DISCUSSION PAPER SERIES

No. 4377

TOWARDS A MONTHLY BUSINESS CYCLE CHRONOLOGY FOR THE EURO AREA

Emanuel Mönch and Harald Uhlig

INTERNATIONAL MACROECONOMICS

Centre for Economic Policy Research

www.cepr.org

Available online at: **www.cepr.org/pubs/dps/DP4377.asp**

ISSN 0265-8003

TOWARDS A MONTHLY BUSINESS CYCLE CHRONOLOGY FOR THE EURO AREA

Emanuel Mönch, Humboldt Universität
Harald Uhlig, Humboldt Universität and CEPR

Discussion Paper No. 4377
May 2004

Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

CEPR Discussion Paper No. 4377

May 2004

ABSTRACT

Towards a Monthly Business Cycle Chronology for the Euro Area*

This Paper is an exercise in dating the euro area business cycle on a monthly basis. We construct several monthly European real GDP series, and then apply the Bry-Boschan (1971) procedure. Using this method we identify four business cycles. Studying further indicators of business activity, we conclude that the euro area has experienced three business cycles since 1970. We propose a simple amplitude/phase-length criterion for the Bry-Boschan procedure 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 NBER and CEPR.

JEL Classification: B41, C22, C82, E32 and E58
Keywords: Bry-Boschan, business cycle, euro area, european business cycle and NBER methodology

Emanuel Mönch
Humboldt University
Wirtschaftswissenschaftliche Fakultät
Spandauer Str. 1
10178 Berlin
GERMANY
Email: moench@wiwi.hu-berlin.de

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=160846

Harald Uhlig
Department of Economics
Humboldt University
Spandauer Strasse 1
10178 Berlin
GERMANY
Tel: (49 30) 2093 5926/7
Fax: (49 30) 2093 5934
Email: uhlig@wiwi.hu-berlin.de

For further Discussion Papers by this author see:
www.cepr.org/pubs/new-dps/dplist.asp?authorid=122164

*This Paper was previously circulated under the title ‘The Euro zone business cycle: A Dating Exercise’. We thank our discussant Gianni Amisano for helpful comments and Jérôme Henry for providing us with the latest update of the ECB’s area-wide model database.

Submitted 23 March 2004

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. This should be a first and useful step, even if one considers it necessary to fine-tune that choice by closely examining more data in a time window close to the dates found by this procedure. 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, see appendix A. We will show that this is indeed the case in section 2, 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, although the Bry-Boschan procedure accounts for minimum cycle and phase length criteria, it does not comprise an amplitude rule. 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 criterion in section 3.4, 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 B.1.We have done so for the exercise in section 2 and discuss the resulting series in appendix B.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. Even there, data availability is a serious problem. The details on available data and our construction are provided in appendix B.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 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 The US and NBER business cycle dates

As a first check on our procedure and for comparison, we have applied the programmed turning point selection algorithm to US data. To that end, we have constructed a monthly time series for real US GDP for the period 1967:1 to 2002:09 (see appendix B.1 for details on the interpolation method) and applied the Bry-Boschan procedure (see appendix A for details on the implementation), augmented with an appropriate amplitude rule.

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.

