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Towards a Monthly Business Cycle Chronology for the Euro Area

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COMMENTS WELCOME

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Abstract

This paper is an exercise in dating the Euro area business cycle on a monthly basis. Using a quite flexible interpolation routine, we construct several monthly series of Euro area real GDP, and then apply the Bry-Boschan (1971) procedure. To account for the asymmetry in growth regimes and duration across business cycle phases, we propose to extend this method with a combined amplitude/phase-length criterion ruling out expansionary phases that are short and flat. Applying the extended procedure to US and European data, we are able to replicate approximately the dating decisions of the NBER and the CEPR.

Keywords: business cycle, European business cycle, Euro area, Bry-Boschan, NBER methodology

JEL codes: B41, C22, C82, **E32**, E58

1 Introduction

Official dating of business cycles has a long tradition in the United States. The dates of peaks and troughs in the US economy's activity are officially announced by the Business Cycle Dating Committee of the National Bureau of Economic Research (NBER). According to the committee, a peak in activity determines the beginning of a recession which is defined 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*", see "The NBERs Business-Cycle Dating Procedure", Business Cycle Dating Committee, National Bureau of Economic Research, October 2003. In accordance with this definition, the Business Cycle Dating Committee is predominantly basing its judgment on the behavior of four monthly observable economic time series: total employment, real personal income less transfer payments, price-adjusted total sales of the manufacturing and wholesale-retail sectors, and industrial production. Since real GDP is only measured quarterly, it plays a minor role in the judgment of the Business Cycle Dating Committee. Information from other economic time series may also influence the decision of the committee, albeit with less weight.

Although the Business Cycle Dating Committee does not specify in more detail the method employed to date peaks and troughs, it seems to be following the traditional NBER view of business cycle behavior as described in Burns and Mitchell (1946). Their approach of measuring business cycles consisted in first identifying turning points in a variety of individual economic time series which usually tend to cluster around certain dates. In a second step, reference cycle dates for aggregate economic activity were selected from within these clusters on the basis of different criteria as, for example, bounds on the length and amplitude of business cycles.

With the creation of the Euro area on January 1st, 1999 and a single currency in circulation as of January 1st, 2002, it has become of greater urgency to establish such an official tradition in Europe as well. Therefore, the Centre for Economic Policy Research (CEPR) has recently formed a committee to set the dates of the Euro area business cycle in a manner similar to the NBER. Taking into account the particular features of the Euro area as a group of national economies, the Committee defines a recession *as a significant decline in the level of economic activity, spread across the economy of the euro area, usually visible in two or more consecutive quarters of negative growth in GDP, employment and other measures of aggregate economic activ-*

ity for the euro area as a whole, and reflecting similar developments in most countries, see "Business Cycle Dating Committee of the Centre for Economic Policy Research", CEPR, September 2003. To make sure that expansions or recessions are widespread over the countries of the area, the CEPR bases its judgment on euro area aggregate statistics as well as country statistics. Further, the committee has decided to date the Euro area business cycle in terms of quarters rather than months, arguing that the most reliable European data for dating purposes are available only on a quarterly basis. However, being well aware of the scarcity of appropriate historical monthly time series for most of the European countries, we think that it is nevertheless useful to establish a monthly business cycle chronology also for the Euro area. In fact, if the figures in some quarterly time series are viewed as the average or sum of the three consecutive months in a quarter, then dating on the quarterly level amounts to identifying turning points in a filtered monthly series. Monthly and quarterly dating of the same underlying monthly series might therefore lead to different results. Hence, dating business cycles at the monthly level is likely to provide a more precise information about the exact turning points than quarterly dating. Furthermore, since the state of the economy is an important variable in empirical models, applications are conceivable which would require knowledge about the business cycle turning points of the Euro area on a monthly basis. Thus, applying the highest diligence in interpreting the available data, this paper aims at filling the gap of a monthly business cycle chronology for the Euro area.

To arrive at such a chronology, two difficulties must be overcome. First, rather than examining a plethora of data for each of the months of the last 30 years, an econometric methodology needs to be found which successfully finds the NBER dates, and then apply that methodology to European data. Second, appropriate Euro area data needs to be found. For solving both of these difficulties, we can build on existing research.

For an econometric methodology, we build on the research which has tried to reverse-engineer a time-series based methodology replicating the dates chosen by the NBER. The methodology by Bry and Boschan (1971) is generally considered to be quite successful at that. We will show that this is indeed the case in section 3.1, although with some caveats: the Bry-Boschan procedure sometimes finds the exact NBER date, but sometimes only comes close to the official dates within a few months. Furthermore, the Bry-Boschan treats business cycle expansions and contractions symmetrically, thus not taking into account differences in terms of growth and duration across regimes. As a consequence, the procedure may identify business cycle phases that

are implausibly flat. To avoid this, we therefore propose to augment the Bry-Boschan procedure with a suitable amplitude/phase-length criterion in section 2.1, ruling out business cycle expansions that are both short and flat.

To use the Bry-Boschan procedure, one needs a monthly time series for real GDP. Even for the US, such a time series is not officially available, although one can construct a pretty good time series with the help of an interpolation procedure which is described in detail in appendix A.1.We have done so for the exercise in section 3.1 and discuss the resulting series in appendix A.2.

For the Euro area, building a good monthly real GDP time series is more difficult than for the US for a number of reasons. First, quarterly real GDP for the Euro area has only been recorded officially as of January 1991. Since our aim is to determine the Euro area business cycle turning points for at least the last 30 years, we have proceeded to construct a Euro area monthly real GDP series by interpolating and then aggregating appropriate country time series.[1] Even there, data availability is a serious problem. The details on available data and our construction are provided in appendix A.3. To check the dating results obtained using our series we have additionally determined the turning points of two different monthly interpolations of the Euro area quarterly real GDP series constructed by Fagan, Henry, and Mestre (2001). For all three series, the results are very similar, see section 3.2 for a comparison.

Section 4 finally provides a summary of the challenges in improving on this exercise, discusses limitations and provides the key conclusions.

2 Bry-Boschan's Method and an Extension

Bry and Boschan (1971) provide a nonparametric, intuitive and easily implementable algorithm to determine peaks and troughs in individual time series. Although the method is quite commonly used in the literature, we briefly sketch its main constituents here. For a detailed description, the reader is referred to Bry and Boschan's paper. The procedure consists of six sequential steps. First, on the basis of some well-specified criterion, extreme observations are identified and replaced by corrected values. Second,

[1] Eurostat has recently launched a project whose aim is the construction of a historical monthly time series for Euro area real GDP. However, this series has not yet been made officially available. Moreover, since their approach seems to differ somewhat from ours in terms of methodology, it would be interesting to compare the time series propoerties of both series.

troughs (peaks) are determined for a 12-month moving average of the original series as observations whose values are lower (higher) than those of the five preceding and the five following months. In case two or more consecutive troughs (peaks) are found, only the lowest (highest) is retained. Third, after computing some weighted moving average, the highest and lowest points on this curve in the ± 5 months-neighborhood of the before determined peaks and troughs are selected. If they verify some phase length criteria and the alternation of peaks and troughs, these are chosen as the intermediate turning points. Fourth, the same procedure is repeated using an unweighted short-term moving average of the original series. Finally, in the neighborhood of these intermediate turning points, troughs and peaks are determined in the unsmoothed time series. If these pass a set of duration and amplitude restrictions, they are selected as the final turning points.

