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Chain-linking in Austrian Quarterly National Accounts and the Business Cycle

by
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In 2005, European Union member countries began to calculate national account volume estimates using prices from the previous year, rather than from a fixed base year. For quarterly national accounts, the average of the total previous year – and not of the previous quarter – began to serve as the price basis. This allows for the use of a Laspeyres-type quantity index.

In order to obtain a time series of absolute values of volume estimates, it is necessary to chain-link growth rates. This is straightforward when calculating annual figures, but when calculating quarterly figures, EU countries can choose from one of three methods. This results in different outputs, time-series properties and, possibly, price-adjusted quarterly national account figures.

The current study demonstrates the different results obtained using the three methods, when applied to Austrian quarterly GDP data. I observe the consequences of consecutive time-series-based processing, such as seasonal adjustment and business cycle analysis. Although dating turning points are rather robust using all three methods, seasonal and workday adjustment and detection of outliers based on time-series modelling can be negatively affected, as can business cycle dating.

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It is conventional wisdom that using a distant base year for price adjustment may result in bias.[1] For this reason, in the area of national accounts, countries have moved from price adjustment related to a fixed base year to one based on previous year prices.[2] This allows calculating growth rates in real terms – but not absolute values. As absolute values are strongly in demand, these growth rates are chained together to construct either an index series or absolute values related to a reference period.

Whereas this is straightforward for annual figures, it is more complicated for sub-annual series. In quarterly national accounts, either the most recent quarter or the entire previous year can be used as the price basis. If the first approach is used – as is the case in the United States – a Fisher index is usually applied in order to avoid distortions from seasonal fluctuations in prices and quantities. EU member countries, instead, use the entire previous year as the basis for calculating a Laspeyres-type index.

Whereas chain-linking using the previous quarter as a basis for price adjustment can be done in the same way as for annual figures, there exist three possible methods for linking quarterly figures if the entire previous year serves as the basis. This can result in different outputs, time-series properties and price-adjusted quarterly national account figures. Nevertheless, countries within the EU are free to choose among them and currently, all three types of approaches are used.

This study demonstrates the different results obtained using the three methods, when applied to Austrian quarterly GDP data. I observe the consequences of consecutive time-series-based processing, such as seasonal adjustment and business cycle analysis.

Section 1 briefly presents the three chain-linking methods (the over-the-year method, the annual overlap method and the quarterly overlap method[3]). The magnitude of time inconsistency based on Austrian quarterly national accounts (QNA) data for all three techniques is presented in Section 2, where a further method for benchmarking that adjusts time series to annually chain-linked totals is also given. Section 3 addresses how the different chain-linking techniques can interfere with time-series modelling. The sensitivity of dating business cycle turning points with the popular Bry and Boschan (1971) method to the different chain-linking methods is discussed in Section 4.

1. Different methods of chain-linking for quarterly data

The choice of the proper base period is less straightforward for sub-annual studies than for annual data. This problem has been solved in the EU by determining that the average (over all four quarters) has to be used for the construction of series at the previous year's prices. However, countries can decide how to calculate growth rates and how to chain them together for producing series in absolute values.[4]

To construct the three different methods – the over-the-year method (OTY), the annual overlap method (AO) and the quarterly overlap method (QO) – two "series"[5] are necessary: one that calculates each quarter at average prices of the current year, and one that calculates each quarter at average prices of the previous year.

The OTY method calculates growth rates by comparing a certain quarter at average prices of the previous year to the respective quarter at average prices of the previous year. These growth rates are chained together analogously to an index series:

$$I_{y,s}^{OTY} = \frac{\overline{p}^{y-1} q^{y,s}}{\overline{p}^{y-1} q^{y-1,s}} I_{y-1,s}^{OTY} \tag{1}$$

where y represents the year, s the respective quarter (s = 1,…,4), q the quantities and $\overline{p}^{y-1}$ the average price level of the previous year.