A comparison of the dates is given in table 1. Note that the Bry-Boschan

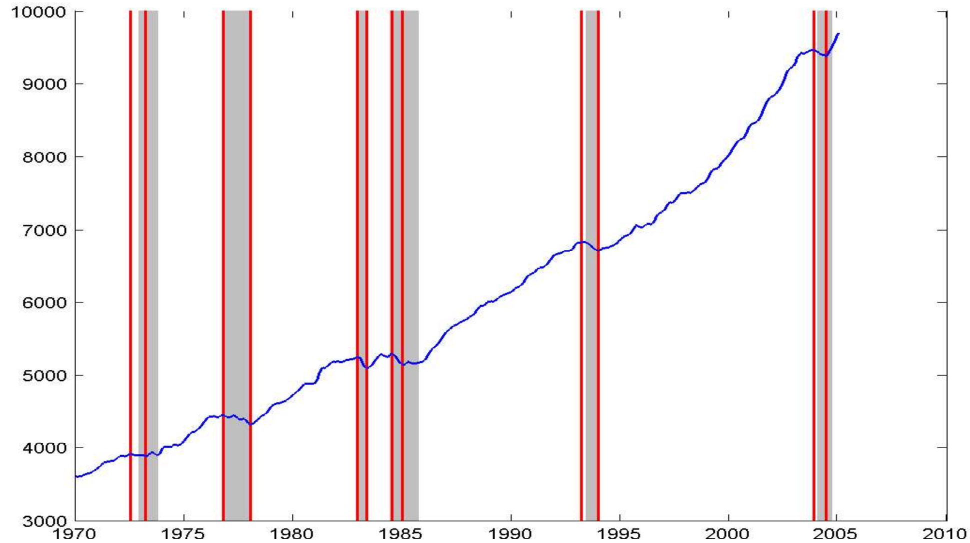

Figure 1: *A comparison of official NBER dates and Bry-Boschan dates. The recessions identified by the NBER are indicated by shaded areas, the peaks and troughs determined by the Bry-Boschan procedure by vertical bold lines.*

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. For the final selection of turning points, we have replaced the phase length criterion in the Bry-Boschan algorithm with a combined amplitude/phase-length criterion, see section 3.4 for a detailed discussion.

Peaks:						
monthly GDP	69M8	73M11	80M1	81M8	90M5	01M1
NBER	69M12	73M11	80M1	81M7	90M7	01M3
Troughs:						
monthly GDP	70M4	75M2	80M6	82M2	91M2	01M8
NBER	70M11	75M3	80M7	82M11	91M3	01M11

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

3 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 3.1, and in more detail in appendix B.3. In section 3.2 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 3.3. Based on these results, we finally suggest in section 3.4 a simple amplitude/phase-length criterion for the Bry-Boschan procedure that rules out short and flat business cycle expansions.

3.1 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 B.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 using the interpolation procedure proposed by Bernanke, Gertler, and Watson (1997, BGW henceforth). This method treats monthly figures of real GDP as the unobserved component in a state-space model, employing the observation equation to ensure that quarterly figures are the averages of three consecutive monthly observations. The method is similar to the well-known Chow-Lin (1971) procedure, albeit allowing for a more general treatment of the serial correlation in the error terms of the regression. We then have aggregated these series to obtain a measure of Euro area real GDP using the same aggregation method and weights as Fagan, Henry, and Mestre in their latest update of the ECB's area wide model dataset.

Since quarterly GDP series are only available from 1970 onwards for seven out of the twelve member countries of the Euro area, we had to adapt BGW's method to interpolate annual GDP data for the remaining five countries. This is easily done in the flexible Kalman filter setup that BGW's procedure is based on. As related variables, we have used monthly series for industrial production, the consumer price index, real retail sales, employment or exports, depending on availability, see table 6.[1]

The other two series are based on interpolations of the quarterly real GDP series constructed by Fagan, Henry and Mestre (2001), FHM in short, 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 B.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.[2]

3.2 The Euro Area Business Cycle Dates

Applying the Bry-Boschan procedure, we obtain the results listed in table 2. As can be seen from the dating results, the programmed turning point selection procedure finds four business cycles for all three series.[3] 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 pro-

[1]Although prices are not necessarily closely related to output, we have included CPI into the set of related variables since it reflects a component of business activity which is not captured by the other related variables. Undocumented results have shown that the use of CPI as related variable does not have an impact on the dating results.

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

[3]Notice that the minimum phase length criterion included in the original Bry-Boschan procedure has been set off here.

Peaks:				
Our series	74M8(QIII)	80M3(QI)	82M3(QI)	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. Further, the quarterly turning points identified by the CEPR are provided.*

duction 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. 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.[4] However, applying the Bry-Boschan algorithm to the linear interpolation of the previous version

[4]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.

