
We then have, after factoring out z near the origin,

$$z^2-2(a-d)z+(a-d)^2+b^2=0 \tag{27}$$

We have again a characteristic equation. The coefficient of the linear term is the negative of the trace, hereafter designated as $T_2$, for a corresponding 2 x 2 characteristic matrix, and the constant terms form the determinant $D_2$. The two terms in the trace represent two contributions to damping. Damping that associated with the quantity $a$ can be said to be structural – arising from the structural equations used to assemble the model, for it is preserved in $T_3$ even if $d$ is zero. If $a$ is positive, it contributes to negative damping. Damping that is associated with the quantity $d$ is systematic error.

Figure 13 shows our results in the trace-determinant plane. The data points track closely the parabolic boundary above which complex eigenvalues are possible. The years after 2010 are not shown because for them there is no sole negative eigenvalue. The parabola in the trace-determinant plane separates the regions in which there are two complex eigenvalues or there are two distinct real eigenvalues of the characteristic equation.

Figure 13. **Crossing of the Neimark-Sacker bifurcation boundary in the trace-determinant plane**




Above the parabola, we have outward-spiralling, or unstable, trajectories if the trace is positive, and inward-spiralling, or stable, trajectories if the trace is negative. If the trace is zero, we have circular trajectories and this is the Neimark-Sacker bifurcation boundary. In continuous-time dynamic systems, the equivalent is the Hopf bifurcation. An illustration of trajectories in the various regions of the trace-determinant plane is given in Lewis and Othmer (1997, p. 367).

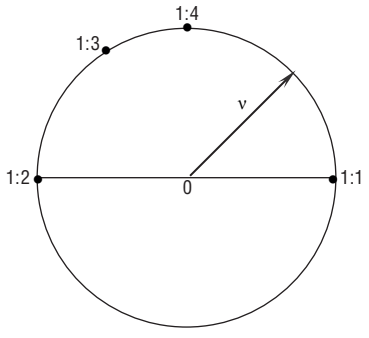
The determinant depends on the "stiffness" of the system or resistance to deformation, while the trace represents the degree of damping in the system, a positive trace indicating negative damping or a negative trace indicating positive damping. The Neimark-Sacker bifurcation boundary is crossed in 2010.

In 2013 we have two negative eigenvalues but no complex eigenvalues. What is strongly suggested is that the two complex eigenvalues of 2012 merged at the point of critical damping and then split into two different real eigenvalues, indicating over-damping, in 2013.

### *9.3. Strong resonance and second-order resonance*

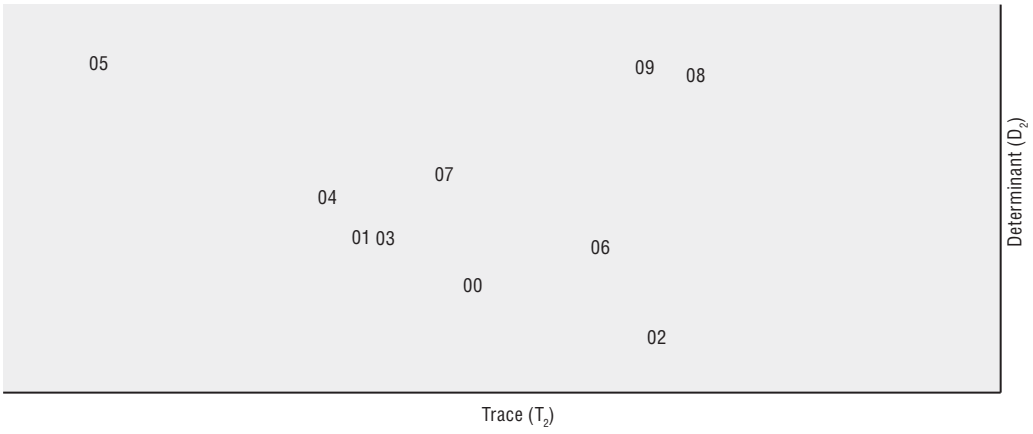
At some places on the unit circle for ν, the nondegeneracy condition for the Neimark-Sacker bifurcation is violated (Kuznetsov, p. 135). At these places, the nonvariant limit cycle might not appear (Kuznetsov, p. 185). Figure 14 shows the loci for all the nondegeneracy conditions, or "strong resonances," for ν.

Figure 14. **Loci for violation of nondegeneracy condition for Neimark-Sacker bifurcation**



For non-zero values of δ, the λ eigenvalue passes near, but does not go through, the loci for the 1:4, 1:3 and 1:2 strong resonances. At the close approaches to the strong resonance points, we can expect to see second-order resonances arising from Taylor series expansions around these points (Dobson, 2001). These second-order resonances occur when two eigenvalues sum to a third. To find these resonances, we return to (27), but select a different set of eigenvalues. Instead of selecting *d* to represent a sole negative eigenvalue, we select *d* to make the difference between *d* and the sum of the two complex eigenvalues – if they have positive real parts – to come as close as possible to vanishing. We plot the results on the $T_2$-$D_2$ plane in Figure 15.

Figure 15. **Trace-determinant diagram for second-order resonances**




We see the data points from 2000 to 2009 situated on four parabolas. The data point for 1999 does not exist. Two older parabolas were manifested in 1997 and 1998, but they are not shown because there is only one data point for each and their labels would obscure the labels for 2001 and 2000, respectively. From Equation (27), the relationship between $T_2$ and $D_2$ can be expressed as follows:

$$D_2 = \left(\frac{T_2}{2}\right)^2 + b^2 \tag{28}$$

A family of points that have a common $b^2$ will fall on the same parabola. If there is a big change in $b^2$, the points jump to a higher parabola. The jump occurs when the magnitude of *a* (which increases as we move to the left) becomes large enough that a new eigenvalue for *d*, the next larger one, must be selected. The bigger *d* eigenvalue reduces the magnitude of $T_2$ and a corresponding increase in $b^2$ and we start a leftward movement from the lower end of the new parabolic arc. The process is repeated when the leftward movement continues long enough to trigger the selection of another higher *d* eigenvalue.

### *9.4. Summary of the findings*

1. The bulk of economic activity is accounted for by the first eigenvalue.
2. Industry lead times result in a precession period of about 10 years. From 1997 to 2005, the oscillation shows only the effects of lead times and instability.
3. In 2006, the rate of precession approaches the 1:4 strong resonance point for the ν eigenvalue, where second-order resonance arises from the sum of two λ eigenvalues being equal to a third.

4. In 2007, the system passes the 1:4 strong resonance point for the $\nu$ eigenvalue.
5. The last "normal" year is 2007, in the sense that whatever is causing the negative damping has remained coherent. Sustained negative damping is abnormal, but having persisted for ten or more years, it has taken on a semblance of normality.
6. In 2008, negative damping begins to drop, and the system passes the 1:3 strong resonance point for $\nu$.
7. In 2009, the 1:2 strong resonance point is approached.
8. In 2010, the Niemark-Sacker bifurcation boundary is passed, and positive damping appears.
9. In 2013, the critical damping point is crossed and over-damping occurs.

## 10. Conclusions and further work

The economy appears not to have returned to, or even begun to return to, the "normal" conditions that existed before 2008. Additional years of observation are needed. We should expect changes arising from the unfolding of the Patient Protection and Affordable Care Act as it takes full effect. We also could see changes arising from the huge overhang of bank reserves that have built up since the Federal Reserve System began paying interest on reserves in 2007. These reserves might "melt" into circulation if interest rates rise.

Value added and final use detail in the tables has not been broken out. The three categories of value added and the six categories of final use can be spliced with an agent-based model similar to that shown in Figure 4.

Petri nets can be employed for other settings that have creative and destructive processes, including the Goodwin cycle (Goodwin, 1967), the Lotka-Volterra predator-prey model (Samuelson, 1971), and shortwave and longwave radiation in climate change models.

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# Frequency based co-movement of inflation in selected euro area countries

*by*
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*This paper investigates the extent to which inflation rates in selected euro area countries are synchronised. The synchronisation of inflation is analysed using the multiple-correlation and multiple cross correlation at different frequencies using the methodology of wavelets. This new measure of cohesion based on wavelets allows us to assess how synchronisation has fevolved across different frequencies. Our results indicate that inflation correlations are more apparent at lower frequencies and the co-movement grows with lower frequencies. When we allow the correlation to be analysed across different frequencies as well as over time, our results indicate that the correlation has increased after the formation of euro area probably because of the common monetary policy.*

*Keywords: Co-movement, wavelets, time-frequency, inflation cycles*

*JEL classification: C40, E31, E32, F44*

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## 1. Introduction

A voluminous body of literature indicates that inflation rates can co-move across nations (Neely and Rapach 2008; Monacelli and Sala 2009; Mumtaz et al., 2011; Tiwari et al., 2015).

It is now a stylised fact that inflation rates can co-move because of host of reasons ranging from similar low frequency changes in monetary policy to the high frequency similar shocks.

In executing a fixed exchange rate sytem; like in case of the Bretton Woods, for example, or the European Economic and Monetary Union (EMU), member countries follows similar monetary policies (Neely and Rapach, 2011). Even under flexible exchange rate system, central banks tend to follow each other's policy shifts in order to stabilise exchange rates (Canzoneri and Gray, 1985; Calvo and Reinhart, 2002; Devereux and Engel, 2007). Similarities in monetary policy reaction functions, hence, act as an important link explaining the observed co-movement in inflation rates (Henriksen et al. 2009). The correlation of economic activity across countries also leads to co-movement of inflation (see Borio and Filardo; 2007). Further, as domestic inflation responds to correlated changes in domestic demand, co-movement in business cycles could also lead to co-movement in inflation. Bernanke (2007) identified two channels through which increased trade integration leads to co-movement of inflation across countries. First, the direct terms of trade channel, which accounts for changes in import prices; and second, a more indirect pro-competitive effect, which work to reduce the pricing power of domestic firms and lower mark-ups. Ultimately, these macroeconomic shocks along with central banks' tendency across nations to respond shocks in a similar fashion, contributes in generating significant co-movement in inflation rates. All these channels however operate at either medium or lower frequencies.

Common macroeconomic shocks such as oil price shocks and financial crises may also potentially link international inflation rates (Neely and Rapach, 2011). The common shocks may generate co-movement if they account for a large share of the variance in inflation and inflation rates respond in a similar fashion across countries. Hence, common shocks to commodity prices seem to be one potential explanation for the global inflation phenomenon (Ciccarelli and Mojon; 2008). This channel would possibly generate inflation co-movement at higher frequencies. Similar response to common shocks by central banks further amplifies such co-movement (e.g. Henriksen et al., 2011). There is a scant but significant literature which focuses on the frequency based co-movements of inflation. Henriksen et al. (2013), for example, documents that, at business cycle frequencies, fluctuations in aggregate price levels and nominal interest rates are substantially more synchronised across countries than fluctuations in output. Tiwari et al. (2015) analyse frequency-based co-movement of inflation in G7 countries and find that inflation co-movement is different at different frequencies.

Theoretical underpinnings therefore indicate that inflation co-movement may occur at different frequencies. The vast body of research work on international co-movement of

inflation rates, nevertheless, does not focus much on frequency based co-movement of inflation rates. Working under a variety of calibrated New Keynesian two-country models, Wang and Wen (2007), show that co-movement in inflation rates is higher than the one in output growth. Cecchetti et al. (2007) analyses the issue for G7 countries during 1970s; the period when most of the G7 economies were facing high inflationary pressure and finds evidence for persuasion of similar monetary policies across these states by the monetary authorities. Monacelli and Sala (2009) using disaggregated CPI data for developed economies i.e. the US, France, Germany and the United Kingdom observe that, international factors account for around 15% to 30% of the variation in domestic inflation. For a panel of 22 OECD countries, Ciccarelli and Mojon (2010), however, observe global inflation to explain up to 70% of the movement in domestic CPI inflation rates. Further, Neely and Rapach (2008) find common and regional factors together to explain around 50% of the variation in national inflation rates for 64 economies. Except Tiwari et al. (2015), co-movements in inflation rates at different frequencies on a regional level have not been analysed systematically so far.

The frequencies over which inflation rates co-move thus remain unaddressed thus far. Given the aforesaid theoretical explanations for the co-movement of inflation at different frequencies, the present study revisits the co-movement of inflation rates among selected euro area countries within time-frequency frame work. The methodology of wavelet multiple correlation, cross-correlation and wavelet coherency in continuous wavelet framework is employed to study the overall co-movement in inflation rates across different frequencies. Our results show that inflation co-movements are more pronounced at lower frequencies than at higher frequencies. Our results further show that after the introduction of euro area the inflation correlation has increased probably due to the low frequency common monetary policy.

The remainder of the paper is organised as follows. Section 2 describes the methodology. Section 3 gives the data description and discussion of results and finally, Section 4 draws the conclusions.

## 2. Data source and methodology

### *2.1. Data source*

The empirical analysis is conducted for four major countries of the euro area namely; France, Germany, Italy and Spain. The period of study spans from 1955:01 thorough 2012:07. The Consumer price Index (CPI) of monthly frequency is considered for the construction of the inflation variable. The CPI is used to construct the inflation rate of these economies. All data are sourced from the International Financial Statistics (IFS) CD-ROM (2012) published by the International Monetary Fund. The inflation co-movement using simple correlation is shown in Table 1 and plotted in the Figure 1.

### *2.2. Methodology*[1]

The conventional pair wise calculation of multi-scale correlations, as pointed by Javier Fernandez (2012), suffers from serious limitations. For example; under the conventional wavelet framework, the calculation of correlation and cross correlation among n inflation rates would result in n (n-1)/2 wavelet correlation graphs and J (order of wavelet transform) times cross correlation graphs.[2] The system ultimately becomes highly cumbersome and confusing for analyst who finally ends up with conflicting results and large set of graphs. Moreover, within the multivariate framework, the pair wise correlation coefficient could be

Figure 1. **CPI-based inflation for the selected euro area economies**

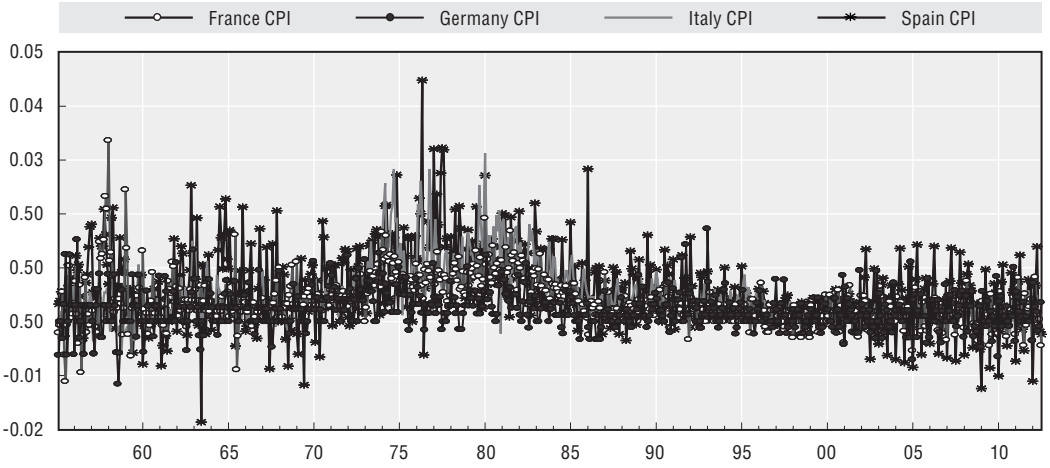



Table 1. **Correlation of CPI based inflation for the selected euro area economies**

| | France-CPI | Germany-CPI | Italy-CPI | Spain-CPI |
|---|---|---|---|---|
| France-CPI | 1 | | | |
| Germany-CPI | 0.2900 | 1 | | |
| Italy-CPI | 0.5428 | 0.3297 | 1 | |
| Spain-CPI | 0.456896 | 0.2007 | 0.4693 | 1 |

spurious given the possible association among the variables. The pair wise correlation, further, amplifies the type-I error in the multi-scale context due to experiment wise error rate (Cohen et al., 2003). For a given wavelet scale, at 5% level of significance, if one estimates the pair wise wavelet correlation significance tests with four unrelated series of inflation rates, the type 1 error will increase to $1-(1-\alpha)^6 = 0.98$ . This enhances the chance of finding significant correlation to 98% at given wavelet scale instead of 5%.

In the light of these limitations, the present study makes the use of the wavelet multiple-correlation and multiple cross-correlations proposed by Javier Fernandez (2012) to analyse the comovement of inflation in four selected euro area countries. The proposed methodology enjoys superiority over the conventional wavelet methods in many respects. First, the entire correlation within multivariate set of different frequencies in inflation rates can be presented in just in two plots of wavelet multiple correlation and wavelet multiple cross correlation. Second, it takes care of spurious correlation that emanates from the pair wise correlations within the multivariate set up. Finally, the proposed method is useful in providing the protection against type I error.

Considering a multivariate stochastic process $X_t = (x_{1t}, x_{2t}, ..., x_{nt})$ the wavelet multiple correlation (WMC) $\phi_X(\lambda_j)$, defined as one single set of multi-scale correlations, is calculated from $X_t$ as follows. If $W_{jt} = (w_{1jt}, w_{2jt}, ..., w_{njt})$ represents different wavelet scales then, applying MODWT to each $x_{it}$ process, the wavelet coefficients $\lambda_j$ are obtained to respective scales. For each wavelet scale $\lambda_j$, the square root of the regression coefficient of determination is calculated in that linear combination of variables $w_{1jt}$, $i = 1,...,n$, for which coefficient of determination is a maximum. The coefficient of determination $R^2 = 1 - 1/\rho^{ii}$ is obtained corresponding to the regression of a variable $z_i$ on a set of regressors $\{z_k, k \neq i\}$ ; where $\rho^{ii}$ is the i-th diagonal element of the inverse of the correlation matrix P.

The WMC $\phi_X(\lambda_j)$ is given as:

$$\phi_X(\lambda_j) = \sqrt{1 - \frac{1}{\max diag\, P_j^{-1}}}, \tag{1}$$

Where $P_j$ represents a $n \times n$ correlation matrix of $W_{jt}$, and the max diag (•) operator provides selection for the largest element in the diagonal of the argument. The coefficient of determination $R_i^2$ that corresponds to regression of variable $z_i$ on the rest of variables in the system is represented as equal to the square of correlation between the observed values of $z_i$ and the fitted values $\hat{z}_i$ obtained from the regression.

The WMC $\phi_X(\lambda_j)$ therefore, is defined as

$$\phi_X(\lambda_j) = Corr(w_{ijt}, \widehat{w}_{ijt}) = \frac{Cov(w_{ijt}, \widehat{w}_{ijt})}{\sqrt{Var(w_{ijt})\ Var(\widehat{w}_{ijt})}}, \tag{2}$$

where the wavelet variances are given as

$$Var(w_{ijt}) = \bar{\delta}_j^2 = \frac{1}{T_j} \sum_{t=:_j-1}^{T-1} w_{ijt}^2 \tag{3}$$

and

$$Var(\widehat{w}_{ijt}) = \bar{\xi}_j^2 = \frac{1}{T_j} \sum_{t=:_j-1}^{T-1} \widehat{w}_{ijt}^2 \tag{4}$$

and the covariance is calculated as

$$Cov(w_{ijt}, \widehat{w}_{ijt}) = \bar{\gamma}_j = \frac{1}{T_j} \sum_{t=L_j-1}^{T-1} w_{ijt}\, \widehat{w}_{ijt} \tag{5}$$

where $w_{ij}$ on the set of regressors $\{w_{kj}, k \neq i\}$ leads to maximisation of the coefficient of determination and $\widehat{w}_{ij}$ represents the corresponding fitted values. The number of wavelet coefficients affected by the boundary associated with a wavelet filter of length L and scale $\lambda_j$ is given by $L_j = (2^j - 1)(L-1) + 1$. Thus we left with the number of coefficients unaffected by the boundary conditions as $\tilde{T}_j = T - L_j + 1$.

Finally, we may also define the wavelet multiple cross-correlation (WMCC) allowing a lag $\tau$ between the observed and the fitted values of the variable selected as the criterion variable at each scale $\lambda_j$ as;

$$\phi_{X,\tau}(\lambda_j) = Corr(w_{ijt}, \widehat{w}_{ijt+\tau}) = \frac{Cov(w_{ijt}, \widehat{w}_{ijt+\tau})}{\sqrt{Var(w_{ijt})\ Var(\widehat{w}_{ijt+\tau})}}$$

The confidence intervals are constructed on the assumption that $X = \{X_1 \ldots . X_T\}$ is a realisation of multivariate Gaussian stochastic process of Equation (1) and $\tilde{W}_j = \{\tilde{W}_{j0} \ldots W_{j,T-1}\} = \{(\tilde{w}_{1j0} \ldots \tilde{w}_{nj0}), \ldots, (\tilde{w}_{1j,T/2^j-1})\}$, $j = 1 \ldots J$, are vectors of wavelet coefficients obtained with the application of MODWT of order J to each of the univariate time series $\{x_{i1} \ldots x_{iT}\} for\ i = 1 \ldots n$.

If $\tilde{\phi}_X(\lambda_j)$ is the sample wavelet correlation obtained from equation (1) then $\tilde{Z}_j \overset{a}{\sim} FN(z_j, (T/2^j - 3)^{-1})$, where $\tilde{Z}_j = \arctan h(\tilde{\phi}_X(\lambda_j))$ and *FN* stands for folded normal distribution. The confidence interval (CI) for the sample wavelet correlation coefficient is defined as;

$$CI_{1-\alpha}(\phi_X(\lambda_j)) = \tanh[\tilde{z}_j \pm \varphi_{1-\alpha/2}^{-1} / \sqrt{T/2^j - 3}] \tag{6}$$

## 3. Data analysis and empirical findings

The sample property of each variable has been analysed through some selective descriptive statistics presented in Table 2. It is evident that, the sample mean and skewness is positive for each series. All the series exhibit excess kurtosis indicating leptokurtic distribution relative to a normal distribution. Moreover, the Jarque-Bera normality test rejects normality of all the series.

Table 2. **Summary statistics of CPI based inflation for the major euro area economies**

| | France-CPI | Germany-CPI | Italy-CPI | Spain-CPI |
|---|---|---|---|---|
| Mean | 0.003745 | 0.002227 | 0.004837 | 0.005779 |
| Median | 0.003053 | 0.002082 | 0.003489 | 0.004320 |
| Maximum | 0.033632 | 0.017221 | 0.031309 | 0.044802 |
| Minimum | -0.011119 | -0.011628 | -0.006170 | -0.018636 |
| Std. dev. | 0.004377 | 0.003511 | 0.005147 | 0.006943 |
| Skewness | 1.117306 | 0.506214 | 1.667435 | 0.820969 |
| Kurtosis | 7.528351 | 4.306233 | 6.598208 | 5.254425 |
| Jarque-Bera | 733.1091 | 78.52361 | 691.9681 | 223.6287 |
| Probability | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Observations | 690 | 690 | 690 | 690 |

We start by decomposing the time series of inflation rates into different frequencies using Maximal Overlap Discrete Wavelet Transform (MODWT). This wavelet filter is preferred over more conventional orthogonal Discrete Wavelet Transform DWT because, by giving up orthogonality, the MODWT gains the characteristics that are needed more desirably in economic applications. For example, the MODWT has an ability to handle input data of any length, not just powers of two; it has other property of translation invariance – that is, a shift in the time series results in an equivalent shift in the transform. Moreover, it offers an enhanced resolution at lower scales since it oversamples data (meaning that more information is captured at each scale). Given the sample of 690 observations and maximum decomposition possibility of $[\log_2(T)]$, we could have decomposed all the inflation rates into nine details and one smooth component. Nevertheless, the viable wavelet coefficients for higher level decompositions get critically smaller. We have therefore chosen to decompose the time series of inflation in all countries into six details ($w_{i1},\ldots w_{i6}$) and one $v_{i6}$ smooth component. Table 3 gives the corresponding time dynamics of each wavelet coefficient.

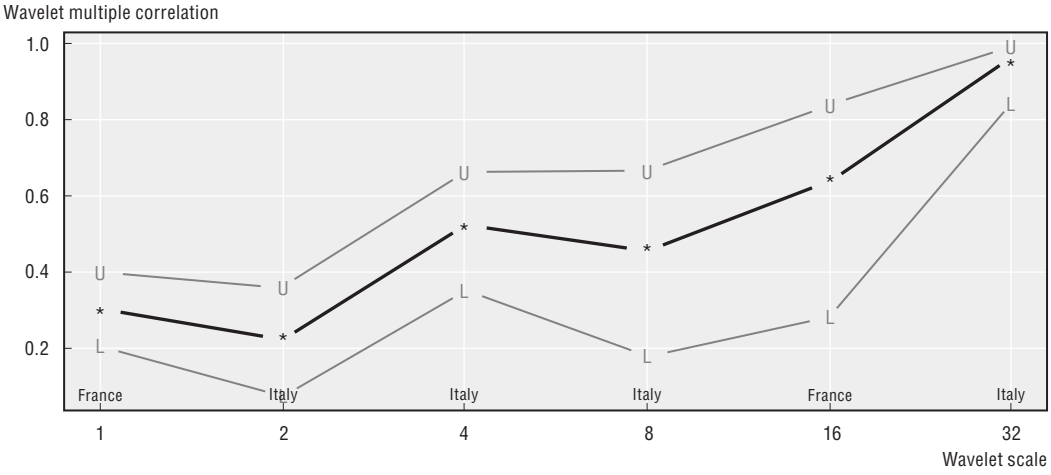
Table 3. **Time interpretation of different frequencies**

| | |
|---|---|
| $w_{i1}$ | 2 ~ 4 months |
| $w_{i2}$ | 4 ~ 8 months |
| $w_{i3}$ | 8 ~ 16 months |
| $w_{4i}$ | 16 ~ 32 months |
| $w_{5i}$ | 32 ~ 64 months |
| $w_{6i}$ | 64 ~ 128 months |

We then calculate the wavelet multiple contemporaneous correlation with upper and lower bound of 95% confidence intervals. The results obtained from the multiple correlation of inflation rates are shown in column 9 of Table 4 and its plots are shown in Figure 2. The results indicate that the multiple correlations are very low at higher frequencies, moderate at intermediate scales and very high at all lowest frequencies. However, since confidence

bounds overlap up to wavelet scale 16, it could therefore be interpreted as a constant correlation up to wavelet scale 16.[3] The inference is that, in these countries, inflation co-movements are more pronounced at lowest frequencies at least. Next, in order to test the leading indicator property of inflation for other countries, we estimate correlation for different wavelet scales with leads and lags up to one month. The multiple cross correlations at different leads is shown in Table 4 and Figure 3. This gives the country which has potential to lead the linear combination of other countries. In our case we show these countries on the x-axis of the Figure 2 and left corner of each frequency plot in Figure 3. Nevertheless, from the examination of figures, it is difficult to say whether inflation in these countries actually leads linear combination of other three countries. It is also seen that multiple cross correlation gets stronger with lower frequencies but gets weaker with successive lags. Our results therefore indicate that there is a substantial co-movement of inflation across selected euro area countries especially at lower frequencies (Long run).

Figure 2. **Wavelet multiple correlations for the selected euro area countries at different frequencies**




*Note:* The lines (U)pper and (L)ower correspond to the upper and lower bounds of the 95% confidence interval.

Table 4. **Wavelet multiple cross correlations at different leads and lags between euro area inflation**

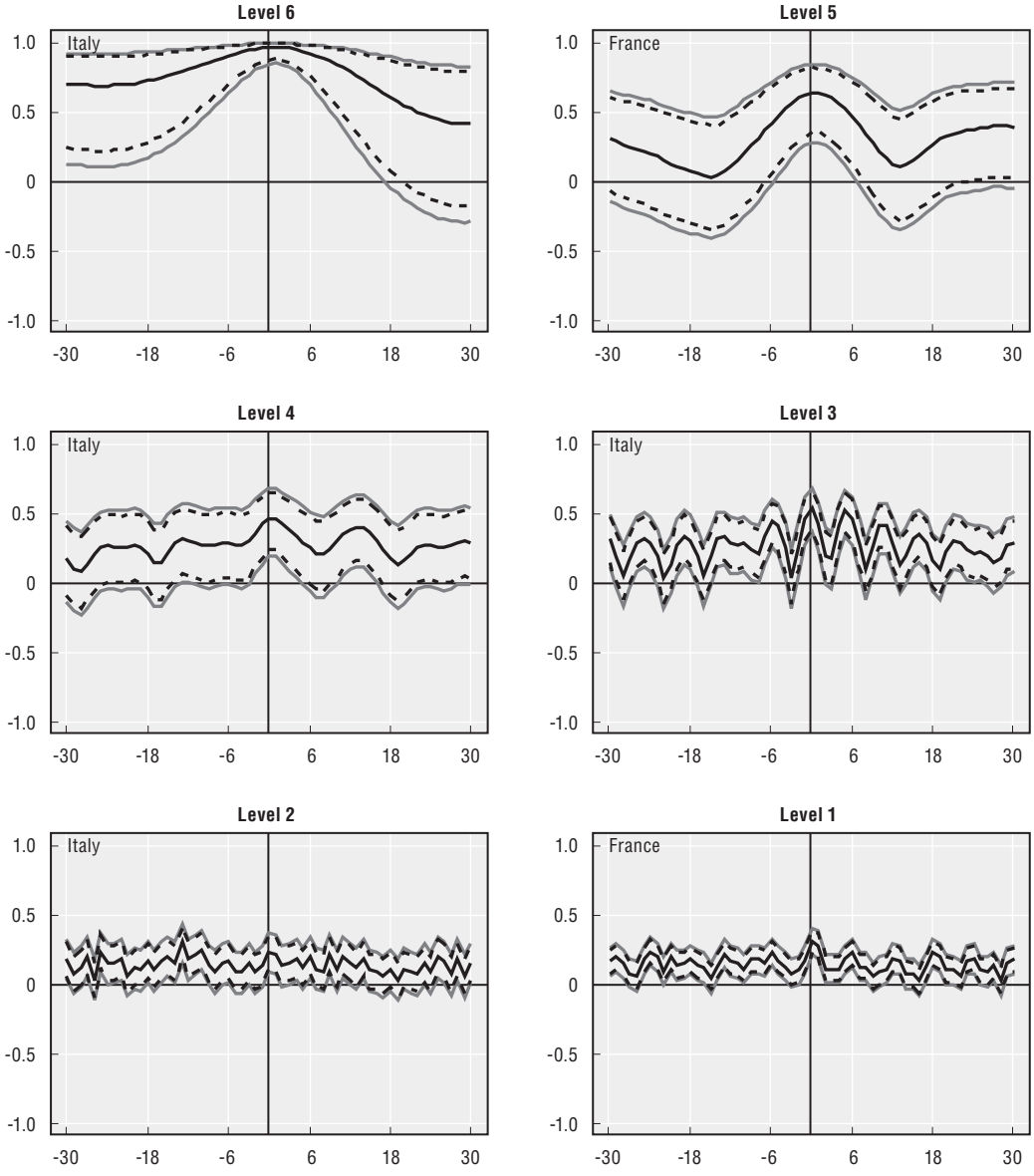
| Lags | -10 | | | -5 | | | 0 | | | +5 | | | +10 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scales | *L* | *Cor* | *U* | *L* | *Cor* | *U* | *L* | *Cor* | *U* | *L* | *Cor* | *U* | *L* | *Cor* | *U* |
| $w_{i1}$ | 0.00 | 0.11 | 0.21 | 0.06 | 0.17 | 0.27 | 0.21 | 0.31 | 0.40 | 0.07 | 0.17 | 0.27 | -0.02 | 0.09 | 0.19 |
| $w_{i2}$ | 0.09 | 0.24 | 0.38 | -0.07 | 0.08 | 0.23 | 0.08 | 0.22 | 0.36 | -0.04 | 0.11 | 0.26 | -0.05 | 0.10 | 0.24 |
| $w_{i3}$ | 0.08 | 0.29 | 0.47 | 0.21 | 0.40 | 0.56 | 0.35 | 0.52 | 0.66 | 0.34 | 0.51 | 0.65 | 0.21 | 0.40 | 0.57 |
| $w_{4i}$ | -0.04 | 0.27 | 0.52 | -0.03 | 0.27 | 0.53 | 0.18 | 0.46 | 0.67 | -0.02 | 0.29 | 0.54 | -0.01 | 0.29 | 0.54 |
| $w_{5i}$ | -0.25 | 0.20 | 0.58 | 0.05 | 0.47 | 0.75 | 0.28 | 0.64 | 0.84 | 0.12 | 0.52 | 0.78 | -0.23 | 0.22 | 0.60 |
| $w_{6i}$ | 0.45 | 0.84 | 0.96 | 0.68 | 0.92 | 0.98 | 0.84 | 0.96 | 0.99 | 0.74 | 0.94 | 0.98 | 0.45 | 0.84 | 0.96 |
| | -20 | | | -15 | | | 0 | | | +15 | | | +20 | | |
| $w_{i1}$ | 0.02 | 0.13 | 0.23 | -0.07 | 0.04 | 0.15 | 0.21 | 0.31 | 0.40 | -0.04 | 0.06 | 0.17 | -0.01 | 0.10 | 0.20 |
| $w_{i2}$ | -0.04 | 0.11 | 0.25 | 0.046 | 0.20 | 0.33 | 0.08 | 0.22 | 0.36 | -0.06 | 0.09 | 0.24 | -0.05 | 0.10 | 0.25 |
| $w_{i3}$ | 0.06 | 0.26 | 0.45 | -0.02 | 0.19 | 0.39 | 0.35 | 0.52 | 0.66 | 0.11 | 0.31 | 0.49 | 0.00 | 0.22 | 0.41 |
| $w_{4i}$ | -0.04 | 0.26 | 0.52 | -0.10 | 0.20 | 0.48 | 0.18 | 0.46 | 0.67 | 0.06 | 0.36 | 0.59 | -0.16 | 0.15 | 0.43 |
| $w_{5i}$ | -0.34 | 0.11 | 0.52 | -0.40 | 0.04 | 0.46 | 0.28 | 0.64 | 0.84 | -0.30 | 0.15 | 0.55 | -0.12 | 0.33 | 0.67 |
| $w_{6i}$ | 0.13 | 0.70 | 0.92 | 0.25 | 0.76 | 0.94 | 0.84 | 0.96 | 0.99 | 0.12 | 0.69 | 0.92 | -0.13 | 0.55 | 0.88 |

Table 4. **Wavelet multiple cross correlations at different leads and lags between euro area inflation** *(cont.)*

| Lags | -30 | | | -25 | | | 0 | | | +25 | | | +30 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scales | *L* | *Cor* | *U* | *L* | *Cor* | *U* | *L* | *Cor* | *U* | *L* | *Cor* | *U* | *L* | *Cor* | *U* |
| $w_{i1}$ | 0.04 | 0.15 | 0.26 | 0.07 | 0.17 | 0.28 | 0.21 | 0.31 | 0.40 | -0.01 | 0.09 | 0.20 | 0.07 | 0.18 | 0.28 |
| $w_{i2}$ | 0.03 | 0.18 | 0.32 | 0.08 | 0.23 | 0.36 | 0.08 | 0.22 | 0.36 | 0.04 | 0.19 | 0.33 | -0.00 | 0.15 | 0.29 |
| $w_{i3}$ | 0.11 | 0.31 | 0.49 | 0.12 | 0.32 | 0.50 | 0.35 | 0.52 | 0.66 | 0.01 | 0.22 | 0.41 | 0.08 | 0.29 | 0.47 |
| $w_{4i}$ | -0.14 | 0.17 | 0.44 | -0.06 | 0.24 | 0.51 | 0.18 | 0.46 | 0.66 | -0.05 | 0.25 | 0.52 | -0.02 | 0.28 | 0.54 |
| $w_{5i}$ | -0.14 | 0.31 | 0.65 | -0.23 | 0.22 | 0.60 | 0.28 | 0.64 | 0.84 | -0.06 | 0.38 | 0.70 | -0.06 | 0.39 | 0.71 |
| $w_{6i}$ | 0.13 | 0.70 | 0.92 | 0.10 | 0.69 | 0.92 | 0.84 | 0.96 | 0.99 | -0.26 | 0.44 | 0.84 | -0.29 | 0.42 | 0.83 |

*Notes:* Cor = Correlation Coefficient. L = Lower bound of 95% confidence Interval. U= Upper bound of 95% confidence Interval.

Figure 3. **Wavelet multiple cross-correlations for the selected euro area inflation rates at different frequencies**




*Note:* The highest and lowest lines correspond to the upper and lower bounds of the 95% confidence interval.