2.1 A Simple Combined Amplitude/Phase-Length Criterion for the Bry-Boschan Procedure

Obviously, as a univariate procedure the Bry-Boschan turning point selection method is unsuited to take into account information from more than one time series as is done by the business cycle dating committees of the NBER and the CEPR. Despite this shortcoming, we would like to stick to the Bry-Boschan algorithm instead of using a multivariate methodology since it is both intuitive and transparent. In its original form, the method incorporates a minimum cycle and phase length criterion, restricting business cycles and phases to last at least 15 and 5 months, respectively. Turning points corresponding to cycles or phases that do not fulfil these criteria are simply deleted. As we will see further below, with the minimum phase length criterion switched off, the Bry-Boschan procedure identifies two recessions in Euro area real GDP in the early 1980s. On the contrary, with the minimum phase length criterion switched on it censors the shorter of the two downturns without taking into account that there has been only a brief period (19 months) of very moderate growth (annualized growth rate of less than 1.4%) in between the two phases of declining GDP. Considering also information from other economic indicators, the CEPR has defined the period starting in the first quarter of 1980 and ending in the third quarter of 1982 as a long recession, see 3.2.3. During the same time, US monthly real GDP has shown a similar behavior, first falling shortly from January to June 1980, then rising until August 1981 and declining again until February 1982. Yet, both recessions and the intermediate upturn were more pronounced in the

US than in the Euro area. For example, US real GDP grew at an annual rate of 3.3 % in between the trough in June 1980 and the peak in August 1981. Accordingly, the NBER has dated two distinct recessions interrupted by a short intermediate upturn.

It is our view that the different patterns that real GDP followed in the US and in the Euro area in the early 1980s suffice to explain the dating decisions of the NBER and the CEPR, without having to take into account further measures of activity. We therefore would like to augment the univariate Bry-Boschan procedure with a combined amplitude/phase-length criterion that embraces both types of pattern. Such a rule should ensure that business cycle phases that are both short and flat are suppressed while phases that are short but pronounced are retained. Hence, it remains to appropriately define what is "short" and what is "flat" in the present context, and whether the criterion shall apply to business cycle expansions or contractions.[2]

As has already been noted above, the original Bry-Boschan procedure provides for a minimum phase-length criterion of five months, i.e. once the turning points in the time series to be dated are determined, business cycle expansions or contractions that are shorter than five months are deleted, independently of their amplitude. Notice, however, that due to the widely documented asymmetry of business cycles that is associated with much longer booms than recessions, this criterion in practice exclusively applies to business cycle contractions. After having studied the time series behavior of GDP for different countries, it is our view that episodes shorter than five months occur which can be classified as business cycle contractions without any doubt. In contrast, the length of expansions seems to be a more distinctive feature of business cycles at least in the postwar period. In fact, there is a comprehensive literature on the stabilization of business cycles in the US and other industrialized countries in the postwar period (see, e.g., Diebold and Rudebusch (1992) and Romer (1994)). It is our reading of this literature that there is widespread agreement that business cycle expansions have been significantly longer in the postwar than in the prewar period, while it is not so clear that business cycle contractions have become shorter over time.

[2]Artis et al. (1997) suggest a turning point selection procedure similar to the Bry-Boschan algorithm which incorporates a minimum amplitude criterion. According to their criterion, phases (peak to trough or trough to peak) are excluded that have an amplitude of less than one standard deviation of log changes of the series to be dated. This rule is obviously aimed at use for rather volatile series such as industrial production which Artis et al. employed for their dating exercise. However, applied to our (comparatively smooth) monthly real GDP series for the US and the Euro area, it did not yield the desired exclusion of flat expansions.

We will therefore base our combined amplitude/phase-length criterion that is designed to date postwar data on the growth rate and length of expansions rather than contractions.

Given this decision, it appears intuitive to designate a "short" business cycle expansion as one that is significantly shorter than the average expansion. We therefore define a short expansion as one whose length is outside the one-standard deviation interval around the average expansion length. Based on the official NBER business cycle dates, the average length of expansions in the US has been 57 months in the postwar period, with a standard deviation of 36 months. Given these numbers, the threshold below which a business cycle upturn would be defined as short according to the above criterion is thus 21 months or 7 quarters.[3]

By similar reasoning we define a "flat" expansion as an upturn in which the annualized growth rate is significantly lower than the average positive annual growth rate, i.e. which is outside the one-standard deviation interval around the average positive annual growth rate.[4] Computing this indicator for the US, we find a value of 2.1 %, whereas for the Euro area it amounts to 1.5 %. In order not to make our rule excessively restrictive, we take the lower of both values as our threshold for minimum annual growth in a short business cycle upturn. Altogether, our combined amplitude/phase-length criterion thus excludes expansions that are not longer than 21 months *and* during which the annualized growth rate is lower than 1.5 %. In practice, applying this criterion amounts to deleting the trough and peak which mark the beginning and the end of a short and flat expansion, respectively, in the ultimate step of the Bry-Boschan procedure.

It might be worth noting that Artis et al. (2002) make a similar point. These authors discuss the usefulness of amplitude restrictions as a censoring device for dating algorithms. Analogously to our reasoning, they conclude that since expansions are usually longer and characterized by a lower average drift rate than recessions, different threshold values for amplitude restrictions should be used for booms and contractions. However, they do not investigate this issue further and do not provide such a phase-dependent amplitude rule.

[3]Obviously, there is some arbitrariness in this choice. Using European data or a longer time span of US data might have led to a slightly different threshold. Yet, given the well-documented business cycle stabilization after world war II and the close correspondence between US and Euro area business cycle characteristics (see Agresti and Mojon (2001)), this choice appears by all means appropriate.

[4]We restrict this indicator to positive annual growth rates since including contractions would obviously result in a biased threshold for low growth during expansions.

3 Monthly Business Cycle Chronologies for the US and the Euro Area

In this section, we apply the original and augmented Bry-Boschan algorithm to our monthly real GDP series for the US and the Euro area and compare the results.

3.1 The US Dates

As a first check on our procedure and for comparison, we apply the programmed turning point selection algorithm to US data. To that end, we construct a monthly time series for real US GDP for the period 1967:1 to 2002:09 (see appendix A.1 for details on the interpolation method) to which we then apply the Bry-Boschan procedure as well as our augmented version of it.

The results can be seen in a "birds eye view" in figure 1. The NBER recessions have been indicated by shaded areas, whereas the peaks and troughs determined by the Bry-Boschan procedure are shown as vertical bold lines. As expected, the dating results for the US do not change by augmenting the Bry-Boschan procedure with our amplitude/phase-length criterion since the short recovery in between the two recessions in the early 1980s was rather pronounced.

A comparison of the dates is given in table 1. Note that the Bry-Boschan procedure sometimes finds the exact NBER date, but sometimes only comes close to the official dates within a few months. Further, for those dates that do not coincide, the Bry-Boschan dates tend to lead the NBER dates slightly, the only exception being the peak in July 1981. Employment is one of the main four monthly time series the Business Cycle Dating Committee of the NBER bases its judgement on. Since employment is known to lag output, this might partly explain the slight lead in the Bry-Boschan dates. Notice further that when the moving average window parameter in the first step of the procedure is set to twelve months as in Bry and Boschan (1971), the procedure misses two complete business cycles towards the beginning and the end of the sample. However, since our objective has been to come as close as possible to the NBER dates, we have set the window parameter for the pre-smoothing to eight months. The business cycle dates we propose for the Euro area have been obtained using the same setting.