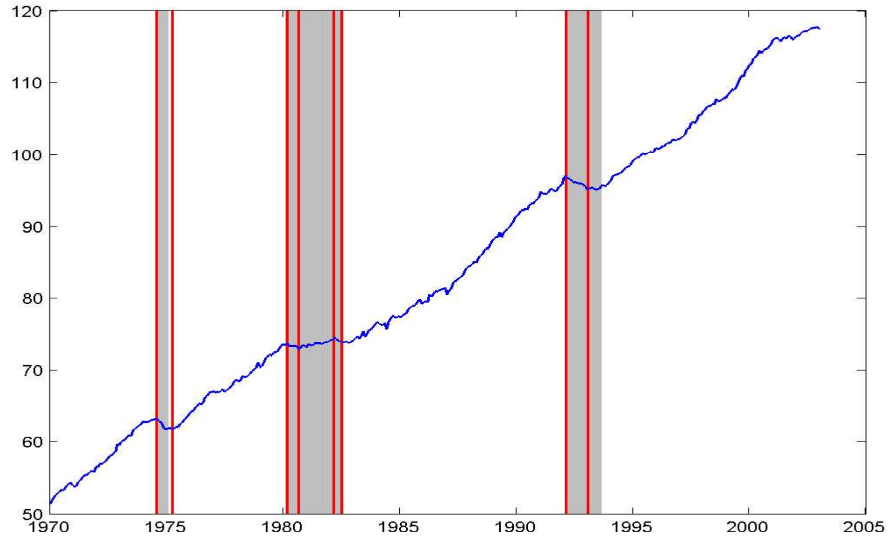

Figure 2: *Dating the Euro area business cycle based on our monthly series for real Euro area GDP. The recessions identified by the CEPR are indicated by shaded areas, the peaks and troughs determined by the Bry-Boschan procedure by vertical bold lines. The quarterly CEPR dates have been interpreted 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.*

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.[5] 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.

[5] 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.

3.3 Examining the 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.[6] 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.[7]

[6] 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.

[7] According to our measure of monthly GDP for the Euro area, output grew only about

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.

3.4 A Simple Combined Amplitude/Cycle-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 have seen above, with the minimum phase length criterion switched off, the Bry-Boschan procedure identifies two recessions in Euro area real GDP in the early 1980s. Both these recessions are short and not very pronounced. Moreover, the business cycle upturn in between these two recessions is very brief (19 months) and characterized by comparably low annualized growth of less than 1.4%. During the same period, 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.

2.2 % in between the two peaks identified by the Bry-Boschan procedure in September 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%.