Index chains constructed this way allow for a comparison of quantities not over consecutive quarters, but over the year.[6] Furthermore, it can be shown that the quarters do not add up to independent annual chained years, which is very often requested by users of national accounts data.

The AO method calculates growth rates by comparing a certain quarter calculated at average prices of the previous year to the average of the quarters of the previous year calculated at average prices of this respective year. These growth rates are chained together analogously to an index series:

$$I_{y,s}^{AO} = \frac{\overline{p}^{y-1} q^{y,s}}{\frac{\sum \overline{p}^{y-1} q^{y-1,s}}{4}} I_{y-1}^{AO} \tag{2}$$

As all quarters of the current year are related to the entire previous year, the index series constitutes a consistent time series until a new year can serve as the next price basis. This happens each first quarter of a new year, causing a break in the series. The size of this break depends on the change in the fraction of the fourth quarter quantities and/or prices relative to the total year between two successive years.[7] In practice, this break will be rather small, unless there is a large change in the price or quantity structure relative to the entire year. In respect of the criterion of time consistency, the annual overlap method is the only one of all three chain-linking approaches in which the sum of the quarters gives the exact respective annually chained totals.

The QO method calculates all growth rates by comparing the current quarter at average prices of the previous year to the fourth quarter of the previous year valued at average prices of the respective year. Once again, these growth rates are chain-linked in the same manner. The index series is calculated as

$$I_{y,s}^{QO} = \frac{\overline{p}^{y-1} q^{y,s}}{\overline{p}^{y-1} q^{y-1,4}} I_{y-1,4}^{QO} \tag{3}$$

Of all three methods, it is the only one that allows a comparison of quantities over consecutive quarters without breaks.[8] This is probably why the IMF[9] strongly recommends this approach for setting up quarterly national accounts, despite the fact that this kind of quarterly series does not add up to annual totals, derived by independently chaining the years. Lippe and Küter (2005) correctly note that the QO method, in this respect, performs even worse than the OTY method.

When deciding in favour of one of these three methods, statistical offices have to choose whether to give more emphasis to the time-consistency criterion (summation of the quarters to annual totals) or to the break-free development of the series over time. As the OTY method fulfils neither the time consistency nor the time-series criterion,[10] the decision usually has to be made between the AO and the QO method.

As time-consistent quarterly series are strongly demanded by users,[11] a further way to achieve this is by applying methods that distribute the differences between the sum of the quarters and the respective annuals in a second step. In national accounts, procedures that force sub-annual data to be consistent with annual totals are called benchmarking techniques. These techniques range from basic forms, like the distribution of differences equally among all quarters or proportionally (*pro rata*), to more sophisticated mathematical or statistical forms.

It is interesting to note that index chains constructed by the QO method produce exactly the same results as the AO where time consistency is achieved, by following implicit *pro rata* distribution of differences.[12] This may be viewed as somewhat problematic, as the IMF regards the explicit application of a *pro rata* benchmarking technique as "unacceptable" in its *Quarterly National Accounts Manual*.[13]

2. Empirical differences due to time inconsistency

In this section, the differences among the three chain-linking methods discussed in Section 1 are given for Austrian GDP data. They range from the first quarter of 1988 to the end of 2006. Table 1 presents the differences from the time inconsistency of all three chain-linking methods.

