

# Change of seasonal adjustment method to X-12-ARIMA

By John Thorp<sup>1</sup>

*From 21 January 2004 the Bank of England will switch from its current method to X-12-ARIMA to seasonally adjust the monetary and related statistical series. This article describes the new method and how the Bank is applying it. The method's greater sophistication enables it to deal better with the characteristics of each individual series; a consequence of this is that the seasonally adjusted series no longer precisely obey the accounting relationships of the non-seasonally-adjusted series. The new series are generally close to the previous ones; comparisons of key series adjusted by the new and by the previous method will be published on the first occasion when a set of statistics adjusted in the new way is released.*

## Introduction

1. In November 2002 the Bank of England issued a consultation paper on its plan to change the seasonal adjustment method that it uses in the monetary statistics, to X-12-ARIMA. The paper set out the reasons for the change, and possible resultant differences in the seasonal adjustments. In the comments received, which were summarised in a note issued in February 2003, there was general support for the change.<sup>2</sup> Subsequently the Bank has continued its work to introduce the new method. The Project Board controlling the work has included Bank statisticians and Bank users of the statistics, the Head of the Time Series Analysis Branch of the Office for National Statistics, and two external consultants. Advice has been readily supplied by the US Census Bureau, which is the main custodian and developer of X-12-ARIMA.

2. This article describes the new methodology, which will be used with effect from the release of the 'Provisional estimates of broad money (M4) and credit (M4 lending)' for December 2003, published on 21 January 2004. Comparisons of key series adjusted by the new and by the previous method will be published on the first occasion when a set of statistics adjusted in the new way is released. The British Bankers' Association and the Building Societies Association also intend to adopt the new methodology.

## Characteristics of X-12-ARIMA<sup>3</sup>

3. X-12-ARIMA is the latest in the family of seasonal adjustment methods that have been developed over several decades by the US Census Bureau and Statistics Canada, with contributions from others. X-12-ARIMA, or a closely related predecessor, is used by many statistical agencies and central banks, including the UK

Office for National Statistics and the European Central Bank. The method is based on a moving-average technique similar to 'GLAS' (General Linear Abstraction of Seasonality), the method that the Bank has used since 1991, but is more sophisticated and readily able to provide adjustments tailored to each series. Key characteristics of X-12-ARIMA are:

- X-12-ARIMA contains a *time-series-modelling component*, which aids the identification of outliers, shifts in the level of a series and calendar effects (all of which could distort the seasonal adjustments), and the estimation of seasonality at the start and end of the series.
- *Filters of several different lengths*, ranging from 3 to 17 years (or the full length of the series, if desired), are readily available to identify the seasonality appropriate to each series. In GLAS the same, linear, moving-average filter was in practice applied to all series, using only a short span of years to determine the seasonality: the seasonality of a particular month was defined essentially as the average deviation from trend in that month in the three years centred on that month (or, for observations at the start or end of the series, the first or last three years of the series).
- X-12-ARIMA can provide *multiplicative* – proportionate – seasonal adjustments, if this is appropriate for an individual series. GLAS was designed to provide only additive – linear – adjustments.
- As mentioned above, X-12-ARIMA includes systematic estimation and removal of *calendar effects*, for the differing lengths of months, public holidays etc. GLAS has a routine for adjusting for the effects of public holidays on notes and coin within M0, but otherwise has to be supplemented by ad hoc adjustments for calendar effects.
- X-12-ARIMA has wide-ranging statistical *diagnostics*, available graphically where appropriate, enabling the nature, robustness and stability of the seasonal adjustments to be easily monitored. Besides aiding the method's use, these diagnostics facilitate greater understanding and analysis of series.
- The method has been *continually developed*, is well *supported and maintained* by the US Census Bureau, and *future development* seems assured; for example, the Census Bureau is currently working on making

<sup>1</sup> John Thorp, previously on the staff of the Bank of England, has assisted the seasonal adjustment project as a consultant. The detailed work on the production of the new seasonal adjustments has been done by another consultant, Peter Kenny, who was previously on the staff of the Central Statistical Office (now the Office for National Statistics), and by Mhairi Burnett, Martin Daines and Robert Westwood from the staff of the Bank of England. Queries can be addressed to the Monetary Statistics Group on 020 7601 5467/3236 or e-mail [mfsd\\_ms@bankofengland.co.uk](mailto:mfsd_ms@bankofengland.co.uk).