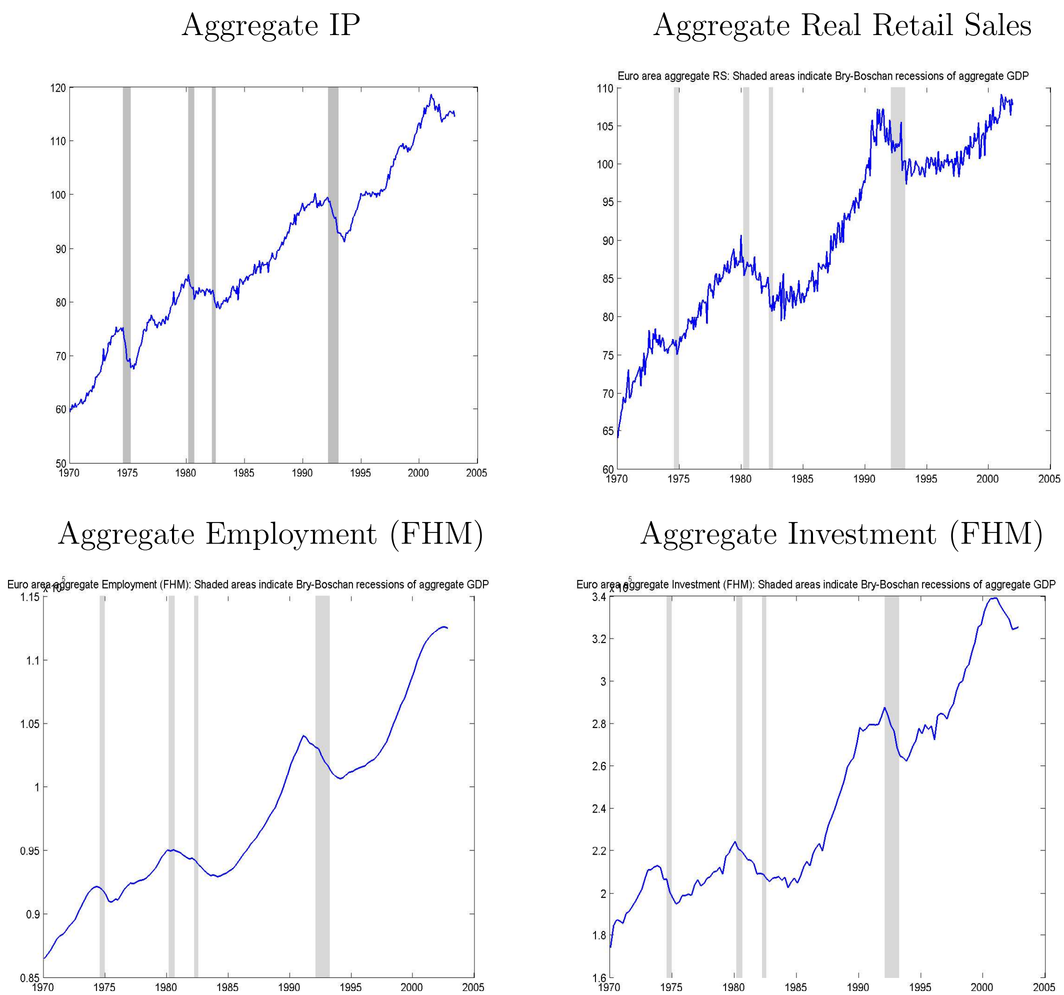

Table 3: *Related aggregate series for the Euro area. The shaded areas indicate the recession periods identified by the Bry-Boschan procedure based on our monthly series of aggregate GDP.*

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.[8]

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.[9] After having studied the time series behavior of GDP for different countries, however, it is our opinion 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.[10] 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 define 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-

[8]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.

[9]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.

[10]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 that 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.

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.[11]

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.[12] 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.

We apply the augmented Bry-Boschan algorithm to our monthly real GDP series for the US and the Euro area. As expected, the dating results for the US do not change since the short recovery in between the two recessions in the early 1980s was rather pronounced. In contrast, the combined amplitude/phase-length rule eliminates the short expansion in the early 1980s for all three monthly time series of Euro area real GDP, matching the dating decision of the CEPR. Figure 3 and table 4 summarize this result.

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.

[11]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 (Agresti and Mojon (2001)), this choice appears by all means appropriate.

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

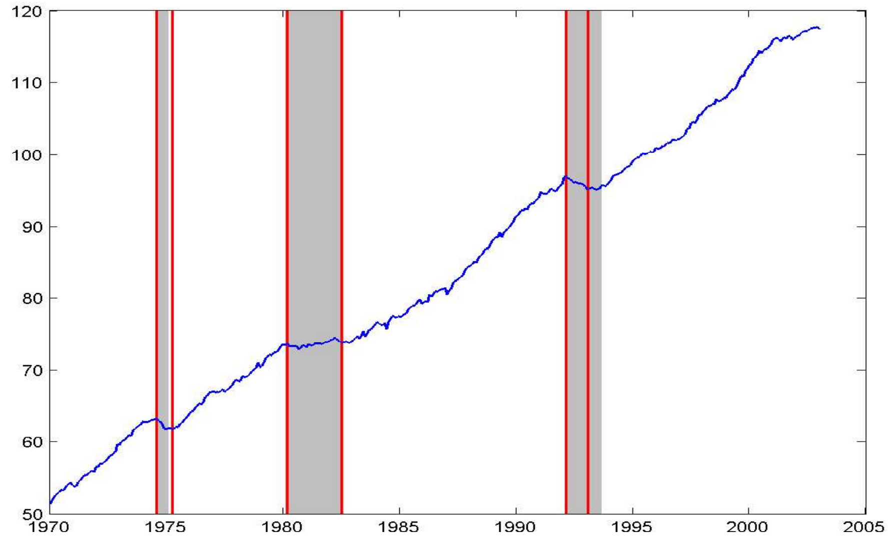

Figure 3: *Dating the Euro area business cycle based on our monthly series for real Euro area GDP. The Bry-Boschan algorithm has been augmented with the combined amplitude/phase-length criterion discussed above. The recessions identified by the CEPR are indicated by shaded areas, the peaks and troughs 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.*

For US data, we have shown that this procedure comes close to replicating the official NBER dates, although it cannot replicate them exactly.