Table 1. **Differences between quarters and annual totals**

	OTY		AO		QO	
	Million EUR	Per cent	Million EUR	Per cent	Million EUR	Per cent
1988	12.02	0.01	0.00	0.00	–128.41	–0.09
1989	12.94	0.01	0.00	0.00	–229.65	–0.15
1990	11.94	0.01	0.00	0.00	422.48	0.26
1991	12.43	0.01	0.00	0.00	761.13	0.45
1992	4.99	0.00	0.00	0.00	730.39	0.42
1993	10.23	0.01	0.00	0.00	839.55	0.48
1994	4.91	0.00	0.00	0.00	497.05	0.28
1995	7.97	0.00	0.00	0.00	266.50	0.15
1996	7.60	0.00	0.00	0.00	98.26	0.05
1997	9.34	0.00	0.00	0.00	–266.37	–0.14
1998	11.24	0.01	0.00	0.00	–721.54	–0.37
1999	9.50	0.00	0.00	0.00	–1 587.38	–0.78
2000	0.00	0.00	0.00	0.00	0.00	0.00
2001	–19.63	–0.01	0.00	0.00	591.10	0.28
2002	–20.52	–0.01	0.00	0.00	1 006.43	0.47
2003	–22.55	–0.01	0.00	0.00	1 458.10	0.67
2004	5.57	0.00	0.00	0.00	1 457.55	0.66
2005	19.59	0.01	0.00	0.00	636.15	0.28
2006	23.59	0.01	0.00	0.00	286.39	0.12

The results given in Table 1 are consistent with the expectations formed on the basis of the theoretical considerations of Section 1. There are no differences between the sum of the quarters – derived by the AO method – and the independent annually chained years. As regards the OTY approach, only small differences in absolute numbers and percentages occur. It is clear that the difference is zero only for the reference year 2000. The largest differences between quarterly and annually chain-linked data result from the QO method. Negative as well as positive deviations have been observed. In absolute values, they range from EUR –1.6 billion (–0.78 per cent of annually chain-linked GDP) to EUR 1.5 billion (0.67 per cent). There does not seem to be a trend, but rather the differences look as if they evolve smoothly.

The size of the differences derived from the QO method may suggest that this method is inferior to others. But it does show the extent of the amount distributed implicitly *pro rata* in the AO chain-linking method. As time consistency may be regarded as an important feature for some users, the question arises if there is an alternative benchmarking technique that can be applied to the series which disturbs the quantitative evolution over time less than the implicit *pro rata* distribution included the AO method. A possible alternative could be the approach taken by Denton (1971), which is strongly recommended by the IMF.[14] In this method, the allocation of the annual difference is distributed over the quarters by minimizing their relative change from quarter to quarter. A drawback of this method is, of course, that each new annual observation requires a recalculation of the minimization process that leads to regular revisions of the entire time series historically.

Figure 1 shows the differences between the quarters calculated by the AO method (which implies a *pro rata* distribution of annual differences) and the QO method after benchmarking with the proportional Denton procedure. Differences are given as percentages of the arithmetic mean of the quarters calculated by both methods. They range from –0.31 per cent (EUR 155 million) in the first quarter of 2000 to +0.22 per cent (EUR 120 million) in the fourth quarter of this year. It may seem odd that in the reference year in which all methods show no deviations from annual totals, the largest differences between the AO method and the benchmarked QO (B-QO) occur. This is because there were very large differences to be distributed over the quarters for 1999 and 2001. The smooth distribution mechanism of the proportional Denton approach requires an adjustment of the quarters of 2000 as well. Figure 2 shows the adjustments relative to the unadjusted QO method, which have to be made in order to reach annual totals.