<sup>2</sup> For fuller references to the two papers, see items 7 and 8 in the Bibliography after this article.

<sup>3</sup> For fuller descriptions and documentation of the method, see items 1, 5 and 9 in the Bibliography after this article.

available within this family more of the capabilities of TRAMO-SEATS, the model-based method developed by V Góñez and Professor A Maravall.

4. As mentioned in the Bank's two earlier papers, 'additivity' in the seasonally adjusted series (ie precisely preserving the accounting relationships of the non-seasonally-adjusted series) is no longer seen as essential, primarily because greater attention is now given to seeking information from individual series within the monetary statistics (especially the sectoral analyses of money and lending) than to examining the relationships between the many elements of the financial matrix. This has opened the way for the change from GLAS, a comparatively simple method that was designed primarily to maintain the accounting relationships across the matrix. Full use of X-12-ARIMA, to produce the best seasonal adjustments for each individual series, entails that additivity will no longer be automatically maintained.<sup>4</sup>

5. *Revisions* caused by the arrival of new observations will tend to go back further than in GLAS, because of the longer time-filters potentially used in X-12-ARIMA and because the new or revised data can cause the modelling part of the method to be re-estimated and the existence and size of outliers to be re-assessed. But the method's use of forecasts at the end of the series will tend to make the total magnitude of revisions smaller.

## How we have applied X-12-ARIMA

6. Work has proceeded steadily over the past 15 months to examine how best to apply the new method. After the initial examination of groups of individual series, the decisions made in that process have been reviewed for consistency across all these statistics; and we have carried out a further summary review on the data for the main series updated to October 2003. The substantial general decisions made are as follows.<sup>5</sup>

### *Multiplicative seasonality*

7. We have assumed that seasonality is *multiplicative* rather than additive, and we have thus generally used X-12-ARIMA's multiplicative option. There is intuitive plausibility for this – one expects the seasonality of financial series to be affected by inflation and real growth in generally the same way as the level of the trend of the series. And our tests on representative series have showed that multiplicative seasonal adjustments are much more stable than additive adjustments, even though in some cases the size of the multiplicative factors has declined in recent years.<sup>6</sup>

<sup>4</sup> Removal of calendar effects and level shifts, robust estimation procedures for seasonal factors, use of multiplicative decomposition and tailoring of filters to individual series all tend to remove the additivity of the original non-seasonally-adjusted series.

<sup>5</sup> Information on how the individual series have been seasonally adjusted will be included on the Bank's website.

<sup>6</sup> In order to produce multiplicative adjustments we have worked with *levels* series (adjusted to exclude breaks in series). So, in the new regime, the main exceptions to use of multiplicative adjustment are in the 'Alternative counterparts to changes in M4', where the existence of some series only in the form of *flows* (which can therefore be zero or negative) has entailed use of additive adjustment.

## *Indirect or direct adjustment*

8. *Indirect* seasonal adjustment is when a seasonally adjusted series is derived from other seasonally adjusted series, for example when a seasonally adjusted aggregate is derived by summing seasonally adjusted components. Indirect adjustment is likely to be better when the time series properties of component series, particularly the strength and stability of their seasonal patterns, vary widely. But *direct* adjustment can often be better than indirect, because aggregate series are often less volatile than their component series. Direct adjustment is also usually more appropriate when a seasonal influence on an aggregate series has the potential to switch between components.<sup>7</sup>

9. Virtually throughout the monetary and related statistics there is interest both in aggregates and in components of those aggregates. Indeed, in some instances an aggregate can be built up in more than one way (eg, for M4, by instrument, or by holding sector, or by 'counterpart' derived from the equivalence of liabilities and assets in a balance sheet). Therefore components and, separately, their aggregates need to be tested for seasonality. The diagnostics provided by X-12-ARIMA indicate whether a series is seasonal and the characteristics of that seasonality. They can also indicate whether direct or indirect adjustment of an aggregate is better, or (where there is interest in more than one way of compiling an aggregate) which of two or more ways of indirect adjustment is better. An important part of our work has been to assess whether direct or indirect adjustment of aggregates is better, in cases where the formal diagnostics indicate that either is valid. In making these decisions we have been guided by our understanding of the economic behaviour underlying each series. For example, we have chosen to seasonally adjust M4 and lending directly, because of the probability that there is strong substitutability between at least some of their components, so that – in the absence of a clear indication from the formal diagnostic tests whether direct or indirect adjustment is better – we rely on an economic understanding of the series.