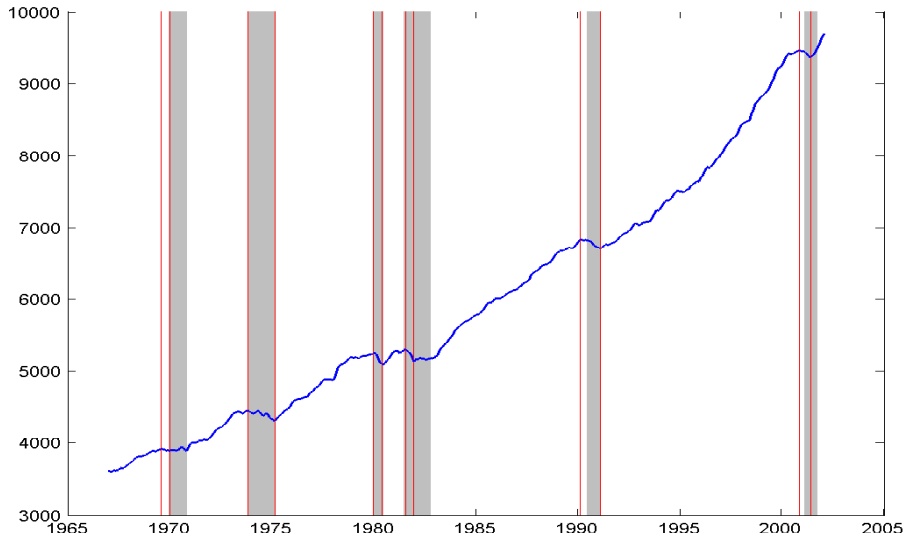


Figure 1: *A comparison of official NBER dates and Bry-Boschan dates. The recessions identified by the NBER are indicated by shaded areas, the peaks and troughs determined by the Bry-Boschan procedure by vertical bold lines.*

3.2 A Monthly Business Cycle Chronology for the Euro Area

The term "Euro area" in this paper refers to the area of the 12 member countries of the European monetary union as of January 1st, 2002, including in particular Greece and Eastern Germany. As already noted above, we perform our business cycle dating exercise on different monthly time series for Euro area real GDP. The construction of these series is briefly sketched in section 3.2.1, and in more detail in appendix A.3. In section 3.2.2 we present the dating results obtained by applying the Bry-Boschan turning point selection procedure to these series, and compare them with the quarterly dates obtained by other authors and those recently published by the CEPR. We discuss the monthly business cycle dates taking into consideration further aggregate measures of Euro area business activity in section 3.2.3 and finally apply the Bry-Boschan procedure augmented with our amplitude/phase-length criterion in section 3.2.4.

Peaks:						
Bry-Boschan	69M8	73M11	80M1	81M8	90M3	00M12
Augmented Bry-Boschan	69M8	73M11	80M1	81M8	90M3	00M12
NBER	69M12	73M11	80M1	81M7	90M7	01M3
Troughs:						
Bry-Boschan	70M1	75M3	80M6	82M1	91M3	01M7
Augmented Bry-Boschan	70M1	75M3	80M6	82M1	91M3	01M7
NBER	70M11	75M3	80M7	82M11	91M3	01M11

Table 1: *Comparison of Bry-Boschan and NBER dates for peaks and troughs.*

3.2.1 Monthly GDP Series for the Euro area

For our business cycle dating experiment, we use three different time series for monthly Euro area real GDP. Our benchmark series is our own series for the period 1970:1 to 2002:12. Although the details about the construction of this series are provided in appendix A.3, we shall briefly outline the main steps here. First, we have constructed monthly time series for GDP volume for all twelve Euro area member countries from interpolating appropriate quarterly and annual time series. For each country separately, we choose the "best" interpolation procedure among a set of possible specifications of a general model which nests some of the most commonly used interpolation methods such as the ones suggested by e.g. Chow-Lin (1971), Fernandez (1981), or Mitchell et al. (2005). The general model treats monthly figures of real GDP as the unobserved component in a state-space model, employing the observation equation to ensure that quarterly (annual) figures are the averages of three (twelve) consecutive monthly observations. We use the Kalman filter to estimate the model and maximum likelihood ratio tests to select the best specification. As related variables, we employ monthly series for industrial production, real retail sales, employment or exports, depending on availability, see table 6. Finally, we aggregate these series to obtain a measure of Euro area real GDP using the same aggregation method and weights as Fagan, Henry and Mestre (2001), FHM in short, in their latest update of the ECB's area wide model dataset.

The other two series are based on interpolations of the quarterly real GDP series constructed by FHM which has recently been updated. The first is a linear interpolation, viewing the quarterly data as referring to the middle of the three months in a quarter. The second has been constructed by interpolating the quarterly FHM series employing the interpolation method described in appendix A.1. As related series, we have used an aggregate

monthly chained volume index series for Euro area industrial production, which we have constructed using the same weights and aggregation method as FHM for their area-wide model dataset.[5]

3.2.2 The Euro Area Dates

Applying the original Bry-Boschan procedure, we obtain the results listed in table 2. As can be seen from the dating results, the original programmed turning point selection procedure finds four business cycles for all three series.[6] A visual "birds-eye" view of the dates obtained for our own monthly time series is provided in figure 2. Concerning the exact dates of the identified turning points, there is a surprising agreement between the three series: three out of four peaks found in our series coincide exactly with those obtained from the monthly interpolation of the FHM series using aggregate industrial production as related variable, and the dates of the third peak only differ by one month. Further, in terms of quarterly business cycle peaks, those dates are fully consistent with the ones obtained using the linear interpolation of the FHM series. There are only slight differences when the identified business cycle troughs are concerned, the maximum deviation between our series and the instrumental variable interpolation of the FHM series being three months. For the first and the fourth trough, however, this deviation results in a different quarterly turning point.

The quarterly turning points can be compared with the dating results obtained by other authors and the turning points recently provided by the CEPR. Let us begin the comparison by considering first the findings of other authors. Krolzig (2001) employs a univariate Markov-switching model for Euro area quarterly GDP growth using the time series constructed by Beyer et al. (2001) which covers the post-1979 period. Over that time span, he identifies two business cycles with peaks in 1980QI and 1992QI, and troughs in 1981QI and 1993QI, respectively. Hence, for the identified cycles, there is a close correspondence with our results, the only difference being the trough in 1980. Interestingly, however, Krolzig's (2001) procedure indicates that the Euro area has experienced only one complete cycle in the 1980s.[7] As will be

[5]Since there is no such series for Ireland covering the entire sample period, we have omitted Ireland from this aggregate.

[6]Notice that the minimum phase length criterion included in the original Bry-Boschan procedure has been set off here. In case this criterion is put on, the third cycle is censored for all three series since the corresponding recession is always shorter than 5 months.

[7]Note that Krolzig (2001) finds very similar results using a multivariate Markov-switching model for GDP growth rates of eight Euro area member countries. Notice

Peaks:				
Our series	74M8(QIII)	80M3(QI)	82M4(QII)	92M2(QI)
FHM IP	74M8(QIII)	80M3(QI)	82M4(QII)	92M2(QI)
FHM lin	74M8(QIII)	80M2(QI)	82M5(QII)	92M2(QI)
CEPR	74QIII	80QI		92QI
Troughs:				
Our series	75M4(QII)	80M9(QIII)	82M7(QIII)	93M1(QI)
FHM IP	75M1(QI)	80M9(QIII)	82M8(QIII)	93M4(QII)
FHM lin	75M2(QI)	80M8(QIII)	82M8(QIII)	93M2(QI)
CEPR	75QI		82QIII	93QIII

Table 2: *Comparison of turning points identified by the Bry-Boschan algorithm when applied to our monthly series of Euro area GDP, a linear interpolation of the quarterly FHM series, and a monthly interpolation of the FHM series constructed using a chained volume index of aggregate Euro area industrial production as related series.*

discussed in section 3.2.3 below, we come to the same conclusion by studying the time series behavior of further business-cycle related variables.