Figure 1. **Relative differences between the AO and the benchmarked QO method**

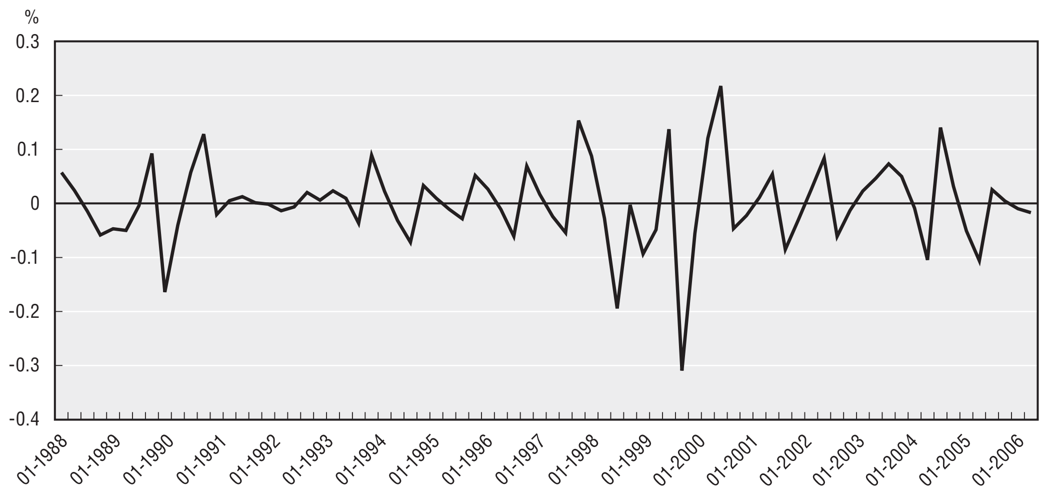
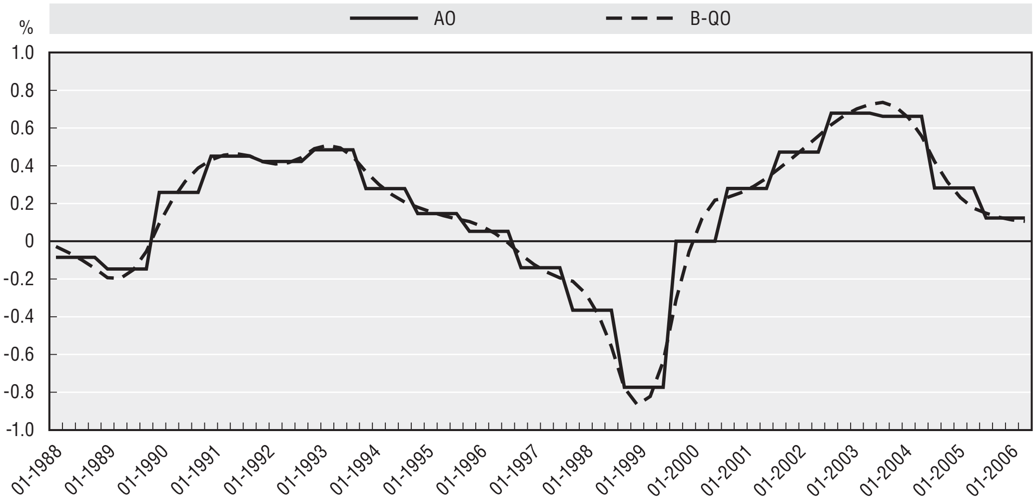


Figure 2. **Distribution of annual differences by the AO and the Denton benchmarked QO method**



3. Consequences for time-series modelling

To show possible consequences for modelling time series, an automatic time-series modelling software has been applied to the output of the three quarterly chain-linking methods, as well as to the one with the benchmarked QO results. This software fits seasonal ARIMA models to economic time series in order to adjust for seasonal and workday effects, as well as for possible outliers. To this end, the software package DEMETRA,[15] which includes the TRAMO-SEATS[16] module, has been used.

For the OTY method, a model has been proposed that represents the seasonal part as an ARIMA (0,1,1) and the regular (trend-cycle) part as a (0,1,0) model. Furthermore, an outlier in the form of a transitory component type was detected in the first quarter of 1993 and removed automatically.