10. The information on seasonal adjustment on the Bank's website will include detail of whether we have adjusted series directly or indirectly.

### *Residuals*

11. Because of the lack of automatic additivity, there are *residuals* between aggregates and their components wherever an aggregate is seasonally adjusted directly (rather than indirectly, by summing the seasonally adjusted components), or where the statistics present more than one set of components that conceptually comprise an aggregate. We shall not spread the residuals in a mechanical way among other series or allocate them to particular series, on the grounds that in principle any such allocation worsens the quality of the statistics.<sup>8</sup>

### *Outliers etc*

12. We shall rely primarily on the automatic adjustments available within X-12-ARIMA for *outliers* and *level*

<sup>7</sup> For detailed discussions of direct versus indirect adjustment, see items 3 and 6 in the Bibliography after this article.

<sup>8</sup> For availability of data of the residuals, see paragraph 21.

*shifts*.<sup>9</sup> Although the program permits judgemental imposition of the existence of an outlier or level shift, automatic adjustment has the advantage of objectivity and may indeed be superior to judgemental adjustment, for example if automatic adjustment captures offsets or other special effects that the judgemental adjustment fails to allow for. Our research into past series has demonstrated that the automatic adjustments are of high quality, in the sense of producing plausible results and of closely mimicking the adjustments that we would have imposed judgementally. The quality of the automatic adjustments will be continually monitored because of the close attention that the series receive in the Bank.<sup>10</sup>

### Concurrent updating

13. We shall continue to use *concurrent* (or ‘current’) *updating*, in the sense of allowing a new observation to affect the estimation of seasonality for that latest period (and, in a complementary way, for previous periods), in order to utilise any new information on changing seasonality as soon as possible. But, in common with other users of the method, we shall generally freeze the underlying RegARIMA model, the length of filters used for the key series, and the major outlier and level shift adjustments identified by the RegARIMA model. We shall do this until at least the next annual review, to prevent unhelpful revisions.

### Monthly and quarterly adjustment

14. Because of its non-linear nature, X-12-ARIMA may produce seasonal adjustments that have some noticeable differences for a series observed *quarterly* from those for the same series observed *monthly*. This is legitimate, for example if a regular event moves between months within the same quarter from year to year, or when a longer span of data is available quarterly than monthly. We have allowed such differences to stand in the seasonally adjusted series.<sup>11</sup>

### Constraining annual totals

15. As mentioned in the Consultation Paper,<sup>12</sup> we shall cease *constraining* the seasonal adjustments to zero *over the financial year* (or any 12-month period), as this in principle worsens the adjustments by restricting the way that they evolve from one 12-month period to the next. X-12-ARIMA contains a normalisation process that prevents 12-month seasonally adjusted totals from moving far from the non-adjusted total.

<sup>9</sup> In the X-12-ARIMA manual, ‘outliers’ refers to outliers identified by the RegARIMA model in the time-series-modelling phase of the program, and ‘extreme values’ refers to outliers identified in the X-11 algorithms that are a subsequent part of the X12-ARIMA program. The ‘outliers’ are fully replaced by the value from the model. The ‘extreme values’ identified are either completely removed from the process of estimating seasonality or – in the case of more modest extreme values – given only partial weighting in the estimation of seasonality.

<sup>10</sup> An example of the effectiveness of the method’s identification of extreme values is that, unprompted, it has identified plausible effects of the celebration of the Queen’s Golden Jubilee in June 2002 on notes and coin (within M0).

<sup>11</sup> An example of a legitimate difference between a monthly-observed series and the same series observed quarterly was given in the November 2002 Consultation Paper (page 11: *Other reasons for non-additivity: 2 Monthly and quarterly*).

<sup>12</sup> Paragraph 8 and Annex page 9-10 (*‘Additivity across time’*) of item 7 in the Bibliography after this article.

## M0

16. As also mentioned in the Consultation Paper,<sup>13</sup> *notes and coin* (in M0) will no longer be seasonally adjusted on a *weekly* frequency. This is because X-12-ARIMA does not have a supported program for weekly series, and we wanted to choose the same seasonal adjustment method for all series. Our tests showed that X-12-ARIMA – with its sophisticated treatment of calendar effects – produces at least as good monthly results for notes and coin as the previous method. Non-seasonally-adjusted weekly data will continue to be available: see paragraph 25.