Nevertheless, one would argue that there are episodes of different monetary policy, different exchange rate regimes, financial crisis, oil price and other shocks. One of the important limitation of the analysis carried out so for is that it cannot take into account the time varying correlation which might have arose due to different exchange rate systems, oil price shocks and the formation of euro area. It is a stylised fact that under fixed exchange rate system the domestic economies are not insulated from nominal shocks originating abroad. Also important shocks like oil price shocks could have been yet another source of the strong cross-country correlation of inflation. In order to avoid limitation we analyse the time varying correlation by using the wavelet coherency in continuous wavelet framework. The methodology is discussed in the Appendix and is heavily drawn from Tiwari et al. (2015). We test the time varying frequency based correlation by using wavelet coherency in continuous wavelet framework. The results are shown in Figure 4. A common interpretational thread goes along all these figures. In all these figures it can be seen that for all countries pairs inflation is correlated at medium to lower frequencies which includes business cycle frequencies. A noteworthy point to be made here is that this correlation arises only after 1999-2000, which marks the formation of euro area. The strong

Figure 4. **Wavelet coherencies between country pairs**

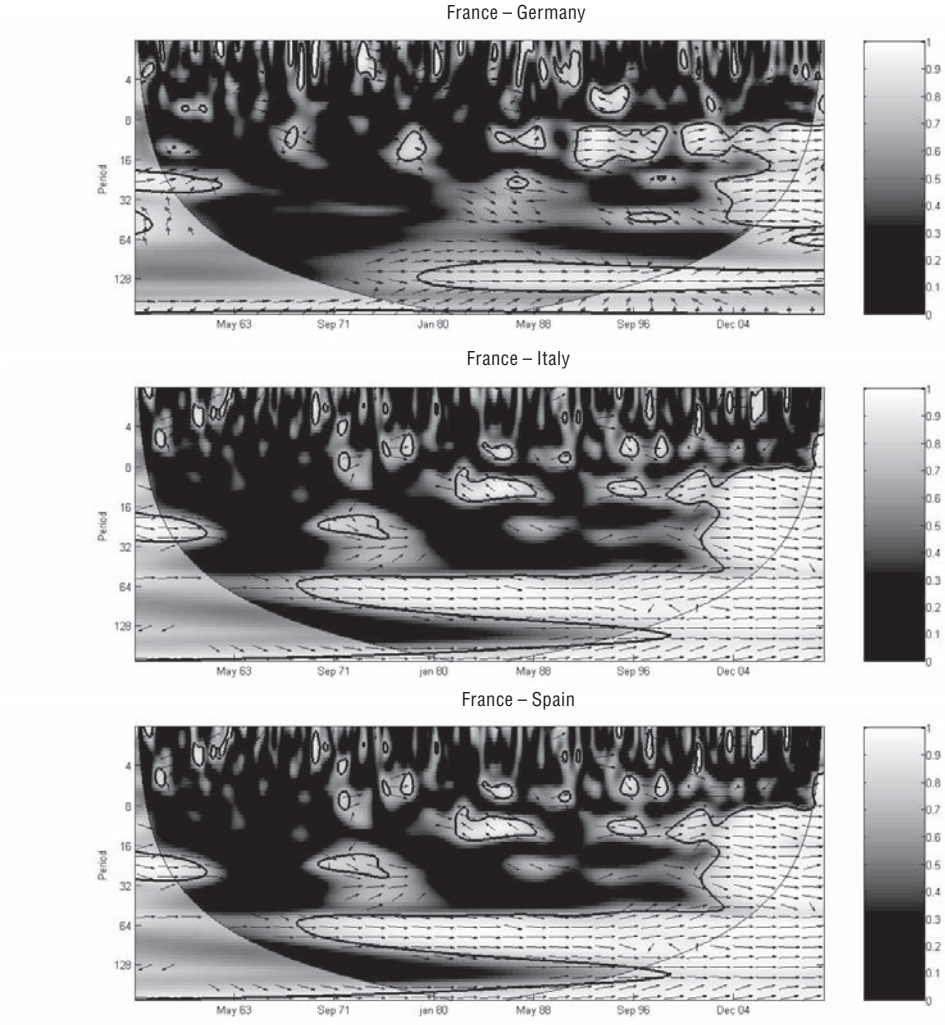
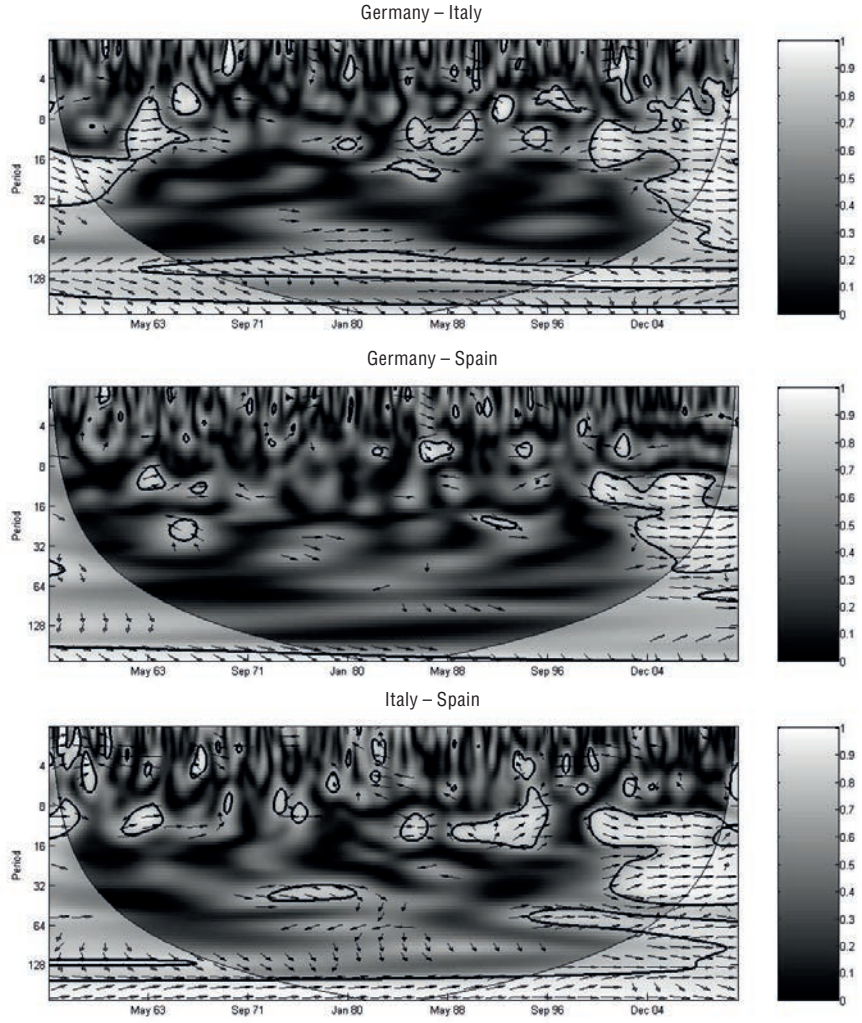


Figure 4. **Wavelet coherencies between country pairs** *(cont.)*




*Note:* The colours range from deep black (low coherency/no correlation) to deep white (high coherency/perfect correlation). The area within the black contours indicates coherency significant at 5% level of significance which is calculated by using Monte-Carlo simulations. The cone of influence indicates the region affected by edge effects. It is represented by the area outside the cone in light shade. Arrows indicate the wavelet phase angle. The phase difference between the two series is indicated by arrows. Arrows pointing to the right indicate that the variables are in phase and vice versa. In phase indicate that the variables are positively correlated and out of phase or anti-phase shows that variable are negatively correlated.

cross correlations of the country pairs could therefore be attributed to the low frequency common monetary policy after the formation of euro area. These results are similar to the results found in Henriksen et al. (2013). Nevertheless, we do not see sequential evidence of correlation induced due to low inflation in the 1950s and 1960s, high in the 1970s and gradually declining in the 1980s. Further during the important crises periods, we do not find any significant correlation for all the country pairs. Our results therefore indicate that the low frequency components of the common monetary policy, after the formation of euro area, could be the probable cause of inflation correlation.

## 4. Conclusion

The co-movement of inflation is analysed across the selected euro area countries using wavelet multiple correlation and wavelet multiple cross correlation. The wavelet multiple correlation is estimated as the square root of the regression coefficient of determination in that linear combination of wavelet coefficients for which the coefficient of determination is maximum. The results drawn from this analysis indicate that inflation rates in selected euro area countries are highly correlated at the lowest frequency. Also, it is shown that the co-movement of inflation increases with the time scales. Next, in order to test the leading indicator property of inflation, we test the inflation correlation at different leads and lags. We estimate the wavelet multiple cross-correlation by allowing thirty lags between observed and fitted values from the same linear combination as before at each of the frequencies. Nevertheless, given the symmetry in the graphs of Figure 3, it is difficult to interpret which country leads the inflation of other countries. We then use wavelet coherency in a continuous wavelet framework to test the correlation of inflation across different frequencies as well as over time for all the country pairs. Our results show that the low to medium frequency correlation of inflation for all the country pairs arises only after 1999-2000, which marks the formation of euro area. We therefore attribute this low to medium frequency correlation of inflation rates to the common monetary policy introduced after the formation of euro area.

### *Notes*

1. In our elaboration of wavelet multiple correlation and wavelet multiple cross-correlation methodology we heavily followed Javier Fernandez (2012) and Tiwari et al. (2013).
2. In this paper since we are using four countries and level six decomposition to measure inflation correlations, using pair wise wavelet correlation and cross correlation we would have end up with 6 wavelet correlation graphs and 36 cross correlation graphs.
3. We are thankful to anonymous referee for highlighting this point.

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# *Appendix*

## Wavelet Coherency[1]: Wavelet coherency in continuous wavelet framework

Wavelet transforms have property to decompose the time series over dilated and translated function called "mother wavelets" u(t).n Mother wavelets are expressed as the function of two parameters, one for the scale of the wavelets and other for the time position(s). Given a time series x(t) with chosen mother wavelet, its wavelet transform is given as:

$$W_x(a,\tau) = \frac{1}{\sqrt{a}} \int_{-\infty}^{+\infty} x(t)\phi^*\left(\frac{t-\tau}{a}\right)dt = \int_{-\infty}^{+\infty} x(t)\phi_{a,\tau}{}^*(t)dt \tag{A.1}$$

The contribution of scales and conjugate form are respectively given by the wavelet coefficients, $W_x(a,\tau)$, and * respectively. Hence we have a two-dimensional surface of $\Re(W_x(a,\tau))$.

In continuous wavelet framework, the wavelet the local wavelet power spectrum is computed as $S_x(f,\tau) = \|W_x(f,\tau)\|^2$.

Quantifying the relationship between two time series is calculated by the wavelet cross spectrum and the wavelet coherence. The wavelet cross-spectrum is given by

$$W_{x,y}(f,\tau) = W_x(f,\tau)W_y^*(f,\tau)$$

The wavelet coherency is given by,

$$R_{x,y}(f,\tau) = \frac{\left\|\left\langle W_{x,y}(f,\tau)\right\rangle\right\|}{\left\|\left\langle W_{x,x}(f,\tau)\right\rangle\right\|^{1/2}\left\|\left\langle W_{y,y}(f,\tau)\right\rangle\right\|^{1/2}} \tag{A.2}$$

The smoothing operator in time and scale is given by '$\langle\ \rangle$'. Following this definition we have $R_{x,y}(f,\tau)$ is bounded by $0 \le R_{x,y}(f,\tau) \le 1$.

Wavelet coherency is useful to detect transient association between the two time series because of its ability to variant over time. The phase difference $\varphi_{x,y}(f,\tau)$ is given by

$$\varphi_{x,y}(f,\tau) = \tan^{-1}\frac{\Im\left(\left\langle W_{x,y}(f,\tau)\right\rangle\right)}{\Re\left(\left\langle W_{x,y}(f,\tau)\right\rangle\right)} \tag{A.3}$$

Here we arrive at the positive or negative association between the two time series.

### *Note*

1. The methodology is heavily drawn from Tiwari et al. (2015). For the more elaborate usefulness of wavelets in testing inflation co-movement please refer Tiwari et al. (2015).

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# The role of data revisions and disagreement in professional forecasts

*by*
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*This study has two primary objectives: 1) To investigate whether official data releases of macroeconomic indicators are systematically revised 2) To evaluate the accuracy and disagreement of professional forecasters with respect to initial releases and final values. The analyses are applied to individual forecasts and real-time releases using a unique data set regarding 52 macroeconomic indicators for the US, the Eurozone, and Germany for the period of 1999-2010. The empirical analysis of data revisions shows that some indicators are considerably and systematically revised. Forecasters tend to account for systematic revisions and try to predict final values for certain indicators. For others, forecasters appear to be targeting initial releases, even though these indicators are systematically revised. In the latter case, forecasters use information inefficiently. Forecasters' disagreement regarding fundamentals is higher during domestic recessions and when the national stock market is volatile.*

*Keywords: Rational expectations, macroeconomic indicators, disagreement, survey analysis, real-time data*

*JEL classification: D81, D84, E17*

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## 1. Introduction

Many households, financial market participants, and policymakers base their expectations on professional forecasts (Carroll, 2003; Croushore, 1993). It is important to know how precise these estimates are, since awareness of forecasters' misperceptions and disagreement provides additional information for decision makers (Ciccarelli and Hubrich, 2010). However, forecast evaluation also depends on the relevant target, in particular whether forecasters aim at predicting the initial announcement or the final revised value. If initially released announcements substantially differ from the latest data revisions, it becomes more important to take the revisions (Croushore, 2011) and the target into account (Aruoba, 2008). For example, if forecasters systematically underestimate the initial release of an indicator that has systematically been revised downwards, this may indicate that they target the revision.

Market participants carefully observe scheduled announcements for economic activity (fundamentals) and monetary policy. These indicators potentially contain new information that is not yet incorporated into the expectations of the market participants. The resulting forecast errors ("news") affect financial markets and, via a number of channels, also the real economy (Basistha and Kurov, 2008). A large body of literature examines the response of financial market prices to the surprise component of major macroeconomic announcements and monetary policy releases (Andersson et al., 2009). Several studies focus on surprise effects stemming from monetary policy announcements and their impact on interest rates (Valente, 2009; Das, 2002; Ederington and Lee, 1993; Doukas and Melhem, 1986; Urich and Wachtel, 1984a; Grossman, 1981) and more recently on global equity indices (Wongswan, 2009), bond and stock markets (Basistha and Kurov, 2008; Andersson, 2007; Beber and Brandt, 2006; Deaves, 1990), as well as on foreign exchange rates (Andersen et al., 2007; Faust et al., 2007; Andersen et al., 2003).

Unexpected announcements of macroeconomic indicators and their revisions can have a significant impact on future activity. Oh and Waldman (1990) find that expectational shocks stemming from revisions of leading indicators explain a substantial part of the volatility in the growth rate of industrial production. They also show that errors in initial announcements are an important cause of expectational shocks. Although these shocks do not reflect real changes in the fundamentals, they can affect aggregate activity (Oh and Waldman, 2005). Faust et al. (2005) examine the predictability of GDP revisions in G-7 countries and find that such revisions are relatively large and highly predictable in several countries. Aruoba (2008) documents that revisions of major US macroeconomic indicators are biased, implying that the initial announcements are not rational forecasts of the final revisions.

Up until now, the literature on forecast accuracy has presented very ambiguous results. Some authors have found evidence of biased and inefficient forecasts (Isiklar et al., 2006; Gramlich, 1983; Friedman, 1980) while other studies documented rational expectations (Ager et al., 2009; Keane and Runkle, 1990; Grossman, 1981).[1]

When evaluating the formation of expectations, most studies focus on professional forecasters. In contrast, Carroll (2003) examines expectations of households and ascertains

that they are adjusted probabilistically towards the values presented in professional forecasts. The growing literature on the evaluation of professional forecasts either compares disagreement among forecasters with regard to announcements of indicators (Dovern et al., 2012a; Fildes and Stekler, 2002) or evaluates the impact of misperceptions and prior beliefs of economists regarding various variables (Lahiri and Sheng, 2008; Oeller and Barot, 2000).

This paper contributes to the literature by combining the analysis of expectation accuracy with an evaluation of data revisions. The study is based on a wide set of US, European, and German macroeconomic and monetary policy indicators. Examining both data revisions and the corresponding expectations allows for a more comprehensive interpretation of forecast errors. Furthermore, it investigates whether the misperceptions of forecasters are affected by economic conditions. This leads to additional insights into revisions and surprises. Finally, the analysis is complemented by an assessment of the process of expectation formation. For this study, a unique data set has been collected from *Bloomberg*, which contains the individual expectations of 509 professional forecasters regarding 57 major macroeconomic indicators for three of the world's most important economies for the period of 1999-2010. The data set also includes the initially announced figures, as well as their respective first and latest revisions. The dimension of the data revisions and expectation errors is investigated with regard to both the initial announcements and the revised data. Moreover, disagreement among forecasters can be observed over time.

The organization of the paper is as follows: A detailed description of the data is provided in Section 2. Data revisions and forecast accuracy are analyzed in Section 3. Sections 4 and 5 assess the impact of economic conditions on revisions, surprises, and disagreement among forecasters. The formation of expectations is discussed in Section 6. The findings are then summarized in Section 7.

## 2. Data

This study uses real-time data of professional forecasts of macroeconomic indicators. The data set contains the initial releases as well as first and last revisions of these official announcements. However, in contrast to a typical compilation of real-time data sets, the revision date is not reported (Croushore, 2011). Nevertheless, is possible to track data revisions to a certain extent.[2]

The data set consists of 52 macroeconomic indicators: 27 US indicators, 14 indicators for the Eurozone and 11 German indicators for the period 1999-2010. For each release date the actually announced (real-time) value, the first and the latest revision of the announcement, the release time,[3] and all individual forecasts are recorded. These releases cover five categories: *Economic Activity and GDP*, *Employment Situation and Housing Market*, *Business Conditions and Consumer Confidence*, *Prices and Monetary Policy*, and (macroeconomic) *Balances*. This is the most extensive data set when compared with other studies. 6 443 announcements were released in total, 442 different companies and 509 economists published 259 300 individual forecasts during the period 1999-2010. Most of the considered indicators are specified as percentage changes, but there are also indices which are expressed as "points", e.g. *ZEW EU Expectations*, or indicators which are denoted in "billions $", e.g. *US Consumer Credit*. Following Aruoba (2008), variables are transformed to growth rates or changes from the previous period if they were expressed in levels or if benchmark revisions (changes in base years) were carried out during the sample period.

For most indicators, announcements for a given period are released after the respective period has passed. For forward-looking indicators, the release date and the period the release refers to (reporting period) coincide. However, most indicators in this study refer to the previous period, with periods ranging from one week (for *Initial Jobless Claims*) to one quarter (predominantly applying to *GDP* data). For these indicators there is a lag between the release time and the reporting period.[4]

In order to capture the impact of economic conditions, dummy variables are constructed for recessions in the US, the Eurozone, and Germany, as well as for a high oil price and volatile stock markets. Following the NBER definition, there were two recessions in the US during the period 1999-2010: 01/2001-11/2001 and 12/2007-06/2009 (NBER, 2008). In accordance with the CEPR definition, the Eurozone was in a recession from 01/2008-04/2009 (CEPR, 2013). Since there is no official definition of recession in Germany, the internal definition of the Deutsche Bundesbank, is used with their kind permission. Accordingly, Germany experienced two recessions during the considered period 1999-2010: 04/2000-06/2003 and 01/2008-03/2009. Data on the oil price and on volatility indices were provided by the Deutsche Bundesbank. Based on the respective equity market, volatility indices are used for the US, the Eurozone, and Germany.[5]

The pool of economists and institutions participating in *Bloomberg* surveys is clearly larger for US indicators than for European and German indicators. In 1999, an average of 27 economists[6] participated in US surveys. Economists' forecasts for European and German indicators have only been available since 2002, starting on average with 14 (13) participating economists in European (German) surveys. In 2010, the pool of forecasters almost doubled with an average of 61 economists publishing their forecasts for US indicators and 24 (25) economists participating in the surveys for European (German) indicators.

Table 1 summarizes the number of announcements that were released for each indicator during the sample period. It also includes the official announcement frequency, the total number of forecasts, and the minimum, maximum and average number of forecasts as well as the standard deviation of participating economists per indicator. The highest number of announcements (618) was released for Initial Jobless Claims, as these figures are announced on a weekly basis. Although on average only 34 economists participated in this survey, the total number of forecasts for the whole period 1999-2010 was very high (20 865 estimates).

Since there is a scarcity of data regarding European and German indicators for the period 1999-2002, the total number of announcements is much higher for US indicators (3 988). Hence, the total number of released forecasts for US indicators (198 791) is considerably higher than the number of estimates for European and German indicators, both resulting from the higher number of US announcements and from the larger pool of economists who, on average, participate in US surveys. With respect to US indicators the survey of the *Federal Funds Rate* includes, on average, the highest number of participants (80). Simultaneously, the standard deviation of participating economists during the period 1999-2010 is also very high ($\sigma$ = 29.90). In contrast, only an average of 17 economists participate in the survey of *US ISM Prices Paid*, although there is less fluctuation with regard to the number of participants ($\sigma$ = 3.47). In general, economists release more forecasts for US indicators than for European and German indicators, but the number of participating forecasters (especially the maximum) is also more volatile for US indicators.

Table 1. **Number of official releases and professional forecasts per indicator for the period 1999-2010**

| | | | | Number of forecasters | | | | |
|---|---|---|---|---|---|---|---|---|
| Indicator | N releases | Frequency | Lag | Min. | Max. | Average | STD | Sum |
| Economic activity and GDP | | | | | | | | |
| US Business Inventories | 133 | Monthly | -2 | 18 | 61 | 47 | 10.64 | 6 226 |
| US Chicago Purchasing Mgrs. | 143 | Monthly | 0 | 7 | 65 | 46 | 14.54 | 6 565 |
| US Durable Goods Orders | 132 | Monthly | -1 | 27 | 81 | 61 | 13.54 | 8 094 |
| US Factory Orders | 134 | Monthly | -2 | 19 | 71 | 54 | 13.24 | 7 265 |
| US Retail Sales | 100 | Monthly | -1 | 50 | 83 | 71 | 7.18 | 7 119 |
| US Retail Sales less Autos | 98 | Monthly | -1 | 52 | 78 | 68 | 5.93 | 6 660 |
| US Industrial Production | 126 | Monthly | -1 | 11 | 82 | 62 | 15.17 | 7 867 |
| US Leading Indicators | 124 | Monthly | -1 | 25 | 63 | 49 | 11.17 | 6 084 |
| US Consumer Credit | 140 | Monthly | -2 | 6 | 46 | 33 | 6.26 | 4 689 |
| US GDP QoQ (A)* | 46 | Quarterly | -1 | 12 | 86 | 66 | 17.34 | 3 056 |
| US GDP QoQ (F)* | 47 | Quarterly | -1 | 33 | 81 | 61 | 14.10 | 2 850 |
| US GDP QoQ (S)* | 47 | Quarterly | -1 | 27 | 81 | 63 | 15.52 | 2 977 |
| EU Ind. Prod. | 94 | Monthly | -2 | 5 | 43 | 29 | 8.98 | 2 697 |
| EU Retail Sales | 87 | Monthly | -2 | 3 | 29 | 17 | 6.37 | 1 495 |
| EU GDP (A)* | 32 | Quarterly | -1 | 10 | 42 | 31 | 8.70 | 991 |
| EU GDP (F)* | 27 | Quarterly | -1 | 4 | 38 | 25 | 10.13 | 669 |
| EU GDP (S)* | 38 | Quarterly | -1 | 5 | 39 | 27 | 9.63 | 1 021 |
| DE Industrial Production | 78 | Monthly | -2 | 21 | 46 | 36 | 5.61 | 2 837 |
| DE Retail Sales | 96 | Monthly | -2 | 3 | 36 | 18 | 9.33 | 1 757 |
| DE GDP QOQ (A)* | 29 | Quarterly | -1 | 24 | 45 | 37 | 4.63 | 1 066 |
| DE GDP QOQ (F)* | 26 | Quarterly | -1 | 15 | 40 | 33 | 4.74 | 861 |
| Employment situation and housing markets | | | | | | | | |
| US Initial Jobless Claims | 618 | Weekly | -1 | 5 | 51 | 34 | 9.18 | 20 865 |
| US Non-farm Payroll | 137 | Monthly | -1 | 11 | 88 | 65 | 17.82 | 8 952 |
| US Building Permits | 100 | Monthly | -1 | 22 | 58 | 38 | 11.45 | 3 754 |
| US Housing Starts | 141 | Monthly | -1 | 28 | 80 | 59 | 13.93 | 8 373 |
| US New Home Sales | 143 | Monthly | -1 | 9 | 78 | 56 | 14.68 | 8 040 |
| EU Unemployment Rate | 125 | Monthly | -1 | 7 | 36 | 24 | 7.95 | 3 021 |
| DE Unemployment Rate | 105 | Monthly | 0 | 5 | 37 | 27 | 7.93 | 2 836 |
| Business conditions and consumer confidence | | | | | | | | |
| US ISM Manufacturing PMI | 142 | Monthly | -1 | 11 | 83 | 60 | 16.15 | 8 565 |
| US Philadelphia Fed Index | 141 | Monthly | 0 | 8 | 62 | 44 | 14.35 | 6 266 |
| US U. of Michigan Confidence | 274 | 2 weeks | 0 | 2 | 74 | 48 | 16.21 | 13 252 |
| US Consumer Confidence | 143 | Monthly | 0 | 9 | 78 | 55 | 15.26 | 7 905 |
| EU Business Climate | 90 | Monthly | 0 | 2 | 19 | 10 | 3.97 | 934 |
| EU Indust. Confidence | 89 | Monthly | 0 | 12 | 38 | 28 | 6.17 | 2 489 |
| EU Economic Confidence | 93 | Monthly | 0 | 9 | 33 | 23 | 5.77 | 2 119 |
| ZEW EU Expectations | 78 | Monthly | 0 | 3 | 12 | 6 | 1.78 | 462 |
| EU Consumer Confidence | 104 | Monthly | 0 | 12 | 40 | 27 | 7.06 | 2 849 |
| IFO DE Business Climate | 82 | Monthly | 0 | 20 | 46 | 40 | 4.24 | 3 246 |
| ZEW DE Current Situation | 83 | Monthly | 0 | 8 | 25 | 18 | 3.95 | 1 512 |
| ZEW DE Expectation | 104 | Monthly | 0 | 8 | 44 | 34 | 8.47 | 3 525 |
| Prices and monetary policy | | | | | | | | |
| US CPI | 123 | Monthly | -1 | 11 | 82 | 62 | 16.72 | 7 639 |
| US PPI | 119 | Monthly | -1 | 21 | 81 | 62 | 14.88 | 7 396 |
| US ISM Prices Paid | 108 | Monthly | -1 | 9 | 25 | 17 | 3.47 | 1 879 |
| US Import Price Index | 115 | Monthly | -1 | 7 | 58 | 39 | 13.47 | 4 448 |

Table 1. **Number of official releases and professional forecasts per indicator for the period 1999-2010** *(cont.)*

| | | | | Number of forecasters | | | | |
|---|---|---|---|---|---|---|---|---|
| Indicator | N releases | Frequency | Lag | Min. | Max. | Average | STD | Sum |
| Federal Funds Rate | 96 | Irregular | 0 | 10 | 157 | 80 | 29.90 | 7 713 |
| EU CPI | 106 | Monthly | -1 | 6 | 37 | 26 | 8.01 | 2 772 |
| EU PPI | 101 | Monthly | -2 | 6 | 31 | 21 | 6.88 | 2 110 |
| ECB Announ. Interest Rates | 123 | 2 weeks | 0 | 14 | 68 | 39 | 14.81 | 4 851 |
| EU M3 | 108 | Monthly | -1 | 10 | 39 | 27 | 7.08 | 2 942 |
| EU M3 3mth avg | 105 | Quarterly | -1 | 5 | 27 | 19 | 4.21 | 2 003 |
| DE CPI | 132 | Monthly | -1 | 11 | 39 | 27 | 6.11 | 3 610 |
| DE PPI | 114 | Monthly | -1 | 6 | 37 | 25 | 6.98 | 2 836 |
| Balances | | | | | | | | |
| US Gov't Budget Balance | 138 | Monthly | -1 | 8 | 42 | 31 | 5.34 | 4 230 |
| US Nominal Current Account | 37 | Quarterly | -1 | 26 | 53 | 42 | 5.82 | 1 560 |
| US Trade Balance | 143 | Monthly | -2 | 11 | 79 | 59 | 15.03 | 8 502 |
| DE Current Account | 100 | Monthly | -2 | 6 | 18 | 11 | 2.90 | 1 080 |
| DE Trade Balance | 106 | Monthly | -2 | 3 | 25 | 18 | 4.19 | 1 918 |
| Total | 6 443 | | | | | | | 259 300 |

*Note:* The lag indicates the reporting period an announcement refers to. * For GDP preliminary values (A) are released first, then a second release (S) follows; "final" figures (F) are announced in the third release. All three GDP releases (A, S, F) refer to the same reporting period (in Germany only two releases are announced: A and F).
*Source:* Bloomberg, own calculations.

## 3. The relationship between misperceptions and revisions

Croushore (2011) argues that data revisions matter for monetary policy, because overreacting to current data might result in a central bank making mistakes. On the other hand, if signals from data revisions are optimally extracted, monetary policy may not be significantly affected by data revisions. However, it is in the nature of things that policy makers' decisions are based on preliminary and partially revised data that are of unequal reliability. Against this background, the following section analyses data revisions, misperceptions, and the relationship between them. Due to data availability and in order to have comparable results across indicators and countries, the analysis is based on the period 2002-10.

According to decision requirements (real-time announcements vs. revised figures), substantial revisions should be taken into consideration by both forecasters and policymakers. This is important because if, for example, economists attempt to forecast the initial announcement, they will underestimate the final release, the more the initial announcement is revised up, and vice versa. In contrast, if all things being equal, economists attempt to forecast the latest release, they will overestimate the initial announcement. For this reason, it is first of all investigated whether the indicators are subject to significant revisions.[7] This implies that revised figures on average differ significantly from initial announcements. The following regression is used for the analysis:

$$(A_{i,t} - y_{i,t}) = \alpha_1 + \varepsilon^1_{i,t} \quad (1)$$

In a second step, the median forecast errors of the economists are analysed. A forecast error is defined as the difference between the official initial release $A_{i,t}$ (or the second ($S_{i,t}$) and the final release ($F_{i,t}$), respectively) and the median estimate $E_{i,t}$[8] of the forecasters. Whether forecast errors have a non-zero mean is assessed using the following specifications:

$$(A_{i,t} - E_{i,t}) = \alpha_2 + \varepsilon_{i,t}^2 \quad or \quad (y_{i,t} - E_{i,t}) = \alpha_2 + \varepsilon_{i,t,}^2, \tag{2}$$

where $A_{i,t}$ is the initial announcement for indicator $i$ at release date $t$, $E_{i,t}$ is the median expectation, $\varepsilon_t$ is the error term and $y \in \{S_{i,t}, F_{i,t}\}$.

Tables 2 and 3 display the mean, the standard deviation, the average absolute revision and the forecast error for each indicator, respectively. Positive mean revisions indicate that revised figures are on average lower than the initial announcements. With respect to economists' misperceptions, positive mean forecast errors imply that forecasters, on average, underestimate the respective release.

Table 2. **Descriptive statistics for data revisions (2002-10)**

| | | Revisions between | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $A$ and $S \equiv R^{AS}$ | | | $S$ and $F \equiv R^{SF}$ | | | $A$ and $F \equiv R^{AF}$ | | |
| Indicator | N | Mean | STD | Abs. | Mean | STD | Abs. | Mean | STD | Abs. |
| Economic activity and GDP | | | | | | | | | | |
| US Business Inventor. | 103 | 0.03 | 0.33 | 0.23 | -0.03 | 0.23 | 0.16 | -0.01 | 0.41 | 0.33 |
| Chicago Purch. Mgrs. | 107 | 0.00 | 0.03 | 0.01 | 0.00 | 0.14 | 0.10 | 0.00 | 0.14 | 0.10 |
| US Goods Orders | 103 | -0.04 | 5.42 | 4.08 | -0.02 | 1.73 | 1.20 | -0.06 | 5.32 | 4.06 |
| US Factory Orders | 102 | -0.18 | 3.15 | 2.33 | 0.05 | 1.15 | 0.79 | -0.12 | 2.88 | 2.22 |
| US Retail Sales | 100 | -0.01 | 1.45 | 1.05 | 0.00 | 0.58 | 0.37 | 0.00 | 1.53 | 1.16 |
| US Retail ex Autos | 98 | -0.11 | 1.00 | 0.72 | 0.10** | 0.41 | 0.28 | 0.00 | 1.08 | 0.81 |
| US Ind. Prod. | 98 | 0.05 | 0.83 | 0.54 | 0.04 | 0.43 | 0.28 | 0.09 | 0.91 | 0.65 |
| US Leading Ind. | 99 | -0.04 | 0.54 | 0.37 | -0.09*** | 0.33 | 0.26 | -0.13** | 0.60 | 0.50 |
| US Cons. Credit | 106 | -0.72 | 8.32 | 6.66 | -1.86*** | 4.41 | 3.73 | -2.58*** | 8.22 | 6.79 |
| US GDP QoQ | 36 | -0.18 | 0.72 | 0.56 | 0.00 | 0.28 | 0.21 | -0.17 | 0.76 | 0.60 |
| EU Ind. Prod. | 90 | 0.00 | 1.29 | 1.02 | -0.03 | 0.52 | 0.35 | -0.03 | 1.26 | 1.01 |
| EU Retail Sales | 83 | -0.04 | 1.09 | 0.86 | 0.06 | 0.40 | 0.32 | 0.02 | 1.06 | 0.81 |
| EU GDP QoQ | 30 | 0.00 | 0.03 | 0.01 | 0.00 | 0.05 | 0.02 | 0.00 | 0.05 | 0.03 |
| DE Ind. Prod. | 78 | -0.01 | 2.28 | 1.76 | 0.04 | 0.60 | 0.39 | 0.03 | 2.42 | 1.88 |
| DE Retail Sales | 79 | -0.20 | 2.52 | 1.94 | 0.27* | 1.30 | 0.98 | 0.07 | 2.67 | 2.18 |
| DE GDP QoQ | 29 | - | - | - | - | - | - | 0.00 | 0.00 | 0.00 |
| Employment situation and housing market | | | | | | | | | | |
| US In. Jobless Claims | 468 | -0.01 | 32.14 | 24.60 | -0.01 | 12.52 | 8.47 | -0.01 | 28.27 | 21.97 |
| US Non-farm Payroll | 103 | -1.96 | 127.28 | 87.98 | 15.14* | 86.36 | 65.89 | 13.17 | 142.11 | 111.31 |
| US Building Permits | 99 | 0.00 | 0.07 | 0.06 | 0.00 | 0.02 | 0.02 | 0.00 | 0.07 | 0.06 |
| US Housing Starts | 108 | 0.00 | 0.13 | 0.10 | 0.00 | 0.02 | 0.02 | 0.00 | 0.13 | 0.10 |
| US New Home Sales | 106 | 0.00 | 0.13 | 0.10 | 0.00 | 0.05 | 0.04 | 0.00 | 0.13 | 0.09 |
| EU Unempl. Rate | 107 | 0.00 | 0.09 | 0.06 | 0.00 | 0.22 | 0.12 | 0.00 | 0.22 | 0.14 |
| DE Unempl. Rate | 98 | 0.00 | 0.14 | 0.09 | 0.00 | 0.02 | 0.01 | 0.00 | 0.14 | 0.08 |
| Business conditions and consumer confidence | | | | | | | | | | |
| ISM Manuf. PMI | 107 | 0.00 | 0.01 | 0.00 | 0.00 | 0.05 | 0.04 | 0.00 | 0.06 | 0.04 |
| Phil. Fed Index | 105 | -0.01 | 0.68 | 0.16 | -0.20 | 4.57 | 1.84 | -0.21 | 4.61 | 1.95 |
| Uni Michigan Conf. | 215 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| US Cons. Conf. | 107 | 0.00 | 0.15 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.11 |
| EU Business Cl. | 88 | 0.31 | 2.91 | 0.84 | -0.05 | 0.34 | 0.16 | 0.26 | 2.73 | 0.77 |
| EU Ind. Conf. | 85 | -0.01 | 0.18 | 0.10 | 0.00 | 0.10 | 0.03 | -0.01 | 0.19 | 0.10 |
| EU Econ. Conf. | 92 | 0.00 | 0.02 | 0.01 | 0.00 | 0.02 | 0.01 | 0.00 | 0.03 | 0.02 |
| ZEW EU Expect. | 77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| EU Cons. Conf. | 103 | -0.01 | 0.19 | 0.08 | 0.00 | 0.01 | 0.00 | -0.01 | 0.19 | 0.09 |
| IFO Business Cl. | 81 | 0.00 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.01 |

Table 2. **Descriptive statistics for data revisions (2002-10)** *(cont.)*

| | | Revisions between | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $A$ and $S \equiv R^{AS}$ | | | $S$ and $F \equiv R^{SF}$ | | | $A$ and $F \equiv R^{AF}$ | | |
| Indicator | N | Mean | STD | Abs. | Mean | STD | Abs. | Mean | STD | Abs. |
| ZEW DE Situation | 82 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ZEW DE Expect. | 103 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Prices and monetary policy | | | | | | | | | | |
| US CPI | 89 | 0.01 | 0.12 | 0.02 | 0.02 | 0.27 | 0.15 | 0.03 | 0.29 | 0.17 |
| US PPI | 92 | 0.05* | 0.25 | 0.05 | 0.02 | 1.08 | 0.71 | 0.06 | 1.11 | 0.75 |
| US ISM Prices Paid | 107 | 0.00 | 0.04 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.04 | 0.01 |
| US Imp. Price Index | 95 | -0.01 | 1.32 | 0.93 | -0.01 | 0.59 | 0.29 | -0.03 | 1.44 | 1.08 |
| Federal Funds Rate | 72 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| EU CPI | 99 | 0.01 | 0.11 | 0.04 | 0.00 | 0.00 | 0.00 | 0.01 | 0.11 | 0.04 |
| EU PPI | 93 | -0.01 | 0.50 | 0.36 | -0.01 | 0.04 | 0.02 | -0.02 | 0.49 | 0.36 |
| ECB Interest Rates | 106 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| EU M3 | 104 | -0.06 | 0.44 | 0.33 | 0.01 | 0.08 | 0.04 | -0.05 | 0.44 | 0.33 |
| EU M3 3mth avg | 103 | -0.10** | 0.40 | 0.32 | 0.02** | 0.09 | 0.03 | -0.08** | 0.38 | 0.30 |
| DE CPI | 132 | 0.00 | 0.00 | 0.00 | 0.01 | 0.07 | 0.01 | 0.01 | 0.07 | 0.01 |
| DE PPI | 88 | 0.02 | 0.44 | 0.23 | 0.00 | 0.00 | 0.00 | 0.02 | 0.44 | 0.23 |
| Balances | | | | | | | | | | |
| US Budget Balance | 105 | 0.00 | 16.59 | 4.13 | 0.44 | 189.95 | 150.26 | 0.44 | 191.69 | 153.22 |
| US Current Account | 36 | -0.46 | 21.43 | 15.41 | 0.28 | 8.43 | 6.01 | -0.18 | 19.60 | 15.27 |
| US Trade Balance | 108 | 0.15 | 5.69 | 4.41 | -0.11 | 2.20 | 1.43 | 0.04 | 5.45 | 4.32 |
| DE Current Account | 99 | -0.03 | 7.57 | 5.78 | 0.01 | 1.57 | 0.94 | -0.02 | 7.66 | 5.89 |
| DE Trade Balance | 105 | 0.00 | 4.80 | 3.64 | -0.01 | 0.73 | 0.30 | -0.01 | 4.87 | 3.75 |

*Note:* Robust standard errors are not displayed. Coefficients significantly different from zero at 1%, 5%, and 10% significance level are denoted with ***, **, and *. A refers to the actual (initial announcement, S and F denote the second and the final release, respectively).
*Source:* Bloomberg, own calculations.