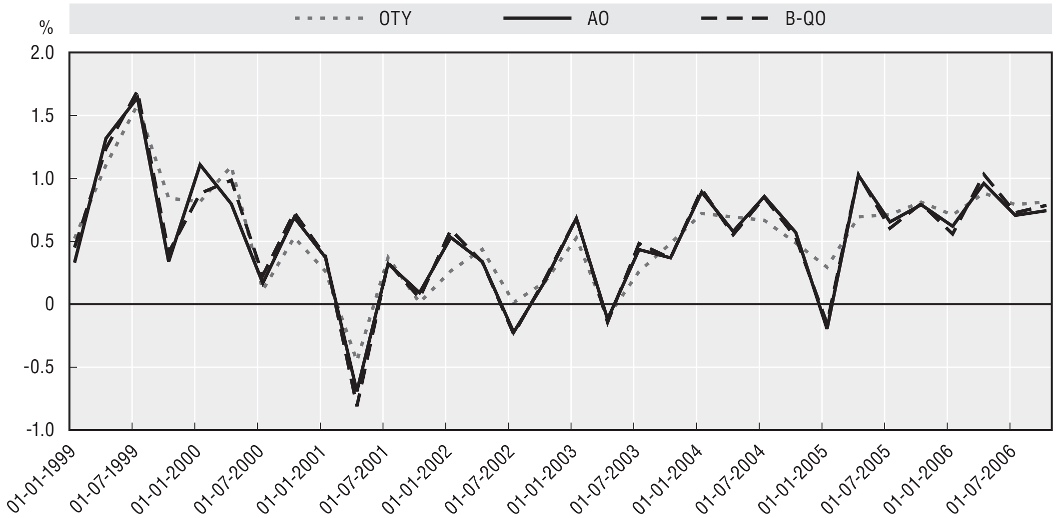
In the case of the AO method, a model that represents the seasonal part as an (0,1,1), but the trend-cycle part as an (0,1,1) process, has been selected. Again an outlier was found in the first quarter of 1993, but this time it was an additive outlier affecting only the quarter.

For the unadjusted QO method, the same type of model has been chosen. While the MA coefficient for the seasonal part is nearly the same as in the AO case, the MA coefficient of the regular part is somewhat lower. In this case, an outlier has also been detected for the same period, but this time a transitory component like in the OTY case.

The QO series adjusted by the proportional Denton procedure has been modelled as an ARIMA (0,1,0)(0,1,1), which is quite different from all other chain-linking methods. The parameter of the trend-cycle MA term is the smallest of all models. As in the case of the AO approach, an additive outlier was detected in the first quarter of 1993.

Figure 3 shows the quarter-on-quarter growth rates of the seasonally and workday-adjusted series for the OTY, the AO and the Denton benchmarked QO method as they were produced by the different time-series models. It may be observed that the ones derived by the AO and benchmarked QO (B-QO) methods show nearly the same pattern, with coinciding local peaks and troughs. However, the model based on the OTY chain-linked data results in growth rates that behave quite differently in that they seem to have a lower

Figure 3. **Quarter-on-quarter growth rates on seasonally and workday-adjusted series**



variance. The OTY series does not seem to have a generally leading or lagging property when compared to the others, but the local maxima at the beginning of 2000 and 2002 were reached one quarter later than in the other series.

If the AO and the B-QO series are compared, the only difference in the local maxima of growth rates can be observed for the beginning of 2000 with the B-QO method showing the peak one quarter later.

4. Extracting the business cycle

Looking at the growth rates over the various methods may suggest that the different chain-linking models come to more or less the same conclusions. But differences in the ARIMA structure of the trend-cycle part may entail severe consequences for business cycle analysis. Fukuda (2008) has shown that existing MA or AR terms in the non-seasonal ARIMA component are indicators of whether the trend can be statistically separated from the cycle. Ignoring this can lead to spurious cycle detection.[17]

For the sake of simplicity, it is assumed here that trend and cycle can be separated from each other. Furthermore, it is done in this case by non-parametric filtering approaches. Here, only the most popular ones – the famous Hodrick-Prescott (HP) and Baxter-King (BK) filters – are applied in order to show possible differences in results.

Figure 4 gives the result in log differences between consecutive quarters of the different series for which a HP-1600 trend has been eliminated. The output is quite similar to the ones in which the trend has been eliminated by first-order differences of logs, which correspond approximately to the calculation of growth rates shown in Figure 3.