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 series for individual countries, using different monthly available variables as instruments. The interpolation has been done employing a variant of the procedure suggested by Bernanke, Gertler, and Watson (1997) which makes use of Kalman filter techniques. In a second step, we have aggregated the individual interpolated series to obtain a monthly real GDP series for the Euro area. For the aggregation we have used the same weights and methodology as Fagan, Henry, and Mestre (2001) in their construction of the ECB's area-wide model dataset.

As a cross-check on the dating results obtained using our series of monthly Euro area real GDP, we have constructed two alternative series. One is a simple linear interpolation of the latest update of the quarterly series provided

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.*

by Fagan, Henry, and Mestre (2001), whereas the other has been obtained by interpolating the same series using a proxy for aggregate Euro area industrial production as related variable. 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 Bry-Boschan dating procedure has identified four peaks and four troughs over the period 1970 to 2002, see table 2. Since the two contractions and the interjacent expansion identified in the early 1980s are not very pronounced, we have 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. Based on this observation we finally propose a combined amplitude/phase-length criterion for the Bry-Boschan procedure that rules out expansionary phases which are short and flat. Applying the modified Bry-Boschan procedure to monthly GDP series for the US and the Euro area, we are able to replicate the turning point decisions of the NBER and the CEPR, respectively.

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.

References

[1] Artis, Michael, Zenon G. Kontolemis, and Denise R. Osborne (1997): "Business Cycles for G7 and European Countries", *Journal of Business* 70(2), 249-279.

[2] Artis, Michael, Massimiliano Marcellino, and Tommasp Proietti (2002): "Dating the Euro Area Business Cycle", mimeo, European University Institute Florence

[3] Beyer, Andreas, Jürgen A. Doornik, and David F. Hendry (2001): "Constructing Historical Euro-Zone Data", *The Economic Journal* 111, F103-F121.

[4] Bernanke, Ben, Gertler, Mark, and Mark Watson (1997): "Systematic Monetary Policy and the Effects of Oil Price Shocks", *Brookings Papers on Economic Activity*, 1997(1), 91-157.

[5] Bry, Gerhard and Charlotte Boschan (1971): "Cyclical Analysis of Economic Time Series : Selected Procedures and Computer Programs", *NBER Technical Working Paper* No. 20.

[6] Centre for Economic Policy Research : "Business Cycle Dating Committee of the Centre for Economic Policy Research", CEPR, September 2003

[7] Chow, Gregory C., and An-loh Lin (1971): "Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series", The Review of Economics and Statistics, 53(4), 372-375.

[8] Diebold, Francis X. and Glenn D. Rudebusch (1992): "Have Postwar Economic Fluctuations Been Stabilized?", *American Economic Review* 82(4), 993-1005.

[9] Fagan, Gabriel and Jérôme Henry (1998): "Long run money demand in the EU: Evidence for area-wide aggregates", *Empirical Economics* 23(3), 483-506.

[10] Fagan, Gabriel, Jérôme Henry, and Ricardo Mestre (2001):"An Area-Wide Model for the Euro Area", ECB Working Paper No. 42.

[11] Harding, Don and Adrian Pagan (2001a): "Dissecting the Cycle: A Methodological Investigation", *Journal of Monetary Economics* 49(2), 365-381.

[12] Harding, Don and Adrian Pagan (2001b): "Extracting, Analysing, and Using Cyclical Information", Mimeo, University of Melbourne.

[13] King, Robert G. and Charles I. Plosser (1994): "Real Business Cycles and the Test of the Adelmans", *Journal of Monetary Economics* 33, 405-438.

[14] OECD (2002): "A complete and consistent macro-economic data set of the Euro area, methodological issues and results", OECD.

[15] Romer, Christina D. (1994): "Remeasuring Business Cycles", *Journal of Economic History* 54(3), 573-609.

[16] Schreyer, Paul (2001): "Some observations on international area aggregates", OECD Statistics Working Paper No. 2001/01.

[17] The Business Cycle Dating Committee: "The NBERs Business-Cycle Dating Procedure", NBER, October 2003.

A The Algorithm of Bry and Boschan (1971)

A.1 Description

Bry and Boschan (1971) provide a nonparametric, intuitive and easily implementable algorithm to determine peaks and troughs in individual time series. Apart from some minor modifications, they broadly follow the analysis of Burns and Mitchell (1946). Applying their procedure to series whose turning points have been officially determined by the NBER, Bry and Boschan show that it identifies 95% of the turns (435 in total) found by the NBER with 90 % having identical dates. Due to this good performance in replicating the NBER's decisions, many authors have adopted Bry and Boschan's algorithm in order to determine NBER reference turning points for individual time series such as industrial production or real GNP.