Employing a business cycle dating method called "ABCD approach", Anas and Ferrara (2004) determine business cycle turning points for the Euro area using Eurostat's aggregate GDP series starting in 1995 and own backward calculations before. They find their method to deliver similar results as e.g. Krolzig (2001) and Anas et al. (2003). The latter paper, using the same methodology and time series as Anas and Ferrara (2004), identifies four business cycles over the 1970-2003 period. Although they do not correspond exactly, the quarterly turning points found by Anas et al. (2003) are rather similar to the ones identified in this paper, differing by one quarter at the most.

Applying a quarterly version of the Bry-Boschan procedure to the previous release of the quarterly FHM series, Harding and Pagan (2001b) and Artis et al. (2002) both obtain slightly different results as we do using interpolations of the latest update of the FHM series.[8] However, applying the

further that Anas and Ferrara (2002) find a very recent business cycle peak in 2001QI by extending the univariate analysis in Krolzig (2001) up to 2002QII.

[8]The latest update of the ECB's area-wide model database has been made available in November 2003 and differs from the previous one in a number of respects : the inclusion of Greece, new availability of data including ESA95 data, revisions to historical data and the interpolation of quarterly historical data using a methodology similar to the one employed here.

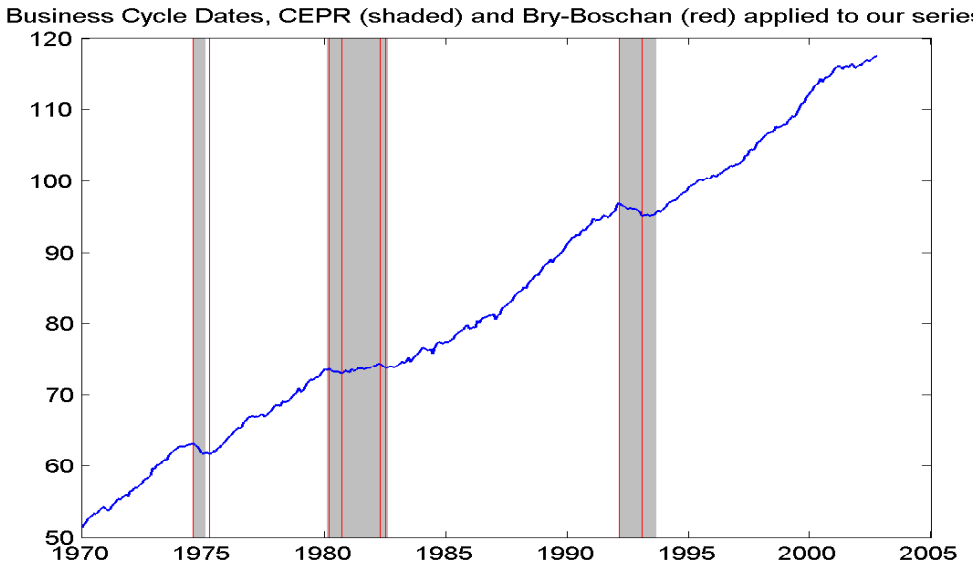


Figure 2: *Dating the Euro area business cycle based on our monthly series for real Euro area GDP. The recessions identified by the CEPR are indicated by shaded areas, the peaks and troughs determined by the Bry-Boschan procedure by vertical bold lines. The quarterly CEPR dates have been interpreted as monthly turning points by taking the middle month of the respective quarter as the monthly date. Notice further that the five month minimum phase length rule in the original Bry-Boschan algorithm has been set off here.*

Bry-Boschan algorithm to the linear interpolation of the previous version of the quarterly FHM series, we obtain exactly the same dates as Harding and Pagan (2001b) and Artis et al. (2002). In fact, dating the old version of the FHM series results in business cycle troughs in 1981Q1 instead of 1980QIII and 1982QIV instead of 1982QIII.[9] This difference emphasizes the importance which exerts the construction method of the employed time series on the dating result. Moreover, the fact that the latest update of the FHM series exhibits turning points which are much more similar to the ones obtained using our series than those of the previous FHM release, clearly underscores the usefulness of our series as a measure of monthly Euro area real GDP.

[9]It may be worth noting that Artis et al. (2002) find the same turning points for the post-1979 period, employing the quarterly real GDP series for the Euro area provided by Beyer et al. (2001) which only covers the post-EMU period.

3.2.3 Examining the Individual Dates

According to the dating results discussed so far, all measures of Euro area GDP that are available to us seem to support the view that the Euro area has experienced four cycles since 1970. Interestingly, however, the CEPR has only identified three business cycles over the same period, considering the short cycle in the early 1980s as a long recession, see table 2. In its inaugural release, the business cycle dating committee of the CEPR notes:

The third recession, in the 1980s, exhibits different and specific characteristics. The recession in terms of aggregate output is milder but longer. GDP does not decline sharply but rather stagnates for almost three years. Our dating is thus based on the behaviour of employment and investment which, unlike GDP, declined sharply during the period. In this episode, we also observe more heterogeneity in output dynamics across the three large economies than in the other two recessions. That affects our designation of the date of the trough, in particular.

To assess whether there have been one or two cycles in the 1980s, we therefore follow the business cycle dating committee by examining further relevant time series. Table 3 provides plots of Euro area aggregates for industrial production, real retail sales, employment, and investment, the latter two being linear interpolations of the quarterly series constructed by Fagan et al. (2001) for the ECB's area wide model.[10] Eye-ball checking is sufficient to see that Euro area employment, investment, and retail sales clearly have exhibited one pronounced cycle in the 1980s instead of two short cycles. The aggregate IP series shows a slightly less clear-cut behavior, declining sharply from March 1980 to September 1980, remaining almost constant until April 1982, and then falling again sharply. A central feature of business cycles is the common movement of different measures of economic activity. Given that three such variables in the Euro area clearly exhibit only one cycle in the 1980s instead of two, and that industrial production does not regain its pre-March 1980 level until 1985, it thus appears appropriate to consider the period between early 1980 and mid 1982 as a long recession even though GDP has recovered slightly in between these dates.[11]

[10] Notice that due to the limited data availability, the aggregate IP series does not include Ireland. The aggregate retail sales series is constructed using data from Belgium, Finland, Germany, Greece, Ireland, and the Netherlands. The aggregation method is the same as the one that has been used to construct the GDP series.

[11] According to our measure of monthly GDP for the Euro area, output grew only about 2.2 % in between the two peaks identified by the Bry-Boschan procedure in September

Interestingly, although Euro area industrial production and investment clearly have experienced a peak towards the end of 2000 (see table 3), the Bry-Boschan procedure does not identify a business cycle peak in real GDP around that time. Indeed, all three monthly time series of Euro area real GDP remain more or less constant in 2001 and start rising again in early 2002. Accordingly, the short-term moving averages of the respective series are rather flat, hence explaining why the Bry-Boschan procedure does not identify a turning point. Thus further data observations will have to be awaited before it can doubtlessly be decided whether there has been a business cycle peak in Euro area real GDP around 2001.