Following Croushore's methodology (Croushore, 2011), Table 2 summarizes the descriptive statistics for revisions for the period 2002-10. For each indicator i, three possible revisions are considered: the revision between the initial announcement $A_{i,t}$ at date $t$ and the second release of this series $S_{i,t}(R_{i,t}^{AS})$, the revision between the second release and the latest-available value $F_{i,t}(R_{i,t}^{SF})$ [9], and the overall revision from the initial announcement to the latest-available value $(R_{i,t}^{AF})$. The second column displays the number of observed releases; columns 3-11 show the mean and standard deviation of revisions for each indicator and revision, as well as the mean absolute revision. Asterisks mark revisions that are, on average, significantly different from zero at the usual significance levels. Hence, 7 indicators are on average significantly revised either between the first and the second release, between the second and the final release, or both.

To some extent, the revision process is also observable: the final release of *US Leading Indicators* is on average higher than the second announcement, which in turn is higher than the initial release. For *EU M3 3 month average*, it seems that the second release "over-corrects" the initial release, leading to a subsequent revision in the opposite direction; however, on average final releases are higher than the first announcements. Finally, there are indicators that are not subject to revisions (*Federal Funds Rate*, *University of Michigan Confidence*, *ZEW EU Expectations*, *ZEW DE Current Situation*, *ZEW DE Expectations*, and *ECB Announ. Interest Rates*).

Table 3. **Descriptive statistics for forecast errors (2002-10)**

| | | Forecast errors regarding | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual | | | *S* | | | *F* | | |
| Indicator | N | Mean | STD | Abs. | Mean | STD | Abs. | Mean | STD | Abs. |
| Economic activity and GDP | | | | | | | | | | |
| US Business Inventor. | 103 | 0.01 | 0.23 | 0.18 | -0.02 | 0.30 | 0.23 | 0.02 | 0.34 | 0.27 |
| Chicago Purch. Mgrs. | 107 | 0.00 | 0.13 | 0.10 | 0.00 | 0.13 | 0.10 | 0.00 | 0.05 | 0.04 |
| US Goods Orders | 103 | -0.14 | 2.45 | 1.86 | -0.10 | 4.28 | 3.19 | -0.08 | 4.16 | 3.21 |
| US Factory Orders | 102 | 0.00 | 0.72 | 0.54 | 0.18 | 3.10 | 2.30 | 0.12 | 2.85 | 2.23 |
| US Retail Sales | 100 | 0.02 | 0.59 | 0.44 | 0.03 | 1.21 | 0.87 | 0.03 | 1.28 | 0.96 |
| US Retail ex Autos | 98 | 0.02 | 0.52 | 0.39 | 0.13* | 0.75 | 0.54 | 0.03 | 0.82 | 0.61 |
| US Ind. Prod. | 98 | -0.06 | 0.40 | 0.30 | -0.11* | 0.65 | 0.43 | -0.15** | 0.73 | 0.49 |
| US Leading Ind. | 99 | 0.01 | 0.18 | 0.12 | 0.04 | 0.48 | 0.35 | 0.13** | 0.53 | 0.44 |
| US Cons. Credit | 106 | -0.33 | 6.30 | 4.89 | 0.39 | 5.30 | 4.04 | 2.25*** | 5.17 | 4.53 |
| US GDP QoQ | 35 | -0.09 | 0.77 | 0.62 | 0.09 | 0.95 | 0.76 | 0.08 | 1.00 | 0.81 |
| EU Ind. Prod. | 90 | -0.07 | 0.49 | 0.38 | -0.08 | 1.23 | 0.99 | -0.05 | 1.24 | 1.00 |
| EU Retail Sales | 83 | -0.10* | 0.53 | 0.41 | -0.06 | 0.88 | 0.71 | -0.12 | 0.87 | 0.69 |
| EU GDP QoQ | 30 | -0.01 | 0.15 | 0.09 | -0.01 | 0.16 | 0.10 | -0.01 | 0.20 | 0.15 |
| DE Ind. Prod. | 78 | -0.28 | 1.54 | 1.22 | -0.27 | 1.60 | 1.28 | -0.31 | 1.76 | 1.45 |
| DE Retail Sales | 79 | -0.66*** | 1.44 | 1.29 | -0.47** | 1.82 | 1.41 | -0.74*** | 2.02 | 1.74 |
| DE GDP QoQ | 29 | 0.03 | 0.35 | 0.24 | - | - | - | 0.05 | 0.36 | 0.25 |
| Employment situation and housing market | | | | | | | | | | |
| Initial Jobless Claims | 468 | 0.01 | 25.46 | 19.29 | 0.01 | 15.72 | 11.31 | 0.02 | 11.83 | 8.87 |
| US Non-farm Payroll | 103 | -18.70** | 79.45 | 61.79 | -16.74 | 107.32 | 73.01 | -31.87*** | 122.07 | 95.31 |
| US Building Permits | 99 | 0.00 | 0.06 | 0.05 | 0.00 | 0.04 | 0.03 | 0.00 | 0.04 | 0.03 |
| US Housing Starts | 108 | 0.00 | 0.11 | 0.08 | 0.00 | 0.05 | 0.04 | 0.00 | 0.05 | 0.04 |
| US New Home Sales | 106 | 0.00 | 0.12 | 0.09 | 0.00 | 0.06 | 0.05 | 0.00 | 0.06 | 0.04 |
| EU Unempl. Rate | 107 | 0.00 | 0.13 | 0.09 | 0.00 | 0.11 | 0.07 | 0.00 | 0.25 | 0.15 |
| DE Unempl. Rate | 98 | 0.00 | 0.14 | 0.11 | 0.00 | 0.12 | 0.09 | 0.00 | 0.12 | 0.09 |
| Business conditions and consumer confidence | | | | | | | | | | |
| ISM Manuf. PMI | 107 | 0.00 | 0.06 | 0.04 | 0.00 | 0.06 | 0.04 | 0.00 | 0.03 | 0.02 |
| Phil. Fed Index | 106 | -0.24 | 4.12 | 2.01 | -0.23 | 4.07 | 1.91 | -0.04 | 4.48 | 1.53 |
| Uni Michigan Conf. | 215 | -0.27 | 2.98 | 2.20 | -0.27 | 2.98 | 2.20 | -0.27 | 2.98 | 2.20 |
| US Cons. Conf. | 107 | 0.00 | 0.13 | 0.09 | 0.00 | 0.05 | 0.04 | 0.00 | 0.05 | 0.04 |
| EU Business Cl. | 88 | 0.29 | 2.57 | 0.71 | -0.02 | 0.48 | 0.25 | 0.03 | 0.27 | 0.16 |
| EU Ind. Conf. | 86 | -0.04 | 0.69 | 0.34 | -0.05 | 0.66 | 0.34 | -0.05 | 0.67 | 0.36 |
| EU Econ. Conf. | 92 | 0.00 | 0.02 | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.03 | 0.02 |
| ZEW EU Expect. | 77 | -0.23 | 1.61 | 0.68 | -0.23 | 1.61 | 0.68 | -0.23 | 1.61 | 0.68 |
| EU Cons. Conf. | 103 | 0.00 | 0.25 | 0.13 | 0.01 | 0.34 | 0.16 | 0.01 | 0.34 | 0.16 |
| IFO Business Cl. | 81 | 0.00 | 0.02 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 |
| ZEW DE Situation | 82 | 0.70 | 4.65 | 0.95 | 0.70 | 4.65 | 0.95 | 0.70 | 4.65 | 0.95 |
| ZEW DE Expect. | 103 | -0.30 | 2.08 | 0.74 | -0.30 | 2.08 | 0.74 | -0.30 | 2.08 | 0.74 |
| Prices and monetary policy | | | | | | | | | | |
| US CPI | 89 | 0.00 | 0.14 | 0.10 | -0.01 | 0.19 | 0.12 | -0.03 | 0.25 | 0.17 |
| US PPI | 92 | 0.06 | 0.55 | 0.41 | 0.01 | 0.56 | 0.42 | 0.00 | 0.80 | 0.62 |
| US ISM Prices Paid | 107 | 0.00 | 0.16 | 0.10 | 0.00 | 0.15 | 0.09 | 0.00 | 0.15 | 0.09 |
| US Imp. Price Index | 95 | 0.06 | 0.64 | 0.48 | 0.07 | 1.11 | 0.83 | 0.09 | 1.21 | 0.94 |
| Federal Funds Rate | 72 | 0.00 | 0.08 | 0.02 | 0.00 | 0.08 | 0.02 | 0.00 | 0.08 | 0.02 |
| EU CPI | 99 | 0.00 | 0.07 | 0.04 | -0.01 | 0.11 | 0.06 | -0.01 | 0.11 | 0.06 |
| EU PPI | 93 | -0.03 | 0.16 | 0.09 | -0.02 | 0.50 | 0.36 | -0.01 | 0.49 | 0.35 |
| ECB Interest Rates | 106 | 0.00 | 0.06 | 0.01 | 0.00 | 0.06 | 0.01 | 0.00 | 0.06 | 0.01 |

Table 3. **Descriptive statistics for forecast errors (2002-10)** *(cont.)*

| | | Forecast errors regarding | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual | | | *S* | | | *F* | | |
| Indicator | N | Mean | STD | Abs. | Mean | STD | Abs. | Mean | STD | Abs. |
| EU M3 | 104 | 0.06 | 0.44 | 0.36 | 0.12*** | 0.33 | 0.27 | 0.11*** | 0.32 | 0.27 |
| EU M3 3mth avg | 103 | 0.02 | 0.17 | 0.13 | 0.12*** | 0.37 | 0.32 | 0.10*** | 0.36 | 0.30 |
| DE CPI | 132 | -0.01 | 0.15 | 0.09 | -0.01 | 0.15 | 0.09 | -0.01 | 0.16 | 0.10 |
| DE PPI | 88 | 0.08** | 0.35 | 0.26 | 0.06 | 0.43 | 0.30 | 0.06 | 0.43 | 0.30 |
| Balances | | | | | | | | | | |
| US Budget Balance | 105 | -0.08 | 22.85 | 11.50 | -0.08 | 28.57 | 14.80 | -0.53 | 183.35 | 148.14 |
| US Current Account | 36 | 0.00 | 9.62 | 7.72 | 0.46 | 19.56 | 14.15 | 0.18 | 17.84 | 12.17 |
| US Trade Balance | 108 | 0.06 | 5.07 | 4.10 | -0.09 | 2.62 | 1.91 | 0.03 | 2.17 | 1.75 |
| DE Current Account | 99 | -0.07 | 4.84 | 3.87 | -0.05 | 4.20 | 3.21 | -0.05 | 4.40 | 3.41 |
| DE Trade Balance | 105 | -0.06 | 3.64 | 2.88 | -0.06 | 2.65 | 2.05 | -0.05 | 2.65 | 2.08 |

*Note:* Robust standard errors are not displayed. Coefficients significantly different from zero at 1%, 5%, and 10% significance level are denoted with ***, **, and *.
*Source:* Bloomberg, own calculations.

Table 3 refers to summary statistics for forecast errors regarding initial announcements Actual, columns 3-5), second releases (S, columns 6-8), and final values (F, columns 9-11).[10] On average the professional forecasters underestimate the final values of 5 indicators and overestimate 4 indicators. In all cases, a significant mean upward (overall) revision corresponds to forecasters underestimating the final values and vice versa. In contrast, with respect to initial announcements, the average forecast error of forecasters are only significantly different from zero for 4 indicators. This finding might indicate that, on average, professional forecasters aim at predicting initial announcements, given the possibility of significant revisions.

### *Testing for systematic revisions and forecast errors*

To assess whether initial announcements are biased forecasts of subsequent revisions, the latter are classified into two categories (Croushore, 2011; Aruoba, 2008; Mankiw and Shapiro, 1986; Mankiw et al., 1984): Revisions are classified as *noise* if the initial release is an observation of the revised series, measured with error. This implies that the revision is correlated with the data available when the estimate is made but uncorrelated with the revised value. Classification as *news* means that the initial release is an efficient estimate that accounts for all available information. Subsequent estimates incorporate new information, thus reducing the forecast error. Against this background, revised values are unpredictable with the information set that is available when the initial estimate is made. Hence, the revision is uncorrelated with the data available for the estimate but correlated with revised values. An increased variance of a revised series suggests that the revision mostly adds news. If, however, revisions mainly reduce noise, we should observe a reduction of the variance in the revised series (Croushore, 2011; Mankiw and Shapiro, 1986).

Table 4 shows the mean and the standard deviation of the initially announced series i ($A_i$), and after both the second (S) and the final release (F).[11] Most revisions to Economic Activity indicators can be characterised as news. We can confirm the finding in Mankiw and Shapiro (1986) that revisions of US GDP announcements are more like unforecastable

Table 4. **Descriptive statistics for Initial announcements, Second releases, Final releases, and Forecasters' median estimates (2002-10)**

| Indicator | Initial announcement | | Second release | | Final release | | Median estimate | |
|---|---|---|---|---|---|---|---|---|
| | Mean | STD | Mean | STD | Mean | STD | Mean | STD |
| Economic activity and GDP | | | | | | | | |
| US Business Inventories | 0.1942 | 0.5574 | 0.1689 | 0.6553 | 0.2019 | 0.7029 | 0.1850 | 0.4623 |
| US Chicago Purchasing Mgrs. | 0.0093 | 0.1047 | 0.0095 | 0.1062 | 0.0067 | 0.0783 | 0.0045 | 0.0610 |
| US Durable Goods Orders | 0.1282 | 3.2461 | 0.1660 | 3.5201 | 0.1903 | 3.5300 | 0.2689 | 1.6223 |
| US Factory Orders | 0.1539 | 2.0543 | 0.3333 | 2.3391 | 0.2784 | 2.1523 | 0.1549 | 1.8663 |
| US Retail Sales | 0.2570 | 1.0007 | 0.2640 | 1.1328 | 0.2600 | 1.1624 | 0.2330 | 0.7589 |
| US Retail Sales ex Autos | 0.3245 | 0.7526 | 0.4296 | 0.8569 | 0.3276 | 0.9090 | 0.2995 | 0.4096 |
| US Industrial Production | 0.1184 | 0.7101 | 0.0653 | 0.7779 | 0.0265 | 0.7894 | 0.1796 | 0.4544 |
| US Leading Indicators | 0.1323 | 0.4848 | 0.1697 | 0.5215 | 0.2596 | 0.5689 | 0.1273 | 0.3870 |
| US Consumer Credit | 3.1816 | 7.8390 | 3.9035 | 8.2889 | 5.7588 | 8.3323 | 3.5118 | 4.9617 |
| US GDP QoQ | 2.2556 | 2.5022 | 2.4361 | 2.7692 | 2.4314 | 2.7911 | 2.3458 | 2.4924 |
| EU Ind. Prod. | -0.0444 | 0.9526 | -0.0467 | 1.1244 | -0.0189 | 0.9973 | 0.0289 | 0.9513 |
| EU Retail Sales | 0.0518 | 0.7239 | 0.0916 | 0.6377 | 0.0325 | 0.6071 | 0.1542 | 0.4804 |
| EU GDP QoQ | 0.2167 | 0.6904 | 0.2200 | 0.6935 | 0.1429 | 0.8340 | 0.2250 | 0.5823 |
| DE Industrial Production | 0.0013 | 1.9505 | 0.0077 | 1.6734 | -0.0333 | 1.7483 | 0.2782 | 1.0094 |
| DE Retail Sales | -0.2304 | 1.6986 | -0.0329 | 1.4628 | -0.3051 | 1.4955 | 0.4335 | 0.6943 |
| DE GDP QoQ | 0.2069 | 1.0569 | - | - | 0.2346 | 1.1150 | 0.1793 | 0.8317 |
| Employment situation and housing market | | | | | | | | |
| US Initial Jobless Claims | 0.0598 | 21.5063 | 0.0662 | 21.5308 | 0.0726 | 16.7088 | 0.0534 | 11.8572 |
| US Non-farm Payroll | 7.7961 | 210.2215 | 9.7573 | 227.3247 | -5.3786 | 260.9788 | 26.4951 | 207.3701 |
| US Building Permits | -0.0101 | 0.0538 | -0.0097 | 0.0561 | -0.0101 | 0.0534 | -0.0102 | 0.0424 |
| US Housing Starts | -0.0064 | 0.0852 | -0.0065 | 0.0800 | -0.0068 | 0.0773 | -0.0081 | 0.0526 |
| US New Home Sales | -0.0061 | 0.0996 | -0.0060 | 0.0916 | -0.0073 | 0.0685 | -0.0072 | 0.0718 |
| EU Unemployment Rate | 0.0159 | 0.1134 | 0.0187 | 0.0933 | 0.0150 | 0.2298 | 0.0159 | 0.1232 |
| DE Unemployment Rate | -0.0194 | 0.1603 | -0.0204 | 0.1546 | -0.0204 | 0.1533 | -0.0194 | 0.1597 |
| Business conditions and consumer confidence | | | | | | | | |
| ISM Manufacturing PMI | 0.0035 | 0.0496 | 0.0035 | 0.0499 | 0.0039 | 0.0413 | 0.0038 | 0.0452 |
| Philadelphia Fed Index | -0.0013 | 3.5443 | 0.0118 | 3.5042 | 0.1919 | 4.3181 | 0.2307 | 2.2801 |
| U. of Michigan Confidence | 81.5609 | 12.0738 | 81.5609 | 12.0738 | 81.5609 | 12.0738 | 81.8309 | 12.1394 |
| US Consumer Confidence | 0.0012 | 0.1140 | 0.0012 | 0.1123 | 0.0012 | 0.1123 | 0.0001 | 0.0948 |
| EU Business Climate | 0.2796 | 2.9710 | -0.0271 | 0.8095 | 0.0227 | 0.6782 | -0.0071 | 0.7307 |
| EU Indust. Confidence | -0.0178 | 0.4712 | -0.0456 | 0.5761 | -0.0438 | 0.5763 | -0.0317 | 0.6476 |
| EU Economic Confidence | 0.0010 | 0.0254 | 0.0007 | 0.0209 | 0.0010 | 0.0326 | 0.0010 | 0.0257 |
| ZEW EU Expectations | -0.2384 | 1.6041 | -0.2384 | 1.6041 | -0.2384 | 1.6041 | -0.0039 | 0.7817 |
| EU Consumer Confidence | 0.0170 | 0.1873 | 0.0283 | 0.2713 | 0.0283 | 0.2715 | 0.0166 | 0.1996 |
| IFO Business Climate | 0.0019 | 0.0166 | 0.0018 | 0.0164 | 0.0019 | 0.0166 | 0.0018 | 0.0173 |
| ZEW DE Current Situation | 0.3917 | 3.8976 | 0.3917 | 3.8976 | 0.3917 | 3.8976 | -0.3037 | 2.3907 |
| ZEW DE Expectation | 0.0081 | 0.8150 | 0.0081 | 0.8150 | 0.0081 | 0.8150 | 0.3060 | 2.1134 |
| Prices and monetary policy | | | | | | | | |
| US CPI | 0.2034 | 0.4001 | 0.1899 | 0.4156 | 0.1730 | 0.3979 | 0.2045 | 0.3115 |
| US PPI | 0.2728 | 0.9736 | 0.2250 | 0.9681 | 0.2098 | 0.8458 | 0.2147 | 0.5692 |
| ISM Prices Paid | 0.0154 | 0.1352 | 0.0154 | 0.1349 | 0.0162 | 0.1348 | 0.0160 | 0.1396 |
| US Import Price Index | 0.3347 | 1.6083 | 0.3495 | 1.6387 | 0.3642 | 1.6974 | 0.2753 | 1.2491 |
| Federal Funds Rate | -0.0208 | 0.2775 | -0.0208 | 0.2775 | -0.0208 | 0.2775 | -0.0208 | 0.2686 |
| EU CPI | 0.1828 | 0.3408 | 0.1747 | 0.3418 | 0.1747 | 0.3418 | 0.1828 | 0.3218 |
| EU PPI | 0.1849 | 0.5256 | 0.1935 | 0.5918 | 0.2000 | 0.5850 | 0.2102 | 0.4316 |
| ECB Announ. Interest Rates | -0.0212 | 0.1763 | -0.0212 | 0.1763 | -0.0212 | 0.1763 | -0.0212 | 0.1862 |
| EU M3 | 7.0269 | 3.0881 | 7.0856 | 3.0713 | 7.0779 | 3.0570 | 6.9678 | 3.0040 |

Table 4. **Descriptive statistics for Initial announcements, Second releases, Final releases, and Forecasters' median estimates (2002-10)** *(cont.)*

| Indicator | Initial announcement | | Second release | | Final release | | Median estimate | |
|---|---|---|---|---|---|---|---|---|
| | Mean | STD | Mean | STD | Mean | STD | Mean | STD |
| EU M3 3mth avg | 7.0136 | 3.0940 | 7.1136 | 3.0761 | 7.0942 | 3.0729 | 6.9898 | 3.0840 |
| DE CPI | 0.1379 | 0.3511 | 0.1379 | 0.3511 | 0.1318 | 0.3517 | 0.1436 | 0.3077 |
| DE PPI | 0.2409 | 0.5247 | 0.2239 | 0.5410 | 0.2239 | 0.5410 | 0.1648 | 0.3308 |
| | | | | Balances | | | | |
| US Gov't Budget Balance | -0.9152 | 113.4440 | -0.9152 | 112.9201 | -1.3590 | 110.4467 | -0.8333 | 106.7316 |
| US Nominal Current Account | -0.8944 | 14.7250 | -0.4333 | 17.2704 | -0.7167 | 15.4552 | -0.8931 | 14.5379 |
| US Trade Balance | -0.0861 | 3.8612 | -0.2370 | 3.8363 | -0.1250 | 3.4282 | -0.1509 | 2.6985 |
| DE Current Account | 0.1051 | 4.9121 | 0.1333 | 4.8787 | 0.1263 | 5.0059 | 0.1798 | 2.8778 |
| DE Trade Balance | 0.0581 | 3.1667 | 0.0581 | 3.0012 | 0.0657 | 3.0173 | 0.1152 | 1.7282 |

*Note:* Variables are transformed to growth rates or changes from the previous period if they were expressed in levels or if benchmark revisions (changes in base years) were carried out during the sample period. This applies to the following indicators: *Chicago Purchasing Mgrs.*, *ISM Manufacturing PMI*, *ISM Prices Paid*, *Philadelphia Fed Index*, *EU Economic Confidence*, *US Consumer Confidence*, *EU Business Climate*, *EU Ind. Confidence*, *ZEW EU Expectations*, *EU Consumer Confidence*, *IFO Business Climate*, *ZEW DE Current Situation*, *ZEW DE Expectation*, *ISM Prices Paid, Initial Jobless Claims, Building Permits, Housing Starts,* and *New Home Sales* are transformed into growth rates from the previous period. *Initial Jobless Claims, DE and EU Unemployment Rates, Federal Funds Rate, ECB Interest Rates, Gov't Budget Balance, Nominal Current Account, US Trade Balance, DE Current Account,* and *DE Trade Balance* are converted into changes from the previous period.
*Source:* Bloomberg, own calculations.

new information. This result also applies to revisions of EU GDP, DE GDP, EU CPI, EU PPI, DE CPI, and DE PPI. In contrast, revised series of US Purchasing Managers, EU Retail Sales, DE Industrial Production, and DE Retail Sales are more like forecastable measurement errors. This is also the case for revisions to US CPI, US PPI, ISM Prices Paid, and EU M3. In most cases revisions of Employment Situation & Housing Market indicators can also be characterised as noise. Although first revisions to most Macroeconomic Balances reduce noise, last revisions of the US Nominal Current Account and the DE Current Account add new information.

The following regressions are considered to distinguish between revisions as noise or news:[12]

$$A_{i,t} = \alpha_3 + \beta_3 F_{i,t} + \varepsilon^3_{i,t} \tag{3}$$

$$F_{i,t} = \alpha_4 + \beta_4 A_{i,t} + \varepsilon^4_{i,t}, \tag{4}$$

where $A_{i,t}$ is the initial release for indicator i at release date t, $F_{i,t}$ is the corresponding last-available release, and ε is a white noise error term. The noise hypothesis is tested by implementing a Wald test for the joint hypothesis $H_0 : \alpha_3 = 0, \beta_3 = 1$, and the news hypothesis by the joint hypothesis $H_0 : \alpha_4 = 0, \beta_4 = 1$. In both cases, rejection of $H_0$ points to some unspecified alternative. In particular, rejection of the noise hypothesis does not imply that the revision can be described as news, nor the reverse.

Table 5 summarized the results for both regressions. The left panel refers to the noise hypothesis and the right panel presents the results of the news hypothesis. Each panel shows the estimated coefficients of the constant and the slope parameter (columns 2 and 3 and columns 5 and 6, respectively). Asterisks indicate that the null hypothesis $H_0 : \alpha = 0$ OR $H_0 : \beta = 1$ have to be rejected at the usual significance levels. Columns 4 and 7 display the p-values of the Wald test. Comparing the two hypotheses, it becomes evident that the news hypothesis cannot be rejected for *US Business Inventories*, *US Non-farm Payroll*, and *EU Consumer Confidence*. In contrast, the noise hypothesis for these indicators is rejected at the

1% significance level. Hence, those revisions are best characterized as news and are therefore unpredictable within this framework. The opposite is observed for the revisions of the *EU Business Climate*, *US CPI*, and the Eurozone money supply (*M3 and M3 3mth average*), which are best described as noise and are therefore predictable with the information set available at the time the initial release was announced. It must be noted that most indicators fail both Wald tests, which means that initial announcements are biased forecasts of the true values. However, this framework provides no guidance for the classification of revisions into noise and news if both the news as well as the noise hypotheses are rejected.[13] It is apparent from Table 5 that for very few indicators neither of the two hypotheses can be rejected. This applies to *GDP* releases as well as to *EU Industrial Confidence*, *US ISM Prices Paid*, and *DE CPI*.

Table 5. **Revision analysis**

| Dependent variable: | | | Initial announcement | | | Final Release | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory variable: | | | Final release (Noise hypothesis) | | | Initial announcement (News hypothesis) | | |
| | | *Noise/Signal* | $\alpha_3$ | $\alpha_3$ | *p* | $\alpha_4$ | $\beta_4$ | *p* |
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Economic activity and GDP | | | | | | | | |
| US Business Inventories | 103 | 0.58 | 0.06* | 0.65*** | 0.000 | 0.00 | 1.03 | 0.920 |
| Chicago Purch. Mgrs. | 107 | 1.74 | 0.01 | -0.11*** | 0.000 | 0.01 | 0.06*** | 0.000 |
| US Durable Goods Orders | 103 | 1.51 | 0.17 | -0.21*** | 0.000 | 0.22 | 0.25*** | 0.000 |
| US Factory Orders | 102 | 1.34 | 0.14 | 0.06*** | 0.000 | 0.27 | 0.06*** | 0.000 |
| US Retail Sales | 100 | 1.32 | 0.26** | 0.00*** | 0.000 | 0.26* | 0.00*** | 0.000 |
| US Retail ex Autos | 98 | 1.19 | 0.28** | 0.14*** | 0.000 | 0.26* | 0.20*** | 0.000 |
| US Ind. Prod. | 98 | 1.16 | 0.11 | 0.23*** | 0.000 | -0.01 | 0.29*** | 0.000 |
| US Leading Ind. | 99 | 1.06 | 0.05 | 0.30*** | 0.000 | 0.21*** | 0.41*** | 0.000 |
| US Cons. Credit | 106 | 0.99 | 0.56 | 0.46*** | 0.000 | 4.12*** | 0.51*** | 0.000 |
| US GDP QoQ | 35 | 0.27 | 0.13 | 0.88* | 0.309 | -0.33 | 1.06 | 0.000 |
| EU Ind. Prod. | 90 | 1.27 | -0.04 | 0.16*** | 0.000 | -0.01 | 0.17*** | 0.000 |
| EU Retail Sales | 83 | 1.74 | 0.06 | -0.31*** | 0.000 | 0.04 | 0.22*** | 0.000 |
| EU GDP QoQ | 30 | 0.07 | 0.00 | 0.98 | 0.340 | -0.00 | 1.02 | 0.420 |
| DE Ind. Prod. | 78 | 1.39 | 0.01 | 0.16*** | 0.000 | -0.03 | 0.13*** | 0.000 |
| DE Retail Sales | 79 | 1.79 | -0.37** | -0.45*** | 0.000 | -0.39** | -0.35*** | 0.000 |
| Employment situation and housing markets | | | | | | | | |
| US In. Jobless Claims | 468 | 1.69 | 0.07 | -0.10*** | 0.000 | 0.08 | -0.06*** | 0.000 |
| US Non-farm Payroll | 103 | 0.54 | 11.43 | 0.68*** | 0.000 | -13.50 | 1.04 | 0.570 |
| US Building Permits | 99 | 1.35 | -0.01 | 0.09*** | 0.000 | -0.01* | 0.09*** | 0.000 |
| US Housing Starts | 108 | 1.64 | -0.01 | -0.24*** | 0.000 | -0.01 | -0.20*** | 0.000 |
| US New Home Sales | 106 | 1.84 | -0.01 | -0.13*** | 0.000 | -0.01 | -0.06*** | 0.000 |
| EU Unempl. Rate | 107 | 0.98 | 0.01 | 0.15*** | 0.000 | 0.01 | 0.60** | 0.070 |
| DE Unempl. Rate | 98 | 0.89 | -0.01 | 0.65*** | 0.030 | -0.01 | 0.60*** | 0.000 |
| Business conditions and consumer confidence | | | | | | | | |
| ISM Manuf. PMI | 107 | 1.38 | 0.00 | 0.28*** | 0.000 | 0.00 | 0.19*** | 0.000 |
| Phil. Fed Index | 105 | 1.07 | -0.06 | 0.27*** | 0.008 | 0.21 | 0.40** | 0.020 |
| US Cons. Conf. | 107 | 1.35 | 0.00 | 0.10*** | 0.000 | 0.00 | 0.10*** | 0.000 |
| EU Business Cl. | 88 | 4.03 | 0.23 | 1.97 | 0.662 | -0.01 | 0.10*** | 0.000 |
| EU Ind. Conf. | 85 | 0.32 | -0.01 | 0.91* | 0.139 | 0.01 | 0.94 | 0.240 |
| EU Econ. Conf. | 92 | 1.01 | 0.00 | 0.29*** | 0.000 | 0.00 | 0.48*** | 0.030 |
| EU Cons. Conf. | 103 | 0.70 | 0.00 | 0.49*** | 0.004 | 0.01 | 1.03 | 0.710 |
| IFO Business Cl. | 81 | 1.04 | 0.00 | 0.46*** | 0.000 | 0.00 | 0.46*** | 0.000 |

Table 5. **Revision analysis** *(cont.)*

| Dependent variable: | | | Initial announcement | | | Final Release | | |
|---|---|---|---|---|---|---|---|---|
| Explanatory variable: | | | Final release (Noise hypothesis) | | | Initial announcement (News hypothesis) | | |
| | | *Noise/Signal* | $\alpha_3$ | $\alpha_3$ | *p* | $\alpha_4$ | $\beta_4$ | *p* |
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Prices and monetary policy | | | | | | | | |
| US CPI | 89 | 0.73 | 0.08* | 0.74* | 0.156 | 0.03 | 0.73** | 0.010 |
| US PPI | 92 | 1.31 | 0.21* | 0.31*** | 0.000 | 0.15 | 0.23*** | 0.000 |
| US ISM Prices Paid | 107 | 0.29 | 0.00 | 0.96 | 0.433 | 0.00 | 0.96 | 0.350 |
| US Imp. Price Index | 95 | 0.85 | 0.12 | 0.59*** | 0.001 | 0.14 | 0.66*** | 0.020 |
| EU CPI | 99 | 0.32 | 0.02 | 0.95** | 0.057 | 0.00 | 0.95** | 0.100 |
| EU PPI | 93 | 0.84 | 0.08 | 0.55*** | 0.000 | 0.07 | 0.68*** | 0.020 |
| EU M3 | 104 | 0.14 | -0.05 | 1.00 | 0.454 | 0.19** | 0.98 | 0.080 |
| EU M3 3mth avg | 103 | 0.12 | -0.08 | 1.00 | 0.101 | 0.18** | 0.99 | 0.040 |
| DE CPI | 132 | 0.20 | 0.01 | 0.98 | 0.606 | 0.00 | 0.98 | 0.610 |
| DE PPI | 88 | 0.82 | 0.10** | 0.64** | 0.019 | 0.06 | 0.68*** | 0.010 |
| Balances | | | | | | | | |
| US Gov't Budget Balance | 105 | 1.74 | -1.57 | -0.48*** | 0.000 | -1.77 | -0.45*** | 0.000 |
| US Current Account | 36 | 1.27 | -0.79 | 0.15*** | 0.000 | -0.57 | 0.16*** | 0.000 |
| US Trade Balance | 108 | 1.59 | -0.10 | -0.13*** | 0.000 | -0.13 | -0.10*** | 0.000 |
| DE Current Account | 99 | 1.53 | 0.13 | -0.19*** | 0.000 | 0.15 | -0.20*** | 0.000 |
| DE Trade Balance | 105 | 1.62 | 0.07 | -0.25*** | 0.000 | 0.08 | -0.23*** | 0.000 |

*Note:* Robust standard errors are not displayed. *, **, and *** indicate that the null hypothesis *Ho* : $\alpha = 0$ OR *Ho* : $\beta = 1$ have to be rejected at a 10%, 5%, and 1% significance level, respectively. If the Wald test of the joint hypothesis *Ho* : ($\alpha$, $\beta = 0, 1$) has to be rejected is indicated by the p-values in columns 4 and 7, respectively.
*Source:* Bloomberg, own calculations.

Column 1 in Table 5 reports the noise-to-signal ratio for final revisions, which is defined as the ratio of the standard deviation of final revisions ($\sigma(R_{i,t}^{AF})$) to the standard deviation of the final release ($\sigma(F_{i,t})$) (Aruoba, 2008). This statistic serves to measure the size of final revisions compared to the size of the initial announcements. Since almost all reported ratios are relatively large, final revisions are found to be sizable in relation to initial releases.[14] A noise-to-signal ratio > 1 implies that initial releases are unreliable. In the case of *EU Business Climate* this ratio is exceptionally large, which is due to the very high volatility of revisions between the initial and the final release compared to the final release.

The previous analysis has shown that a part of the data are significantly revised. It is not clear *a priori* whether economists are attempting to forecast the initial release or the final values. Therefore, economists' misperceptions vis-à-vis the initial announcement as well as vis-à-vis the latest revision are to be examined in the next section. The empirical approach is equivalent to the common test of expectation unbiasedness (Urich and Wachtel, 1984a; Batchelor and Dua, 1991; Fildes and Stekler, 2002; Ehrmann and Fratzscher, 2003): The rational expectations hypothesis implies that the released and the expected values must be identical except for completely random disturbance, and that the expectations are unbiased (Figlewski and Wachtel, 1981). Following the terminology in the literature, expectations are biased[15] with respect to the initial release, if the joint null hypothesis $H_0 : (\alpha, \beta) = (0,1)$ has to be rejected for the regression

$$A_{i,t} = \alpha_5 + \beta_5 E_{i,t}^{A} + \varepsilon_{i,t}^{5}, \tag{5}$$

where $A_{i,t}$, is the initial announcement for indicator $i$ at release date $t$, $E^{A}_{i,t}$ is the corresponding median expectation, and $\varepsilon_{i,t}$ is a white noise disturbance term. Accordingly, expectations regarding the final release $E^{F}_{i,t}$ are unbiased if the joint null hypothesis $H_0 : (\alpha, \beta) = (0,1)$ cannot be rejected for

$$F_{i,t} = \alpha_6 + \beta_6 E^{F}_{i,t} + \varepsilon^{6}_{i,t}. \quad (6)$$

Table 6 has two panels corresponding to the regressions in Equation 5 and Equation 6 for median expectations over the period 2002-10. The first striking finding is that for 6 indicators the consensus is unbiased with respect to both the initial release and the final values. Almost all of these unbiased forecasts refer to indicators that are not subject to (systematic) revisions; exceptions being *US Retail Sales (ex autos)* and *EU CPI*.[16] In contrast, professional forecasters make systematic forecast errors regarding both the initial announcement and the final ("true") value for 23 out of the 52 indicators, most of them belonging to the categories "*Economic Activity and GDP*" and "*Business Conditions and Consumer Confidence*".[17] For 8 indicators forecasters make systematic errors with respect to final values but their median estimate is unbiased concerning the initial announcements. A possible explanation for this result might be that forecasters intend to predict initial releases. However, taking into account that final revisions of *EU M3 3mth avg.*, for example, have a significant non-zero mean (see Table 2) and are found to reduce noise (see Table 4) we might conclude that forecasters use information inefficiently. These results are in line with findings of other studies, in which forecasts are found to be inefficient, although they seem to be unbiased (Croushore, 1996). In contrast to these findings, however, are the results of 15 other indicators, where forecasts of first releases are biased, but those of final values are not. Among those indicators are *EU M3 3mth average* and *US CPI*, for which previous analysis showed that revisions can be classified as noise. Taken together, these results suggest that forecasters mostly aim at forecasting first releases of indicators which belong to the category *Economic Activity*. The opposite can be observed for indicators regarding *Employment Situation* & *Housing Market*, *Prices*, and *Balances*, where forecasters are more likely to make unbiased forecasts for final values.