Bry and Boschan's procedure consists of six sequential steps. First, on the basis of some well-specified criterion, extreme observations are identified and replaced by corrected values.[13] Second, 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 Spencer curve), 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 criteria concerning the length of cyclical phases and the alternation of peaks and troughs, these are chosen as the intermediate turning points. Fourth, the same procedure is repeated using a short-term moving average with the number of lags included depending on the MCD (months of cyclical dominance) measure. 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.

Since Bry and Boschan's algorithm is designed for monthly series, they treat quarterly as monthly time series that take on the same value in the three consecutive months of a quarter and define the middle month of a quarter as the turning point. However, the procedure can also be easily adapted to quarterly time series (see, e.g., Harding and Pagan (2001a)). Several authors show that application of Bry and Boschan's method to quarterly measures

[13] For a detailed description of the procedure, the reader is referred to Bry and Boschan's paper.

of real GNP obtains turning points that are very similar to those determined by the NBER for aggregate activity in the US economy (King and Plosser (1994), Harding and Pagan (2001b)).

A.2 Implementation

A Matlab program that determines the business cycle turning points according to the Bry-Boschan algorithm, available from the authors on request, has been run on the logarithm of monthly real GDP to determine the business cycle turning points listed in section 3.2. The program leaves unconsidered two minor features of the original procedure, namely the adjustment for outliers in the original time series and a calculation rather than an a priori choice of the MCD (months of cyclical dominance) measure. Following Bry and Boschan (1971), the MCD is the "number of months required for the systematic trend-cycle forces to assert themselves against the irregular time series component" (ibid, p. 25). For details on the way it can be calculated, the authors refer to Shiskin (1960). According to Bry and Boschan, MCD usually falls into the range from 3 to 6 months. Thus, for simplicity, we set the MCD to 3. We have further reduced the moving average window parameter in the first step of Bry and Boschan's procedure from twelve to eight months. This seemed required in order to obtain the NBER dates, especially at the beginning and at the end of the sample. Finally, we have turned off the minimum-phase-duration requirement in step III and V of the procedure. With that criterion we find one short cycle in Euro area real GDP in the early 1980s. As has been discussed in section 3.4, we replace it with a combined amplitude/phase-length criterion, ruling out business cycle expansions shorter than 21 moths during which growth is below an annual rate of 1.5 %.

B Constructing monthly time series for real GDP

B.1 Interpolation

We adopt the interpolation approach suggested by Bernanke, Gertler, and Watson (1997, BGW henceforth), which treats monthly figures of real GDP as the unobserved component in a state-space model that can be estimated using the Kalman filter. In this setting, the observation equation is employed to ensure that quarterly figures are the averages of the three consecutive monthly observations. BGW assume the following regression model, allowing for autoregressive error terms.[14]

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

This regression model forms the basis of the transition equation of the state-space form. Defining the indicator variable y^+ as

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

BGW have the following measurement equation:

$$\begin{aligned} y_t^+ &= \frac{1}{3}\sum_{i=0}^{2} y_{t-i}, \quad t = 3, 6, 9, 12, \ldots \\ y_t^+ &= 0 \quad \text{otherwise.} \end{aligned}$$

Notice that there is no error term in this equation since the mean of three consecutive months shall exactly equal the quarterly observation.

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, BGW's 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.[15]

To assess the quality of interpolation, BGW suggest using R^2 measures of fit. Denoting $y_{t|T}$ the expected value of monthly GDP in period t conditional on

[14] BGW suggest scaling y prior to interpolation by the quarterly averages of some monthly observable time series such that the scaled series is nontrending. Afterwards, the interpolated series is multiplied by the monthly observations of this scaling variable. To alleviate notation, the scaling step is omitted here. For their interpolation exercise with US data, BGW use the monthly available personal consumption expenditure series as scaling variable. Due to the lack of appropriate scaling variables for the Euro area countries, we adopt BGW's method without scaling the series. To deal with the problem of a diffuse initial prior for the Kalman filter that results from this omission, we adopt the common approach to start with an arbitrarily large variance-covariance matrix of the unobserved state.