17. Under the previous method, we did not use concurrent updating for *notes and coin* for *December*, because of our experience that the seasonal adjustments were sometimes unstable until the large Christmas-related surge had unwound in mid-January. Our tests have shown that the new method does produce acceptably stable results for December (perhaps because of the longer span of years that the new method tends to use), so we shall update the seasonal adjustments then as in other months. The seasonal factors around the Christmas period should nonetheless be regarded as less precise, because of the huge flows in the series prior to seasonal adjustment.

### Securitisations

18. *Securitisations* typically result in packages of loans being transferred from the balance sheet of banks to special-purpose lending vehicles. In the previous methodology, securitisations were routinely assumed to be non-seasonal and therefore treated like outliers, even where they were modest in size. Thus their effects were removed from the series before the seasonal adjustments were estimated; their effects were then restored to the seasonally adjusted series (except for series defined to exclude securitisations). In the new methodology, securitisations are no longer treated as special events; they are thus allowed to be seasonal, subject to the general outlier regime described above. Our tests using X-12-ARIMA have confirmed that securitisations have no identifiable seasonality so far; but the new approach will automatically adjust for any emerging seasonality, especially given the greater volume of securitisation in the past few years.

19. Because securitisations do not affect the indebtedness of borrowers, *lending series excluding the effects of securitisations* are published to complement the main lending series. To enable the estimation of multiplicative (rather than additive) seasonality in the new methodology, we have for the first time created *levels* series for all the ‘lending excluding securitisations’ series (so that the levels series are no longer depleted by the outstanding amounts that have been securitised). As the growth rates for ‘lending excluding the effects of securitisations’ are now derived from these new – higher – levels series, the rates are slightly lower than those previously published.

<sup>13</sup> Paragraph 11 of item 7 in the Bibliography after this article. See also paragraph 5 of the paper summarising responses to the Consultation Paper (item 8 in the Bibliography after this article).

## Changes in presentation of the seasonally adjusted series

20. Changes in presentation of the statistics in conjunction with the introduction of the new method include the following.

21. Although it is unclear whether the *residuals* (between directly adjusted aggregates and their components, and between different ways of producing the aggregates) have any informational content about the processes being measured, their size can give some indication of the uncertainty in the adjustment process. Their existence will therefore be noted in the relevant tables in *Bankstats* and they will be published on the Interactive Database.<sup>14</sup>

22. Under the definition of seasonality that underlay the old method, all series were deemed to be seasonal and thus allowed to be seasonally adjusted. Where the diagnostics available in the new method show that a series that currently forms part of a set of seasonally adjusted statistics has no significant seasonality, the *unadjusted series will be shown in the 'seasonally adjusted' statistics*, annotated to the effect that it is unadjusted. Among the series found to be not significantly seasonal are capital issues (as published in the monthly *Capital Issues* release and in *Bankstats* section E), so the seasonally adjusted sections of these statistics will be discontinued.

23. As a result of the potential for X-12-ARIMA to generate differences between monthly and quarterly seasonally adjusted data (see paragraph 14 above), *separate monthly and quarterly series* will be published for series such as 'Components of M4' and 'Lending to individuals', in the same way that the sectoral analyses of M4 and M4 lending are currently presented.

24. The supplementary series for the *number of loans approved for house purchase adjusted for the number of working days* in a month will be discontinued, as such calendar effects are now dealt with automatically by X-12-ARIMA.

25. For the reason mentioned in paragraph 16, *notes and coin* (and M0) will no longer be seasonally adjusted on a weekly frequency. Non-seasonally-adjusted weekly data will continue to be published weekly on the Bank's website, supplemented by year-on-year growth rates and indications of instances where the growth rates are likely to be distorted by effects such as the position of public holidays.

26. *Seasonally adjusted levels* will replace the non-adjusted levels in the presentation of the detailed statistics for the components of *Divisia Money*. This is a consequence of the creation of the seasonally adjusted levels to enable *Divisia Money* and its sectoral breakdown to be seasonally adjusted indirectly, by summing their instrument components (instead of only directly from the seasonally adjusted indices for aggregate *Divisia* and for its sectoral breakdown).