Table 6. **Unbiasedness test for the median estimate**

| Dependent variable: | | | Initial announcement | | | | Final release | | |
|---|---|---|---|---|---|---|---|---|---|
| Explanatory variable: | | | Final release (Noise hypothesis) | | | | Initial announcement (News hypothesis) | | |
| | | $\alpha_3$ | $\beta_3$ | $p$ | $R^2$ | $\alpha_4$ | $\beta_4$ | $p$ | $R^2$ |
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Economic activity and GDP | | | | | | | | | |
| US Business Inventories | 103 | -0.01 | 1.10** | 0.10 | 0.84 | -0.05* | 1.38*** | 0.00 | 0.83 |
| Chicago Purch. Mgrs. | 107 | 0.01 | -0.20*** | 0.00 | 0.01 | 0.00 | 1.00 | 0.91 | 0.60 |
| US Durable Goods Orders | 103 | -0.24 | 1.36** | 0.09 | 0.46 | 0.30 | -0.42*** | 0.00 | 0.04 |
| US Factory Orders | 102 | -0.01 | 1.03 | 0.80 | 0.88 | 0.28 | 0.00*** | 0.00 | 0.00 |
| US Retail Sales | 100 | 0.01 | 1.07 | 0.65 | 0.66 | 0.20 | 0.24*** | 0.00 | 0.02 |
| US Retail ex Autos | 98 | -0.09 | 1.37** | 0.11 | 0.56 | 0.04 | 0.95 | 0.95 | 0.18 |
| US Ind. Prod. | 98 | -0.12** | 1.33*** | 0.02 | 0.73 | -0.10 | 0.71 | 0.04 | 0.17 |
| US Leading Ind. | 99 | -0.02 | 1.18*** | 0.00 | 0.89 | 0.18*** | 0.63*** | 0.00 | 0.19 |
| US Cons. Credit | 106 | -0.13 | 0.94 | 0.72 | 0.36 | 0.96 | 1.37*** | 0.00 | 0.66 |
| US GDP QoQ | 35 | 0.01 | 0.96 | 0.61 | 0.91 | -0.40 | 1.03 | 0.82 | 0.87 |
| EU Ind. Prod. | 90 | -0.07 | 0.87*** | 0.00 | 0.75 | -0.02 | 0.21*** | 0.00 | 0.04 |
| EU Retail Sales | 83 | -0.11* | 1.04 | 0.21 | 0.47 | 0.09 | -0.36*** | 0.00 | 0.08 |
| EU GDP QoQ | 30 | -0.05** | 1.17*** | 0.00 | 0.97 | -0.04 | 1.20*** | 0.00 | 0.97 |

Table 6. **Unbiasedness test for the median estimate** *(cont.)*

| Dependent variable: | | Initial announcement | | | | Final release | | | |
|---|---|---|---|---|---|---|---|---|---|
| Explanatory variable: | | Final release (Noise hypothesis) | | | | Initial announcement (News hypothesis) | | | |
| | | $\alpha_3$ | $\beta_3$ | $p$ | $R^2$ | $\alpha_4$ | $\beta_4$ | $p$ | $R^2$ |
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| DE Ind. Prod. | 78 | -0.33* | 1.21 | 0.18 | 0.39 | -0.17 | 0.48* | 0.02 | 0.08 |
| DE Retail Sales | 79 | -0.81*** | 1.34 | 0.00 | 0.30 | 0.30* | -1.40*** | 0.00 | 0.42 |
| DE GDP QoQ | 29 | -0.01 | 1.22*** | 0.00 | 0.92 | 0.00 | 1.22*** | 0.00 | 0.93 |
| Employment situation and housing markets | | | | | | | | | |
| US In. Jobless Claims | 468 | 0.07 | -0.16*** | 0.00 | 0.01 | 0.02 | 0.99 | 1.00 | 0.50 |
| US Non-farm Payroll | 103 | -17.12** | 0.94 | 0.02 | 0.86 | -35.02*** | 1.12** | 0.01 | 0.79 |
| US Building Permits | 99 | -0.01 | 0.18*** | 0.00 | 0.02 | 0.00 | 0.86 | 0.43 | 0.47 |
| US Housing Starts | 108 | -0.01 | -0.21*** | 0.00 | 0.02 | 0.00 | 1.12 | 0.36 | 0.58 |
| US New Home Sales | 106 | -0.01 | 0.08*** | 0.00 | 0.00 | 0.00 | 0.66*** | 0.00 | 0.47 |
| EU Unempl. Rate | 107 | 0.01 | 0.38*** | 0.00 | 0.17 | 0.01 | 0.25*** | 0.00 | 0.02 |
| DE Unempl. Rate | 98 | -0.01 | 0.62*** | 0.00 | 0.38 | -0.01 | 0.67*** | 0.00 | 0.48 |
| Business conditions and consumer confidence | | | | | | | | | |
| ISM Manuf. PMI | 107 | 0.00 | 0.29*** | 0.00 | 0.07 | 0.00 | 0.72*** | 0.00 | 0.63 |
| Phil. Fed Index | 106 | -0.02 | 0.08*** | 0.00 | 0.00 | 0.11 | 0.37*** | 0.00 | 0.04 |
| Uni Michigan Conf. | 215 | 2.63** | 0.96** | 0.05 | 0.94 | 2.63** | 0.96** | 0.05 | 0.94 |
| US Cons. Conf. | 107 | 0.00 | 0.33*** | 0.00 | 0.08 | 0.00 | 1.05 | 0.79 | 0.78 |
| EU Business Cl. | 88 | 0.30 | 2.60 | 0.46 | 0.41 | 0.03 | 0.86 | 0.01 | 0.86 |
| EU Ind. Conf. | 85 | -0.02 | 0.06*** | 0.00 | 0.00 | -0.04 | 0.33*** | 0.00 | 0.11 |
| EU Econ. Conf. | 92 | 0.00 | 0.54*** | 0.02 | 0.29 | 0.00 | 0.69 | 0.29 | 0.30 |
| ZEW EU Expect. | 77 | -0.24 | 0.47 | 0.01 | 0.05 | -0.24 | 0.47 | 0.01 | 0.05 |
| EU Cons. Conf. | 103 | 0.01 | 0.18*** | 0.00 | 0.04 | 0.03 | -0.05*** | 0.00 | 0.00 |
| IFO Business Cl. | 81 | 0.00 | 0.45*** | 0.00 | 0.22 | 0.00 | 0.88*** | 0.02 | 0.85 |
| ZEW DE Curr. Situation | 82 | 0.37 | -0.06*** | 0.00 | 0.00 | 0.37 | -0.06*** | 0.00 | 0.00 |
| ZEW DE Expect. | 103 | -0.02 | 0.09*** | 0.00 | 0.05 | -0.02 | 0.09*** | 0.00 | 0.05 |
| Prices and monetary policy | | | | | | | | | |
| US CPI | 89 | -0.05** | 1.22*** | 0.00 | 0.90 | -0.03 | 0.99 | 0.45 | 0.60 |
| US PPI | 92 | -0.05 | 1.50*** | 0.00 | 0.77 | 0.08 | 0.61* | 0.15 | 0.17 |
| US ISM Prices Paid | 107 | 0.01 | 0.33*** | 0.00 | 0.12 | 0.01 | 0.36*** | 0.00 | 0.14 |
| US Imp. Price Index | 95 | 0.01 | 1.20** | 0.01 | 0.87 | 0.10 | 0.96 | 0.77 | 0.50 |
| Federal Funds Rate | 72 | -0.00 | 0.99 | 0.95 | 0.93 | -0.00 | 0.99 | 0.95 | 0.93 |
| EU CPI | 99 | -0.01 | 1.03* | 0.17 | 0.95 | -0.01 | 1.01 | 0.72 | 0.90 |
| EU PPI | 93 | -0.06** | 1.17*** | 0.02 | 0.92 | 0.04 | 0.77 | 0.19 | 0.32 |
| ECB Interest Rates | 106 | -0.00 | 0.90 | 0.19 | 0.90 | -0.00 | 0.90 | 0.19 | 0.90 |
| EU M3 | 104 | -0.06 | 1.02 | 0.21 | 0.98 | 0.03 | 1.01 | 0.00 | 0.99 |
| EU M3 3mth avg | 103 | 0.01 | 1.00 | 0.36 | 1.00 | 0.18** | 0.99 | 0.01 | 0.99 |
| DE CPI | 132 | -0.01 | 1.04*** | 0.52 | 0.82 | -0.01 | 1.01 | 0.59 | 0.79 |
| DE PPI | 88 | 0.04 | 1.21 | 0.03 | 0.58 | 0.06 | 0.98 | 0.36 | 0.36 |
| Balances | | | | | | | | | |
| US Gov't Budget Balance | 105 | -0.05 | 1.04*** | 0.03 | 0.96 | -1.73 | -0.44*** | 0.00 | 0.18 |
| US Current Account | 36 | -0.19 | 0.79* | 0.21 | 0.61 | -0.44 | 0.31*** | 0.00 | 0.09 |
| US Trade Balance | 108 | -0.12 | -0.24*** | 0.00 | 0.03 | 0.02 | 0.98 | 0.96 | 0.60 |
| DE Current Account | 99 | 0.01 | 0.54*** | 0.04 | 0.10 | -0.03 | 0.84 | 0.57 | 0.24 |
| DE Trade Balance | 105 | 0.06 | -0.04*** | 0.00 | 0.00 | -0.03 | 0.85 | 0.46 | 0.24 |

*Note:* Robust standard errors are not displayed. *, **, and *** indicate that the null hypothesis $H_0 : \alpha = 0$ OR $H_0 : \beta = 1$ have to be rejected at a 10%, 5%, and 1% significance level, respectively. If the Wald test of the joint hypothesis $H_0 : (\alpha, \beta = 0, 1)$ has to be rejected is indicated by the p-values in columns 3 and 7, respectively.
*Source:* Bloomberg, own calculations.

The results of the forecast analysis also point to some country-specific differences. For instance, for U.S. and German indicators the median forecast is found more often to be biased with regard to the initial release compared with the final values. Interestingly enough, for German indicators forecasters make systematic errors regarding only one final release (*DE Industrial Production*). Concerning Eurozone indicators, forecasts of final values are approximately as often biased as forecasts of initial announcements.

The previous news vs. noise framework also has implications for the interpretation of the unbiasedness tests. If news errors are being eliminated as data are revised, the $R^2$ of the unbiasedness test with respect to the latest release should be smaller compared to the forecast error analysis regarding initial announcements. This holds true for all three indicators, for which data revisions are characterized as news. The opposite should be observed if noise errors are being eliminated. The $R^2$ increases as we move from forecasts of initial to latest releases for *EU Business Climate* and *EU M3*. However, this is not the case for *US CPI* and *EU M3 3mth avg.*, which suggests that not all available information is incorporated into forecasters' estimates.

## 4. The impact of economic conditions on revisions and surprises

The previous analysis has shown that some releases are revised systematically and that these revisions are also economically significant. The following specification investigates the impact of economic conditions (recessions, highly volatile stock markets, and a high oil price) on data revisions. Since announcements that are released at release date $t$ refer to a reporting period ($rp$) that for most indicators differs from the release date ($t \neq rp$), economic conditions during the reporting period are presumed to impact later revisions. Hence, dummy variables are constructed for each country in the following manner:

Following the methodology outlined in Bloom (2009), indicators are constructed to take a value of 1 if stock markets are highly volatile (the oil price is significantly high), and zero otherwise. Stock markets (the oil price) are defined to be highly volatile at release date $t$ and reporting period $rp$ respectively if the peak of the Hodrick-Prescott (HP) detrended ($\lambda = 129{,}600$) implied volatility[18] (oil price) significantly exceeds the mean.[19]

Due to different units across the considered indicators, standardized revisions and forecast errors (revisions and surprises are divided by their respective sample standard deviations) are used to facilitate interpretation. Standardized revisions and surprises associated with indicator $i$ at time $t$ are defined as

$$R^{AF}_{i,t} = \frac{(A_{i,t} - F_{i,t})}{\sigma^R_i} \quad and \quad S^y_{i,t} = \frac{(y_{i,t} - E^y_{i,t})}{\sigma^{S^y}_i}, \tag{7}$$

where $A_{i,t}$ is the initially announced value of indicator $i$, and $F_{i,t}$ is the correspondingly revised final value. The median forecast $E^y_{i,t}$, where ($y \in \{A,F\}$), is associated either with the initial announcement $A_{i,t}$ or the revised value ($F_{i,t}$). $\sigma^R_i$ and $\sigma^S_i$ denote the sample standard deviation of $(A_{i,t} - F_{i,t})$ and $(y_{i,t} - E^y_{i,t})$, respectively. Since $\sigma^R_i$ and $\sigma^S_i$ are constant for any indicator $i$, standardization has no effect either on the statistical significance of the estimates or on the fit of the regression.

In order to examine the impact of *current* economic conditions on revisions, the following specification is used for each indicator $i$:

$$\begin{aligned} R^{AF}_{i,t} &= \alpha + \beta_1 resUS_t + \beta_2 volUS_t + \beta_3 resEU_t + \beta_4 volEU_t \\ &\quad + \beta_5 resDE_t + \beta_6 volDE_t + \beta_7 hOil_t + \beta_8 date_t + \varepsilon_{i,t}. \end{aligned} \tag{8}$$

The regression in Equation 8 analyses the impact of recessions ($resUS_t$, $resEU_t$, and $resDE_t$) and volatile stock markets ($volUS_t$, $volEU_t$, and $volDE_t$) in all countries, as well as a high oil price $hOil_t$ at release date $t$ on the *standardized revision* $R^{AF}_{i,t}$ for indicator $i$ at time $t$. A time trend, implemented by the respective release date ($date_t$), is also included in these specifications. Standardized revisions are not affected by economic conditions, and do not have a time trend if $H_0 : (\beta_1, \ldots, \beta_8 = 0)$ is not rejected.

The specification in Equation 8 is also used to assess the impact of economic conditions on forecasters' *standardized surprises* regarding the initial announcement ($S^{A}_{i,t}$) and the final value ($S^{F}_{i,t}$), respectively. The regressands in Equation 8 are then changed to the respective standardized surprise. In addition, the estimations in Equation 8 are also run with dummy variables referring to the reporting period *rp* relevant for indicator *i*. This is based on the hypothesis that both revisions and surprises are influenced by economic conditions during the reporting period rather than by the economic situation at the release of the initial announcement.

With respect to revisions, the results indicate that economic conditions during the reporting period seem to be more relevant for revisions of *GDP* and *Prices & Monetary Policy* indicators. The economic situation at the time when initial announcements are released is more often correlated with revisions of indicators regarding the *Economic Activity*, the *Employment Situation & Housing Markets* as well as *Prices & Monetary Policy*.

As for surprises, economic conditions have a greater impact on (standardized) forecast errors regarding initial releases than regarding final values. Compared to the effect of the economic situation during the reporting period the economic conditions at release time seem to have a stronger influence on experts' forecast errors with regard to initial releases. The opposite is observed for surprises about final values. The analysis also points to some interconnections between the economies. For instance, a volatile S&P 500 during the reporting period of *US GDP* is negatively correlated with forecasters' surprises regarding initial releases. On the contrary, a volatile EuroStoxx50 increases surprises with regard to initial announcements of *US GDP*. Overall, however, the effect of economic conditions on standardized revisions and surprises is mixed and inconclusive (results not reported).

## 5. Determinants of disagreement

Disagreement among forecasters is measured by the standard deviation of individual forecasts $\sigma_{i,t}$ for indicator $i$ at release date $t$. Expectations are assumed to be more volatile during recessions, when stock markets are volatile, or during high oil price periods. Furthermore, economic conditions prevalent during the reporting period are expected to have an impact on $\sigma_{i,t}$, as opposed to economic conditions that are valid when the official announcement is released. Moreover, in order to capture the relationship between the number of participating economists and disagreement about the outcome of the respective announcements, this variable is also included. Therefore, dummy variables are used for recessions and for volatile stock markets (in the US, Eurozone and Germany) during the reporting period ($resUS_{rp}$, $resEU_{rp}$, $resDE_{rp}$; $volUS_{rp}$, $volEU_{rp}$, $volDE_{rp}$) and during the month the announcement was released ($resUS_t$, $resEU_t$, $resDE_t$; $volUS_t$, $volEU_t$, $volDE_t$). Dummy variables also include a high oil price during the reporting period ($hOil_{rp}$) and during the month of the release ($hOil_t$), and the number of participating economists in the survey for indicator $i$ at release date $t$ ($NumE_{i,t}$).

Previous results have shown that economic conditions both during the reporting period and at the time of the announcement have an impact on data revisions and on

experts' forecast errors. Thus, the following analysis of disagreement among forecasters takes these two influencing factors into account, only concentrating on "domestic" factors only, e.g. dummy variables indicating US recessions, a volatile S&P 500 and a high oil price, both during the reporting period (*rp*) and at release time (*t*) enter the regressions for US indicators. Therefore, for each indicator *i* for country *C* ($C \in \{US, EU, DE\}$) the following regression is estimated:

$$\sigma_{i,t}^{C} = \alpha + \beta_1 resC_t + \beta_2 volC_t + \beta_3 resC_{rp} + \beta_4 volC_{rp} + \beta_5 hOil_t + \beta_6 hOil_{rp} + \beta_7 NumE_t + \varepsilon_{i,t}, \quad (9)$$

where $\sigma_{i,t}^{C}$ is the standard deviation of individual forecasts for indicator *i* for country *C* at release date *t*, and $\varepsilon_{i,t}$ is the error term.

Table 7 summarizes the results for the regression in Equation 9. Recessions in the domestic economy during the reporting period increase disagreement with regard to the announced figures for 16 of the considered 42 indicators,[20] which mainly refer to the categories Economic Activity & GDP and Prices & Monetary Policy, respectively. If the respective economy experiences a recession when indicators are officially announced, forecasters disagree more about DE Retail Sales, US PPI, and DE Trade Balance; in contrast, they disagree less about the releases for EU Retail Sales, DE Industrial Production, and EU M3 3month average. Regarding the impact of a volatile domestic stock market, the evidence is mixed: During the reporting period volatile stock markets are related to increased disagreement with regard to 6 indicators and to less disagreement with regard to 3 indicators. Experts' forecasts are more dispersed regarding US Retail Sales, EU GDP (F), and US Trade Balance, if the respective stock markets are volatile at the time of the announcement. In contrast, forecasters agree more about DE Retail Sales, DE GDP (A), and US Building Permits. However, for most indicators disagreement is not at all affected by volatile stock markets. A high oil price is not related to disagreement regarding Employment Situation & Housing Markets and Balances indicators. In case of a high oil price at release time, forecasters agree more about the releases for some indicators regarding Economic Activity and GDP (US Business Inventories, and both US and EU Industrial Productions) as well as regarding Prices and Monetary Policy (US CPI, EU PPI, and EU M3 3month average), whereas forecasts regarding EU Retail Sales and EU GDP (S) are more dispersed. A significant negative[21] (positive) impact of a high oil price during the reporting period on forecasters' disagreement is found concerning the announcements for US Retail Sales ex autos, both the initial and the second release for EU GDP, as well as for US ISM Manufacturing PMI (EU GDP (F)). The more forecasters participate in the survey, the less (more) dispersed are their estimates for 7 (5) indicators.

In order to determine how foreign economic conditions are related to disagreement, two different specifications are employed: First, the impact of economic conditions at the time when releases are published is analysed using the following specification:

$$\begin{aligned}\sigma_{i,t} = {} & \alpha + \beta_1 resUS_t + \beta_2 volUS_t + \beta_3 resEU_t + \beta_4 volEU_t \\ & + \beta_5 resDE_t + \beta_6 volDE_t + \beta_7 hOil_t + \beta_8 numE_t + \varepsilon_{i,t}.\end{aligned} \quad (10)$$

Second, the effect of the economic situation during the reporting period is assessed by estimating the following regression:

$$\begin{aligned}\sigma_{i,t} = {} & \alpha + \beta_1 resUS_{rp} + \beta_2 volUS_{rp} + \beta_3 resEU_{rp} + \beta_4 volEU_{rp} \\ & + \beta_5 resDE_{rp} + \beta_6 volDE_{rp} + \beta_7 hOil_{rp} + \beta_8 numE_t + \varepsilon_{i,t},\end{aligned} \quad (11)$$

where $\sigma_{i,t}$ is the standard deviation of individual forecasts for indicator *i* and release time *t*.

Table 7. **The impact of domestic economic conditions on forecasters' disagreement about domestic announcements**

| | *Constant* | $resC_t$ | $volC_t$ | $resC_{rp}$ | $volC_{rp}$ | $hOil_t$ | $hOil_{rp}$ | $numE_t$ | $R^2$ | *N* |
|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| **Economic activity and GDP** | | | | | | | | | | |
| US Business Inventories | 0.15** | -0.01 | -0.03 | 0.12*** | 0.01 | -0.08** | -0.03 | 0.00 | 0.35 | 103 |
| US Goods Orders | 1.14*** | 0.21 | 0.12 | -0.16 | 0.04 | 0.17 | -0.32 | 0.00 | 0.05 | 103 |
| US Factory Orders | 0.61*** | -0.04 | 0.11 | 0.35*** | 0.05 | -0.18 | -0.19 | 0.00 | 0.31 | 102 |
| US Retail Sales | 0.50*** | -0.01 | 0.15** | 0.09 | 0.04 | 0.06 | -0.14 | -0.00* | 0.29 | 100 |
| US Retail ex Autos | 0.14* | 0.03 | 0.03 | 0.11** | 0.09** | -0.03 | -0.09* | 0.00 | 0.54 | 98 |
| US Ind. Prod. | 0.13* | 0.02 | 0.04 | 0.14** | 0.06 | -0.13** | -0.04 | 0.00 | 0.52 | 98 |
| US Leading Ind. | 0.08 | 0.00 | -0.01 | 0.09 | 0.00 | -0.07 | -0.02 | 0.00 | 0.13 | 99 |
| US Cons. Credit | 3.74*** | -0.04 | -0.19 | 0.33 | -0.01 | -0.59 | -0.56 | -0.04** | 0.14 | 106 |
| US GDP (A) | 0.63** | -0.22 | -0.09 | 0.28** | 0.23* | 0.04 | | 0.00 | 0.37 | 35 |
| US GDP (F) | -0.05 | -0.01 | 0.03 | 0.02 | 0.01 | 0.02 | -0.05 | 0.00** | 0.29 | 35 |
| US GDP (S) | 0.15 | -0.03 | 0.07 | -0.02 | 0.09 | -0.01 | 0.01 | 0.00 | 0.19 | 36 |
| EU Ind. Prod. | 0.28*** | 0.08 | -0.06 | 0.35*** | 0.12 | -0.20* | -0.18 | 0.00 | 0.44 | 90 |
| EU Retail Sales | 0.38*** | -0.21* | 0.13 | -0.15 | 0.29*** | 0.25** | 0.18 | 0.00 | 0.23 | 83 |
| EU GDP (A) | 0.00 | | -0.07 | 0.16*** | | -0.01 | -0.13* | 0.00* | 0.46 | 30 |
| EU GDP (F) | 0.02 | 0.00 | 0.04* | 0.00 | -0.03 | -0.04 | 0.09*** | 0.00 | 0.64 | 27 |
| EU GDP (S) | 0.01 | 0.01 | 0.02 | 0.00 | -0.01 | 0.07** | -0.05* | 0.00 | 0.36 | 36 |
| DE Ind. Prod. | 1.02*** | -0.37** | 0.13 | 0.17 | 0.62*** | 0.15 | 0.11 | -0.01** | 0.44 | 78 |
| DE Retail Sales | 0.60*** | 0.26** | -0.20* | 0.10 | -0.02 | -0.20 | -0.07 | 0.00 | 0.27 | 79 |
| DE GDP (A) | 0.10 | | -0.17* | 0.16** | 0.15 | -0.06 | -0.07 | 0.00 | 0.37 | 29 |
| DE GDP (F) | 0.02 | 0.00 | | 0.04* | -0.05* | -0.01 | -0.04 | 0.00 | 0.36 | 26 |
| **Employment situation and housing markets** | | | | | | | | | | |
| US In. Jobless Claims | 9.08*** | 3.83 | 0.53 | -0.35 | 2.61 | -2.02 | -0.46 | -0.03 | 0.07 | 468 |
| US Non-farm Payroll | 48.05*** | -9.27 | -4.43 | 19.38** | 3.96 | -7.40 | -12.88 | -0.18 | 0.13 | 103 |
| US Building Permits | 57.22*** | 6.93 | -9.25** | -1.81 | -1.83 | -3.96 | 0.08 | -0.75*** | 0.52 | 100 |
| US Housing Starts | 92.60*** | 2.81 | -6.21 | -3.90 | -1.20 | -0.53 | -0.20 | -0.89*** | 0.37 | 108 |
| US New Home Sales | 52.24*** | -1.51 | 1.37 | -6.57 | -5.00 | 0.18 | -2.57 | -0.42*** | 0.32 | 106 |
| EU Unempl. Rate | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.01 | -0.01 | 0.00 | 0.02 | 107 |
| **Business conditions and consumer confidence** | | | | | | | | | | |
| ISM Manuf. PMI | 1.36*** | -0.21 | -0.12 | 0.35** | 0.23** | 0.07 | -0.29* | -0.01** | 0.22 | 107 |
| **Prices and monetary policy** | | | | | | | | | | |
| US CPI | 0.05 | 0.01 | -0.01 | 0.08*** | 0.01 | -0.07*** | -0.01 | 0.00 | 0.48 | 89 |
| US PPI | 0.07 | 0.13** | -0.04 | 0.05 | 0.02 | -0.09 | -0.04 | 0.00* | 0.35 | 92 |
| US ISM Prices Paid | 1.56 | 0.35 | 0.30 | -0.26 | 0.16 | -0.94 | 0.81 | 0.07 | 0.04 | 108 |
| US Imp. Price Index | 0.16 | 0.08 | 0.09 | 0.25* | 0.09 | -0.20 | -0.03 | 0.00** | 0.49 | 95 |
| EU CPI | 0.06* | -0.02 | 0.00 | -0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.02 | 99 |
| EU PPI | 0.15*** | 0.05 | 0.02 | 0.21*** | -0.05 | -0.17*** | -0.06 | 0.00 | 0.46 | 93 |
| EU M3 | 0.23*** | 0.02 | -0.03 | 0.09** | -0.04 | -0.05 | -0.03 | 0.00 | 0.11 | 104 |
| EU M3 3mth avg | 0.11** | -0.28*** | -0.05 | 0.51*** | -0.11** | -0.27*** | 0.06 | 0.00 | 0.40 | 103 |
| DE CPI | -0.10*** | 0.00 | -0.02 | 0.07 | -0.01 | 0.03 | -0.09 | 0.01*** | 0.30 | 132 |
| DE PPI | 0.23*** | -0.07 | -0.03 | 0.09 | 0.10** | -0.05 | 0.08 | 0.00 | 0.23 | 88 |
| **Balances** | | | | | | | | | | |
| US Budget Balance | 20.20*** | 4.21 | -1.24 | 2.25 | 3.92 | 0.67 | 1.49 | -0.35 | 0.17 | 105 |
| US Current Account | 0.31 | 0.51 | -0.57 | 1.68 | 1.26 | -1.00 | -0.95 | 0.07 | 0.28 | 36 |
| US Trade Balance | -0.16 | -0.09 | 0.28** | 0.13 | 0.72*** | -0.05 | 0.09 | 0.02*** | 0.51 | 108 |
| DE Current Account | 2.32*** | 0.25 | 0.10 | -0.35 | -0.06 | 0.34 | -0.13 | -0.05* | 0.05 | 100 |
| DE Trade Balance | 1.16*** | 0.37* | 0.22 | -0.13 | -0.30* | -0.02 | -0.22 | 0.00 | 0.10 | 106 |

*Note:* OLS standard errors are not displayed. Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *. Indicators for which the reporting and release period coincide are not considered due to collinearity.
*Source:* Bloomberg, own calculations.

Since results are similar for both regressions, Table 8 only presents the estimation results for the specification in Equation 11. Dummy variables for economic conditions are applied during the reporting period.[22] For 3 indicators, these two estimations differ considerably: Firstly, disagreement about *German Industrial Production* is positively related to volatile US stock markets during the reporting period. Using indicators about the economic situation when official figures are released, a positive impact on disagreement is also found for US and Eurozone recessions, as well as for volatile US and German stock markets; disagreement decreases if the EUROSTOXX is volatile and if Germany experiences a recession when official figures are announced. Secondly, in both regressions for *US New Home Sales*, forecasters disagree less during recessions in the US and in Germany. Additionally, disagreement is lower if the European stock market is volatile during the reporting period, and it is higher in case of a recession in the Eurozone in the respective period. Thirdly, forecasts for *US Trade Balance* are more dispersed if the US stock market is volatile during the reporting period, and if the Eurozone is experiencing a recession or the German stock market is volatile. A high number of participating economists reduces disagreement regarding the *German Industrial Production* and *US New Home Sales*, but increases disagreement regarding the *US Trade Balance*. In general, forecasters disagree more about releases if the economy to which the announcement refers to is in a recession or if the domestic stock market is volatile. The impact of a high oil price is ambiguous, although a negative effect is more often observed.

Table 8. **The impact of international economic conditions during the reporting period on forecasters' disagreement**

| | *Constant* | $resUS_{rp}$ | $volUS_{rp}$ | $resEU_{rp}$ | $volEU_{rp}$ | $resDE_{rp}$ | $volDE_{rp}$ | $hOil_{rp}$ | $numE_t$ | $R^2$ | *N* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| Economic activity and GDP | | | | | | | | | | | |
| US Busin. Inventor. | 0.20*** | 0.08*** | 0.05 | 0.02 | -0.05 | -0.01 | 0.01 | -0.07** | 0.00 | 0.33 | 103 |
| Purch. Mgrs. | 2.22*** | 0.13 | 0.16 | 0.44 | -0.04 | -0.48*** | 0.16 | -0.47** | -0.01* | 0.27 | 107 |
| US Goods Orders | 1.92*** | -0.02 | 0.02 | 0.31 | 0.04 | -0.32** | 0.19 | -0.06 | -0.01* | 0.09 | 103 |
| US Factory Orders | 0.95*** | 0.34*** | -0.07 | -0.01 | 0.22 | -0.16** | 0.12 | -0.16 | -0.01 | 0.32 | 102 |
| US Retail Sales | 0.61*** | 0.07 | -0.02 | 0.16 | -0.03 | -0.06 | 0.18*** | -0.14* | -0.00** | 0.33 | 100 |
| US Retail ex Autos | 0.18* | 0.08** | 0.09 | 0.12** | -0.05 | -0.01 | 0.05 | -0.16*** | 0.00 | 0.57 | 98 |
| US Ind. Prod. | 0.25*** | 0.08* | 0.03 | 0.12** | 0.08 | -0.06** | 0.00 | -0.14*** | 0.00 | 0.52 | 98 |
| US Leading Ind. | 0.07 | 0.05 | -0.03 | 0.05 | 0.05 | 0.00 | -0.04 | -0.08 | 0.00 | 0.14 | 99 |
| US Cons. Credit | 3.73*** | 0.25 | 0.12 | -0.12 | -0.21 | -0.28 | 0.39 | -0.62 | -0.04** | 0.14 | 106 |
| US GDP (A) | 0.32 | 0.12 | 0.09 | 0.10 | -0.19 | 0.11 | 0.04 | -0.21 | 0.00 | 0.42 | 35 |
| US GDP (F) | -0.02 | 0.01 | -0.05 | 0.06 | 0.01 | 0.00 | 0.01 | -0.09* | 0.00 | 0.31 | 35 |
| US GDP (S) | 0.07 | -0.04 | -0.02 | 0.09 | 0.02 | 0.00 | 0.11* | -0.11 | 0.00 | 0.32 | 36 |
| EU Ind. Prod. | 0.32** | 0.20** | 0.05 | 0.23 | 0.00 | -0.12 | 0.17* | -0.21* | 0.00 | 0.47 | 90 |
| EU Retail Sales | 0.52*** | -0.10 | 0.16 | -0.07 | 0.20 | -0.13** | 0.03 | 0.36*** | -0.01** | 0.25 | 83 |
| EU GDP (A) | -0.03 | 0.00 | 0.15** | 0.01 | -0.11* | 0.01 | 0.06 | | 0.00 | 0.51 | 30 |
| EU GDP (F) | -0.01 | -0.02 | -0.02 | 0.01 | -0.03 | 0.03 | 0.02 | 0.05 | 0.00 | 0.54 | 27 |
| EU GDP (S) | -0.01 | 0.02 | 0.02 | -0.04 | -0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.08 | 36 |
| DE Ind. Prod. | 1.05*** | 0.14 | 0.83*** | -0.09 | -0.35 | -0.21 | 0.26 | 0.22 | -0.01** | 0.50 | 78 |
| DE Retail Sales | 0.56*** | 0.02 | -0.17 | -0.29 | 0.11 | 0.36*** | -0.01 | -0.04 | 0.00 | 0.33 | 79 |
| DE GDP (A) | 0.17 | 0.03 | 0.32*** | | -0.31*** | -0.03 | 0.14* | 0.03 | 0.00 | 0.68 | 29 |
| DE GDP (F) | 0.02 | -0.02 | 0.05** | | 0.00 | 0.00 | -0.05* | 0.00 | 0.00 | 0.38 | 26 |
| Employment situation and housing markets | | | | | | | | | | | |
| Initial Jobless Cl. | 7.70*** | 1.93 | 0.15 | 2.79 | 0.91 | 0.46 | 1.24 | -3.97* | 0.00 | 0.07 | 468 |
| US Non-farm Payroll | 46.69*** | 3.41 | 0.38 | 12.68 | -11.40 | -0.01 | 7.59 | -25.57*** | -0.17 | 0.15 | 103 |

Table 8. **The impact of international economic conditions during the reporting period on forecasters' disagreement** *(cont.)*

| | *Constant* | $resUS_{rp}$ | $volUS_{rp}$ | $resEU_{rp}$ | $volEU_{rp}$ | $resDE_{rp}$ | $volDE_{rp}$ | $hOil_{rp}$ | $numE_t$ | $R^2$ | *N* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| US Building Permits | 60.30*** | -1.53 | 0.65 | 9.09 | -4.44 | -8.51** | 1.78 | 1.41 | -0.81*** | 0.53 | 100 |
| US Housing Starts | 115.69*** | -4.89 | 2.86 | 10.01 | -6.42 | -11.18*** | 3.81 | 3.89 | -1.22*** | 0.44 | 108 |
| US New Home Sales | 73.72*** | -13.20** | 3.80 | 14.45** | -11.44* | -10.66*** | 5.69 | 0.62 | -0.74*** | 0.43 | 106 |
| EU Unempl. Rate | -0.03 | 0.01 | 0.02 | -0.03 | -0.02 | 0.03 | -0.01 | -0.03 | 0.00 | 0.02 | 107 |
| DE Unempl. Rate | 0.07*** | -0.01 | -0.01 | 0.01 | -0.01 | 0.00 | 0.00 | -0.01 | 0.00 | 0.04 | 98 |
| Business conditions and consumer confidence | | | | | | | | | | | |
| ISM Manuf. PMI | 1.45*** | 0.14 | 0.11 | 0.07 | 0.04 | -0.11 | 0.05 | -0.21 | -0.01** | 0.20 | 107 |
| Phil. Fed Index | 2.14* | -0.01 | 0.31 | -0.53 | -0.20 | 0.79** | 0.01 | 0.50 | 0.02 | 0.12 | 107 |
| Uni Michigan Conf. | -0.18 | 0.11 | -0.20 | 0.26 | 0.08 | 0.21* | 0.04 | -0.41** | 0.02*** | 0.18 | 215 |
| US Cons. Conf. | 2.20*** | -0.03 | 0.70 | -0.05 | 0.06 | 0.46** | -0.73*** | -0.44 | -0.01 | 0.18 | 107 |
| EU Business Cl. | 0.17* | -0.04 | 0.12 | 0.14 | -0.02 | -0.10 | 0.02 | 0.18 | 0.00 | 0.08 | 88 |
| EU Ind. Conf. | 0.81** | -0.19 | -0.58 | 1.52*** | 0.47 | -0.46 | 1.22*** | -0.89** | 0.00 | 0.45 | 89 |
| EU Econ. Conf. | 0.04 | 0.09 | -0.12 | 0.27 | 0.25 | -0.13 | 0.07 | -0.14 | 0.02*** | 0.33 | 93 |
| ZEW EU Expect. | 2.31** | 1.44 | 6.60* | -4.22 | -4.01 | | 2.05 | 1.56 | 0.19 | 0.12 | 78 |
| EU Cons. Conf. | -0.44 | 0.12 | -4.70* | 0.11 | 15.47*** | 4.37*** | -12.46*** | -4.65*** | 0.04 | 0.48 | 104 |
| IFO Business Cl. | 0.86*** | -0.01 | 0.08 | -0.02 | 0.24 | -0.03 | 0.21 | 0.17 | -0.01 | 0.33 | 82 |
| ZEW DE Situation | 1.61* | 0.03 | 1.87 | 0.25 | 2.95 | -0.95 | -0.97 | 1.15 | 0.08 | 0.34 | 83 |
| ZEW DE Expect. | 4.32*** | 1.60* | 2.05* | -1.97* | -0.07 | 0.40 | -0.02 | -0.95 | -0.01 | 0.24 | 104 |
| Prices and monetary policy | | | | | | | | | | | |
| US CPI | 0.08 | 0.07** | 0.02 | 0.00 | 0.00 | -0.02 | 0.01 | -0.04* | 0.00 | 0.45 | 89 |
| US PPI | 0.09 | 0.09* | 0.10 | 0.08 | -0.08 | -0.02 | -0.01 | -0.10 | 0.00 | 0.33 | 92 |
| US SM Prices Paid | 1.57 | -1.05 | -0.36 | 1.84 | 0.46 | -0.40 | 0.19 | -0.31 | 0.07 | 0.05 | 108 |
| US Imp. Price Index | 0.17 | 0.20* | -0.03 | 0.28* | 0.06 | -0.01 | 0.04 | -0.32** | 0.00* | 0.49 | 95 |
| Federal Funds Rate | -0.09*** | 0.02 | -0.10*** | 0.09** | 0.05 | 0.05*** | 0.01 | -0.10*** | 0.00*** | 0.56 | 72 |
| EU CPI | 0.07 | -0.03 | 0.00 | 0.00 | 0.00 | -0.02 | 0.02 | 0.01 | 0.00 | 0.03 | 99 |
| EU PPI | 0.19*** | 0.01 | 0.08 | 0.20*** | -0.03 | -0.05 | -0.01 | -0.07 | 0.00 | 0.40 | 93 |
| ECB Interest Rates | 0.01 | 0.01 | -0.15*** | 0.04 | 0.08*** | 0.05*** | 0.06*** | -0.09*** | 0.00 | 0.45 | 106 |
| EU M3 | 0.21*** | 0.06 | 0.02 | 0.02 | -0.07 | 0.02 | 0.00 | -0.06 | 0.00 | 0.13 | 104 |
| EU M3 3mth avg | 0.14** | 0.03 | -0.18** | 0.27*** | -0.02 | -0.04 | 0.04 | -0.21*** | 0.00 | 0.23 | 103 |
| DE CPI | -0.10*** | -0.01 | -0.13 | 0.10 | -0.05 | 0.11*** | 0.01 | -0.20*** | 0.01*** | 0.34 | 132 |
| DE PPI | 0.28*** | 0.05 | 0.01 | 0.09 | -0.02 | -0.03 | 0.06* | -0.04 | -0.00** | 0.33 | 88 |
| Balances | | | | | | | | | | | |
| US Budget Balance | 21.23*** | -2.34 | 2.84 | 14.50** | -1.82 | -5.76** | 3.20 | 0.89 | -0.35* | 0.24 | 105 |
| US Current Account | 2.69 | 0.73 | 1.77 | 2.24 | -1.22 | -1.81** | 1.64 | -0.91 | 0.02 | 0.39 | 36 |
| US Trade Balance | 0.04 | 0.14 | 0.61*** | 0.03 | 0.12 | -0.08 | 0.16 | 0.09 | 0.02*** | 0.49 | 108 |
| DE Current Account | 2.30*** | 0.48 | -0.45 | -0.41 | -0.01 | -0.04 | 0.18 | 0.01 | -0.05* | 0.05 | 100 |
| DE Trade Balance | 1.43*** | -0.12 | -0.24 | 0.72** | 0.23 | 0.02 | -0.31 | -0.57** | -0.01 | 0.14 | 106 |

*Note:* OLS standard errors are not displayed. Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *.
*Source:* Bloomberg, own calculations.