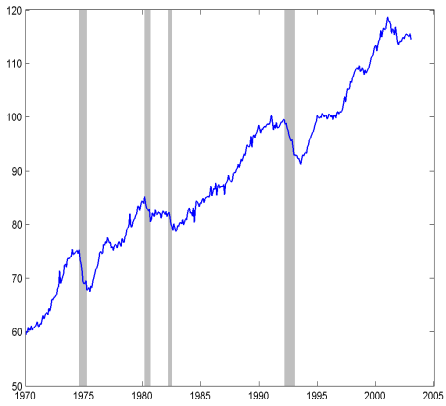
3.2.4 Applying the Augmented Bry-Boschan Method

To assess whether our combined amplitude/phase-length criterion is able to identify this feature of the data, we now apply the augmented Bry-Boschan procedure to the three monthly time series of Euro area real GDP. A visual representation of the outcome of this exercise is provided in figure 3, while the corresponding business cycle chronologies are stated in table 4. As can be seen from these results, the extended algorithm identifies the two short recessions in the 1980s connected by a very brief and moderate upturn as a long recession, and thus matches very closely the dating decision of the CEPR.

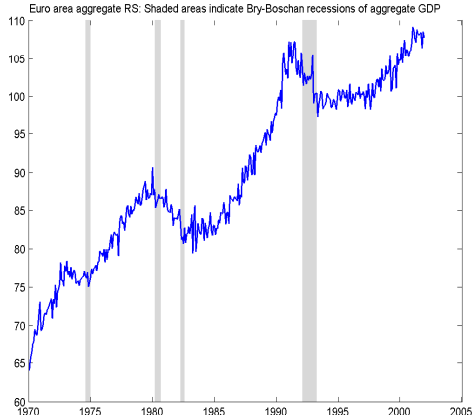
Rather than dating the Euro area business cycle, some recent studies have focussed on the European business cycle, thus also considering countries that are not member of the European Monetary Union, as for example the UK. Applying a multivariate Markov-Switching model to quarterly GDP growth rates of six European countries including the UK, Krolzig and Toro (2001) identify three cycles over the 1970-1996 period, with business cycle peaks in 1974QI, 1980QI, and 1992QII, and troughs in 1975QII, 1982QIV and 1993QII, respectively. These dates are rather similar to our findings when we apply the amplitude/phase-length criterion. This might indicate that UK GDP has experienced a more pronounced downturn in the early 1980s whereas Euro area member countries such as Belgium and the Netherlands that are excluded from Krolzig and Toro's (2001) dataset, contributed to the long and flat expansion distinctive for Euro area GDP in the early 1980s.

1980 and April 1982. This corresponds to an annual rate of less than 1.4 % which appears unusually low for a business cycle upturn. During the same period, the quarterly FHM series grew about 1.45 % corresponding to an annual rate of less than 1%.

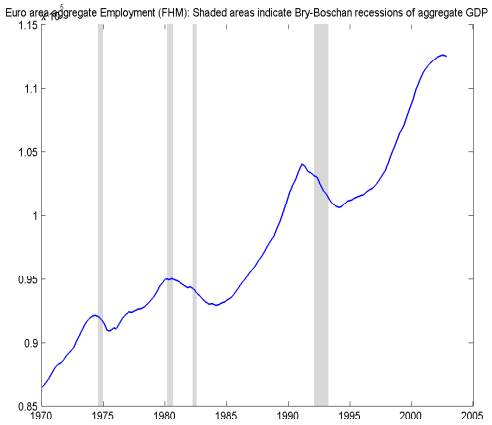
Aggregate IP



Aggregate Real Retail Sales



Aggregate Employment (FHM)



Aggregate Investment (FHM)

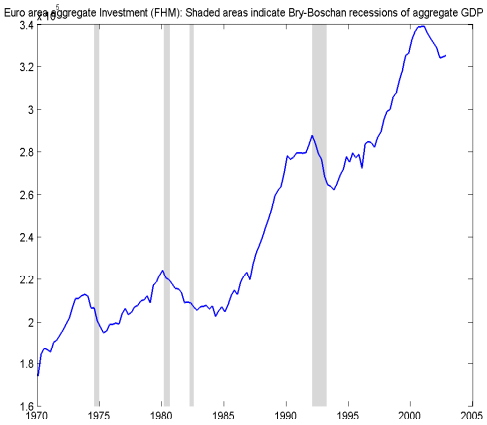


Table 3: *Related aggregate series for the Euro area. The shaded areas indicate the recession periods identified by the Bry-Boschan procedure based on our monthly series of aggregate GDP.*

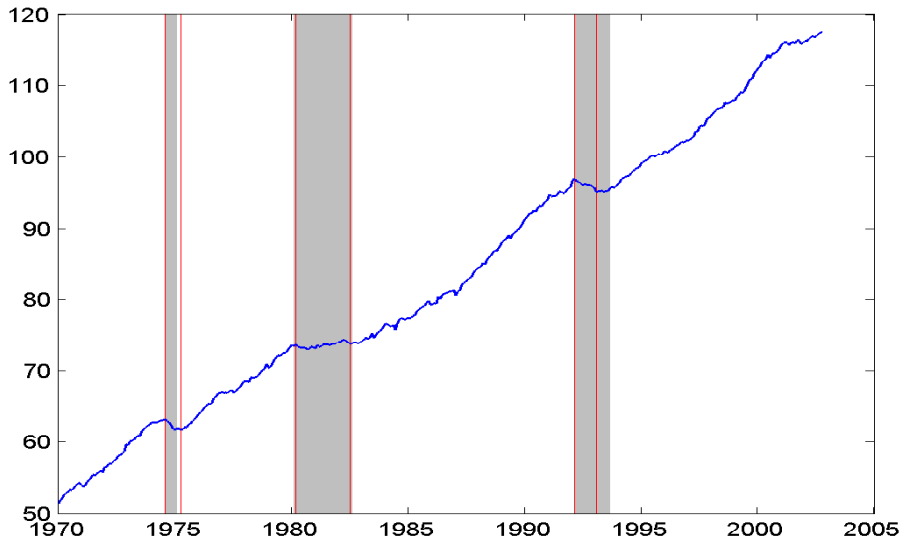


Figure 3: *Dating the Euro area business cycle based on our monthly series for real Euro area GDP. The Bry-Boschan algorithm has been augmented with the combined amplitude/phase-length criterion discussed above. The recessions identified by the CEPR are indicated by shaded areas, the peaks and troughs determined by the Bry-Boschan procedure by vertical bold lines. The quarterly CEPR dates have been interpreted as monthly turning points by taking the middle month of the respective quarter as the monthly date.*

4 Conclusions

We have performed an exercise in dating the business cycle in the Euro area from 1970 to 2002 on a monthly basis. We construct several monthly European real GDP series, and then apply the Bry-Boschan (1971) procedure. The Bry-Boschan procedure comprises a censoring rule which treats business cycle expansions and contractions symmetrically without taking into account the differences in average drift rate and duration across regimes. To overcome this shortcoming, we propose a combined amplitude/phase-length criterion for the Bry-Boschan procedure that rules out expansionary phases which are short and flat.