Table 2 gives the corresponding dates of the business cycle turning points as detected by the routine proposed by Bry and Boschan (1971), by demanding a minimum cycle length of five quarters and a minimum length of three quarters. The unbenchmarked QO series serves as the reference cycle to which all other results are compared.[18]

Figure 4. **Differences in log of HP-1600 transformed series**

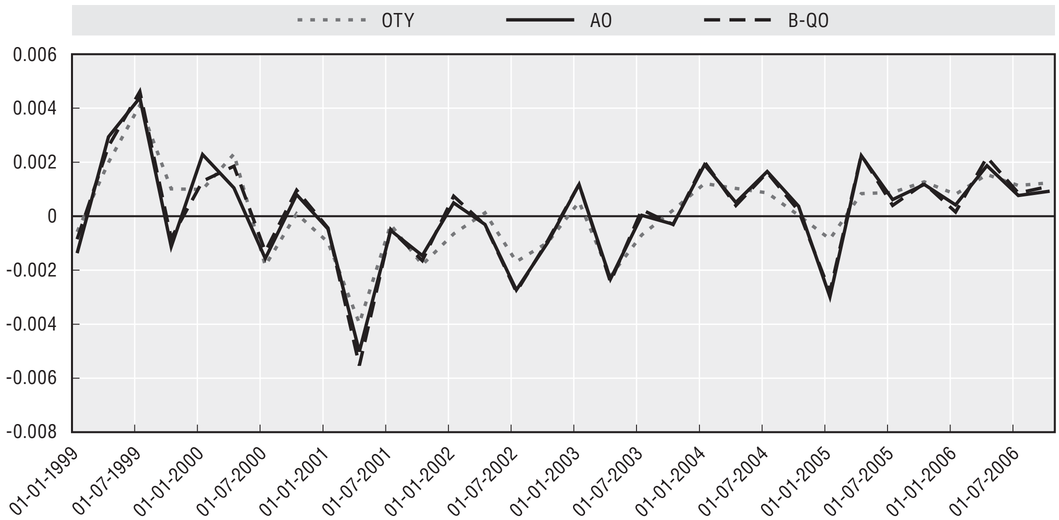


Table 2. **Turning point analysis for HP-1600 filtered series**

Series	Peak	Trough	Peak	Trough	Peak	Trough	Peak	Trough	# of extra cycles
	Q3-1991	Q1-1993	Q1-1994	Q1-1995	Q1-1996	Q2-1997	Q2-2000	Q4-2003	
QO	0	0	0	0	0	0	0	0	0
AO	0	None	None	0	0	–1	0	0	–1
B-QO	0	None	None	0	0	–1	0	0	–1
OTY	0	None	None	0	0	0	0	–1	–1

Note: + (–) denotes a lag (lead) with respect to the reference series.

The reference series (QO) given in the first line shows the largest number of completed cycles between 1988 and 2006. It counts four cycles, while all chain-linking methods show only three. The one starting with a trough in the first quarter of 1993 and showing its peak in the first quarter of 1994 has not been recognised by all other chain-linked series. A possible explanation for this is that the outlier detected in all series has not been removed sufficiently by the QO method or has been removed too much by the other methods.[19]

There is some evidence in the literature that the period around 1993 was indeed a cyclical trough. For the Austrian case, Artis, Krolzig and Toro (2004) reported a trough in the third quarter of 1993 for the Austrian economy.* For the euro area, Mönch and Uhlig (2004) also identify a trough in the first quarter of 1993. The CEPR Business Cycle Dating Committee (2003) places it in the fourth quarter of 1992, Artis, Krolzig and Toro (2004) in the second quarter of 1993, Artis, Marcellino and Proietti (2004) in the fourth quarter of 1993 and Forni *et al.* (2004) in the first quarter of 1994.

From the above, one can conclude that the benchmarking process – done either explicitly or implicitly – can potentially interfere with the appropriate detection and estimation of outliers, which may in turn hamper the detection of business cycle turning points.