## 6. Formation of expectations

Section 3 has shown that professional forecasters on average under- or overestimate some indicators and that most estimates are biased. This section aims at analysing the process of expectation formation underlying professional forecasts.

Dovern and Weisser (2011) point out that forecast accuracy is assumed to be the only objective of forecasters and that only true expectations are published. Although forecasters might also, for example, be interested in gaining maximum public attention, which could provide an incentive to over- or underestimate outcomes, such an assumption carries little weight, due to the identities of the panelists being revealed in the data set used for this analysis. De Canio (1979) argues that "rational expectations" as defined by Muth (1961) require unreasonably high costs if a forecaster is to collect all necessary information. Recent models of expectation formation assume that after weighing costs and benefits, agents rationally decide to restrict their information set to information they are likely to acquire (Demery and Duck, 2007). Following DeCanio (1979), the operational significance of the concept of rational expectations can be improved by specifying certain methods of learning. For example, an error-learning model as in Gramlich (1983) could be applied. Since (adaptive) learning also presupposes more persistent data than models with rational expectations, the former is used in forward-looking models (Chevillon et al., 2010).

In this study two expectation formation hypotheses are tested that are widely used in the literature on expectation formation (Hafer, 1983; Tanzi, 1980; Lahiri, 1976; Turnovsky, 1970; Muth, 1961): the *extrapolative* and the *adaptive* hypothesis. The *extrapolative hypothesis* is based on the estimation of

$$E_{i,t} = \alpha_0 + \alpha_1 A_{i,t-1} + \alpha_2 (A_{i,t-1} - A_{i,t-2}) + \varepsilon_{i,t}, \tag{12}$$

where $E_{i,t}$ is the median forecast for indicator $i$ at time $t$ (which is formed between $t-1$ and $t$); $A_{i,t-1}$ is the announced growth rate of indicator $i$ in $t-1$, the term $(A_{i,t-1} - A_{i,t-2})$ corresponds to the trend in growth rates during the previous period, and $\varepsilon_{i,t}$ is a white noise error term. The original version of this hypothesis is consistent with the analysis in Section 3 and stipulates $H_0 : (\alpha_0, \alpha_1 = 0,1)$. If $H_0 : \alpha_2 > 0$ is not rejected, forecasters expect the past trend to continue and hence extrapolate the past trend. In contrast, not rejecting $H_0 : \alpha_2 > 0$ corresponds to forecasters' expectations being regressive, i.e. they expect the past trend to reverse itself, whereas $H_0 : (\alpha = \alpha_2 = 0, \alpha_1 = 1)$ is related to static expectations.

The *adaptive hypothesis* assumes that when forming expectations, forecasters add a fraction of their latest forecast error to their latest forecast (Figlewski and Wachtel, 1981; Carlson and Parkin, 1975):

$$E_{i,t} = E_{i,t-1} = \tau (A_{i,t-1} - E_{i,t-1}) \quad 0 \leq \tau \leq 1. \tag{13}$$

However, this formulation implies that if there is a trend in the announced growth rates, forecasters systematically underestimate the actual announcement in $t$. This is accounted for by estimating

$$E_{i,t} = \beta_0 + \beta_1 E_{i,t-1} + \beta_2 A_{i,t-1} + \varepsilon_{i,t}, \tag{14}$$

which is equivalent to Equation 13 if $H_0 : \beta_1 + \beta_2 = 0 \; and \; \beta_0 = 0$ is not rejected. If $H_0 : \beta_1 + \beta_2 > 1$ cannot be rejected, forecasters would presume a maintained trend and thus continue to elevate their expectations above their previous forecasts (even if last month's forecasts were realized and $\beta_0 = 0$). The opposite is the case if $H_0 : \beta_1 + \beta_2 < 1$ is not rejected.

Table 9 presents estimation results of Equation 12 and Equation 14. Concerning extrapolative expectations the null hypothesis $H_0 : \alpha_2 < 0$ (see column 5) cannot be rejected for five (mainly US related) out of 14 analysed indicators, for which regressive forecasts are implied. In particular, forecasters expect the latest trends of *US Business Inventories*, *US and German Industrial Production*, *US Retail Sales* (ex autos), and *US Leading*

*Indicators* to reverse themselves. In contrast, forecasters extrapolate the latest trends of *German Retail Sales* (see column 4). Moreover, apart from *EU and German Unemployment Rate* forecasters' expectations are biased as $H_0 : (\alpha_0, \alpha_1 = 0,1)$ is rejected (see columns 1 and 2), and forecasters never expect trends to be static (see column 6). Column 12 of Table 9 shows the results for adaptive expectations. For all indicators, except the *EU Unemployment Rate* and the *US Import Price Index*, forecasters expect reversed trends in the announced growth rates and therefore lower their forecasts.

Table 9. **Expectations formation analysis for selected indicators with respect to initial announcements**

| Extrapolative expectations | | | | | | | |
|---|---|---|---|---|---|---|---|
| | p-Values for $H_0$ : | | | | | | |
| Indicators | $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_2 > 0$ | $\alpha_2 < 0$ | $\alpha_2 = 0$ | $R^2$ |
| US Bus. Inventories | 0.0513* [0.0246] | 0.7876* [0.0473] | -0.2595* [0.0803] | **0.00** | 0.99 | **0.00** | 0.81 |
| US CPI | 0.0982* [0.0378] | 0.4780* [0.1176] | 0.2127 [0.1129] | 0.97 | **0.03** | 0.06 | 0.48 |
| US Factory Orders | 0.1136 [0.2160] | -0.1908* [0.2237] | 0.0809 [0.1314] | 0.73 | 0.27 | 0.54 | 0.02 |
| US Imp. Price Index | 0.0397 [0.1410] | 0.6050* [0.1302] | -0.0959 [0.0982] | 0.17 | 0.83 | 0.33 | 0.49 |
| US Industrial Prod. | 0.1558* [0.0473] | 0.4554* [0.1080] | -0.2521* [0.0838] | **0.00** | 0.99 | **0.00** | 0.35 |
| US Leading Indic. | 0.1244* [0.0418] | 0.3615* [0.0946] | -0.1887* [0.0800] | **0.01** | 0.99 | **0.02** | 0.13 |
| US Retail Sales | 0.1831 [0.0962] | 0.1932* [0.1715] | -0.1528 [0.0806] | **0.03** | 0.97 | 0.06 | 0.04 |
| US Retail Sales ex Auto | 0.2524* [0.0549] | 0.2917* [0.1208] | -0.1785* [0.0599] | **0.00** | 0.99 | **0.00** | 0.25 |
| EU PPI | 0.1315* [0.0479] | 0.4904* [0.1047] | -0.1563 [0.0959] | **0.05** | 0.95 | 0.11 | 0.32 |
| EU Retail Sales | 0.0878 [0.0544] | -0.3106* [0.1193] | -0.0866 [0.0858] | 0.16 | 0.84 | 0.32 | 0.39 |
| EU Unempl. Rate | -0.0007 [0.0046] | 1.0418 [0.0442] | -0.0464 [0.0501] | 0.18 | 0.82 | 0.36 | 0.87 |
| DE Ind. Prod. | 0.2449* [0.1119] | 0.3601* [0.0907] | -0.2013* [0.0677] | **0.00** | 0.99 | **0.00** | 0.29 |
| DE Retail Sales | 0.3091* [0.0845] | -0.4740* [0.0927] | 0.1349* [0.0467] | **0.99** | **0.00** | **0.00** | 0.60 |
| DE Unempl. Rate | -0.0045 [0.0079] | 0.9121 [0.0532] | -0.0747 [0.0459] | **0.05** | 0.95 | 0.11 | 0.78 |

| Adaptive expectations | | | | | | |
|---|---|---|---|---|---|---|
| p-Values for $H_0$ : | | | | | | |
| $\beta_0$ | $\beta_1$ | $\beta_2$ | $\beta_1 + \beta_2 > 1$ | $\beta_1 + \beta_2 < 1$ | $\beta_1 + \beta_2 = 1$ | $R^2$ |
| 0.0315 [0.0217] | 0.6908* [0.1160] | 0.2062* [0.0945] | **0.02** | 0.98 | **0.03** | 0.84 |
| 0.0658 [0.0585] | 0.291 [0.4781] | 0.2844* [0.3222] | **0.02** | 0.98 | **0.04** | 0.39 |
| 0.1546 [0.1932] | -0.5363 [0.3398] | 0.3583* [0.3261] | **0.00** | 0.99 | **0.00** | 0.05 |
| 0.1221 [0.1282] | 0.8004* [0.4043] | -0.0753* [0.2762] | 0.07 | 0.93 | 0.14 | 0.50 |
| 0.0435 [0.0456] | 0.9745* [0.1737] | -0.2326* [0.1320] | **0.00** | 0.99 | **0.01** | 0.49 |

Table 9. **Expectations formation analysis for selected indicators with respect to initial announcements** *(cont.)*

| Adaptive expectations | | | | | | |
|---|---|---|---|---|---|---|
| | | | p-Values for $H_0$ : | | | |
| $\beta_0$ | $\beta_1$ | $\beta_2$ | $\beta_1 + \beta_2 > 1$ | $\beta_1 + \beta_2 < 1$ | $\beta_1 + \beta_2 = 1$ | $R^2$ |
| 0.0867* | 0.8132* | -0.3582* | **0.00** | 0.99 | **0.00** | 0.17 |
| [0.0387] | [0.2849] | [0.2263] | | | | |
| 0.2373* | 0.0418 | 0.0114* | **0.00** | 0.99 | **0.00** | 0.00 |
| [0.0891] | [0.1909] | [0.1515] | | | | |
| 0.1440* | 0.7002* | -0.0853* | **0.00** | 0.99 | **0.01** | 0.41 |
| [0.0633] | [0.1551] | [0.0846] | | | | |
| 0.1725* | -0.4574 | 0.8050 | **0.00** | 0.99 | **0.00** | 0.32 |
| [0.0479] | [0.3546] | [0.2671] | | | | |
| 0.1518* | -0.1856 | -0.3053* | **0.00** | 0.99 | **0.00** | 0.27 |
| [0.0551] | [0.1444] | [0.1051] | | | | |
| -0.0017 | -0.0346 | 1.0183 | 0.36 | 0.64 | 0.71 | 0.84 |
| [0.0049] | [0.0427] | [0.0467] | | | | |
| -0.0848 | 0.9443* | -0.1829* | **0.02** | 0.98 | **0.05** | 0.60 |
| [0.0960] | [0.1236] | [0.0600] | | | | |
| 0.0336 | 0.5031* | -0.4146* | **0.00** | 0.99 | **0.00** | 0.69 |
| [0.0755] | [0.0949] | [0.0385] | | | | |
| -0.0131 | -0.0680 | 0.8253* | **0.00** | 0.99 | **0.00** | 0.73 |
| [0.0090] | [0.0661] | [0.0595] | | | | |

*Note: * indicate that the null hypotheses Ho : ($\alpha_o = \alpha_2 = 0$, $\alpha_1 = 1$) and Ho : ($\beta o = \beta_1 = 0$, $\beta_2 = 1$), respectively, have to be rejected at least at a 5% significance level. Brackets denote heteroskedasticity-robust standard errors.*
*Source:* Bloomberg, own calculation.

The same analysis has also been carried out for expectations concerning latest-available releases (results not reported). In general, the process of expectation formation for the latest revision does not differ from expectations formation concerning the initial announcement. However, forecasters seem to expect a regressing trend in the latest revisions of *US Factory Orders* and *EU and German Unemployment Rate*. Similarly, when testing the adaptive hypothesis, the analysis using the latest revisions shows that, in contrast to the initial announcement, forecasters expect the latest revision of the *EU Unemployment Rate* to reverse the previous trend and therefore lower their expectations.

## 7. Concluding remarks

For this paper a unique data set has been used to analyse data revisions and economists' forecasts regarding a wide set of major macroeconomic indicators.

The empirical analysis of data revisions has shown that some announcements are considerably and systematically revised. At the same time, forecasters' expectation errors are also systematic for a number of indicators. The comparison of forecast accuracy across countries and indicators shows that in general forecasts for US and Eurozone indicators are biased to a certain degree with respect to final values. In contrast, expectations about German indicators are biased to some degree regarding initial announcements. In addition, the analysis shows that for some indicators forecasters are able to account for systematic revisions and form unbiased forecasts of the latest values. For other indicators, forecasters do not seem to take systematic revisions into account. Thus, although their forecasts are unbiased with respect to initial releases, they make systematic forecast errors with respect to final values.

The overall evidence on the effects of economic conditions on standardized revisions and surprises is mixed and unclear. In general the hypothesis, that economic conditions during the reporting period have a stronger impact on revisions and surprises than the economic situation at the time of the release, has to be rejected. A positive impact of domestic recessions and volatile stock markets (predominantly during the reporting period) is observed regarding forecasters' disagreement, i.e. economists disagree more during domestic recessions and when the national stock market is volatile.

Expectation formation regarding latest values is generally found not to differ from expectation formation concerning initial announcements. This result has raised many questions in need of further investigation. It would be interesting to learn more about the expectation formation process taking the panel structure of the data into account. Moreover, the information transmission process could also be investigated. The main implication of this study is that both forecast accuracy and data revisions should be taken into consideration when incorporating professional forecasts into a decision-making process.

Table 10. **The impact of economic conditions when announcements are released on standardized revisions**

| | | *constant* | $resUS_t$ | $volUS_t$ | $resEU_t$ | $volEU_t$ | $resDE_t$ | $volDE_t$ | $hOil_t$ | $date_t$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Economic activity and GDP | | | | | | | | | | |
| US Business Invent. | 103 | -1.35 | 0.32 | 0.12 | -0.43 | 0.05 | 1.13*** | -1.30*** | -1.03 | 0.00 |
| US Goods Orders | 103 | -0.12 | 0.37 | -0.11 | 0.29 | -0.71 | 0.49 | -0.04 | -1.17* | 0.00 |
| US Retail Sales | 100 | -0.32 | 0.41 | -1.33* | -0.19 | 1.54** | 0.24 | -0.46 | -0.41 | 0.00 |
| US Ind. Prod. | 98 | 0.21 | 0.60 | 0.19 | -0.52 | -1.06 | -0.18 | 1.03* | 0.12 | 0.00 |
| US Leading Ind. | 99 | -5.02** | 0.77 | -0.53 | -0.40 | 0.48 | 0.25 | 0.23 | -0.49 | 0.00** |
| US Cons. Credit | 106 | -5.42** | -0.14 | -0.26 | -0.25 | -0.04 | 0.34 | 0.00 | 0.23 | 0.00** |
| US GDP QoQ | 35 | -12.03*** | -0.16 | -0.15 | | 0.57 | 0.43 | | -1.35 | 0.00*** |
| EU GDP QoQ | 21 | -5.39 | -0.01 | | -1.54 | | -0.15 | 2.64** | 1.80 | 0.00 |
| DE GDP QoQ | 26 | -3.78* | 4.85*** | -4.35*** | | | | | -4.58*** | -0.00* |
| Employment situation and housing markets | | | | | | | | | | |
| US Non-farm Payroll | 103 | -2.64 | 0.92 | 0.06 | -0.98 | 0.67 | 0.84** | -0.90* | -0.42 | 0.00 |
| US Building Permits | 99 | 0.09 | 0.57 | 2.28** | -1.76** | -0.33 | 0.06 | -0.71 | 0.96 | 0.00 |
| US Housing Starts | 108 | -1.03 | 0.36 | 2.98*** | -1.62** | -2.03*** | 0.41 | -0.36 | 0.95 | 0.00 |
| Business conditions and consumer confidence | | | | | | | | | | |
| ISM Manuf. PMI | 107 | 0.27 | 0.32 | 0.61 | -0.99 | 0.73 | -0.25 | -0.28 | 1.10* | 0.00 |
| US Cons. Conf. | 107 | 0.65 | -1.04* | -0.01 | 1.74** | -0.18 | 0.01 | -0.49 | -0.70 | 0.00 |
| Prices and monetary policy | | | | | | | | | | |
| US PPI | 92 | -1.11 | 0.82 | -0.28 | -1.66* | 0.57 | -0.16 | 0.29 | 1.15 | 0.00 |
| US Imp. Price Index | 95 | 0.27 | 0.54 | 0.63 | -0.83 | -0.46 | -0.76* | 1.10** | 0.47 | 0.00 |
| EU CPI | 99 | 1.49 | 0.00 | 1.56** | -0.73 | -0.67 | -0.02 | -0.02 | 0.74 | 0.00 |
| EU M3 | 104 | -1.19 | -0.17 | 1.02 | -1.27 | -1.33** | 0.35 | 0.34 | 0.44 | 0.00 |
| EU M3 3mth avg | 103 | -2.16 | -1.78*** | -0.68 | 0.56 | -0.16 | 0.78** | -0.21 | -0.40 | 0.00 |
| DE PPI | 88 | 1.51 | 0.42 | 0.55 | -0.76 | -1.43 | -0.66 | 1.59*** | 1.53** | 0.00 |

*Note:* OLS standard errors are not displayed. Standardized revisions refer to revisions between the initial announcement and the last revision and are defined as $R^{AL}_{i,t} = (A_{i,t} - R^{L}_{i,t}) / \sigma^{R}_{i}$. A negative (positive) coefficient indicates that initial announcements are revised upwards (downwards). Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *. Estimation results are only reported for indicators with significant coefficients.
*Source:* Bloomberg, own calculations.

Table 11. **The impact of economic conditions during the reporting period on standardized revisions**

| | | *constant* | $resUS_{rp}$ | $volUS_{rp}$ | $resEU_{rp}$ | $volEU_{rp}$ | $resDE_{rp}$ | $volDE_{rp}$ | $hOil_{rp}$ | $date_t$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Economic activity and GDP | | | | | | | | | | |
| US Business Invent. | 103 | -1.24 | 0.63 | -0.09 | -0.29 | -0.43 | 0.81** | -0.27 | -1.20* | 0.00 |
| US Goods Orders | 103 | 0.70 | 0.07 | -0.21 | -0.10 | 1.21* | -0.17 | -0.15 | 0.41 | 0.00 |
| US Factory Orders | 102 | 0.70 | -0.42 | -0.60 | 0.73 | 1.32** | -0.36 | 0.18 | 0.22 | 0.00 |
| US GDP QoQ | 35 | -9.86** | -0.52 | -3.27** | -2.78** | 2.05** | -0.21 | 1.18** | -3.16*** | 0.00** |
| EU GDP QoQ | 21 | -11.09 | 0.20 | -1.14 | | -0.06 | 0.86 | 2.11** | -0.94 | 0.00 |
| DE Ind. Prod. | 78 | -0.71 | 1.52** | 1.26 | -1.60 | -4.20*** | 0.21 | 2.69** | -0.06 | 0.00 |
| DE GDP QoQ | 26 | 3.83* | -0.05 | 4.90*** | | -4.36*** | | 0.02 | 0.51 | -0.00* |
| Employment situation and housing markets | | | | | | | | | | |
| US Housing Starts | 108 | -0.53 | 0.22 | -1.69** | 0.26 | 1.23* | -0.11 | 0.30 | -0.37 | 0.00 |
| Business conditions and consumer confidence | | | | | | | | | | |
| ISM Manuf. PMI | 107 | 0.37 | -0.82 | -0.82 | 2.07*** | -0.72 | 0.04 | 0.44 | -1.38** | 0.00 |
| US Cons. Conf. | 107 | 0.65 | -1.04* | -0.01 | 1.74** | -0.18 | 0.01 | -0.49 | -0.70 | 0.00 |
| Prices and monetary policy | | | | | | | | | | |
| US Imp. Price Index | 95 | -0.51 | -0.40 | 0.03 | 0.97 | -0.02 | -0.27 | 0.44 | -1.31* | 0.00 |
| EU CPI | 99 | -0.09 | -0.02 | -0.54 | 0.18 | -0.80 | 0.25 | 0.98** | -0.43 | 0.00 |
| EU M3 | 104 | -0.78 | -1.05* | -0.39 | 0.16 | 0.20 | 0.01 | 0.28 | 0.14 | 0.00 |
| EU M3 3mth avg | 103 | -1.77 | -1.20** | 0.04 | -0.48 | -0.43 | 0.26 | 0.44 | 0.53 | 0.00 |
| DE PPI | 88 | 1.39 | -0.91 | 1.72* | 0.25 | -0.02 | -0.05 | -0.81 | 0.43 | 0.00 |
| Balances | | | | | | | | | | |
| US Current Account | 36 | -1.21 | -1.74** | -0.14 | 2.36 | 0.74 | -0.26 | 0.46 | -0.68 | 0.00 |

*Note:* OLS standard errors are not displayed. Standardized revisions refer to revisions between the initial announcement and the last revision and are defined as $R^{AL}_{i,t} = (A_{i,t} - R^{L}_{i,t}) / \sigma^{R}_{i}$. A negative (positive) coefficient indicates that initial announcements are revised upwards (downwards). Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *. Estimation results are only reported for indicators with significant coefficients.
*Source:* Bloomberg, own calculations.

Table 12. **The impact of economic conditions when announcements are released on standardized surprises about initial announcements**

| | | *constant* | $resUS_t$ | $volUS_t$ | $resEU_t$ | $volEU_t$ | $resDE_t$ | $volDE_t$ | $hOil_t$ | $date_t$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Economic activity and GDP | | | | | | | | | | |
| US Business Invent. | 103 | 1.17 | -0.25 | -0.76 | -0.22 | 0.86 | 0.61 | -0.81* | 0.07 | 0.00 |
| US Goods Orders | 103 | 0.10 | 0.45 | 0.53 | 0.06 | -1.60** | 0.47 | 0.19 | -0.99 | 0.00 |
| US Retail Sales | 100 | -1.68 | 0.37 | 0.61 | -1.57* | 0.16 | 0.34 | -0.57 | 0.74 | 0.00 |
| US Cons. Credit | 106 | -0.95 | -0.87 | -0.50 | 0.68 | -0.24 | 0.67* | -0.49 | -0.08 | 0.00 |
| EU GDP QoQ | 30 | -0.07 | -3.37*** | | 2.70* | | -0.39 | 0.33 | 1.64 | 0.00 |
| DE GDP QoQ | 29 | -4.73 | -2.69*** | 1.48 | | | | | 3.46*** | 0.00 |
| Employment situation and housing markets | | | | | | | | | | |
| Initial Jobl. Claims | 468 | 0.07 | 0.08 | 0.04 | -0.05 | -0.03 | 0.01 | -0.02 | -0.11 | 0.00 |
| US Non-farm Payroll | 103 | -1.83 | 1.16* | 0.03 | -1.52* | 0.38 | 0.15 | -0.95* | 0.27 | 0.00 |
| US Building Permits | 99 | -0.21 | 0.59 | 2.38*** | -2.08** | -0.61 | 0.20 | -0.48 | 1.42** | 0.00 |
| US Housing Starts | 108 | -0.79 | 0.37 | 3.39*** | -1.91*** | -2.12*** | 0.33 | -0.31 | 1.40** | 0.00 |
| EU Unempl. Rate | 107 | -0.58 | -2.40*** | -0.77 | 2.86*** | 0.02 | 0.00 | 0.41 | -0.62 | 0.00 |
| Business conditions and consumer confidence | | | | | | | | | | |
| ISM Manuf. PMI | 107 | -0.07 | 0.09 | 0.91 | -1.02 | 0.82 | -0.17 | -0.54 | 1.30** | 0.00 |
| Uni Michigan Conf. | 215 | 0.21 | 0.45 | -0.49 | 0.47 | -0.05 | 0.37 | -0.54 | -1.38*** | 0.00 |
| US Cons. Conf. | 107 | 0.91 | -0.99 | -0.10 | 1.80* | -0.23 | -0.08 | -0.33 | -0.68 | 0.00 |
| ZEW DE Expect. | 103 | -0.28 | -1.33* | 1.29* | 0.54 | 0.99 | -0.21 | -1.53* | 1.03 | 0.00 |
| Prices and monetary policy | | | | | | | | | | |
| US CPI | 89 | 0.35 | 1.42 | 0.75 | -2.19* | -0.23 | -0.04 | -0.30 | 1.41* | 0.00 |
| US ISM Prices Paid | 107 | 1.04 | 0.82 | -2.12*** | -0.23 | 1.55** | -0.71* | 1.05** | 0.13 | 0.00 |
| US Imp. Price Index | 95 | -0.64 | 0.63 | 0.52 | -1.21 | -0.88 | -0.40 | 0.70 | 1.18* | 0.00 |
| Federal Funds Rate | 72 | 0.84 | -0.78 | 0.69 | 1.43 | -2.09*** | -0.31 | 1.30** | -0.33 | -0.00 |
| EU CPI | 99 | -2.59 | 0.00 | -0.65 | -0.39 | 1.28** | 0.97** | -1.22** | -0.56 | 0.00 |
| EU PPI | 93 | 1.52 | -0.24 | -1.73** | -0.50 | 1.02 | -0.09 | -0.17 | 1.22** | 0.00 |
| ECB Interest Rates | 106 | 1.57 | -1.37** | -1.33 | 2.82** | -0.09 | -0.60 | 1.20** | -0.84 | -0.00 |
| EU M3 | 104 | 2.63 | -0.59 | 1.55** | -0.34 | -1.49** | 0.06 | 0.06 | 0.60 | 0.00 |
| EU M3 3mth avg | 103 | 0.95 | -1.13 | 1.70** | 0.25 | -1.56** | 0.11 | -0.15 | 0.22 | 0.00 |
| DE PPI | 88 | 2.31 | 1.05 | -1.47* | -1.26 | 1.63* | -0.39 | 0.7 | 1.88*** | 0.00 |
| Balances | | | | | | | | | | |
| US Trade Balance | 108 | -0.13 | -0.87 | -0.57 | 1.39* | -0.51 | -0.10 | 0.63 | -0.21 | 0.00 |
| DE Current Account | 99 | 0.10 | -0.55 | -2.07** | 1.32 | 1.27 | -0.39 | 0.60 | -0.38 | 0.00 |

*Note:* Standardized surprises about initial announcement are defined as $S^A_{i,t} = (A_{i,t} - E^A_{i,t}) / \sigma_i^{S^A}$. A negative (positive) coefficient indicates that forecasters overestimate (underestimate) initial announcements. OLS standard errors are not displayed. Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *. Estimation results are only reported for indicators with significant coefficients.
*Source:* Bloomberg, own calculations.

Table 13. **The impact of economic conditions during the reporting period on standardized surprises about initial announcements**

| | | *constant* | $resUS_{rp}$ | $volUS_{rp}$ | $resEU_{rp}$ | $volEU_{rp}$ | $resDE_{rp}$ | $volDE_{rp}$ | $hOil_{rp}$ | $date_t$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Economic activity and GDP | | | | | | | | | | |
| US Factory Orders | 102 | 1.83 | 0.38 | -0.03 | -0.64 | -0.33 | -0.56 | 0.77 | 1.30** | 0.0 |
| US Leading Ind. | 99 | -1.77 | 0.55 | -0.48 | -0.25 | 1.02 | 0.45 | -0.53 | -1.65** | 0.00 |
| US Cons. Credit | 106 | -0.27 | 0.52 | 0.73 | -1.52** | 0.23 | 0.21 | -0.51 | 0.90 | 0.00 |
| US GDP QoQ | 36 | -6.18 | -0.11 | -3.92** | 1.09 | 3.32** | 1.01 | -0.40 | -2.18 | 0.00 |
| EU Ind. Prod. | 90 | 1.45 | -0.94 | -2.30** | 1.38 | 2.30** | 0.16 | 0.24 | -0.18 | 0.00 |
| EU GDP QoQ | 30 | -0.22 | 0.57 | -3.95*** | 0.12 | 2.83** | -0.12 | -0.40 | | 0.00 |
| DE GDP QoQ | 29 | -4.13 | 0.47 | -3.28** | | 1.48 | 0.22 | -0.02 | 0.68 | 0.00 |
| Employment situation and housing markets | | | | | | | | | | |
| US Non-farm Payroll | 103 | -1.73 | 0.17 | 0.81 | -0.74 | 0.04 | -0.05 | -0.88* | 0.82 | 0.00 |
| US Building Permits | 99 | 0.31 | 0.50 | -1.68* | 0.12 | 0.87 | -0.16 | 0.73 | -0.54 | 0.00 |
| US Housing Starts | 108 | -0.51 | 0.31 | -1.58** | 0.07 | 1.20* | -0.12 | 0.40 | -0.33 | 0.00 |
| Business conditions and consumer confidence | | | | | | | | | | |
| ISM Manuf. PMI | 107 | 0.15 | -0.60 | -0.72 | 1.66** | -0.85 | -0.12 | 0.93* | -1.10* | 0.00 |
| Uni Michigan Conf. | 215 | -0.11 | 0.33 | -0.38 | 0.49 | -0.05 | 0.32 | -0.52 | -1.22*** | 0.00 |
| US Cons. Conf. | 107 | 0.91 | -0.99 | -0.10 | 1.80** | -0.23 | -0.08 | -0.33 | -0.68 | 0.00 |
| ZEW DE Expect. | 103 | -0.28 | -1.33** | 1.29* | 0.54 | 0.99 | -0.21 | -1.53*** | 1.03 | 0.00 |
| Prices and monetary policy | | | | | | | | | | |
| Federal Funds Rate | 72 | 0.84 | -0.78 | 0.69 | 1.43 | -2.09*** | -0.31 | 1.30** | -0.33 | -0.00 |
| EU CPI | 99 | -2.93 | -0.01 | -0.64 | -0.03 | -0.35 | 1.01** | -0.26 | -0.76 | 0.00 |
| EU PPI | 93 | 0.53 | -0.40 | 0.14 | -1.06* | -0.46 | 0.23 | -0.67 | 1.47*** | 0.00 |
| ECB Interest Rates | 106 | 1.57 | -1.37** | -1.33 | 2.82*** | -0.09 | -0.60 | 1.20** | -0.84 | -0.00 |
| EU M3 | 104 | 3.65 | -1.30** | -0.27 | 1.22 | 0.61 | -0.34 | -0.20 | 0.00 | 0.00 |
| EU M3 3mth avg | 103 | 1.68 | -1.00* | -0.65 | 1.15 | -0.17 | -0.43 | 0.86* | -0.37 | 0.0 |
| DE PPI | 88 | 2.50 | -1.28* | -0.10 | 1.13 | 0.59 | -0.12 | -0.54 | 1.25* | 0.00 |
| Balances | | | | | | | | | | |
| US Current Account | 36 | -0.49 | 0.76 | -1.33 | -1.53 | 2.58* | -0.14 | -0.08 | 0.11 | 0.00 |

*Note:* Standardized surprises about initial announcement are defined as $S^A_{i,t} = (A_{i,t} - E^A_{i,t}) / \sigma_i^{S^A}$. A negative (positive) coefficient indicates that forecasters overestimate (underestimate) initial announcements. OLS standard errors are not. Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *. Estimation results are only reported for indicators with significant coefficients.

*Source:* Bloomberg, own calculations.

Table 14. **The impact of economic conditions when announcements are released on standardized surprises about latest revisions**

| | | *constant* | $resUS_t$ | $volUS_t$ | $resEU_t$ | $volEU_t$ | $resDE_t$ | $volDE_t$ | $hOil_t$ | $date_t$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Economic activity and GDP | | | | | | | | | | |
| US Business Invent. | 103 | 2.41 | -0.55 | -0.66 | 0.36 | 0.53 | -0.94** | 1.02** | 1.29** | 0.00 |
| US Goods Orders | 103 | 0.21 | -0.21 | 0.46 | -0.33 | -0.04 | -0.34* | 0.16 | 0.91 | 0.0 |
| US Retail Sales | 100 | -0.39 | -0.32 | 1.87** | -0.49 | -1.77*** | -0.13 | 0.29 | 0.82 | 0.00 |
| US Retail ex Autos | 98 | -0.21 | -0.75 | 0.48 | 0.80 | -1.37** | 0.46 | -0.24 | -0.70 | 0.00 |
| US Leading Ind. | 99 | 4.78** | -0.70 | 0.62 | 0.20 | -0.68 | -0.10 | -0.11 | 0.27 | -0.00* |
| US Cons. Credit | 106 | 7.47*** | -0.82 | -0.20 | 1.23 | -0.22 | 0.28 | -0.60 | -0.47 | -0.00*** |
| EU Ind. Prod. | 90 | 1.01 | -1.04 | -0.61 | 1.98** | -0.02 | 0.10 | -0.07 | -0.82 | 0.00 |
| EU GDP QoQ | 21 | 1.04 | -2.64** | | 2.50 | | -0.29 | -0.48 | 0.75 | -0.00 |
| DE GDP QoQ | 26 | -6.04 | -2.74*** | 1.43 | | | | | 3.36*** | 0.00 |
| Employment situation and housing markets | | | | | | | | | | |
| US Non-farm Payroll | 103 | 1.89 | -0.32 | -0.05 | 0.15 | -0.53 | -0.87** | 0.43 | 0.66 | 0.0 |
| DE Unempl. Rate | 98 | 0.86 | -0.37 | -1.43 | 1.26 | 1.79** | -0.55 | 0.04 | -0.44 | -0.00 |
| Business conditions and consumer confidence | | | | | | | | | | |
| Uni Michigan Conf. | 215 | -0.21 | 0.45 | -0.49 | 0.47 | -0.05 | 0.37 | -0.54 | -1.38*** | 0.00 |
| ZEW DE Expect. | 103 | -0.28 | -1.33** | 1.29* | 0.54 | 0.99 | -0.21 | -1.53*** | 1.03 | 0.00 |
| Prices and monetary policy | | | | | | | | | | |
| US CPI | 89 | -0.21 | 0.90 | 0.53 | -1.94* | -0.24 | 0.38 | -0.68 | 1.16 | 0.00 |
| US PPI | 92 | 1.77 | -0.38 | -0.53 | 1.49 | -0.29 | 0.11 | -0.10 | -1.02 | 0.00 |
| US ISM Prices Paid | 107 | 1.09 | 0.84 | -2.16*** | -0.25 | 1.57** | -0.69* | 1.04** | 0.10 | 0.00 |
| US Imp. Price Index | 95 | -0.67 | -0.30 | -0.47 | 0.35 | 0.08 | 0.70* | -0.94* | 0.06 | 0.00 |
| Federal Funds Rate | 72 | 0.84 | -0.78 | 0.69 | 1.43 | -2.09*** | -0.31 | 1.30** | -0.33 | -0.00 |
| EU CPI | 99 | -3.22 | 0.00 | -1.98*** | 0.46 | 1.53** | 0.67* | -0.80* | -1.11* | 0.00 |
| EU PPI | 93 | -1.76 | -0.19 | -0.60 | -0.61 | 1.28* | -0.06 | -0.02 | 0.97 | 0.00 |
| ECB Interest Rates | 106 | 1.57 | -1.37** | -1.33 | 2.82*** | -0.09 | -0.60 | 1.20** | -0.84 | -0.00 |
| EU M3 | 104 | 5.27** | -0.58 | 0.74 | 1.27 | -0.24 | -0.40 | -0.38 | 0.23 | -0.00* |
| EU M3 3mth avg | 103 | 2.72 | 1.34* | 1.52** | -0.48 | -0.57 | -0.77** | 0.15 | 0.53 | 0.00 |
| DE PPI | 88 | 0.31 | 0.41 | -1.74* | -0.23 | 2.77*** | 0.36 | -1.06* | -0.06 | 0.00 |

*Note:* Standardized surprises about final values are defined as $S^{RL}_{i,t} = (RL_{i,t} - E^{LR}_{i,t}) / \sigma_i^{S^{RI}}$. A negat ive (positive) coefficient indicates that forecasters overestimate (underestimate) revised values. OLS standard errors are not displayed. Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *. Estimation results are only reported for indicators with significant coefficients.