For US data, we show that this procedure comes close to replicating the official NBER dates. For European data, a number of additional issues needed to be resolved. In particular, a monthly real GDP series had to be constructed, to which to apply the Bry-Boschan procedure. We have constructed such a series by first interpolating quarterly and annual GDP

Peaks:			
Our series	74M8(QIII)	80M3(QI)	92M2(QI)
FHM IP	74M8(QIII)	80M3(QI)	92M2(QI)
FHM lin	74M8(QIII)	80M2(QI)	92M2(QI)
CEPR	74QIII	80QI	92QI
Troughs:			
Our series	75M4(QII)	82M7(QIII)	93M1(QI)
FHM IP	75M1(QI)	82M8(QIII)	93M4(QII)
FHM lin	75M2(QI)	82M8(QIII)	93M2(QI)
CEPR	75QI	82QIII	93QIII

Table 4: *Turning points identified by the augmented Bry-Boschan algorithm when applied to our monthly series of Euro area GDP. Further, the quarterly turning points determined by the CEPR are provided.*

series for individual countries, using different monthly available variables as instruments. In a second step, we have aggregated the individual interpolated series to obtain a monthly real GDP series for the Euro area.

As a cross-check on the dating results obtained using our series of monthly Euro area real GDP, we have constructed two alternative series. We find a surprising agreement between the dating results obtained from the three different series. However, since our benchmark series has been constructed using information contained in a number of different monthly available instruments, we think this series reflects the monthly variation of business activity in the Euro area most appropriately.

The original Bry-Boschan dating procedure has identified four peaks and four troughs over the period 1970 to 2002, see table 2. Yet the two contractions and the interjacent expansion identified in the early 1980s are not very pronounced. We have therefore examined other measures of business activity in order to assess whether the Euro area has experienced one or two cycles in that period. As all these series do exhibit only one complete cycle during that time, we consider the period of very low GDP growth in the early 1980s as a long recession. Applying the Bry-Boschan procedure augmented with our combined amplitude/phase-length criterion to the different monthly GDP series for Euro area, we are able to replicate this feature and match the turning point decision of the CEPR quite closely.

It is important to keep in mind that the Bry-Boschan procedure cannot detect peaks and troughs very close to the beginning or the end of the sample. In particular, the procedure may have missed turning points in the Euro area

since mid 2002. However, the methodology applied in this paper can be easily used to determine more recent turning points of the Euro area business cycle when new data becomes available. Moreover, the flexibility of our approach to construct a monthly time series of real GDP for the Euro area makes it readily applicable in case of future enlargements of the European Monetary Union.

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A Constructing monthly time series for real GDP

A.1 Interpolation

A variety of different interpolation methods has been suggested in the literature. While some methods estimate higher frequency representations of a low frequency time series on the basis of a time series model, others explicitly take into account the information in related series and thus perform interpolation on the basis of a regression model. Here, we focus on this second class of models since we would like to derive monthly estimates of real GDP using the information in economically related time series which are available at the monthly frequency.

A very prominent and often applied interpolation model that makes use of related high frequency information is the method suggested by Chow and Lin (1971). These authors assume the high frequency observations of the series to be interpolated as being generated by a linear regression model in the related series with first-order autocorrelated residuals. Depending on the time series properties of both the interpoland and interpolator variables, however, different specifications might be more appropriate. For example, Fernandez (1981) suggests a regression model in first differences to take account of potential non-stationarity of the data. A somewhat more general formulation has been used by e.g. Gregoir (1995) and Mitchell et al. (2005) who suggest to perform the interpolation using dynamic regression models, i.e. they incorporate lagged observations of the interpoland in the regression equation.[12]

Since there is no a priori criterion to decide upon the superiority of any of these approaches, we derive here a unified framework which nests a few of the prominent interpolation methods. This allows us to gauge the relative performance of different models for a given set of series and we will choose the one that is most appropriate on the basis of likelihood ratio tests. Following the work by Bernanke, Gertler, and Watson (1997) and Proietti (2004), we cast the models in a state-space setup in which it is particularly straightforward to handle the aggregation restrictions implied by the interpolation problem. We will now describe the most general interpolation method considered and then show how different approaches suggested in the literature

[12]For a more exhaustive overview on different interpolation methods, the reader is referred to the nice reviews provided in Di Fonzo (2003) and Proietti (2004), respectively.

can be obtained by imposing simple restrictions on individual parameters of the model. Consider the following dynamic regression model

$$\begin{aligned}(1-\phi(L))y_t &= x_t'\beta + u_t, \\ u_t &= \rho u_{t-1} + \epsilon_t, \quad \epsilon_t \sim N(0,\sigma^2),\end{aligned}$$

where y_t is the high frequency observation of the variable to interpolated, $\phi(L)$ is a lag polynomial of order p, x_t are the time t observations of a set of related series, and u_t is the regression residual which is assumed to follow an AR(1) process.[13]

We assume here that the quarterly GDP figures are the average of the unobserved three consecutive monthly observations. Hence, defining the quarterly indicator variable y^+ as

$$y^+ = (0 \;\; 0 \;\; y_3^+ \;\; 0 \;\; 0 \;\; y_6^+ \;\; 0 \;\; 0 \;\; y_9^+ \ldots)',$$

we obtain the following measurement equation:

$$\begin{aligned}y_t^+ &= \frac{1}{3}\sum_{i=0}^{2} y_{t-i}, \quad t = 3,6,9,\ldots \\ y_t^+ &= 0 \quad \text{otherwise.}\end{aligned}$$

Notice that there is no error term in this equation since the mean of three consecutive months shall *exactly* equal the quarterly observation. Moreover, the Kalman filter proves particularly useful in such a setup since it can easily handle missing observations by letting the Kalman update be zero in the periods where no new information becomes available.

Cast in state-space form, the model is

$$y_t^+ = H_t' \;\; \xi_t \tag{1}$$

$$\xi_t = \begin{pmatrix} y_t \\ y_{t-1} \\ y_{t-2} \\ u_t \end{pmatrix} = \begin{pmatrix} \phi & 0 & 0 & \rho \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & \rho \end{pmatrix} \begin{pmatrix} y_{t-1} \\ y_{t-2} \\ y_{t-3} \\ u_{t-1} \end{pmatrix} + \begin{pmatrix} x_t'\beta \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} \epsilon_t \\ 0 \\ 0 \\ \epsilon_t \end{pmatrix} \tag{2}$$

where

$$H_t' = \left\{ \begin{array}{ll} [\frac{1}{3} \;\; \frac{1}{3} \;\; \frac{1}{3} \;\; 0] & \text{for } \; t = 3,6,9,\ldots \\ [0 \;\; 0 \;\; 0 \;\; 0] & \text{otherwise} \end{array} \right\}$$

[13] For simplicity, we assume $p = 1$ since otherwise the number of different models to compare to one another would be quite large. Unreported results based on higher order values of p showed that in most cases, higher order autoregressive parameters were insignificant.

Notice that due to the limited data availability in the Euro area, for our purpose of constructing monthly GDP series for all member countries of the Euro area, the interpolation method needed to be generalized to incorporate the possibility of using also annual data for interpolation. This is easily done by letting the indicator variable contain observations in annual frequency. As a matter of course, the measurement equation has to be adapted accordingly.[14]

We now briefly show how different interpolation models suggested in the literature can be obtained by fixing either the ϕ or the ρ parameter in the above model. Chow-Lin (1971) suggest a regression model without lagged dependent variables, but autoregressive errors, hence the Chow-Lin model obtains by fixing ϕ to be zero and by letting ρ be estimated freely. Fernandez (1981) suggests a model in first differences to take account of nonstationarity in the data. As the reader will easily notice, this model is obtained by letting the regression residuals be a random walk, i.e. $\rho = 1$ and $\phi = 0$. Notice that one can easily generalize this model to become a dynamic regression model in first differences by allowing ϕ to be nonzero. As noted above, Mitchell et al. (2005) suggest a dynamic regression model with IID errors, i.e. they let ϕ be nonzero, but have $\rho = 0$. Again, this model can be generalized to have autocorrelated residuals.[15] Table A.1 summarizes the different interpolation methods and their corresponding parameter restrictions.