Further results indicate that the trough in the second quarter of 1997 was indicated by the AO and the benchmarked QO method one period earlier than by the other methods.

* Scheiblecker (2008) dated it to the third or fourth quarter of 1993, respectively.

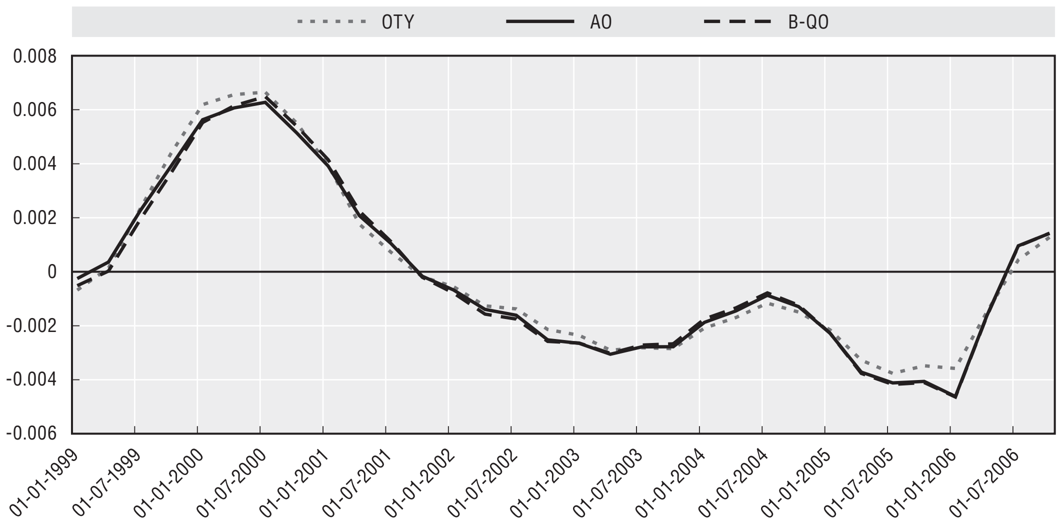
The same goes for the trough in the fourth quarter of 2003, which was detected by the OTY method one quarter earlier.

A further method for business cycle extraction was used to explore whether the differences in business cycle analysis stem from the differences in time series modelling – used for outlier detection and seasonal and workday adjustment – or from the chain-linking process itself. The band-pass filter proposed by Baxter and King (1995) was applied to all four chain-linking methods as an alternative. As this filter removes not only the trend but also frequencies higher than the business cycle like seasonal variations, it can be applied directly to the series without prior adjustment for seasonal fluctuations.[20]

To make sure that seasonal variations are properly extracted, the filter was set to retain only variations with a frequency of between 8 and 2 years (32 and 8 quarters, respectively) instead of the common 8 and 1½ years. Additionally, the filter length has been expanded to 8 quarters in order to reduce leakage, but this advantage comes at the expense of a higher loss of observations at either end of the series (which are usually extended by an ARIMA forecast). This is not, however, a drawback in this study.

Figure 5 shows the cyclical component after applying the BK-filter to the logs of the series of OTY, AO and the Denton benchmarked QO chain-linked series. They look quite similar in their ups and downs between 1999 and 2006. The only remarkable difference is that the OTY series seems to reach its lowest point two quarters before the AO and the B-QO series.

Figure 5. **Baxter-King 8-2 filtered series**



This result can be confirmed by looking at the turning points as detected by the Bry-Boschan dating procedure given in Table 3. The trough found by the three other series in the first quarter of 2006 is dated by the OTY series two quarters earlier.[21] This time, five complete cycles have been found which can be attributed to dropping a prior outlier detection procedure. As a consequence, the second quarter of 1993 has been dated as a trough, followed by a peak in the first quarter of 1996.