*Source:* Bloomberg, own calculations.

Table 15. **The impact of economic conditions during the reporting period on standardized surprises about latest revisions**

| | | *constant* | $resUS_{rp}$ | $volUS_{rp}$ | $resEU_{rp}$ | $volEU_{rp}$ | $resDE_{rp}$ | $volDE_{rp}$ | $hOil_{rp}$ | $date_t$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | N | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Economic activity and GDP | | | | | | | | | | |
| US Business Invent. | 103 | 1.71 | -1.29** | -0.09 | 0.49 | 0.29 | -0.54 | 0.27 | 1.50** | 0.00 |
| Chicago Purch. Mgrs. | 107 | -0.68 | 0.12 | 0.60 | -0.33 | -0.98 | -0.07 | 0.82* | -0.06 | 0.00 |
| US Goods Orders | 103 | -0.75 | 0.35 | -0.23 | -0.07 | -1.32** | 0.18 | 0.59 | -0.80 | 0.00 |
| US Factory Orders | 102 | -0.24 | 0.52 | 0.60 | -0.90 | -1.42** | 0.23 | 0.01 | 0.11 | 0.00 |
| US Retail ex Autos | 98 | -0.59 | 0.83 | -1.02 | -1.87** | 0.83 | 0.01 | 0.15 | 1.07 | 0.00 |
| US Cons. Credit | 106 | 5.18** | 0.02 | -0.36 | -0.65 | -0.07 | 0.38 | -0.01 | 0.42 | -0.00** |
| EU Ind. Prod. | 90 | 1.55 | -1.06* | -1.63 | 1.69* | 1.59 | -0.09 | 0.03 | -0.31 | 0.00 |
| EU Retail Sales | 83 | 1.22 | -0.53 | -2.37* | 1.16 | 1.40 | -0.12 | 0.68 | -0.64 | 0.00 |
| EU GDP QoQ | 21 | 2.65 | 0.29 | -2.53 | | 2.16* | -0.38 | -0.88 | 0.40 | -0.00 |
| DE Ind. Prod. | 78 | 0.44 | -1.10 | -1.86 | 2.41* | 3.98*** | -0.48 | -3.51*** | -0.87 | 0.00 |
| DE GDP QoQ | 26 | -5.19 | 0.31 | -2.96*** | | 1.44 | | -0.03 | 0.87 | 0.00 |
| Employment situation and housing markets | | | | | | | | | | |
| US Non-farm Payroll | 103 | 1.27 | 0.17 | -0.75 | -0.36 | 0.29 | -0.71* | 0.08 | 0.34 | 0.00 |
| Business conditions and consumer confidence | | | | | | | | | | |
| ISM Manuf. PMI | 107 | -0.45 | 0.42 | 0.18 | -0.80 | -0.28 | -0.33 | 1.01** | 0.53 | 0.00 |
| Uni Michigan Conf. | 215 | -0.11 | 0.33 | -0.38 | 0.49 | -0.05 | 0.32 | -0.52 | -1.22*** | 0.00 |
| ZEW DE Expect. | 103 | -0.28 | -1.33** | 1.29* | 0.54 | 0.99 | -0.21 | -1.53*** | 1.03 | 0.00 |
| Prices and monetary policy | | | | | | | | | | |
| US Imp. Price Index | 95 | 0.85 | 0.66 | -0.04 | -1.28 | -0.05 | -0.02 | -0.18 | 1.71** | 0.00 |
| Federal Funds Rate | 72 | 0.84 | -0.78 | 0.69 | 1.43 | -2.09*** | -0.31 | 1.30** | -0.33 | -0.00 |
| EU CPI | 99 | -1.89 | 0.01 | 0.10 | -0.20 | 0.56 | 0.43 | -1.15** | -0.09 | 0.00 |
| EU PPI | 93 | -1.63 | -0.48 | -0.05 | -0.40 | 0.01 | 0.10 | -0.38 | 1.22* | 0.00 |
| ECB Interest Rates | 106 | 1.57 | -1.37** | -1.33 | 2.82*** | -0.09 | -0.60 | 1.20** | -0.84 | -0.00 |
| EU M3 | 104 | 6.12** | -0.35 | 0.16 | 1.46* | 0.56 | -0.49 | -0.66 | -0.20 | -0.00** |
| DE PPI | 88 | 0.58 | -0.09 | -1.85** | 0.64 | 0.50 | -0.05 | 0.39 | 0.56 | 0.00 |
| Balances | | | | | | | | | | |
| US Current | 36 | 1.06 | 2.32*** | -0.56 | -3.42** | 0.58 | 0.21 | -0.55 | 0.81 | 0.00 |
| Account US Trade Balance | 108 | 0.02 | 0.26 | 0.60 | -0.13 | -0.05 | 0.35 | -0.68 | -1.13* | 0.00 |

*Note:* Standardized surprises about final values are defined as $S^{RL}_{i,t} = (RL_{i,t} - E^{LR}_{i,t}) / \sigma_i^{S^{RL}}$. A negative (positive) coefficient indicates that forecasters overestimate (underestimate) revised values. OLS standard errors are not displayed. Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *. Estimation results are only reported for indicators with significant coefficients.

*Source:* Bloomberg, own calculations.

Table 16. **The impact of international economic conditions at release time on forecasters' disagreement**

| | *constant* | $resUS_t$ | $volUS_t$ | $resEU_t$ | $volEU_t$ | $resDE_t$ | $volDE_t$ | $hOil_t$ | $numE_t$ | $R^2$ | *N* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | |
| Economic activity and GDP | | | | | | | | | | | | |
| US Business Invent. | 0.23*** | 0.10*** | 0.02 | -0.03 | -0.02 | -0.02 | 0.02 | -0.04 | 0.00 | 0.19 | 103 | |
| Purch. Mgrs. | 2.22*** | 0.13 | 0.16 | 0.44 | -0.04 | -0.48*** | 0.16 | -0.47** | -0.01* | 0.27 | 107 | |
| US Goods Orders | 1.82*** | -0.04 | 0.09 | 0.30 | 0.03 | -0.25* | 0.07 | -0.03 | -0.01 | 0.06 | 103 | |
| US Factory Orders | 0.96*** | 0.12 | 0.15 | 0.23 | -0.13 | -0.11 | 0.13 | -0.27* | -0.01 | 0.24 | 102 | |
| US Retail Sales | 0.49*** | 02 | 0.17* | 0.08 | -0.06 | 0.02 | 0.02 | -0.09 | 0.00 | 0.27 | 100 | |
| US Retail ex Autos | 0.16 | 08** | 0.05 | 0.12** | -0.07 | 0.00 | 0.07* | -0.17*** | 0.00 | 0.50 | 98 | |
| US Ind. Prod. | 0.23** | 10** | 0.05 | 0.11* | -0.03 | -0.06** | 0.07* | -0.17*** | 0.00 | 0.50 | 98 | |
| US Leading Ind. | 0.07 | 10** | 0.02 | -0.06 | -0.02 | 0.00 | 0.01 | -0.04 | 0.00 | 0.11 | 99 | |
| US Cons. Credit | 3.97*** | .22 | -0.07 | 0.50 | -0.14 | -0.10 | -0.12 | -0.94* | -0.05*** | 0.13 | 106 | |
| US GDP (A) | 0.59* | 15* | 0.11 | | -0.14 | 0.07 | | -0.12 | 0.00 | 0.21 | 35 | |
| US GDP (F) | -0.05 | 00 | 0.16*** | -0.07 | -0.11*** | 0.02 | -0.03 | 0.05 | 0.00** | 0.49 | 35 | |
| US GDP (S) | -0.17 | 03 | | -0.08 | 0.08 | 0.11* | -0.03 | -0.13 | 0.01 | 0.27 | 36 | |
| EU Ind. Prod. | 0.37*** | 17 | 0.35** | 0.11 | -0.21* | -0.06 | 0.06 | -0.17 | 0.00 | 0.38 | 90 | |
| EU Retail Sales | 0.48*** | 0.04 | 0.24 | -0.16 | -0.04 | -0.11 | 0.11 | 0.30** | -0.01 | 0.13 | 83 | |
| EU GDP (A) | -0.04 | 0.16*** | | -0.11 | | 0.04 | -0.01 | -0.08 | 0.00* | 0.47 | 30 | |
| EU GDP (F) | 0.02 | -0.02 | 0.07 | | 0.03 | 0.00 | -0.02 | 0.01 | 0.00 | 0.32 | 27 | |
| EU GDP (S) | 0.01 | 0.01 | -0.03 | 0.00 | 0.00 | 0.00 | | 0.03 | 0.03 | 0.00 | 0.32 | 36 |
| DE Ind. Prod. | 0.95*** | 0.41*** | 0.61** | 0.92**** | -0.53** | -1.56*** | 0.49** | | 0.24 | -0.01** | 0.58 | 78 |
| DE Retail Sales | 0.57*** | -0.20 | -0.08 | -0.07 | -0.07 | 0.43*** | | | -0.09 | 0.00 | 0.37 | 79 |
| DE GDP (A) | 0.20** | 0.31*** | -0.24*** | | | | | | -0.32*** | 0.00 | 0.61 | 29 |
| DE GDP (F) | 0.01 | 0.04* | -0.03 | | | | | | -0.05** | 0.00 | 0.23 | 26 |
| Employment situation and housing markets | | | | | | | | | | | | |
| Initial Jobless Cl. | 7.45*** | 2.54 | 0.85 | 1.85 | -0.13 | 0.49 | 1.64 | | -3.75* | 0.01 | 0.07 | 468 |
| US Non-farm Payroll | 47.31*** | 7.61 | 8.09 | -1.46 | -9.21 | 2.70 | -3.46 | | -17.09* | -0.17 | 0.08 | 103 |
| US Building Permits | 60.08*** | 0.14 | -0.96 | 9.97 | -10.63 | -5.39 | 2.12 | | -3.32 | -0.81*** | 0.55 | 100 |
| US Housing Starts | 113.50*** | -6.03 | -6.04 | 14.67* | -1.07 | -11.09*** | 4.20 | | 1.04 | -1.19*** | 0.44 | 108 |
| US New Home Sales | 74.36*** | -11.09** | 8.76 | 8.59 | -4.31 | -12.84*** | 0.09 | | 6.41 | -0.74*** | 0.43 | 106 |
| EU Unempl. Rate | 0.00 | -0.01 | -0.01 | 0.00 | 0.01 | 0.00 | -0.01 | | -0.03 | 0.00 | 0.02 | 107 |
| DE Unempl. Rate | 0.07*** | 0.00 | -0.01 | 0.01 | -0.01 | 0.00 | 0.00 | | -0.01 | 0.00 | 0.04 | 98 |
| Business conditions and consumer confidence | | | | | | | | | | | | |
| ISM Manuf. PMI | 1.53*** | 0.09 | 0.01 | | 0.13 | -0.07 | -0.12 | 0.10 | -0.15 | -0.01** | 0.11 | 107 |
| Phil. Fed Index | 2.14* | -0.01 | 0.31 | | -0.53 | -0.20 | 0.79** | 0.01 | 0.50 | 0.02 | 0.12 | 107 |
| Uni Michigan Conf. | -0.13 | 0.14 | -0.18 | | 0.22 | 0.08 | 0.19 | 0.05 | -0.34 | 0.02*** | 0.18 | 215 |
| US Cons. Conf. | 2.20*** | -0.03 | 0.70 | | -0.05 | 0.06 | 0.46** | -0.73*** | -0.44 | -0.01 | 0.18 | 107 |
| EU Business Cl. | 0.17* | -0.04 | 0.10 | | 0.16 | -0.04 | -0.11 | 0.04 | 0.17 | 0.00 | 0.08 | 88 |
| EU Ind. Conf. | 0.79** | -0.12 | -0.24 | | 1.24** | 0.35 | -0.59* | 1.30*** | -0.55 | 0.00 | 0.43 | 89 |
| EU Econ. Conf. | 0.04 | 0.18 | -0.04 | | 0.12 | 0.21 | -0.17 | 0.09 | -0.06 | 0.02*** | 0.33 | 93 |
| ZEW EU Expect. | 2.31** | 1.44 | 6.60* | | -4.22 | -4.01 | | 2.05 | 1.56 | 0.19 | 0.12 | 78 |
| EU Cons. Conf. | -0.51 | 0.10 | -3.45 | | -0.65 | 15.03*** | 3.87*** | -12.17*** | -3.40** | 0.05 | 0.47 | 104 |
| IFO Business Cl. | 0.86*** | -0.01 | 0.08 | | -0.02 | 0.24 | -0.03 | 0.21 | 0.17 | -0.01 | 0.33 | 82 |
| ZEW DE Situation | 1.61* | 0.03 | 1.87 | | 0.25 | 2.95 | -0.95 | -0.97 | 1.15 | 0.08 | 0.34 | 83 |
| ZEW DE Expect. | 4.32*** | 1.60* | 2.05* | | -1.97* | -0.07 | 0.40 | -0.02 | -0.95 | -0.01 | 0.24 | 104 |
| Prices and monetary policy | | | | | | | | | | | | |
| US CPI | 0.05 | 0.01 | -0.03 | | 0.09*** | 0.02 | -0.01 | 0.02 | -0.08*** | 0.00 | 0.46 | 89 |
| US PPI | 0.11 | 0.16*** | -0.10 | | 0.06 | 0.05 | -0.03 | 0.03 | -0.12** | 0.00 | 0.36 | 92 |
| US ISM Prices Paid | 1.68* | -1.14 | 0.12 | | 2.27* | -0.16 | -0.23 | -0.07 | -1.13 | 0.06 | 0.07 | 108 |
| US Imp. Price Index | 0.20 | 0.14 | -0.18 | | 0.37*** | 0.20 | -0.08 | 0.12 | -0.33*** | 0.00 | 0.52 | 95 |

Table 16. **The impact of international economic conditions at release time on forecasters' disagreement** *(cont.)*

| | *constant* | $resUS_t$ | $volUS_t$ | $resEU_t$ | $volEU_t$ | $resDE_t$ | $volDE_t$ | $hOil_t$ | $numE_t$ | $R^2$ | *N* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indicator | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | |
| Federal Funds Rate | -0.09*** | 0.02 | -0.10*** | | 0.09** | 0.05 | 0.05*** | 0.01 | -0.10*** | 0.00*** | 0.56 | 72 |
| EU CPI | 0.06 | -0.03 | 0.02 | | 0.00 | -0.01 | 0.00 | 0.01 | 0.01 | 0.00 | 0.03 | 99 |
| EU PPI | 0.19*** | 0.17*** | 0.18** | | -0.01 | -0.08 | -0.05 | 0.02 | -0.08 | 0.00 | 0.45 | 93 |
| ECB Interest Rates | 0.01 | 0.01 | -0.15*** | | 0.04 | 0.08*** | 0.05*** | 0.06*** | -0.09*** | 0.00 | 0.45 | 106 |
| EU M3 | 0.20*** | 0.08 | 0.00 | | -0.03 | -0.02 | 0.03 | -0.05 | -0.05 | 0.00 | 0.12 | 104 |
| EU M3 3mth avg | 0.08 | 0.51*** | 0.04 | | -0.47*** | 0.01 | 0.01 | -0.08 | -0.04 | 0.00 | 0.34 | 103 |
| DE CPI | -0.10*** | 0.00 | 0.00 | | -0.01 | -0.04 | 0.06* | 0.02 | -0.05 | 0.01*** | 0.29 | 132 |
| DE PPI | 0.28*** | -0.05 | 0.11* | | 0.16** | -0.10 | -0.03 | 0.02 | -0.04 | -0.00** | 0.34 | 88 |
| | | | | | Balances | | | | | | | |
| US Budget Balance | 19.48*** | 3.38 | 0.76 | | 7.55 | 1.03 | -5.05* | 1.21 | 1.51 | -0.30 | 0.20 | 105 |
| US Current Account | 0.97 | 1.95* | 7.13*** | | -2.06 | -6.78*** | -0.73 | 0.01 | 1.32 | 0.06 | 0.50 | 36 |
| US Trade Balance | 0.13 | 0.12 | 0.14 | | 0.50* | -0.20 | 0.01 | 0.34** | -0.56** | 0.02** | 0.41 | 108 |
| DE Current Account | 2.44*** | -0.56 | 0.49 | | 0.01 | -0.36 | 0.00 | 0.06 | 0.74 | -0.06** | 0.06 | 100 |
| DE Trade Balance | 1.24* | 0.03 | 0.50 | | -0.04 | -0.03 | 0.05 | -0.06 | 0.07 | 0.00 | 0.11 | 106 |

*Note:* OLS standard errors are not displayed. Coefficients significantly different from 0 at 1%, 5%, and 10% significance level are distinguished with ***, **, and *.
*Source:* Bloomberg, own calculations.

Table 17. **Expectations formation analysis with respect to last revisions**

| | Extrapolative expectations | | | | | | |
|---|---|---|---|---|---|---|---|
| | p-Values for $H_0$: | | | | | | |
| Indicators | $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_2 > 0$ | $\alpha_2 < 0$ | $\alpha_2 = 0$ | $R^2$ |
| Bus. Inventories | 0.0728* [0.0282] | 0.6096* [0.0422] | -0.1743* [0.0767] | **0.01** | 0.99 | **0.03** | 0.75 |
| CPI | 0.1338* [0.0598] | 0.2547* [0.2057] | 0.1335 [0.1388] | 0.83 | 0.17 | 0.34 | **0.15** |
| Factory Orders | 0.0417 [0.2045] | 0.2287* [0.1426] | -0.2740* [0.0940] | **0.00** | 0.99 | **0.00** | **0.09** |
| Import Price Index | 0.1455 [0.1648] | 0.3469* [0.1263] | 0.1804 [0.1303] | 0.91 | 0.09 | 0.17 | 0.31 |
| Industrial Prod. | 0.1833* [0.0412] | 0.4407* [0.0633] | -0.1952* [0.0734] | **0.00** | 0.99 | **0.01** | 0.41 |
| Leading Indic. | 0.0918 [0.0507] | 0.2626* [0.0875] | -0.0449 [0.0806] | 0.29 | 0.71 | 0.58 | 0.13 |
| Retail Sales | 0.1750 [0.0918] | 0.2039* [0.0971] | -0.0285 [0.0702] | 0.34 | 0.66 | 0.69 | **0.07** |
| Retail Sales ex Auto | 0.2706* [0.0464] | 0.2202* [0.0733] | -0.0702 [0.0398] | **0.04** | 0.96 | 0.08 | 0.27 |
| DE Ind. Prod. | 0.1476 [0.1198] | 0.4047* [0.1085] | -0.1793* [0.0861] | **0.02** | 0.98 | **0.04** | 0.28 |
| DE Retail Sales | 0.5183* [0.1232] | 0.0619* [0.1203] | -0.0459 [0.0689] | 0.25 | 0.75 | 0.51 | 0.01 |
| DE Unempl. Rate | -0.0152 [0.0135] | 0.6578* [0.1069] | -0.2633* [0.0874] | **0.00** | 0.99 | **0.00** | 0.33 |
| EU PPI | 0.1473* [0.0497] | 0.3820* [0.0910] | -0.1866 [0.1015] | **0.04** | 0.97 | 0.07 | 0.23 |
| EU Retail Sales | 0.0854 [0.0667] | 0.2915* [0.2522] | -0.1901 [0.1331] | 0.08 | 0.92 | 0.16 | **0.06** |
| EU Unempl. Rate | 0.0087 [0.0101] | 0.4631* [0.0946] | -0.2669* [0.0595] | **0.00** | 0.99 | **0.00** | 0.26 |

Table 17. **Expectations formation analysis with respect to last revisions** *(cont.)*

| Adaptive expectations | | | | | | |
|---|---|---|---|---|---|---|
| | | | p-Values for $H_0$: | | | |
| $\beta_0$ | $\beta_1$ | $\beta_2$ | $\beta_1 + \beta_2 > 1$ | $\beta_1 + \beta_2 < 1$ | $\beta_1 + \beta_2 = 1$ | $R^2$ |
| 0.0333<br>[0.0223] | 0.7823*<br>[0.1148] | 0.1034*<br>[0.0869] | **0.01** | 0.99 | **0.02** | 0.83 |
| 0.0517<br>[0.0515] | 0.7906*<br>[0.1374] | -0.1667*<br>[0.1480] | **0.02** | 0.98 | **0.04** | 0.40 |
| 0.1533<br>[0.2043] | -0.1648<br>[0.1052] | 0.0227*<br>[0.1252] | **0.00** | 0.99 | **0.00** | 0.03 |
| 0.1195<br>[0.1287] | 0.6978*<br>[0.1625] | 0.0141*<br>[0.1040] | **0.04** | 0.96 | **0.08** | 0.50 |
| 0.0871<br>[0.0455] | 0.5534*<br>[0.1160] | 0.1599*<br>[0.0526] | **0.00** | 0.99 | **0.01** | 0.52 |
| 0.0552<br>[0.0422] | 0.2519*<br>[0.1153] | 0.1953*<br>[0.0734] | **0.00** | 0.99 | **0.00** | 0.21 |
| 0.2089*<br>[0.0837] | 0.0160<br>[0.1463] | 0.1711*<br>[0.0681] | **0.00** | 0.99 | **0.00** | 0.07 |
| 0.1517*<br>[0.0642] | 0.4969*<br>[0.1650] | 0.0883*<br>[0.0371] | **0.00** | 0.99 | **0.01** | 0.43 |
| 0.0423<br>[0.0941] | 0.6636*<br>[0.0942] | 0.1228*<br>[0.0542] | **0.03** | 0.97 | 0.06 | 0.57 |
| 0.4898*<br>[0.1209] | -0.1615<br>[0.1802] | -0.0501*<br>[0.0681] | **0.00** | 0.99 | **0.00** | 0.01 |
| -0.0186<br>[0.0994] | 0.2348<br>[0.1972] | 0.3128*<br>[0.1919] | **0.00** | 0.99 | **0.00** | 0.29 |
| 0.1160*<br>[0.0493] | 0.3539*<br>[0.1332] | 0.1689*<br>[0.0775] | **0.00** | 0.99 | **0.00** | 0.28 |
| 0.1917*<br>[0.0588] | -0.4718*<br>[0.1394] | -0.0638*<br>[0.0883] | **0.00** | 0.99 | **0.00** | 0.17 |
| 0.0086<br>[0.0106] | 0.3359*<br>[0.1243] | 0.0744<br>[0.0451] | **0.00** | 0.99 | **0.00** | 0.15 |

*Note:* * indicate that the null hypotheses $H_0 : (\alpha_0 = \alpha_2 = 0, \alpha_1 = 1)$ and $H_0 : (\beta_0 = \beta_1 = 0, \beta_2 = 1)$, respectively, have to be rejected at least at a 5% significance level. Brackets denote heteroskedasticity-robust standard errors.
*Source:* Bloomberg, own calculation.

Table 18. **Description of indicators**

| Indicator | Unit | Description |
|---|---|---|
| | | Economic activity and GDP |
| Business Inventories (US) | % | Monthly percentage changes of goods and materials held available in stock by U.S. business. |
| Chicago Purchasing Mgrs. (US) | P | The index is compiled by the Purchasing Managers Association of Chicago and is released for every month on the last day of that month. If more firms report improved business conditions than deteriorating business conditions, the index is above 50. The series is transformed to growth rates. |
| Durable Goods Orders (US) | % | Data from the Census Bureau's report on durable goods, manufacturers' shipments, inventories and orders; expressed as monthly percentage changes. |
| Factory Orders (US) | % | Monthly percentage changes of new orders reported by U.S. manufacturers. |
| Retail Sales (US) | % | Monthly percentage changes adjusted for seasonal variation, for holiday and trading day differences, but not for price changes. |
| Retail Sales less Autos (US) | % | Monthly percentage changes adjusted for seasonal variation, for holiday and trading day differences, but not for price changes. |
| Industrial Production (US) | % | Monthly percentage changes, seasonally adjusted. The production index measures real output and is expressed as a percentage of real output in a base year, currently 2007. The production indexes are computed as Fisher indexes since 1972; the weights are based on annual estimates of value added. |
| Leading Indicators (US) | % | This index is composed of: (1) Average weekly hours, manufacturing (27.37%); (2) Average weekly initial jobless claims (3.22%); (3) Manufacturers' new orders, consumer (8.17%); (4) Vendor performance, slower deliveries (7.17%); (5) Manufacturers' new orders, capital (1.95%);(6) Building permits, new private housing units (2.64%); (7) Stock prices, 500 common stocks (3.7%); (8) Money supply, M2 (32.3%); (9) Interest rate spread (10.52%); (10) Index of consumer expectations (2.96%). Monthly percentage changes. |

Table 18. **Description of indicators** *(cont.)*

| Indicator | Unit | Description |
|---|---|---|
| Consumer Credit (US) | $B | Total net changes, seasonally adjusted. Most short-term and intermediate-term credit extended to individuals are covered by this index. Loans secured by real estate are not included. |
| GDP QoQ A (US) | % | Advanced release for the U.S. gross domestic product (GDP). Quarterly percentage changes. |
| GDP QoQ F (US) | % | Third release (final). GDP equals the total income of everyone in the economy or the total expenditure on the economy's (final) goods and services. Quarterly percentage changes. |
| GDP QoQ S (US) | % | Second release for the U.S. gross domestic product (GDP). Quarterly percentage changes. |
| EU Ind. Prod. (EU) | % | This data is the monthly percentage change of the volume index of production and includes mining and quarrying, manufacturing, electricity, gas and water supply. Monthly percetage changes, base year 2005 = 100, seasonally adjusted. |
| EU Retail Sales (EU) | % | The index of deflated turnover for retail trade shows the monthly activity in volume of retail trade, except of motor vehicles and motorcycles. It is a short-term indicator for final domestic demand. Seasonally adjusted monthly percentage changes. |
| EU GDP A (EU) | % | Advanced release for the gross domestic product (GDP) in the Eurozone. Quarterly percentage changes. |
| EU GDP F (EU) | % | Final figures. Real Eurozone GDP (quarter on quarter %). The data is seasonally adjusted and at market prices. |
| EU GDP S (EU) | % | Second release for the gross domestic product (GDP, quarter on quarter %) in the Eurozone. |
| DE Industrial Production (DE) | % | The overall index includes: mining, electricity and as supply, manufacturing and construction indices. Monthly percentage changes, seasonally adjusted. |
| DE Retail Sales (DE) | % | Monthly percentage changes of German retail sales, seasonally adjusted. |
| DE GDP QOQ A (DE) | % | Advanced release for the German gross domestic product (GDP, quarter on quarter %). |
| DE GDP QOQ F (DE) | % | Final figures. Real German GDP (quarter on quarter %). The data is seasonally and working days adjusted. Base year 2000 = 100. |
| | | Employment situation and housing market |
| Initial Jobless Claims (US) | K | Weekly change in Initial Jobless Claims. |
| Non-farm Payroll (US) | K | Total month on month net change in Non-farm Payroll, seasonally adjusted. |
| Building Permits (US) | % | Monthly growth rate of private residential real estate activity. Seasonally adjusted rates. |
| Housing Starts (US) | % | Monthly growth rate of new privately owned housing units started. Seasonally adjusted rates. |
| New Home Sales (US) | % | Monthly growth rate of median sales and average sales for new one-family houses in dollars. Data is seasonally adjusted annual rates, put out by the U.S. Dept. Of Commerce's bureau of the Census and the U.S. Dep't of Housing and Urban Development. |
| EU Unemployment Rate (EU) | % | Monthly changes in EU Unemployment Rates. The basis for the calculation of a monthly unemployment rate is the Community Labour Force Survey, where the main statistical objective is to classify the population in employed, unemployed and inactive groups. |
| DE Unemployment Rate (DE) | % | Monthly changes in German Unemployment Rates. The unemployment rate is calculated as a percentage of unemployed to the total labour force, including both West and East Germany. Figures are seasonally adjusted. |
| | | Business conditions and consumer confidence |
| ISM Manufacturing PMI (US) | P | ISM indices compare the changes in various market areas on a month to month basis. Series is transformed to monthly growth rates. |
| Philadelphia Fed Index (US) | P | Federal Reserve Bank of Philadelphia: Business outlook survey diffusion. Each January seasonally adjusted history is revised. |
| U. of Michigan Confidence (US) | P | A survey (conducted by the University of Michigan) of consumer attitudes regarding both the present situation as well as expectations concerning economic conditions. |
| Consumer Confidence (US) | R | Average of responses to the following five questions (response options: Positive, Negative, Neutral): (1) Respondents appraisal of current business conditions. (2) Respondents expectations regarding business conditions six month hence. (3) Respondents appraisal of the current employment conditions. (4) Respondents expectations regarding employment conditions six month hence. (5) Respondents expectations regarding their total family income six month hence. |
| EU Business Climate (EU) | P | European Commission Euro Area Business Climate Indicator. |
| EU Indust. Confidence (EU) | P | Respondents answer questions about their current and future expectation of industry. Weightings are given to answers based on importance. Respondents can either give positive or negative answers. |
| EU Economic Confidence (EU) | % | Monthly percentage changes of the economic sentiment indicator, which reflects the general economic activity of the EU. This indicator combines assessments and expectations stemming from business and consumer surveys, which include various components of the economy: industry, consumers, construction and retail trade. In August 2003 the base year was changed from 1995 to 2000. |
| ZEW EU Expectations (EU) | P | This indicator measures the expectations of future economic growth in the Eurozone within the next six month. It represents the difference between positive and negative responses in a survey of about 350 institutional investors and analysts. |
| EU Consumer Confidence (EU) | P | This indicator represents the arithmetic average of the balances of four questions: the financial situation of households, the general economic situation, unemployment expectations (with inverted sign) and savings, all over the next 12 month. |

Table 18. **Description of indicators** *(cont.)*

| Indicator | Unit | Description |
|---|---|---|
| IFO Business Climate (DE) | P | The Ifo Business Climate index is based on approx. 7,000 monthly survey responses of firms in manufacturing, construction, wholesale and retail. The firms can characterize their situation concerning the current business situation as "good", "satisfactory" or "poor" and their expectations for the next six month as "more favorable", "unchanged" or "more unfavorable". |
| ZEW DE Current Situation (DE) | P | Assessment of the current economic situation in Germany, conducted by the ZEW (Centre for European Economic Research). |
| ZEW DE Expectation (DE) | P | Expectation of economic growth for Germany, conducted by the ZEW (Centre for European Economic Research). |
| | | Prices and monetary policy |
| CPI (US) | % | The Consumer Price Index (CPI) represents changes in prices of all goods and services purchased for consumption by urban households, user fees, and sales and excise taxes paid by the consumer. The CPI represents the expenditures of about 80% of the total U.S. population. |
| PPI (US) | % | Producer Price Index (PPI) measure average changes in prices received by domestic producers of commodities in all stages of processing, imports are not included. Each month approximately 100,000 prices are collected from 30,000 participating establishments. |
| ISM Prices Paid (US) | % | The ISM index includes prices paid for all purchases including import purchases and purchases of food and energy excluding crude oil. Series is transformed to monthly growth rates. |
| Import Price Index (US) | % | Base year 2000 = 100. Monthly % changes. |
| Federal Funds Rate (US) | % | Changes in Federal Funds Rates. Usually members of the Federal Open Market Committee determine the federal funds target rate about eight times a year. |
| EU CPI (EU) | % | Harmonized Consumer Price Index; Base year 2005 = 100. The Eurozone is treated as a separate entity by Eurostat. The Eurozone consists of 11 member states up until 31 December 2000, then 12 members as of January 1st 2001 when Greece joined. |
| EU PPI (EU) | % | Producer Price Index (PPI) for the total industry: monthly % changes, seasonally adjusted. |
| ECB Announ. Interest Rates (EU) | % | Changes in the announcements of the base borrowing rate. |
| EU M3 (EU) | % | ECB M3 annual growth rate, seasonally adjusted. |
| EU M3 3mth avg (EU) | % | M3 money supply 3 month moving average of the annual rate. |
| DE CPI (DE) | % | German Consumer Price Index (CPI), base year 2005 = 100. |
| DE PPI (DE) | % | German Producer Price Index (PPI) |
| | | Balances |
| Gov't Budget Balance (US) | $B | This statement summarizes the financial activities of the Federal Government and off-budget federal entities conducted in accordance with the budget of the U.S. Government. Major sources include accounting data reported by federal entities, disbursing officers, and Federal Reserve banks. |
| Nominal Current Account (US) | $B | US nominal account balance in Billions of USD. |
| US Trade Balance (US) | $B | Balance of payments. Total trade balance = Goods + Services. |
| DE Current Account (DE) | €B | German current account, including former East Germany. Last figures are subject to significant uncertainty owing to changes in method of data collection in foreign trade. |
| DE Trade Balance (DE) | B | German Trade Balance, not seasonally adjusted. |

*Source:* Descriptions are from Bloomberg. B = Billion, K = Thousand, P = Points, R = Rate.

### *Notes*

1. For an overview of evaluation methods for forecasts see Stekler and Petrei (2003).
2. Although data can be revised numerous times, the respective data set only contains the first and the last revisions that were published before December 2010.
3. The description of all indicators, their sample periods, and an overview of official release times is available from the author.
4. This applies to the following indicators: *Chicago Purchasing Mgrs., ISM Manufacturing PMI, ISM Prices Paid, Philadelphia Fed Index, EU Economic Confidence, US Consumer Confidence, EU Business Climate, EU Ind. Confidence, ZEW EU Expectations, EU Consumer Confidence, IFO Business Climate, ZEW DE Current Situation, ZEW DE Expectation, ISM Prices Paid, Initial Jobless Claims, Building Permits, Housing Starts,* and *New Home Sales* are transformed into growth rates from the previous period. *Initial Jobless Claims, DE and EU Unemployment Rates, Federal Funds Rate, ECB Interest Rates, Gov't Budget Balance, Nominal Current Account, US Trade Balance, DE Current Account,* and *DE Trade Balance* are converted into changes from the previous period.

5. Based on the DAX, the implied volatility of the German equity market is measured by VDAX-NEW. The Chicago Board Options Exchange Volatility Index (VIX) measures the implied volatility of S&P 500 index options, and VSTOXX assesses the implied volatility of the EuroStoxx50.
6. The terms institutions and economists are subsequently used interchangeably in this study.
7. A revision is defined as the difference between two releases: $R^{AS} \equiv A - S$ and $R^{AF} \equiv A - F$.
8. All regressions were also run with average expectations, however there is hardly any difference in the results (results are available upon request).
9. The latest-available value reflects the value available at the time when the data was collected from Bloomberg (March, 2011).
10. Please note that final values equal initial announcements for those indicators that are not subject to revisions. Therefore, forecast errors regarding initial announcements equal forecast errors regarding second releases and final values, respectively.
11. For GDP, advanced values (A) are released first, then a second release (S) follows; "final" figures (F) are announced in the third release. All three GDP releases (A, S, F) refer to the same reporting period (in Germany only two releases are announced: A and F). Apart from the analysis regarding revisions and forecast errors, the three GDP announcements (A, S, F) are regarded as independent series.
12. Please note that subsequently the analysis will not consider first revisions, as they seem less relevant to decision makers.
13. This holds especially when the unconditional mean of revisions is not equal to zero (Aruoba, 2008).
14. The ratio is bounded below by zero, but can exceed unity if the final revision and the initial announcement are negatively correlated (Aruoba, 2008).
15. Unbiasedness is a necessary condition for partial rationality, which means that information is used efficiently (Brown and Maital, 1981).
16. In general, due to the small number of observations all results for GDP announcements need to be interpreted with caution.
17. Please note that for indicators which are never revised, estimation results do not differ in the two regressions.
18. Implied volatility is measured by the respective volatility index, as described in Section 2.
19. The threshold is 1.65 standard deviations above the mean, which corresponds to the 5% one-tailed significance level. Each month is treated as an independent observation. Calculation is based on the period 2002-10.
20. Indicators for which the reporting period coincides with the release period are not considered in this specification due to collinearity.
21. A negative coefficient implies reduced disagreement, and vice versa.
22. Results for the estimation with dummy variables regarding the economic situation at the time of the release are available upon request.

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*Report*

# A comparison of economic indicator analysis and Markov switching methods concerning the cycle phase dynamics

*by*
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*This paper compares the dating of growth rate cycles obtained from a Markov switching approach with the reference chronologies based on Economic Indicator Analysis (EIA) given by the Economic Cycle Research Institute (ECRI), focusing on a set of developed and emerging economies. The developed countries include US, UK, Germany and Japan, which are compared with an emerging economy, India. Using a univariate Markov regime switching model we characterise growth rate cycle phenomena for these countries by identifying turning points and distinct economic regimes, employing data on the growth rate of the coincident index given by ECRI.*

*Keywords: Economic Indicator Analysis, Growth rate cycles, Markov switching models, business cycle phases*

*JEL Classification: C22, E32*

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We thank the Economic Cycle Research Institute, New York for providing us with the data on the coincident indices and their growth rates used in this paper.

## 1. Introduction

The issue of identification, dating and characterisation of cyclical fluctuations for describing the cycle has been a core concern in business cycle research. Burns and Mitchell (1946) suggested that a comprehensive analysis of the business cycle should consider durations, amplitudes and shape of the cycle and its phases. The study of these specific features of a cycle needs identification of a set of turning points that define periods of recession and expansion (Krolzig and Toro, 2005). The analysis of durations, amplitudes, volatility and persistence, and other features of the cycle across phases has been essentially based on a preliminary dating exercise. A large body of literature has examined the question using various approaches. Beginning with Burns and Mitchell (1946) methodology of dating turning points and analyzing the business cycle, other methods used to identify turning points are the indicator approach (Bry and Boschan, 1971), sequential signaling procedures using leading indicators (Neftci, 1982; Zarnowitz and Moore, 1983), Stock and Watson's (1989) experimental indicators and Markov switching models (Hamilton, 1989).