[15] 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.

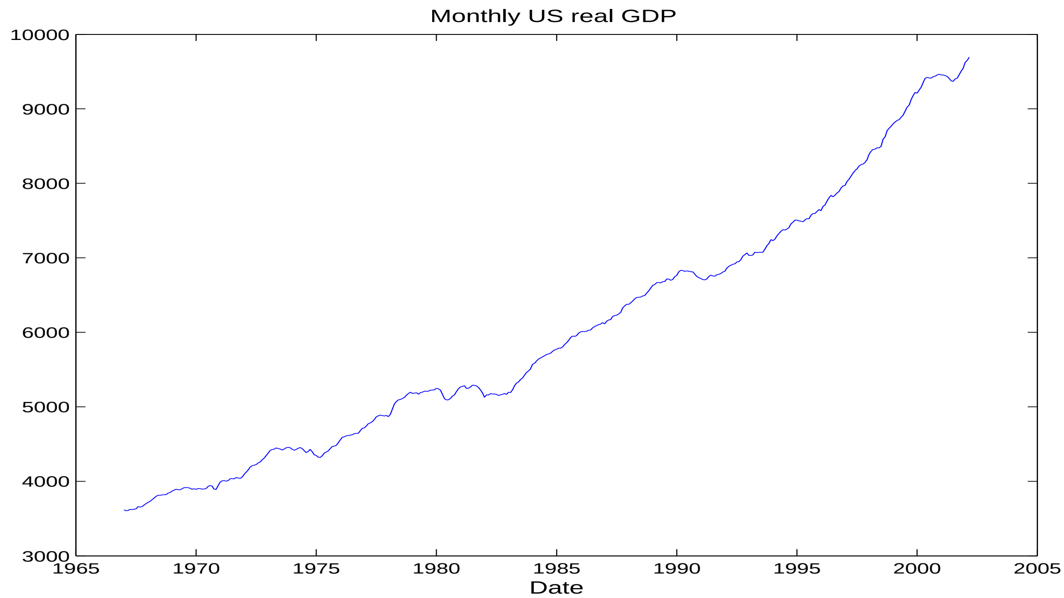

Figure 4: *Monthly real GDP series for the US, based on the four time series GDP96, INDPRO, CPI, CE16OV, and DSPIC96, obtained from the Federal Reserve Bank of St. Louis web site. The interpolation is done using the procedure described above.*

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

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

B.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 2. It is based on time series for quarterly real GDP, industrial production, the consumer price index, 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. As indicated by a R^2 of 0.98, the interpolation quality is rather good. Figure 4 provides a plot of the resulting series.

B.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.

B.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. Table 5 summarizes the availability of GDP series in the databases of the OECD and the IMF for each

[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.

	OECD		IMF	
Country	real GDP	GDP volume	real GDP	GDP volume
Austria	1988Q	1964Q	1976Q	1964Q
Belgium	1980Q	1980Q	1980Q	1980Q
Finland	1975Q	1964Q	1975Q	1970Q
France	1978Q	1964Q	1997Q	1970Q
Germany	1991Q	1991Q	1991Q	1960Q
Greece	1961A	1970A	1971Q	1975Q
Ireland	1961A	1970A	1997Q	1997Q
Italy	1970Q	1964Q	1988Q	1960Q
Luxembourg	1971A	1970A	1997A	1996Q
Netherlands	1977Q	1964Q	1977Q	1977Q
Portugal	1995Q	1988Q	1988Q	1977Q
Spain	1980Q	1964Q	1970Q	1970Q

Table 5: *This table summarizes the availability of different GDP series for the EMU12 countries in the OECD and IMF database. In each cell, the year of the first observation, and the frequency of observations (Q for quarterly and A for annual) are provided.*

of the Euro area member countries. It shows that for most of the countries chained indices of GDP volume are available over longer time spans than real GDP series. According to Schreyer (2001), volume indices can be easily transformed into 'constant price' level data by setting the volume index to equal one in a given reference year and by multiplying through with the current price value of the same year. Hence, these chained indices of GDP volume can be used to generate an aggregate monthly series of real GDP for the Euro area which is the approach we apply here. 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 the consumer price index 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, monthly employment or export series have been used as additional related series.