In our interpolation exercise, we estimate for all countries the six models summarized above via Maximum Likelihood using the Kalman filter. We then perform country by country a set of bilateral likelihood ratio tests to discover whether the imposed restrictions are borne by the data or not and select the most appropriate model accordingly. We then aggregate the corresponding series using the method described below to obtain our benchmark series of monthly real GDP for the Euro area.

To assess the quality of interpolation, we follow Bernanke, Gertler, and Watson (1997) by using R^2 measures of fit. Denoting $y_{t|T}$ the expected value of monthly GDP in period t conditional on the estimated model parameters

[14]The countries for which the adapted algorithm had to be used were Belgium, Greece, Ireland, Luxembourg, and Portugal. Since those five countries only have a total weight of 6.7 % in our series of Euro area GDP, the uncertainty introduced by performing annual to monthly interpolations is rather small.

[15]It is important to note that the model we refer to here effectively is only a simplified version of the model suggested by Mitchell et al. (2005) who in addition allow the dependent variable to be stated in logarithms and also allow lagged observations of the related series to enter the regression.

Model	ϕ	ρ
Static model in levels with IID residuals	0	0
Static model in levels with AR(1) residuals (Chow-Lin)	0	free
Static model in 1st differences with IID residuals (Fernandez)	0	1
Dynamic model in levels with IID residuals (Mitchell et al)	free	0
Dynamic model in 1st differences with IID residuals	free	1
Dynamic model in levels with AR(1) residuals	free	free

Table 5: This table summarizes the parameter restrictions that have to be imposed on the model (1)-(2) in order to obtain a particular type of interpolation model.

and the full information set, this measure of fit is given by

$$R^2_{levels} = \frac{Var(y_{t|T})}{Var(y_{t|T}) + Var(u_{t|T})}.$$

As we will see below, when both the interpoland and interpolator variables are upward trending, this measure of fit will be very close to unity in most cases. Hence, it appears more informative to report the R^2 in first differences:

$$R^2_{diffs} = \frac{Var(\Delta y_{t|T})}{Var(\Delta y_{t|T}) + Var(\Delta u_{t|T})}.$$

A.2 A monthly time series for real US GDP

This appendix documents the monthly real GDP series from 1967:1 to 2002:09, used for the US in section 3.1. It is based on time series for quarterly real GDP, industrial production, the total civilian employment, and real disposable personal income, which have all been obtained from the Federal Reserve Bank of St. Louis web site. The interpolation is done using the procedure described above. According to the results of bilateral likelihood ratio tests, the best interpolation method for the set of series used is the Chow-Lin model, i.e. the static model in levels with autocorrelated residuals. Values of 0.99 and 0.58 for R^2_{levels} and R^2_{diffs} indicate a good overall interpolation quality. Figure 4 provides a plot of the resulting series and a comparison of the implied quarterly growth rates with the actual quarterly growth rates.

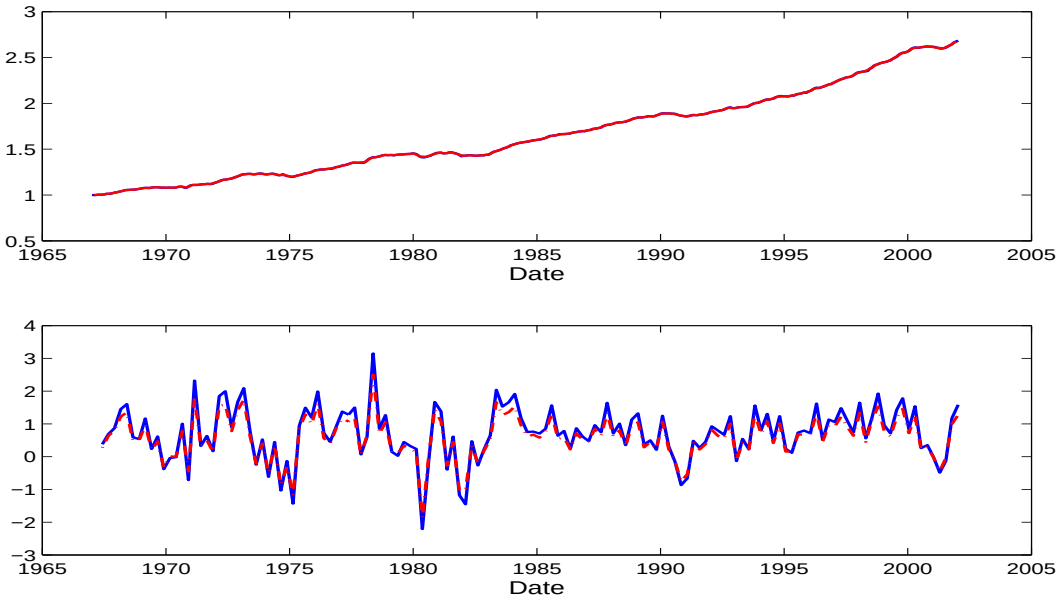

Figure 4: *Monthly real GDP series for the US, based on the four time series GDP96, INDPRO, CE16OV, and DSPIC96, obtained from the Federal Reserve Bank of St. Louis web site. The interpolation is done using the procedure described above.*

A.3 A monthly time series for real Euro area GDP

This section suggests a monthly time series for real Euro area GDP, and points to a number of difficulties.

A.3.1 Difficulties

Official data covering the Euro area as a whole only exist from 1991 on. Hence, to obtain Euro area aggregates that cover a longer time span, one has to perform some aggregation of individual countries' real GDP series. However, since exchange rate changes have to be taken into account in the pre-Euro period, aggregation of real GDP series across the Euro area member countries is not a trivial task. Competing methods with different merits and shortcomings have been proposed in the literature, and the choice of an appropriate aggregation method seems largely to depend on the requirements one wants it to fulfil. Two often cited references for constructing Euro area aggregates from the individual countries' series are Fagan, Henry, and Mestre (2001) and Beyer, Doornik, and Hendry (2001). To be used for estimation in the area-wide econometric model of the ECB, Fagan et al. have constructed a dataset of quarterly Euro area aggregates covering the period from 1970q1

to 2000q4 and including a series of real GDP.[16] They adopt an aggregation method with fixed weights that are computed as the countries' respective shares in total GDP at market prices in 1995. Beyer, Doornik, and Hendry (2001) propose an aggregation method with time-varying weights that are computed on the basis of exchange rates for converting into a common currency (i.e. the ECU in applications to the Euro area). The authors claim their method to be more general than the one adopted by Fagan et al. However, it only delivers estimates of euro area aggregates from 1979 onwards when the European monetary system was constituted. Beyer et al. provide aggregated Euro area time series for real GDP, nominal GDP, and M3 over the post-1979 period.

The availability of historical quarterly real GDP time series varies considerably across the Euro area member countries. While, for example, real GDP data for Italy is available from 1960 onwards, the equivalent time series for Ireland only covers the post 1997 period. For most of the Euro area countries, chained indices of GDP volume are available over longer time spans than real GDP series. Since volume indices can be directly transformed into 'constant price' level data, we use these to generate our aggregate monthly time series of real GDP for the Euro area on the basis of which we then perform the business cycle dating exercise. Yet, since such series are not available for all Euro area countries on a quarterly basis from 1970 onwards, annual series had to be used for some countries, namely Belgium, Greece, Ireland, Luxembourg, and Portugal.