Since Hamilton's (1989) analysis of the US business cycles using the regime switching autoregressive model, non-linear parametric methods have become a dominant approach for dating and classifying business cycles.[1] In this paper we compare the dating chronology obtained from the Markov specification with that given by Economic Cycle Research Institute (ECRI). We focus on growth rate cycles, characterised by growth rates of the coincident index of economic activity given by ECRI, which is a composite of variables that represent current economic activity. This study covers five countries picked from three regional groups, the United States (US), United Kingdom (UK), Germany, Japan and India over the period 1974 to 2010. The US (from Americas) has been taken being the largest economy,[2] UK is the oldest industrial economy, Germany (both from Europe group) represents the largest economy in the European Union; and Japan (from Asia Pacific) is the largest Asian industrial developed country. These four countries, taken together as developed are compared with India, which represents an emerging developing economy.

The estimation results based on the Markov switching model identify three regimes as best characterising the growth rate cycles, in contrast with the conventional notion which consists of a two phase representation (an expansion and a recession in case of a business cycle; and a slowdown and a pickup in case of a growth rate cycle). The three regimes obtained are a negative growth regime, a high growth phase and a moderate growth phase. The turning point dates of the negative growth regime from the Markov model have close correspondence with the business cycle reference chronology given by ECRI. We further show that growth slowdowns in the two phase representation given by ECRI can be attributed to the three regimes obtained from the Markov approach.

The paper is divided into five sections. Section 2 discusses classical and growth rate cycles using economic indicator analysis. Section 3 gives briefly the estimation procedure,

the Markov regime switching model and the dating rule based on the probabilities obtained. Data used in the paper is also described in this section. Section 4 describes the estimation results in details, and Section 5 concludes.

## 2. Economic indicator analysis: Classical and growth rate cycles

To gain insight into the cyclical process of growth, it is important to understand the phases of business cycles and growth rate cycles that characterise it. One of the earliest and empirically the most accepted definition of the business cycle given by Burns and Mitchell (1946) states that

> "Business cycles … consist(s) of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle…"

A measure of "aggregate economic activity", thus, needs to be larger than that conveyed by a summary measure like the GDP alone (Dua and Banerji, 1999; Layton and Banerji, 2001). Such a broad measure recognises that the business cycle is a consensus of cycles in many activities, which have a tendency to peak and trough around the same time. This is captured by a comprehensive measure, the coincident index, which comprises various coincident indicators that represent current economic activity such as output, income, employment and sales.[3]

A business cycle measures ups and downs in economic activity, with absolute levels of coincident indicators entering the coincident index. Growth rate cycles, on the other hand, are cyclical upswings and downswings in the growth rate of economic activity, measured by the growth rate of the coincident index. Cyclical turns in this growth rate define the growth rate cycle.

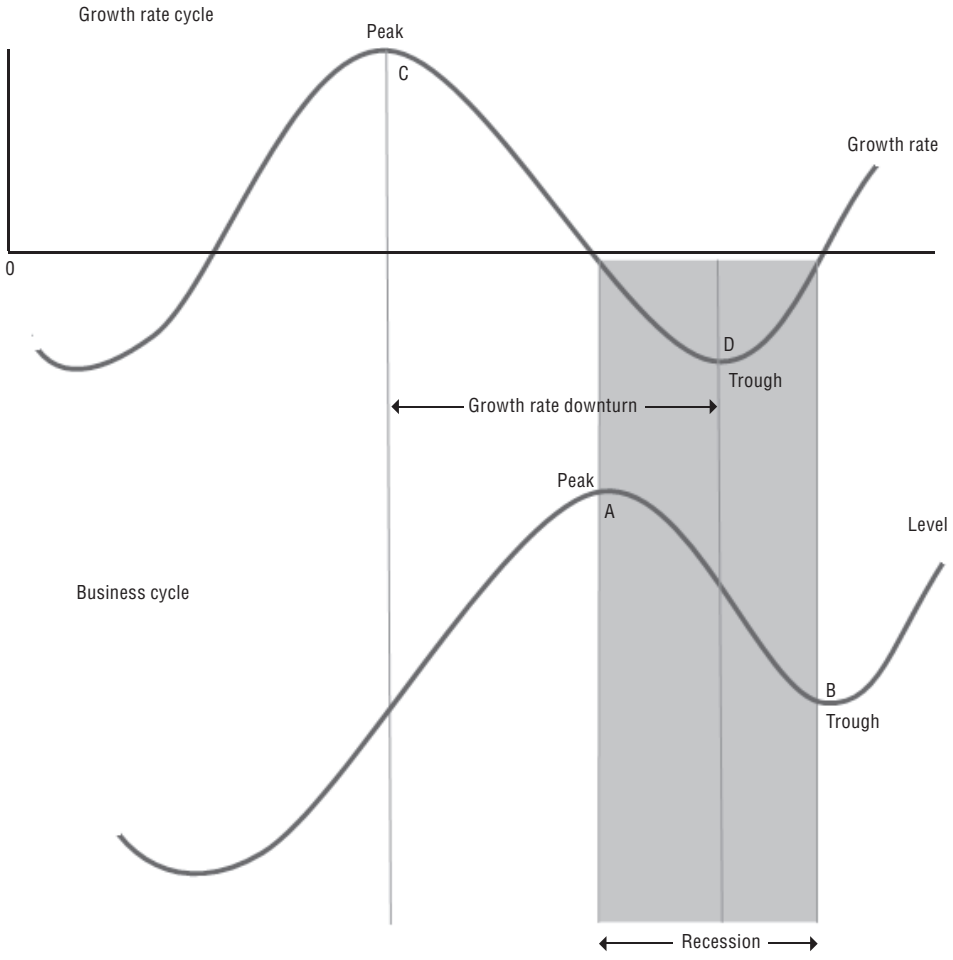
The reference chronology method (based on the Economic Indicator Analysis) of dating cycles defines peaks and troughs in the cycle. A movement from a peak to a trough is said to constitute a contraction while that from a trough to a peak an expansion. The level of the coincident index identifies peaks and troughs in the business cycle giving the dating of recessions[4] and expansions.

The growth rate of the coincident index, on the other hand, gives slowdowns and pickups in the economy. A slowdown, a milder counterpart of a recession, is a downshift in the pace of growth in economic activity. Economic slowdowns begin with reduced but still positive growth rates, which may eventually develop into recessions.

The relationship between the business cycle and the growth rate cycle is depicted in Figure 1. Since the growth rate is the first derivative of the level of the coincident index (measuring the business cycle), the relationship between the two can be inferred in terms of slopes. The maximum and minimum of the coincident index (business cycle) are, therefore, the points where the growth rates are zeroes. Importantly, when the level of the coincident index falls, it is equivalent to the growth rate being negative. Thus, when the growth rate is negative, there is a business cycle recession.

Figure 1 shows that the peak of the growth rate cycle is expected to precede that of the business cycle as also the trough. So long as the growth rate is positive, even if declining, it will count for an expansion in the business cycle but a slowdown in the growth rate cycle. Thus, a growth rate slowdown (depicted as CD) would comprise of a part of the business cycle expansion (CA), and a part of business cycle recession (AD).

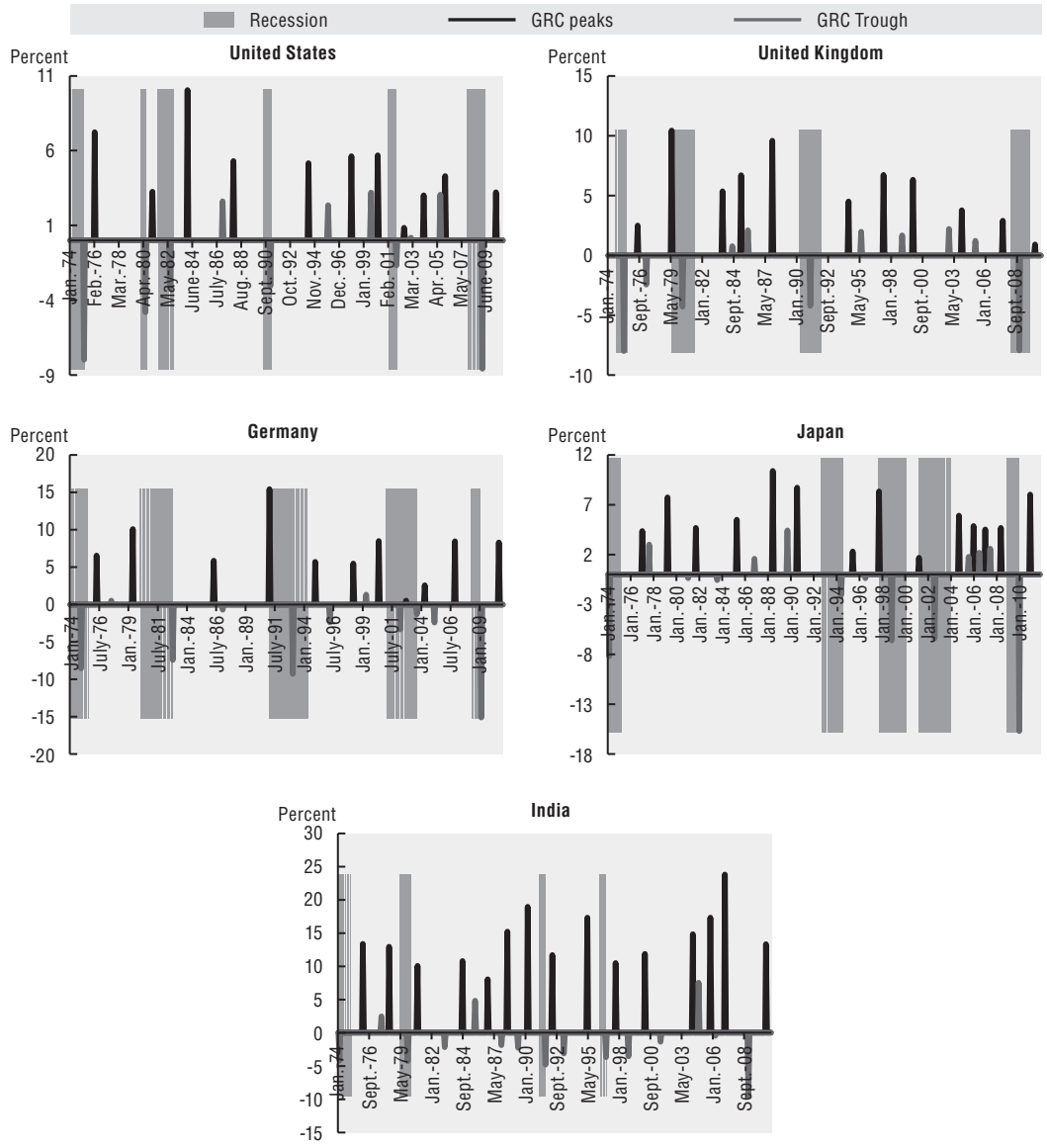
Figure 1. **A graphical depiction of the relationship between the growth rate cycle and business cycle phases**




In Figure 2 the shaded regions show periods of recessions for all the countries of analysis given by ECRI reference chronology,[5] while the peaks and troughs correspond to the underlying growth rate cycle. What can be observed is that the duration of an expansion in a business cycle (unshaded area lying in between two shaded regions) is dotted with episodes of ups and downs in the growth rate cycle. The duration of the growth rate cycle slowdown, on the other hand, consists of durations of positive growth slowdowns, as well as, in some instances, recessions into which the slowdown phase may sometimes merge. Thus, every episode of a business cycle recession has a corresponding growth slowdown, but every slowdown may not have a corresponding business cycle recession.[6]

It is with reference to these relationships across phases that we set the backdrop for a comparative analysis of the two approaches – reference chronology from EIA and the regimes identified by the Markov switching approach. The methodology we follow is discussed in the following section.

Figure 2. **Periods of recessions as indicated by ECRI reference chronology and the underlying growth rate cycle**




*Notes:* The shaded bands depict the ECRI recession periods, inferred from the business cycle peak and trough dates. The growth rate cycle (GRC) peaks and troughs are superimposed to show that instances of growth rate ups and downs lying between two recessions are more frequent. We can also see that the peak of the growth rate cycle precedes that of the business cycle as also the trough.

## 3. Methodology

Markov switching autoregressive time series models are commonly used for measuring macroeconomic fluctuations, where the stochastic process generating output growth has distinct states or regimes (e.g. contractions and expansions).

### *3.1. A Markov regime switching model*

Hamilton (1989) modelled contractions and expansions as switching regimes of the stochastic process generating output growth and considered a univariate two-state Markov-switching model in the mean with a lag polynomial of order 4 as:

$\Delta y_t - \mu(s_t) = \sum_{j=1}^{4} \alpha_j(\Delta y_{t-j} - \mu(s_{t-j})) + \varepsilon_t$ where $\varepsilon_t \sim N(0, \sigma^2)$ and $s_t = 1,2$. The regimes are associated with different conditional distributions of the growth rate of real GNP. The mean is positive in the expansion regime and negative in the contraction regime. A number of extensions and refinements have subsequently been worked on, one of which is to allow for more than two states (M > 2).

The general idea behind this class of regime switching models is that the parameters of an autoregressive model depend upon a stochastic, unobservable regime variable $s_t \in \{1,.....,M\}$. The stochastic process generating the unobservable regimes is an ergodic Markov chain defined by the transition probabilities:

$$p_{ij} = \Pr(S_t = i \mid S_{t-1} = j), \quad \sum_{i=1}^{M} p_{ij} = 1 \; \forall i, j \in \{1,.....,M\}$$

In situations where M = 3, i.e. a third regime is statistically identified for the growth process, we may classify the regimes as "negative growth" recessionary regime, a "low growth" and a "high growth" regime.

### *3.2. Specification tests*

We use specification tests for confirming that a series follows a non-linear structure, using the Hinich (1989) bispectral non-linearity (Table 1) and Tsay (1996) non-linearity tests (Table 2) and follow Krolzig (1997) for choosing the optimum MS(M)-AR(p) specification in each case on the basis of AIC, SBC and the HQ criteria.

Table 1. **Hinich bispectrum test for linearity**

| Variable | Test statistic | p-value | Inference |
|---|---|---|---|
| US | 17.90 | 0.000 | Non-linear |
| UK | 2.42 | 0.008 | Non-linear |
| Germany | 6.99 | 0.000 | Non-linear |
| Japan | 4.06 | 0.000 | Non-linear |
| India | 21.57 | 0.000 | Non-linear |

Table 2. **TsayNLTest (Tsay Ori-F test) for neglected non-linearities in an autoregression**

| Variable | Test statistic | p-value | Inference |
|---|---|---|---|
| US | 5.025 | 0.000 | Non-linear |
| UK | 3.590 | 0.000 | Non-linear |
| Germany | 2.367 | 0.029 | Non-linear |
| Japan | 6.766 | 0.000 | Non-linear |
| India | 5.784 | 0.017 | Non-linear |

The quadratic probability score (QPS) originally suggested by Diebold and Rudebusch (1990) was also taken into account for the choice of the final model. An important criterion in determining the preferred model for the coincident index growth rate is the degree of closeness between the model generated regime probabilities and the "true" regime probabilities as determined by the NBER chronology (Layton and Smith, 2000). In evaluating a model for the coincident index growth rate we should look at the consistency of the

implied regime probabilities with the official business cycle chronology for countries. To evaluate this, the quadratic probability score is defined as

$QPS = \frac{1}{T}\sum_{t=1}^{T}(P_t - D_t)^2$ where $P_t$ denotes the model derived probability of a contractionary phase and $D_t$ is a binary variable taking the value 1 during a contractionary phase and 0 otherwise as defined by the business cycle phase chronology. The closer these values are to zero, the more consistent are the model generated regime probabilities with the official business cycle chronology.

To further capture the quality of regime classification, we use a summary point statistic proposed by Ang and Bekaert (2002). An ideal regime switching model with sharp regime classification should have $p_t$ (smooth ex-post regime probability) close to 1 or 0; in inferior models, $p_t$ may be close to a half. To measure the quality of regime classification, the regime classification measure (RCM), is defined as

$RCM(K) = 100K^2 \frac{1}{T}\sum_{t=1}^{T}(\prod_{i=1}^{K} p_{i,t})$ for K regimes, where $p_{i,t} = p(s_t = i \mid \tau_T)$

Good regime classification is associated with low RCM statistic values: A value of 0 means perfect regime classification and a value of 100 implies that no information about the regimes is revealed.

### *3.3. Dating rule*

The ECRI/NBER dating scheme is broadly based on the Bry and Boschan (1971) algorithm for dating turning points, which places some duration constraints in searching for peak and trough dates such that no cycle (measured peak to peak or trough to trough) can be less than 15 months in duration and no phase (expansion or contraction) can be less than five months in duration.

The rule for dating the business cycle using the Markov switching approach uses the estimated regime probabilities to determine the timing of phase shifts. It is based on whether the economy is more likely than not to stay in one of the possible regimes e.g. $S_t = 1$ if $Pr(S_t = 1) \geq \alpha$ and the growth rate is classified as having come from regime 1. Following Layton (1996), we set $\alpha = 0.5$, as also used by Hamilton (1989). This means that the growth rate would have likely come from regime 1 with a likelihood of at least 50%. In addition, a minimum duration requirement is essential in eliminating spurious cycles in monthly series. We require that each phase has minimum duration of five months. The dating rule used is in conformity with the duration requirements of the Bry and Boschan (1971) algorithm.

If a series is in an expansionary phase, a contractionary phase shift is identified as having occurred if a run of at least five of these probabilities in a row exceeded 0.5. An expansionary phase shift[7] is identified as having occurred if a run of at least five of these probabilities in a row are less than 0.5.

For the Markov switching model, the actual date of the peak (trough) is selected as the month preceding the beginning of the run of probabilities greater than 0.5 (less than 0.5). The only exception to this is where the identified month is followed by 1 or more months with zero growth rates. In such cases, these months are considered as belonging to the current expansion (contraction). This approach, Layton (1996) proposes, is analogous to the NBER convention that when the local highest (lowest) value is repeated, the peak (trough) date is selected as the latest occurring.

### *3.4. Data*

ECRI constructs the coincident index of economic activity and their growth rates for 22 major countries, five regional groups and the world economy. From the three major regions, North America, Europe and Asia Pacific, we analyse US, UK, Germany, India and Japan. The set of four countries (US, UK, Germany and Japan), taken together as developed are compared with India, an emerging developing economy. The time period of analysis covers 1974.01 to 2010.12.

We use the growth rate of the coincident index of economic activity for the said countries.

## 4. Results

We lay out the results in two sub-sections. Based on the Markov model parameters, the first sub-section is an overview of the results, presenting the common cyclical features for all countries, followed by a detailed country wise discussion in the next sub-section.

### *4.1. Overview of results*

The model selection procedure indicates that a Markov switching model with three regimes and no autoregressive structure is chosen for all the countries. The parameters of the chosen Markov switching specification are reported in Table 3. This is in line with

Table 3. **MS(M)-AR(p) Regime-switching estimates**

| | US | UK | Germany | Japan | India |
|---|---|---|---|---|---|
| $\mu_1$ | -2.606<br>(-6.15) | -3.015<br>(-25.65) | -3.384<br>(-10.41) | -3.40<br>(-9.27) | -0.455<br>(-2.29) |
| $\mu_2$ | 2.320<br>(2.88) | 1.552<br>(16.22) | 3.089<br>(3.09) | 2.46<br>(21.91) | 5.874<br>(27.54) |
| $\mu_3$ | 4.563<br>(11.25) | 4.541<br>(42.98) | 7.939<br>(7.94) | 6.03<br>(8.84) | 11.295<br>(48.38) |
| $p_{11}$ | 0.888<br>(16.23) | 0.904<br>(25.80) | 0.883<br>(126.7) | 0.892<br>(61.72) | 0.886<br>(56.58) |
| $p_{12}$ | 0.064<br>(2.43) | 0.082<br>(2.18) | 0.018<br>(6.71) | 0.086<br>(4.47) | 0.068<br>(8.27) |
| $p_{21}$ | 0.104<br>(1.93) | 0.096<br>(5.58) | 0.112<br>(1.99) | 0.108<br>(18.10) | 0.11<br>(8.05) |
| $p_{22}$ | 0.916<br>(30.81) | 0.875<br>(36.55) | 0.973<br>(96.94) | 0.884<br>(47.24) | 0.847<br>(30.71) |
| $p_{13}$ | 0.000<br>(0.00) | 0.000<br>(-0.01) | 0.033<br>(3.58) | 0.063<br>(0.921) | 0.000<br>(-0.002) |
| $p_{23}$ | 0.016<br>(2.02) | 0.081<br>(2.51) | 0.000<br>(-0.002) | 0.093<br>(1.38) | 0.129<br>(4.46) |
| $p_{31}$ | 0.008<br>(0.11) | 0.000<br>(0.00) | 0.005<br>(0.21) | 0.000<br>(0.00) | 0.004<br>(0.14) |
| $p_{32}$ | 0.020<br>(0.42) | 0.043<br>(1.40) | 0.009<br>(0.47) | 0.030<br>(1.14) | 0.085<br>(2.86) |
| $p_{33}$ | 0.984<br>(61.89) | 0.919<br>(28.63) | 0.967<br>(75.55) | 0.844<br>(8.05) | 0.871<br>(31.00) |
| $(1-p_{11})^{-1}$ | 8.93 | 10.42 | 8.55 | 9.26 | 8.77 |
| $(1-p_{22})^{-1}$ | 11.91 | 8.00 | 37.04 | 8.62 | 6.54 |
| $(1-p_{33})^{-1}$ | 62.50 | 12.35 | 30.30 | 6.40 | 7.75 |
| $\sigma_1^2$ | 10.018 | 2.151 | 19.29 | 14.41 | 7.21 |
| $\sigma_2^2$ | | | | 2.75 | |
| $\sigma_3^2$ | | | | 12.17 | |
| QPS | 0.065 | 0.091 | 0.096 | 0.068 | 0.457 |

*Note:* t-statistics are reported in parantheses.

Layton and Smith (2000), who also obtain an MSM(3)-AR(0) specification as best fitting the data using the ECRI coincident index growth rates for the US economy (over the period 1950:2 to 1994:11). When the simple Markov characteristic without an AR structure provides the most appropriate dynamic representation for identifying turning points, the addition of an AR structure, by adding a further degree of persistence to the process assumed to be the DGP, may produce higher estimated probabilities of the turning point occurring with a delay. This is because it works into increasing the estimated probability that the series will continue to be in the prevailing regime (Layton and Smith, 2000).

The Ang and Bakeart (2002) regime classification measures reported in Table 4 also show that the chosen Markov regime switching model produces a clean regime specification. For all the countries, this is less than one, and for India it takes the value 0.978, which is well below the accepted benchmark of 50 for the RCM.[8]

Table 4. **Ang and Bekaert (2002) Regime Classification Measures**

| US | UK | Germany | Japan | India |
|---|---|---|---|---|
| 0.382 | 0.001 | 0.115 | 0.149 | 0.978 |

In a three-regime model of the cycle the process switches between three states: "growth recession" (mean < 0), "low growth" and "high growth", where both the regimes have a positive mean rate of growth, but the high growth regime is characterised by a conditional mean larger than that in the low growth regime. For matters of inference, as brought out in the discussion in Section 2, the negative growth regime is taken as the recessionary regime.

While the Markov regime switching approach gives a three state characterisation of the growth rate cycles, the conventional notion of the business cycle and the growth rate cycle consists of a two phase characterisation (of an expansion and a contraction in the case of a business cycle; a pickup and a slowdown in the case of a growth rate cycle). We bring out how the three regime framework can be seen to furnish additional details in the cycle dynamics within the traditional two phase analysis. The two phase representation of the growth rate cycle and the business cycle given in Figure 1 is already described in Section 2.

Figure 3 shows the distribution of the three regimes obtained from the Markov switching approach[9] over time for all countries. We observe that for all the countries there are distinct periods of recessions, low and high growth. The recession periods are invariably preceded by the low growth regime, except the 7/91-12/93 recession episode for the German economy. A second exception is for the Indian economy, wherein the recessions in 5/96-4/97 and 12/08-1/10 are preceded by high growth regimes.[10] This indicates that, in general, the process of slipping into recessions is a gradual process, moving from low growth into negative growth. Further, we note that some recessions are followed by periods of high growth (1973/75 and 1981/82 episodes) for the US economy, lending weight to Sichel's (1994) proposition[11] that contractions are followed by high growth expansions and then by periods of normal growth. These findings are again in line with the results obtained by Layton and Smith (2000). This pattern, however, does not seem to hold for the other four countries studied, where recessions are followed by low growth regimes.

For all the countries, the expansionary regimes are much longer in duration than the recessionary regimes. While the average duration of recessions does not vary much over the set of five countries, the high growth regimes are longer for US, UK and India. Germany and Japan spend more time in the low growth regimes.

Figure 3. **Distribution of regimes from the Markov regime switching model**

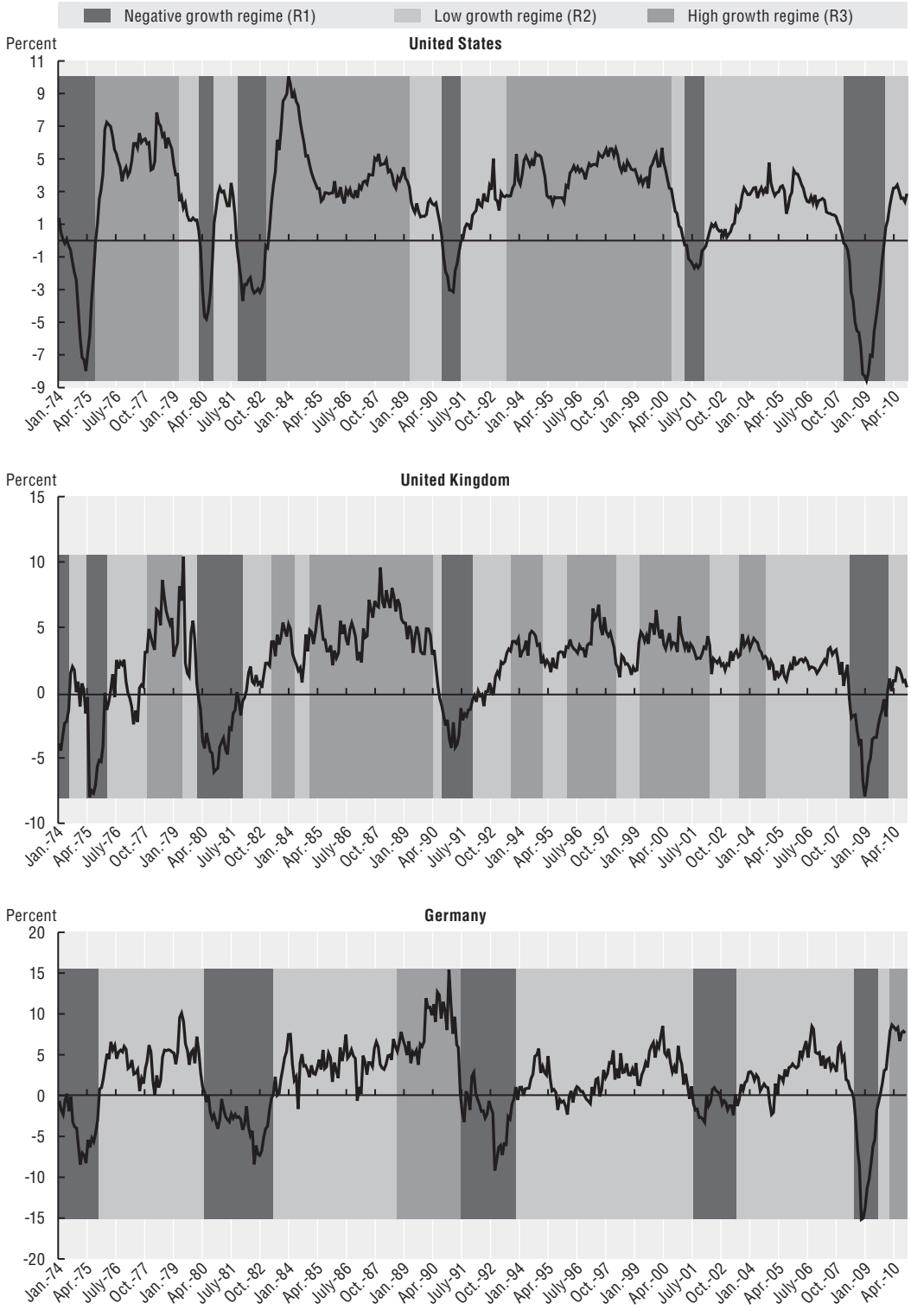
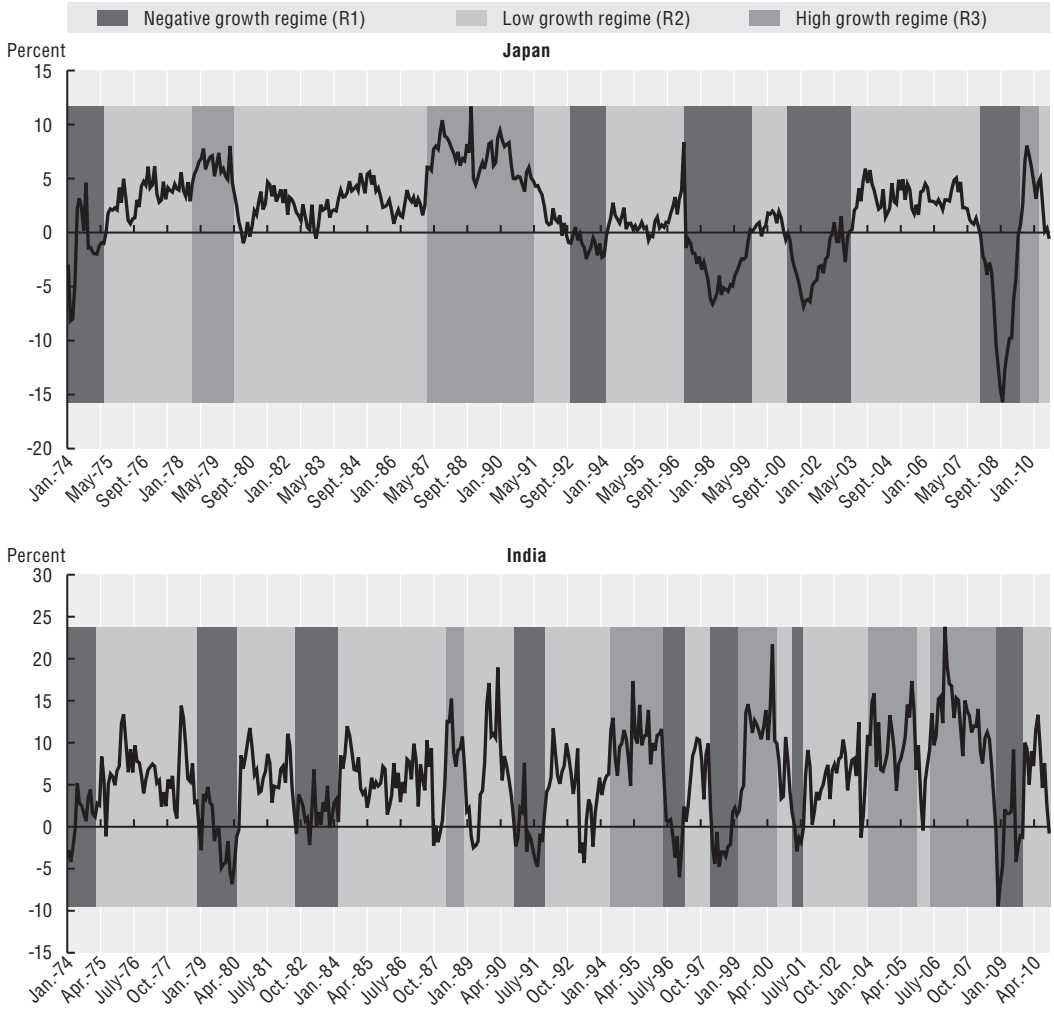


Figure 3. **Distribution of regimes from the Markov regime switching model** *(cont.)*




For the US economy, it is evident that for much of the 1990s, 1993-2000 is a period of high growth, with the economy sliding into the low growth regime before the 2001 recession. The period after the end of this recession in 2002 is marked by the presence of the low growth regime. The UK economy has alternating periods of high and low growth regimes throughout the period from 1970s to 2010. None of the recessions are followed by high growth regimes. The economy went through a long period of sustained high growth from 1984 to 1990. Although between the two recessions in 1994 and 2008, there are periods of low and high growth, the economy settles into the low growth regime in 2004, before finally going into a recessionary phase in 2008.

The Japanese cyclical dynamics make for an interesting case. Unlike most other developed economies, which spent a substantial part of the 1990s in the high growth regime, Japan spent all of the 1990s in the low growth regime, corresponding with its long decade of stagnation. The period after the 2001 recession too comprises of the low growth regime.

With reference to Germany's model parameters and Figure 3, it is worth noting that while the economy witnessed long periods in the low growth regime over the entire period of analysis, the mean growth rate in this regime stands much higher than that in other

developed economies. Therefore, what is inferred to be the low growth regime in the German economy might, in fact, be comparable to the high growth regimes in other developed countries.

The three regimes for the Indian economy show that the high growth regime, with a notable high mean growth rate has existed very sparsely overtime, with the duration not exceeding six months, except in 1994/96. Much of the expansionary period is the moderate growth regime. ECRI has identified four recessions for the Indian economy over the period 1974 to 2010, the Markov model identifies all four, but additionally identifies four more episodes. Two recessions identified by the Markov method (1996 and 2008) are preceded immediately by the high growth regime. This makes for an interesting observation, since the Indian economy, post liberalisation in 1991 seems to be abruptly jumping into short lived recessions, while the earlier period saw a more moderate growth preceding the recessions.

Since the entire duration of the cycle is made up of different regimes, it is possible to construct the duration of the growth rate cycle slowdown as being attributable to the three underlying Markov regimes prevailing at that time, the recessionary regime (R1),[12] the low growth regime (R2) and the high growth regime (R3). Coming to the details of the growth rate cycle, we find that within the duration of the growth rate cycle, there are intermittent regime shifts, so that the duration of a slowdown, for instance, may be seen to consist of contributions from the three regimes. Most slowdowns have a significant duration in the low growth regime. For those slowdowns that lead to recessions, it is mostly the low growth regime that gives way to the negative growth regime, with exceptions for a few episodes in Germany and India.

Figure 5 shows the breakup of the period of ECRI growth slowdowns into underlying regimes. This corresponds to the country-wise results given in Tables 6 to 10. While Figure 3 pertains to the distribution of regimes over the entire duration of the cycle in terms of the three regimes, Figure 5 shows how the ECRI slowdowns may be broken down by different regimes.

### *4.2. Country-wise results*

We now begin with the country wise discussion of our model results. Based on statistics reported in Table 3, we first describe the cycle characteristics for each country – mean growth rates across phases, persistence of regimes, their average durations and probabilities of one regime transiting into another. We then report the comparisons of the dating from Markov methodology with the ECRI reference chronology.

#### *United States*

**Cycle characterisation from Markov specification**

Statistics reported in Table 3 indicate the presence of three regimes in the growth rates, one with a negative growth rate of 2.61%, a moderate growth regime with mean growth rate of 2.32% and a high growth regime with conditional mean of 4.56, with corresponding conditional regime probabilities being 0.88, 0.92 and 0.98 respectively.