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

Due to this problem, a preliminary choice had to be made concerning the measure of GDP to employ for the construction of an Euro area aggregate. According to the better availability of the OECD's GDP volume index series than other measures of GDP for most of the Euro area member countries, we have decided to use these series as measures of GDP. Since those are available on a quarterly basis from 1970 onwards only for seven out of the twelve countries, we had to perform annual to monthly interpolations for the remaining five countries. The construction of our monthly real GDP series encompassed the following steps:

1. Interpolation of the individual countries' GDP volume series via the method described above, using industrial production, the consumer price index and, if available, real retail sales, employment or exports 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. Table 6 summarizes for all countries the set of related series that have been used for interpolation and provides R^2 statistics as a measure 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. [17]

[17] 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

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	Related Series	R^2	weight (%)
Austria	IP, CPI, Empl	0.84	3.0
Belgium	IP, CPI, Rsal	0.79	3.6
Finland	IP,CPI, Rsal	0.83	1.7
France	IP, CPI	0.97	20.1
Germany	IP, CPI, Rsal	0.93	28.3
Greece	IP,CPI, Rsal	0.55	2.5
Ireland	Rsal, Expts	0.80	1.5
Italy	IP, CPI	0.94	19.5
Luxembourg	IP, CPI, Empl	0.81	0.3
Netherlands	IP, CPI, Rsal	0.93	6.0
Portugal	IP, CPI	0.69	2.4
Spain	IP, CPI	0.96	11.1
			100.0

Table 6: *Monthly interpolation of quarterly and annual GDP volume data: 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.*

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.

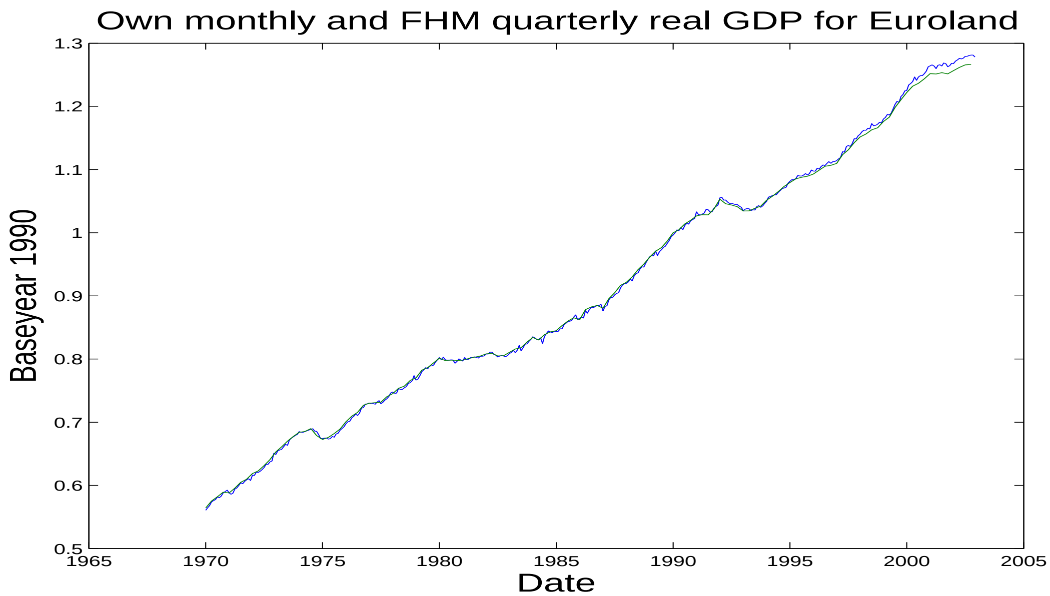

Figure 5: *Comparison of our monthly Euro area real GDP time series to the quarterly Euro area real GDP time series by Fagan, Henry and Mestre (2001). The two a very close, with our interpolated monthly series having a slightly more jagged appearance than the quarterly series.*

B.3.3 Result

The resulting time series is available from the authors on request. A visual comparison to the latest update of the time series by Fagan, Henry and Mestre (2001) is given in figure 5. 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. There is a slight deviation in level at the end of the sample period that might be due to the use of recently revised data in the FHM series. However, this deviation will not have an influence on the dating result since the last identified turning point was in 1993.