The availability of related monthly series that can be used for interpolating quarterly real GDP is also very limited. While monthly series for industrial production and are available from 1970 onwards for all Euro area member countries except for Ireland, additional variables that are potentially useful for interpolating real GDP are rather scarce. For some countries, a chained index of real retail sales is available from the OECD. For others, if available, monthly employment or export series have been used as additional related series.

A.3.2 The Approach Employed

This section describes our approach to constructing a monthly real GDP series for the Euro area subject to the requirements and limitations mentioned

[16]The authors note that to construct the dataset they have used data from different sources, some of which are not publicly available. Further, when only annual data were available, quarterly time series were constructed by means of some interpolation method similar to the one used in this paper.

above, especially the problem of data availability for the individual member countries.

1. Interpolation of the individual countries' GDP volume series via the method described above, using industrial production, and, if available, real retail sales, and/or employment as related series. The instrumental variables have been obtained from the OECD and the IMF database, respectively, the chained indices of GDP volume are from the OECD database. All country data is seasonally adjusted before aggregating.[17] Table 6 summarizes for all countries the set of related series that have been used for interpolation, the method that has been found to perform best, as well as R^2 statistics as measures of interpolation quality.

2. Next, we compute a weighted average of the interpolated GDP volume series using the so-called "index method" for aggregation (see Fagan and Henry (1998)). According to this method, the log level index for aggregate monthly GDP is given by

$$log(Y) = \sum_{i=1}^{N} w_i log(Y_i).$$

   We use the weights provided by Fagan, Henry and Mestre (2001) in their latest update of the ECB's area-wide model dataset for the aggregation.[18]

[17] There clearly is a potential sensitivity of the dating outcome with respect to the seasonal adjustment method employed. Lommatzsch and Stephan (2001) study this issue in detail and find that for quarterly Euro area real GDP series, the dating of the classical cycle is almost completely unaffected by the choice of seasonal adjustment method. Although we expect this issue to be more relevant for the monthly dating exercise that we perform, it is not the focus of this paper to study the sensitivity of our results to different seasonal adjustment methods. We instead rely on the seasonal adjusted data from official sources to make our procedure as transparent as possible.

[18] To see whether the weighting scheme used for aggregation has an impact on the business cycle dating results, we have also constructed an aggregate series using time-varying weights computed as linear interpolations of the annual shares of total GDP at market prices. This series has a peak in 1975:5 instead of 1975:4, all other turning points being equal. Moreover, it exhibits an additional peak in 2001:5. However, since this method of computing time-varying weights is unusual in the literature, we do not rely on this series for the dating exercise. Notice that the OECD's methodology of constructing international area aggregates with time-varying weights for volume indices requires data on the corresponding value series (see OECD(2002) and Schreyer (2001)). However, as Schreyer (2001) notes, in case such information is missing, value-added shares at exchange rates or PPPs of a fixed base-year should be used. This is exactly the approach adopted here. As already note above, we could not adopt the aggregation method suggested by Beyer et al. (2001) since this approach can only be used for constructing aggregates in the post 1979-period.

Since the OECD's GDP volume series for unified Germany only starts in 1991, we have used the West-German series as the historical German series, rescaled to the whole German series by multiplying it with the ratio of the two series in the first quarter of 1991. This is the approach that has also been used by FHM for the construction of their area-wide model dataset.

Country	Interpolation Method	Rel. Series	R^2_{levels}	R^2_{diffs}	$w_i(\%)$
Austria	Dynamic, levels, AR(1)	IP, Empl	0.99	0.49	3.0
Belgium	Static, 1st diffs, IID	IP, Rsal	0.99	0.89	3.6
Finland	Static, levels, AR(1)	IP, Rsal	0.99	0.72	1.7
France	Static, levels, AR(1)	IP	0.99	0.69	20.1
Germany	Static, levels, AR(1)	IP, Rsal	0.99	0.81	28.3
Greece	Static, levels, AR(1)	IP, Rsal	0.98	0.89	2.5
Ireland	Dynamic, levels, IID	Rsal, Expts	0.99	0.24	1.5
Italy	Static, levels, AR(1)	IP	0.99	0.57	19.5
Luxembourg	Dynamic, levels, IID	IP, Empl	0.99	0.13	0.3
Netherlands	Static, levels, AR(1)	IP, Rsal	0.99	0.70	6.0
Portugal	Static, levels, AR(1)	IP	0.99	0.69	2.4
Spain	Static, levels, AR(1)	IP	0.99	0.55	11.1
					100.0

Table 6: *Monthly interpolation of quarterly and annual GDP volume data: Interpolation specification, related series used for interpolation, goodness of fit, and weights in the aggregate series corresponding to the countries' shares in total Euro area GDP in 1995.*

A.3.3 Result

The resulting time series is available from the authors upon request. A visual comparison to the latest update of the time series by Fagan, Henry and Mestre (2001) is given in figure 5. The upper panel plots our series (solid) against the FHM series (dash-dotted) in levels, whereas the lower panel plots the quarterly growth rates of both series. Obviously, our monthly series is close to the quarterly series, with a slightly more jagged appearance (as desired) due to the interpolation using related series. On the other hand, the FHM series exhibits slightly more volatile quarterly growth rates.

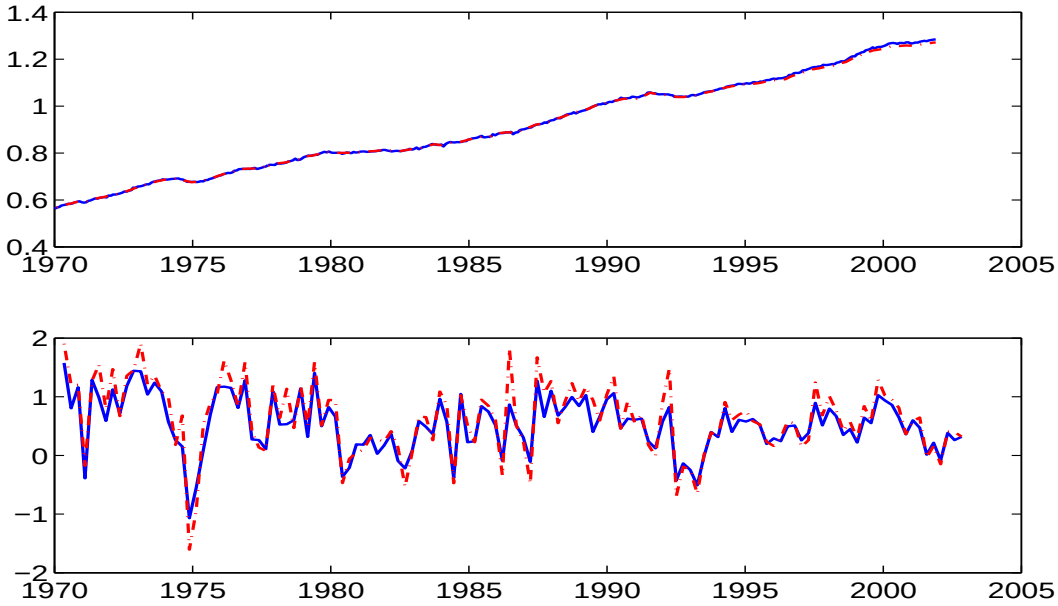

Figure 5: *Comparison of our monthly Euro area real GDP time series to the quarterly Euro area real GDP time series by Fagan, Henry and Mestre (2001). The two a very close, with our interpolated monthly series having a slightly more jagged appearance than the quarterly series.*

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