The average expected duration of being in regime 1 (recession) is estimated to be 8.9 months while that in regime 2 (moderate growth) is approximately 11.9 months while the high growth expansionary regime lasts for about 62.5 months. We observe that the persistence of regimes (given by the probability that the process continues to be in the same regime in the current period as the last period) is the highest for the high growth

Table 5. **ECRI Business Cycle Chronology and model derived turning point dates**

| | ECRI BCs | | Markov Regime 1 | |
|---|---|---|---|---|
| | Peak | Trough | Peak | Trough |
| US | | | | |
| | 11/73 | 3/75 | 4/74 | 9/75 |
| | 1/80 | 7/80 | 2/80 | 10/80 |
| | 7/81 | 11/82 | 10/81 | 2/83 |
| | 7/90 | 3/91 | 9/90 | 8/91 |
| | 3/01 | 11/01 | 4/01 | 3/02 |
| | 12/07 | 6/09 | 3/08 | 1/10 |
| UK | | | | |
| | | | | 7/74 |
| | 9/74 | 8/75 | 3/75 | 3/76 |
| | 6/79 | 5/81 | 3/80 | 1/82 |
| | 5/90 | 3/92 | 5/90 | 1/92 |
| | 5/08 | 1/10 | 7/08 | 2/10 |
| | 8/10 | 2/12 | | |
| Germany | | | | |
| | 8/73 | 7/75 | | 10/75 |
| | 1/80 | 10/82 | 5/80 | 5/83 |
| | 1/91 | 4/94 | 7/91 | 12/93 |
| | 1/01 | 8/03 | 9/01 | 7/03 |
| | 4/08 | 1/09 | 9/08 | 11/09 |
| Japan | | | | |
| | 11/73 | 2/75 | | 6/75 |
| | 4/92 | 2/94 | 10/92 | 5/94 |
| | 3/97 | 7/99 | 3/97 | 10/99 |
| | 8/00 | 4/03 | 1/01 | 6/03 |
| | 2/08 | 3/09 | 5/08 | 10/09 |
| | 8/10 | 4/11 | | |
| India | | | | |
| | 11/73 | 2/75 | | 3/75 |
| | 4/79 | 3/80 | 11/78 | 6/80 |
| | | | 7/82* | 4/84* |
| | 3/91 | 9/91 | 10/90 | 1/92 |
| | 5/96 | 11/96 | 5/96 | 4/97 |
| | | | 3/98* | 5/99* |
| | | | 4/01* | 10/01* |
| | | | 12/08* | 1/10* |

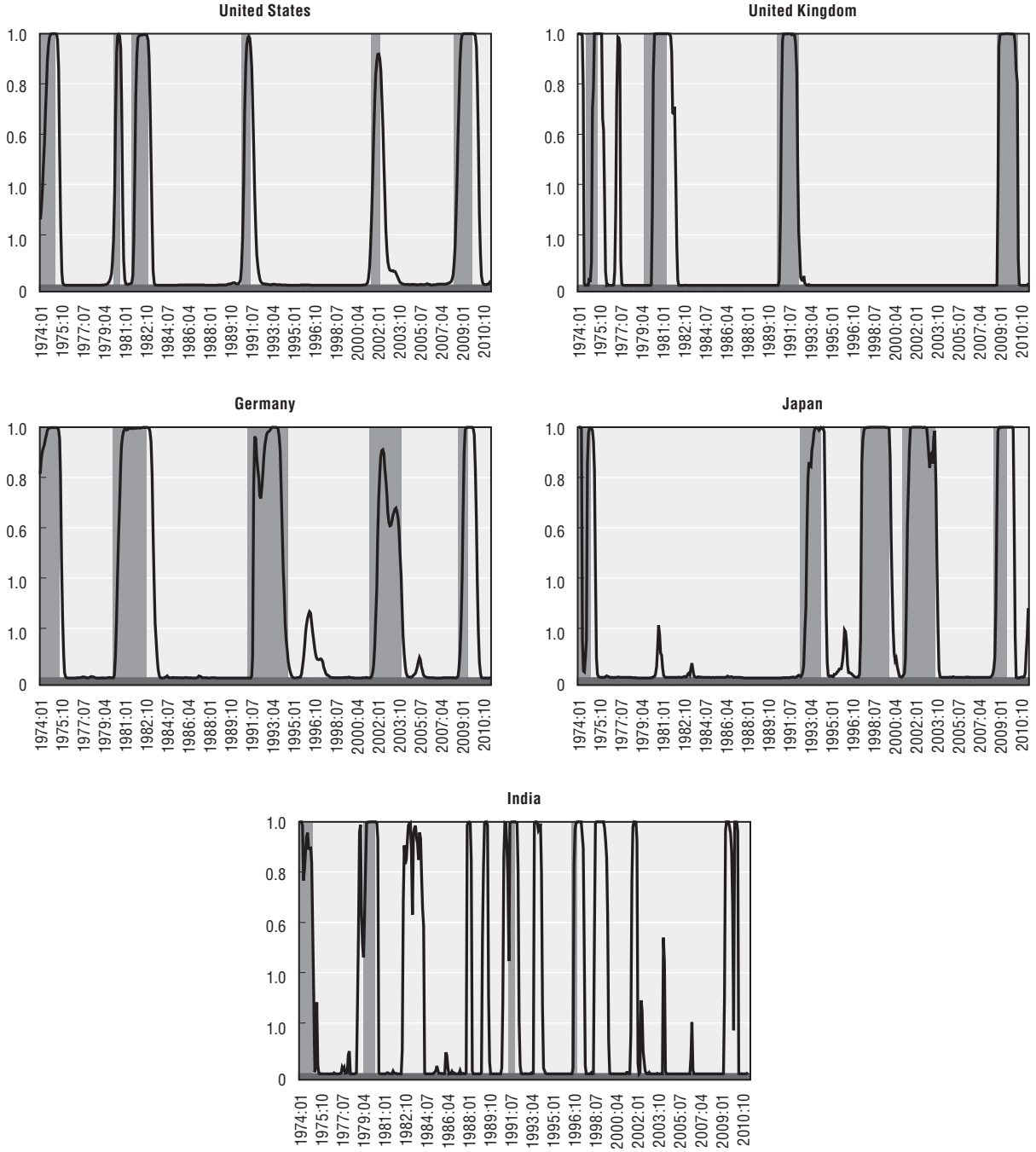
* Extra cycles reported by the Markov regime switching method.

regime (regime 3). From the point estimates, it emerges that given the economy is in a recessionary phase, it is more likely to transit to the slow growth phase than the high growth phase following it ( $p_{21} > p_{31}$ ).[13]

**Dating comparisons: EIA vs Markov**

Following the dating rule discussed in Section 3, we obtain peak and trough dates for the contractionary (recession) regime. These are reported in Table 5, and placed alongside the business cycle chronologies for US given by ECRI. There is a very close correspondence between the ECRI dates and those obtained by the Markov method. Figure 4 shows the probability of being in regime 1, the negative growth regime. The shaded region corresponds to ECRI contractions, inferred from their reference chronologies. We observe that the Markov regime switching model is able to capture all the periods of contractions.

Figure 4. **Probabilities of being in the recession regime**




*Note:* Shaded regions are periods of business cycle recessions given by ECRI.

Figure 3 shows the distribution of regimes over time. What emerges for the US economy is that the 1973/75 recession, and the 1981/82 recession episodes are immediately followed by high growth regimes, indicating that these have been instances of high growth recoveries. However, the fact that $p_{31}$ is not significant may limit us from inferring Sichel's (1994) proposition.

Table 6 shows slowdowns in the US growth rates given by ECRI. We break down the period of a slowdown and attribute it to various regimes. Slowdowns from the period 1991 to 2001 (coinciding with the period of "the Great Moderation") have not culminated in recessions, as has happened on all other occasions of slowdowns. It may be noted that immediately preceding all recessions have been periods of low growth. The process of sliding into recessions, has been from the high growth regime to low growth regime and then into negative growth, and seems to be gradual.

Table 6. **US growth rate cycle slowdown decomposition by Markov regimes**

| ECRI slowdown dates (Peak to trough) | MS regime dates | Regime end date* | MS regimes in ECRI slowdown# | Total duration (months) |
|---|---|---|---|---|
| 1/73-3/75 | Regime 2 (-4/74) | 4/74 | 15 | 26 |
| | Regime 1 (4/74-9/75) | 3/75 | 11 | |
| 2/76-6/80 | Regime 3 (9/75-5/79) | 5/79 | 39 | |
| | Regime 2 (5/79-2/80) | 2/80 | 09 | 52 |
| | Regime 1 (2/80-10/80) | 6/80 | 04 | |
| 1/81-7/82 | Regime 2 (10/80-10/81) | 10/81 | 09 | 18 |
| | Regime 1 (10/81-2/83) | 7/82 | 09 | |
| 1/84-1/87 | Regime 3 (2/83-4/89) | 1/87 | 36 | 36 |
| 12/87-2/91 | Regime 3 (2/83-4/89) | 4/89 | 16 | |
| | Regime 2 (4/89-9/90) | 9/90 | 17 | 38 |
| | Regime 1 (9/90-8/91) | 2/91 | 05 | |
| 5/94-1/96 | Regime 3 (7/93-8/00) | 1/96 | 20 | 20 |
| 1/98-9/99 | Regime 3 (7/93-8/00) | 9/99 | 20 | 20 |
| 4/00-11/01 | Regime 3 (7/93-8/00) | 8/00 | 04 | |
| | Regime 2 (8/00-4/01) | 4/01 | 08 | 19 |
| | Regime 1 (4/01-3/02) | 11/01 | 07 | |
| 7/02-2/03 | Regime 2 (3/02-3/08) | 2/03 | 07 | 07 |
| 3/04-8/05 | Regime 2 (3/02-3/08) | 8/05 | 17 | 17 |
| 1/06-3/09 | Regime 2 (3/02-3/08) | 3/08 | 26 | |
| | Regime 1 (3/08-1/10) | 3/09 | 12 | 38 |

* Refers to the actual end date of a Markov regime, or the ECRI slowdown end date whichever is earlier within the duration of the slowdown.
# Duration is counted from the beginning date of an ECRI slowdown.
*Note:* Of the 291 months of slowdown from 1973 to 2009, regime 1 (contractionary regime) contributes 48 months, regime 2 contributes 108 months and regime 3 counts for 135 months.

### *United Kingdom*

#### Cycle characterisation from Markov specification

For the UK economy, the model parameter estimates are given in Table 3 and the corresponding plot in Figure 3. The three-regime model shows a negative growth regime (regime 1, with conditional mean -3.02), a moderate growth regime (conditional mean 1.55) and a high growth regime (regime 3, with conditional mean 4.54). The plot shows that the Markov regime 1 probability is able to capture all periods of contractions very well. The expected durations for the three regimes were calculated to be 10.4,8 and 12.4 months respectively.

The regime probabilities indicate that the persistence of regime is the highest for the high growth regime. Also, it is more likely for the UK economy to transit into the slow growth regime than into the fast growth regime given that it was in the contractionary regime 1. As for the case of the US economy, it is more likely for the UK economy to transit to the slow growth phase than the high growth phase following a contractionary phase it ( $p_{21} > p_{31}$ ).

#### Dating Comparisons: EIA vs Markov

Given the Markov parameters, the peak and trough dates for the recessionary regime (regime 1) are presented in Table 5 along with the ECRI business cycle chronology. There is close correspondence of the dates by the two methods. Table 7 looks at ECRI slowdowns in terms of how they are made up of slowdowns from different regimes. From the growth slowdown of 1988-91, the slowdowns do not slide down further into recessions until the 2007 slowdown, indicating that the moderation has lasted longer in the UK than in the US. This is depicted in Figure 3. Again, the movement into a recession seems to be a gradual process, with high growth regime leading low growth regime, which in all cases immediately precede recession episodes.

Table 7. **UK growth rate cycle slowdown by Markov regimes**

| ECRI slowdown dates (Peak to trough) | MS regime dates | Regime end date | MS regimes in ECRI slowdown | Total duration (months) |
|---|---|---|---|---|
| 1/73-5/75 | Regime 1 (-7/74) | 7/74 | 18 | |
| | Regime 2 (7/74-3/75) | 3/75 | 08 | 28 |
| | Regime 1 (3/75-3/76) | 5/75 | 02 | |
| 7/76-4/77 | Regime 2 (3/76-11/77) | 4/77 | 09 | 09 |
| 6/79-5/80 | Regime 3 (11/77-7/79) | 7/79 | 01 | |
| | Regime 2 (7/79-3/80) | 3/80 | 08 | 11 |
| | Regime 1 (3/80-1/82) | 5/80 | 02 | |
| 10/83-8/84 | Regime 3 (4/83-4/84) | 4/84 | 06 | 10 |
| | Regime 2 (4/84-10/84) | 8/84 | 04 | |
| 5/85-12/85 | Regime 3 (10/84-5/90) | 12/85 | 07 | 07 |

Table 7. **UK growth rate cycle slowdown by Markov regimes** *(cont.)*

| ECRI slowdown dates (Peak to trough) | MS regime dates | Regime end date | MS regimes in ECRI slowdown | Total duration (months) |
|---|---|---|---|---|
| 1/88-4/91 | Regime 3 (10/84-5/90) | 5/90 | 28 | 39 |
| | Regime 1 (5/90-1/92) | 4/91 | 11 | |
| 7/94-8/95 | Regime 3 (8/93-1/95) | 1/95 | 06 | 13 |
| | Regime 2 (1/95-1/96) | 8/95 | 07 | |
| 7/97-2/99 | Regime 3 (1/96-4/98) | 4/98 | 09 | 19 |
| | Regime 2 (4/98-4/99) | 2/99 | 10 | |
| 1/00-2/03 | Regime 3 (4/99-6/02) | 6/02 | 29 | 37 |
| | Regime 2 (6/02-8/03) | 2/03 | 08 | |
| 3/04-5/05 | Regime 3 (8/03-9/04) | 9/04 | 06 | 14 |
| | Regime 2 (9/04-7/08) | 5/05 | 08 | |
| 9/07-2/09 | Regime 2 (9/04-7/08) | 7/08 | 10 | 17 |
| | Regime 1 (7/08-2/10) | 2/09 | 07 | |
| 6/10- | Regime 2 (2/10-) | | | |

*Note:* Of the total 204 months of slowdown over the period, regime 1 contributes 36; regime 2 contributes 76 and 92 months from regime 3.

### *Germany*

#### Cycle characterisation from Markov specification

With reference to parametric tests for the German economy, the model selection led to a three-regime Markov switching coefficients model with no autoregressive lags. The three regimes are, a negative growth rate, contraction regime 1, with conditional mean of -3.38, a low growth regime (regime 2), with a low but positive conditional mean of 3.09 and a high growth regime (regime 3) with conditional mean 7.94.

Probability estimates show that the contractionary regime duration is around 8.55 months, the moderate growth regime around 37.04 months, while a high growth regime lasts for around 30.3 months. Given that the economy is in a contractionary phase (regime 1), the model's point estimates suggest that, like the US and the UK economies, it is more likely to switch into the "slow expansion" phase than into the "high growth recovery" phase.

#### Dating Comparison

Inferred from the Markov regime probabilities, the peak and trough dates for the negative growth regime are given in Table 5. Figure 3 shows how the regimes are captured with contractions depicted as shaded portions. Table 8 and Figure 5 shows the breakdown of the growth slowdown into sub-regimes,[14] and we can observe that it is overwhelmingly attributable to regime 1 and regime 2. Like the case of the US and UK discussed above, the period from 1993 to 2001 does not have any episode of the growth slowdown culminating

Table 8. **German growth rate cycle slowdown by Markov regimes**

| ECRI slowdown dates (Peak to trough) | MS regime dates | Regime end date | MS regimes in ECRI slowdown | Total duration (months) |
|---|---|---|---|---|
| 1/73-12/74 | Regime 1 (-10/75) | 12/74 | 23 | 23 |
| 4/76-7/77 | Regime 2 (10/75-5/80) | 7/77 | 15 | 15 |
| 5/79-10/82 | Regime 2 (10/75-5/80) | 5/80 | 12 | 41 |
| | Regime 1 (5/80-5/83) | 10/82 | 29 | |
| 4/86-1/87 | Regime 2 (5/83-10/88) | 1/87 | 09 | 09 |
| 1/91-1/93 | Regime 3 (10/88-7/91) | 7/91 | 06 | 24 |
| | Regime 1 (7/91-12/93) | 1/93 | 18 | |
| 12/94-3/96 | Regime 2 (12/93-9/01) | 3/96 | 15 | 15 |
| 3/98-4/99 | Regime 2 (12/93-9/01) | 4/99 | 13 | 13 |
| 5/00-3/02 | Regime 2 (12/93-9/01) | 9/01 | 16 | 22 |
| | Regime 1 (9/01-7/03) | 3/02 | 06 | |
| 9/02-8/03 | Regime 1 (9/01-7/03) | 7/03 | 10 | 23 |
| | Regime 2 (7/03-9/08) | 8/03 | 13 | |
| 4/04-2/05 | Regime 2 (7/03-9/08) | 2/05 | 10 | 10 |
| 11/06-2/09 | Regime 2 (7/03-9/08) | 9/08 | 22 | 36 |
| | Regime 1 (9/08-11/09) | 2/09 | 14 | |

into a recession. What is striking for the German case is that the recession 7/91-12/93 (as identified by the Markov switching method) is characterised by a direct jump from the high growth regime into a recessionary regime. This recession, the first since the German reunification in 1990, has an abrupt jump across regimes, and does not indicate a gradual phenomenon. This could be symptomatic of the macroeconomic adjustments that had to follow the reunification. It may be indicative of sudden and abrupt changes, not necessarily associated with changes in fundamentals.

### *Japan*

#### Cycle characterisation from Markov specification

The Japanese growth rate cycle fitted a three regime MSMH(3)-AR(0) specification, with a contraction regime (regime 1) having a conditional mean of -3.40, a low growth regime (regime 2) with a conditional mean of 2.46 and a high growth regime with conditional mean of 6.03. The duration estimates show that the recessionary regime lasts for about 9.3 months, while low growth regime for about 8.60 months. Figures 3 shows plot of smoothed probabilities of being in regimes 1 along with the ECRI recession periods.

The mean switching specification with heteroscedasticity indicates that the growth rate cycle is characterised by regime-dependent variance. The volatility of growth is more than

five times as great in either the recessionary phase or the fast growth expansionary phase than it is in the slow growth expansionary phase. We find that all three regimes are very persistent in Japan, and that the recessionary regime is the most volatile one, followed closely by the rapid growth regime. These results are in line with those obtained by Girardin (2005), who chooses a three regime model with heteroscedasticity for Japan and finds that that all regimes in Japan are very persistent. He, however, finds that the most volatile regime is the rapid growth regime. He also finds that growth recessions are long lasting in Japan, while rapid growth periods last still longer. Altug and Bildirici (2012) obtain a three regime specification for Japan using quarterly real GDP data over the period 1970.1 to 2009.2.

**Dating Comparison**

The model derived dating of regimes, using smoothed probabilities, are presented in Table 5 along with the ECRI business cycle dates. The dates of peaks and troughs in regime 1 fall very close to the ECRI chronology. We see that the Japanese business cycle has long-lasting growth recessions, corresponding to long periods of stagnation. The Japanese economy went through extended period of low growth and stagnation in the 1990s, with the early period interrupted temporarily by a period of "normal" growth (Krolzig, 1997, 2001). However, coinciding with the time of the financial bubble in the late 1980s, we can see the re-emergence of the rapid-growth regime for three years 1987-91.

Table 9 gives the breakup of the slowdown in terms of different regimes. We find that till the end of 1992, growth slowdowns have no contribution from the contractionary regime. Contrary to our findings for the other countries, however, we find that for the Japanese economy, it is the period of the 1990-2001 that has all episodes of growth slowdowns culminating into recessions. This fits well with our description of the Japanese economy above.

Table 9. **Japanese growth rate cycle slowdown by Markov regimes**

| ECRI slowdown dates (Peak to trough) | MS regime dates | Regime end date | MS regime in ECRI slowdown | Total duration (months) |
|---|---|---|---|---|
| 12/76-7/77 | Regime 2 (6/75-9/78) | 7/77 | 07 | 07 |
| 2/79-11/80 | Regime 3 (9/78-4/80) | 4/80 | 14 | 21 |
| | Regime 2 (4/80-7/87) | 11/80 | 07 | |
| 7/81-5/83 | Regime 2 (4/80-7/87) | 5/83 | 22 | 22 |
| 1/85-7/86 | Regime 2 (4/80-7/87) | 7/86 | 18 | 18 |
| 2/88-5/89 | Regime 3 (7/87-8/91) | 5/89 | 15 | 15 |
| 3/90-12/93 | Regime 3 (7/87-8/91) | 8/91 | 17 | |
| | Regime 2 (8/91-10/92) | 10/92 | 14 | 45 |
| | Regime 1 (10/92-5/94) | 12/93 | 14 | |
| 12/94-1/96 | Regime 2 (5/94-3/97) | 1/96 | 13 | 13 |
| 3/97-4/98 | Regime 1 (3/97-10/99) | 4/98 | 13 | 13 |

Table 9. **Japanese growth rate cycle slowdown by Markov regimes** *(cont.)*

| ECRI slowdown dates (Peak to trough) | MS regime dates | Regime end date | MS regime in ECRI slowdown | Total duration (months) |
|---|---|---|---|---|
| 8/00-12/01 | Regime 2 (10/99-1/01) | 1/01 | 05 | 16 |
| | Regime 1 (1/01-6/03) | 12/01 | 11 | |
| 1/04-11/04 | Regime 2 (6/03-5/08) | 11/04 | 10 | 10 |
| 4/05-10/05 | Regime 2 (6/03-5/08) | 10/05 | 06 | 06 |
| 4/06-9/06 | Regime 2 (6/03-5/08) | 9/06 | 05 | 05 |
| 8/07-3/09 | Regime 2 (6/03-5/08) | 5/08 | 09 | 19 |
| | Regime 1 (5/08-10/09) | 3/09 | 10 | |
| 2/10- | Regime 3 (10/09-6/10) | | | |

### *India*

#### Cycle characterisation from Markov specification

From the model selection criteria, a three-regime MSM(3)-AR(0) model is chosen for the Indian data. The three regimes are a negative growth (regime 1) with conditional mean of -0.46%, a moderate growth regime (regime 2) with mean growth rate of 5.87% and a high growth regime, with conditional mean 11.30%. It may, however, be noted that the high growth regime has not existed on a sustained basis for more than six months, except 1994/96, with the frequency of being in this regime too being low. Looking at Figure 2, we see that there have been only four instances of recessions according to the ECRI dating between the period 1974 and 2010. They are all very short lived compared to episodes in other economies, surviving on an average, less than a year.

Figure 4 shows the plot of the probability of being in the recessionary regime. There are four additional recessions that are picked up by the Markov exercise, not reported by ECRI.

#### Dating Comparisons

Table 5 shows the model derived regime dates along with the ECRI business cycle dates. Figure 5 shows the distribution of these regimes overtime. We observe that the period till 1994 is predominantly comprised of the moderate growth regime, with the high growth regime prevalent in 6/94 to 5/96, 5/99 to 10/00, 2/04 to 12/05 and 6/06 to 12/08. These are periods when the economy witnessed high GDP growth rates, with the average GDP growth rate in the latter two periods exceeding 8%. The recessions reported by ECRI are all identified by the Markov method as well, but four additional episodes are identified.

It is interesting to note that the two recessions identified by the Markov method (5/96-4/97 and 12/08-1/10) are preceded by the high growth regime. There were many changes in the Indian economy since 1991 when it was faced with an unprecedented balance of payments crisis. Following this, a structural adjustment program was introduced which constituted large scale structural reforms in the economy, alongside financial sector reforms. This included liberalisation and privatisation with fiscal

restructuring. Again in 1997 second generation of broad based financial sector reforms were introduced. Such large scale reforms may imply a paradigm shift in the development process and may partly explain the non-gradual transition from high growth regimes to recessionary regimes in the episodes identified by the Markov methodology.

Table 10. **Indian growth rate cycle slowdown decomposition by Markov regimes**

| ECRI slowdown dates (Peak to trough) | MS regime dates | Regime end date | MS Regimes in ECRI slowdown | Total duration (months) |
|---|---|---|---|---|
| 2/76-9/77 | Regime 2 (3/75-11/78) | 9/77 | 19 | 19 |
| 5/78-12/79 | Regime 2 (3/75-11/78) | 11/78 | 06 | 19 |
| | Regime 1 (11/78-6/80) | 12/79 | 13 | |
| 10/80-2/83 | Regime 2 (6/80-7/82) | 7/82 | 21 | 28 |
| | Regime 1 (7/82-4/84) | 2/83 | 07 | |
| 8/84-9/85 | Regime 2 (4/84-4/88) | 9/85 | 13 | 13 |
| 10/86-12/87 | Regime 2 (4/84-4/88) | 12/87 | 14 | 14 |
| 6/88-5/89 | Regime 3 (4/88-12/88) | 12/88 | 06 | 11 |
| | Regime 2 (12/88-10/89) | 5/89 | 05 | |
| 3/90-9/91 | Regime 3 (10/89-5/90) | 5/90 | 02 | 18 |
| | Regime 2 (5/90-10/90) | 10/90 | 05 | |
| | Regime 1 (10/90-1/92) | 9/91 | 11 | |
| 4/92-4/93 | Regime 2 (1/92-6/94) | 4/93 | 12 | 12 |
| 4/95-11/96 | Regime 3 (6/94-5/96) | 5/96 | 13 | 19 |
| | Regime 1 (5/96-4/97) | 11/96 | 06 | |
| 9/97-10/98 | Regime 2 (4/97-3/98) | 3/98 | 06 | 13 |
| | Regime 1 (3/98-5/99) | 10/98 | 07 | |
| 3/00-7/01 | Regime 3 (5/99-10/00) | 10/00 | 07 | |
| | Regime 2 (10/00-4/01) | 4/01 | 06 | 16 |
| | Regime 1 (4/01-10/01) | 7/01 | 03 | |
| 4/04-10/04 | Regime 3 (2/04-12/05) | 10/04 | 06 | 06 |
| 10/05-3/06 | Regime 3 (2/04-12/05) | 12/05 | 02 | 05 |
| | Regime 2 (12/05-6/06) | 3/06 | 03 | |
| 1/07-1/09 | Regime 3 (6/06-12/08) | 12/08 | 3 | 24 |
| | Regime 1 (12/08-1/10) | 1/09 | 01 | |

Figure 5. **Growth slowdown periods broken down by regimes**

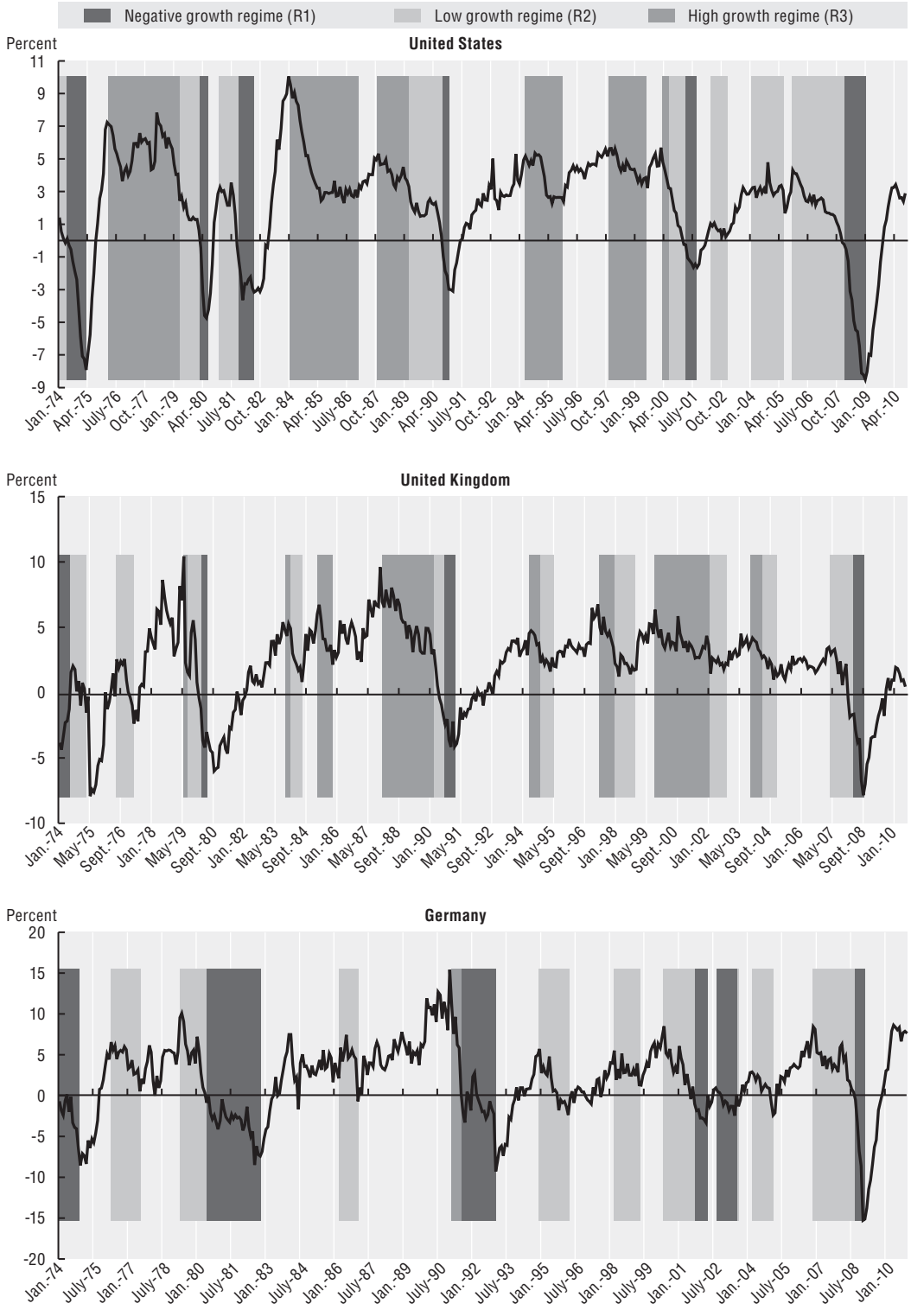
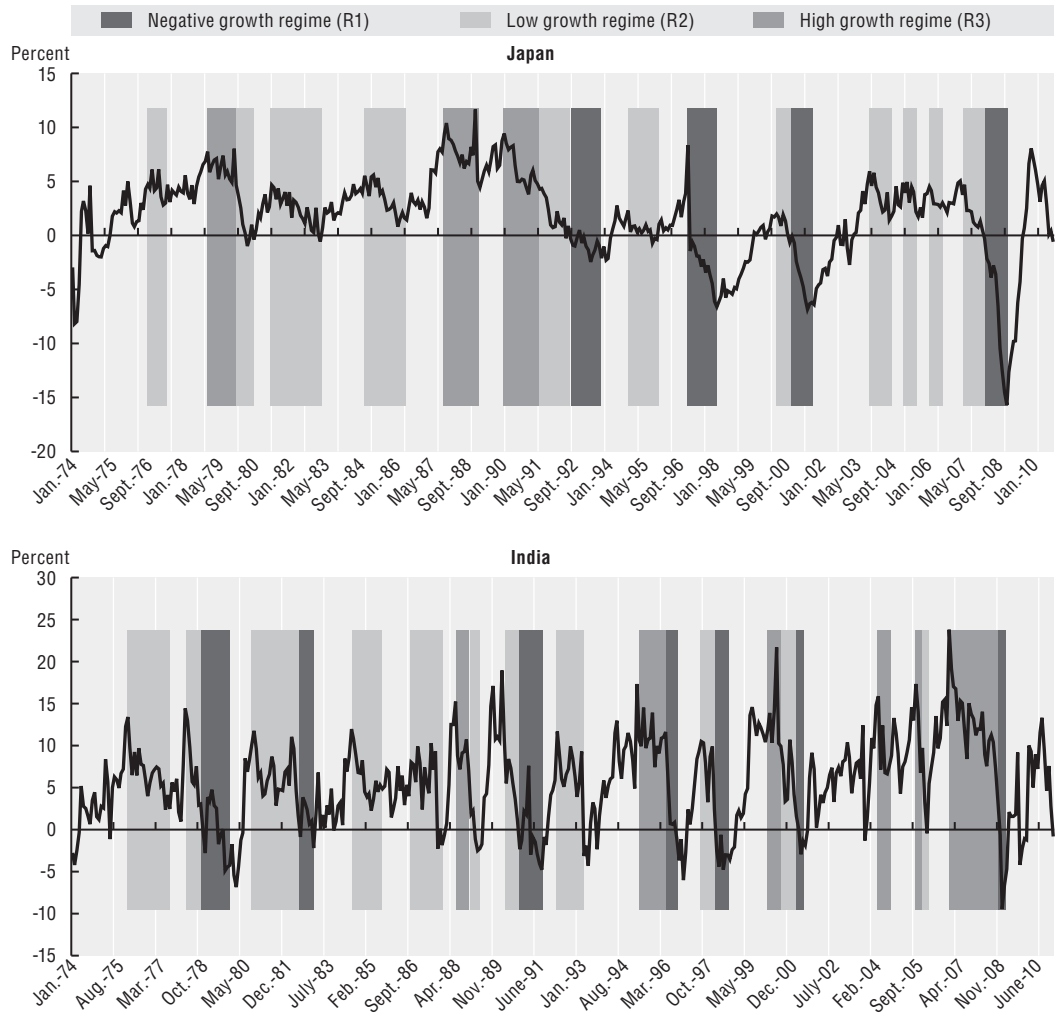


Figure 5. **Growth slowdown periods broken down by regimes** *(cont.)*




The severity of the global recession and the resulting severe downturn in the Indian economy also results in a non-gradual transition. It is also interesting to note that the 2008 downturn is classified as a slowdown based on the Economic Indicator Analysis (ECRI) but a purely econometric analysis based on the Markov model identifies it as a recession.

If we look at the expansions as defined by ECRI, we find that they may be seen to be consisting in large part of the moderate growth regime before 1994. The high growth regime becomes more prevalent after this period. Also, the recessions are relatively much shorter than those in other countries. We may be able to explain this in terms of active central bank intervention to insulate the economy from negative shocks on the onset of early signals of a coming downturn.

## 5. Conclusions

In this paper, we compare the dating of growth rate cycles obtained from a Markov switching approach with the reference chronologies based on EIA given by ECRI, focusing on a set of developed and emerging economies. The growth rate cycles are best captured as three regime processes from the Markov regime switching specification. We find that

although in terms of the number of regimes, all countries were similar; there are still heterogeneities among them in terms of cycle dynamics. The recession periods are invariably preceded by the low growth regime, indicating that the process of slipping into recessions is a gradual process, moving from low growth into negative growth. There is an exception to this pattern for the Indian economy post 1990s, which might be reflective of external factors playing a significant role in cyclical dynamics.

For the US economy, along with UK much of the 1990s is a period of high growth, while the period after the end of this recession in 2002 is marked by the presence of the low growth regime. Further, we note that some recessions are immediately followed by periods of high growth for the US economy, lending weight to Sichel's (1994) proposition that contractions are followed by high growth expansions and then by periods of normal growth. This pattern, however, does not seem to hold for other countries.

Unlike other developed economies, which spent a substantial part of the 1990s in the high growth regime, Japan spent all of the 90s in the low growth regime, corresponding with its long decade of stagnation. After the 2001-03 recession, the economy again settles in the low growth regime, till 2009. The German economy witnessed long periods in the moderate growth regime (mean growth rate being 3.09%) over the entire period 1974-2010.

The Indian growth rate cycle, on the other hand, is unique, since it has a more gradual pattern of moderate growth leading to recessionary periods before its liberalisation in 1991. However, not only is growth high in the 2000s, but recessions too are preceded by high growth regimes. It may be indicative of the fact that recessions, in being abrupt jumps, are processes associated with cycles in other countries.

In sum, the three regime characterisation seems to yield interesting information on cycle dynamics. It may be useful and instructive to bring together the results from the two different approaches – the EIA and the Markov switching approach. We show that growth slowdowns in the two phase representation given by ECRI can be defined in terms of the three regimes obtained from the Markov regime switching model. In this regard we may consider the two approaches as complementary.

### *Notes*

1. Krolzig (2001), Layton (1996), Layton and Smith (2000), Krolzig and Toro (2005). Multivariate extensions include Boldin (1996), Krolzig (1997) and Krolzig (2001). Diebold and Rudebusch (1994), Chauvet (1998) combine Markov switching model with the dynamic factor framework. Rand and Tarp (2002), Moolman (2004), Girardin (2005) and Tastan and Yildirim (2008) among others describe the business cycle using a Markov switching autoregressive model. Harding and Pagan (2002) have used the Markov switching model in comparison with other dating methods.
2. Based on IMF's *World Economic Outlook Database*, October 2014, Purchasing Power Parity (PPP) valuation of country GDP for the year 2010.
3. The coincident index is revised periodically to incorporate all data revisions in the underlying series.
4. A recession is a vicious cycle of pronounced, pervasive and persistent declines in output, income, employment and sales, eventually giving way to an expansion, which is an analogous virtuous cycle of rising economic activity.
5. The latest updates to the chronology are available at *www.businesscycle.com/international cycledates.php*
6. The study of growth rate cycles was put into practice in the late 1980s (Layton and Moore, 1989; Banerji and Hiris, 2001) at a time when the frequency of business cycles had fallen, as is evident form Figure 2. The fluctuations in economic activity were thus better captured by changes in the growth rate of the economy. The growth rate cycles thus capture upswings and downswings in the economy's rate of growth even when economies may not exhibit business cycle recessions.

It is also important to note that turning points in the growth rate cycle can be identified by the same objective procedures such as Bry and Boschan (1971) as are used to identify business cycle turning points.

7. Weak regime inference, indicative of possible misspecification, implies that the regime switching model cannot successfully distinguish between regimes from the behaviour of the data.

8. A probability exceeding 0.5 implies the corresponding growth rate would more likely have come from the contractionary regime than from the expansionary regime. The specification of the number of months in the dating rule used is in conformity with the duration requirements of the Bry and Boschan (1971) algorithm.

9. While the statistic value for the Indian data is higher than that for the other four countries, it is well below the accepted threshold cut-off value of 50. The relatively higher value for India may be reflective of the fact that regime 3 was not classified properly especially during the time before the 1990s. Moreover, the high growth regime has been more persistent and frequent in the post liberalisation period than before, consistent with the observation that the large scale reforms have defined a higher growth trajectory for the Indian economy in the 1990s. To examine the source of the higher value, we undertake a sub-sample analysis to see if the liberalisation policy has implications for the capturing of the high growth regime. Accordingly, corresponding to the dates of large scale reforms in the Indian economy we divide the sample into two parts, 1974-90 and 1991-2010. We find that the value of the statistic is marginally higher in the period 1974-90 (1.1) than in the post 1990s (0.84).

10. Increasing the value of $\alpha$ more than 0.5 would be equivalent to making the inference of being in any given regime based on the regime probabilities more stringent. e.g. $\alpha = 0.7$ would mean that we can infer that the growth rate came from a particular regime with a 70% likelihood. Because with $\alpha \geq 0.5$, the regime probabilities associated with regime 1 are already very high (in the range of 0.7-0.99), all the recession episodes obtained in regime 1 using $\alpha$ as 0.5 still go through even when we choose a higher value of $\alpha = 0.7$.

11. In both instances these abrupt changes from high growth regime (regime 3) directly into the recessionary regime (regime 1) occur at a time when their economies were undergoing fundamental changes.

12. Schultze (1964), Balke and Wynne (1992), Dijk and Franses (1999) and Layton and Smith (2000) also proposed that a business cycle recession may be followed by rapid expansion during the early stages of the recovery phase, proceeded by a period of more normal expansionary growth. This also finds significant theoretical ground when fluctuations are recognised to have a transitory component ("plucking" model by Friedman, 1993), and can be meaningfully captured empirically by a three-regime model of the cycle (Krolzig, 2001; Krolzig and Toro, 2005).

13. We have also worked out business cycle expansions as consisting of two sub-phases – a high growth regime and a moderate growth regime. Results for this exercise are available with the authors. We find that our results for the US economy stand very close to those obtained by Layton and Smith (2000), who have done the analysis for the US economy. We extend the same for UK, Germany, Japan and India.

14. $p_{ij} = P(S_t = i, S_{t-1} = j \mid T)$

15. The MS regimes may be used to infer the beginning and end of the recessionary regime (regime 1), while the low growth regime is not analogous to the slowdown periods. This is because slowdowns are decline in the growth rates, which may either be in the low growth regime or the high growth regime. Therefore, it may not be correct to interpret or identify the low growth regime with slowdowns. Accordingly, when we look at Figure 5(c) it may be seen that while the high growth regime corresponding to the slowdown (1/91-1/93) begins from 10/88, the decline in growth rate for this regime starts around 3/91, which is the point of time that the high growth regime would be associated with a slowdown.

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