Generally, the dating calendar of the BK-8-2 transformed series looks quite different from the one for the HP-1600 seasonally filtered ones. However, it is conventional wisdom that the Bry and Boschan (1971) procedure detects fewer turning points in HP-filtered series

Table 3. **Turning point analysis for BK-8-2 filtered series**

Series	Peak	Trough	Peak	Trough	Peak	Trough	Peak	Trough	Peak	Trough	# of extra cycles
	Q4-1988	Q1-1990	Q4-1991	Q2-1993	Q1-1996	Q2-1997	Q1-2000	Q2-2003	Q3-2004	Q1-2006	
QO	0	0	0	0	0	0	0	0	0	0	0
AO	0	0	0	0	0	0	2	0	0	0	0
B-QO	0	0	0	0	0	0	2	0	0	0	0
OTY	0	0	0	0	0	0	2	0	0	–2	0

Note: + (–) denotes a lag (lead) with respect to the reference series.

that are still plagued by high frequency components. This makes it difficult for this dating procedure to find turning points in such highly erratic series.

From Tables 2 and 3, one can conclude that the Denton benchmarked QO method and the AO method give the same business cycle turning points for the Austrian GDP between 1988 and 2006. However, the unadjusted QO method, which represents the only breakless quantity index, and the OTY method produce different dates and number of cycles, with the latter sometimes showing some leading properties when compared to the QO method.

This analysis has demonstrated that the different methods of quarterly chain-linking give quite robust results for business cycle analysis based on non-parametric filtering. However, modelling such data by time-series models can give quite different results, not only in respect of the model type but also concerning the detection of outliers. The analysis was based on data drawn from a period that did not have significant changes in prices and weights. In times of strong economic change, results concerning differences between quarterly chain-linking methods can be more pronounced.

Notes

1. See, *e.g.* Boskin *et al.* (1998).
2. In 2003 EU member countries were obliged to deliver national accounts data from 2005 onwards on a previous-year price basis.
3. The quarterly overlap method is frequently called the “one-quarter overlap method”.
4. Unlike annual figures, QNA figures are usually not published as index series.
5. These series cannot be regarded as time series in a narrower sense, as they show breaks at the beginning of each new year.
6. See, *e.g.* Bikker (2005, p. 9) or Kirchner (2007).
7. For a more formal explanation, the reader is referred to Kirchner (2007, p. 5).
8. This is apart from the usual ones due to permanent weight changes. See also Bikker (2005).
9. See Bloem, Dippelsman and Maehle (2001).
10. Therefore, the EU statistical office EUROSTAT does not recommend this method.
11. Hence the EU is demanding the production of benchmarked chained national accounts data.
12. See Bikker (2005).
13. See Bloem, Dippelsman and Maehle (2001, p. 84).
14. See Bloem, Dippelsman and Maehle (2001, p. 87).
15. DEMETRA 2.1 © European Communities, 1999-2007.
16. The TRAMO-SEATS software package used here has been developed by Gomez and Maravall (1992) and is strongly recommended by the EC for seasonal adjustment in QNA.

17. Per Harvey (1989, p. 46), a distinction must be made between a trend-plus-cycle and a cyclical-trend model.
18. This is done on practical grounds, as here one more cycle has been found and is not based on some priority reasoning.
19. The detection of a trough makes the Bry-Boschan routine look for a following peak in the series, as changing signs for business variations is a precondition for this procedure.
20. It has to be noted that, for a sensible business cycle analysis, a prior adjustment for working days and outliers is indispensable, but here the focus is just on the difference between methods and not on finding the correct business cycle.
21. It must be noted that this difference has to be disregarded, as it concerns the margin of the time series, which has been enlarged by the ARIMA forecast. In Section 4, it was shown that the different chain-linking methods interfere quite strongly with this kind of time-series models.

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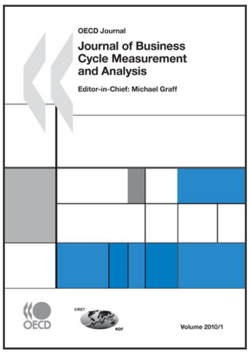

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