27. As explained in paragraph 12, *outliers* that are to be prevented from distorting the seasonal adjustments will now generally be identified automatically, and they will

be modified in a way that means that it will no longer be possible to precisely identify the impact of any individual 'outlier event' on the seasonally adjusted series. The list of 'Outliers etc modified before the seasonal adjustments are derived', previously published as Section E of Part 2 of the Bank's *Statistical Abstract*, will therefore be discontinued. Events relevant to the interpretation of the monetary statistics will however still be noted in a successor (on the Bank's website) to the 'Diary of events' that forms Section D of the present *Statistical Abstract*.<sup>15</sup>

## Results, and how they will be published

28. The new series are generally close to the old ones. A comparison of key series adjusted by the old and new methods will be published whenever the first set of statistics adjusted in the new way is issued, starting with the *Provisional estimates of broad money (M4) and credit (M4 lending)* for December 2003, published on 21 January 2004. When the fuller, detailed statistics up to end-December are issued on 30 January 2004 in *Bankstats* and on the Interactive Database, further comparisons will be published, and the data adjusted by the previous method will be published on the Interactive Database up to end-November 2003 (notes and coin and M0 up to end-December 2003); these 'old' data will remain on the Interactive Database until the detailed statistics up to end-January are published, on 1 March 2004.

## Future reviews

29. We shall re-assess annually the way that the method is applied to each series, including the choices of models and the lengths of filters used to determine seasonality. Any substantial change to the way that a series is seasonally adjusted will be noted in the first release in which the change is used.

30. We shall also consider at each annual review whether to introduce any updates that have been released to the X-12-ARIMA program.

<sup>14</sup> See further item 6 in the Bibliography after this article.

<sup>15</sup> Pending the *Statistical Abstract's* complete replacement by material on the Interactive Database or elsewhere on the Bank's website, the last issue of the relevant part of it is at [www.bankofengland.co.uk/mfsd/abst/part2.htm](http://www.bankofengland.co.uk/mfsd/abst/part2.htm)

## Bibliography<sup>16</sup>

1. *New capabilities and methods of the X-12-ARIMA seasonal adjustment program*, David F Findley, Brian C Monsell, William R Bell, Mark C Otto and Bor-Chung Chen, *Journal of Business and Economic Statistics*, April 1998; also available on the US Census Bureau's website ([www.census.gov/srd/www/x12a](http://www.census.gov/srd/www/x12a)). Describes the method and includes comments (not on the website version) by seasonal adjustment specialists.
2. *Seasonal adjustment: comparison of philosophies*, Andrew Sutcliffe, Working Paper 99/2, Australian Bureau of Statistics, December 1999; available on the Australian Bureau of Statistics website ([www.ausstats.abs.gov.au](http://www.ausstats.abs.gov.au)). Compares 'direct-filter' (eg the X-11 component of X-12-ARIMA) and model-based methodology.
3. *Diagnostic measures for comparing direct and aggregate seasonal adjustments*, Jeff Cannon, Working Paper 2000/1, Australian Bureau of Statistics, June 2000; available on the Australian Bureau of Statistics website ([www.ausstats.abs.gov.au](http://www.ausstats.abs.gov.au)).
4. *Seasonal adjustment of monetary aggregates and HICP for the euro area*, European Central Bank, August 2000; available on the European Central Bank's website ([www.ecb.int](http://www.ecb.int)). As well as discussion of how to seasonally adjust the euro area monetary aggregates (and HICP), it includes a more extensive bibliography on seasonal adjustment methodology.
5. *Seasonal adjustment with the X-11 method*, Dominique Ladiray and Benoît Quenneville, Springer-Verlag New York, 2001. Provides a detailed review both of the X-11 module that remains at the core of X-12-ARIMA and of the additional features of X-12-ARIMA.
6. *Comparing direct and indirect seasonal adjustments of aggregate series*, C C Hood and D F Findley, American Statistical Association proceedings, October 2001; also available on the US Census Bureau's website ([www.census.gov/srd/www/x12a](http://www.census.gov/srd/www/x12a)).
7. *Prospective change in seasonal adjustment methodology: consultation with users*, Bank of England, 20 November 2002; also published in the November 2002 (internet-only) issue of *Monetary and Financial Statistics* ('Bankstats'), on the Bank's website at [www.bankofengland.co.uk/mfsd/artnov02sa.doc](http://www.bankofengland.co.uk/mfsd/artnov02sa.doc).
8. *Prospective change in seasonal adjustment methodology: consultation with users: summary of responses*, Bank of England, 20 February 2003; also published in the February 2003 (internet-only) issue of *Monetary and Financial Statistics* ('Bankstats'), on the Bank's website at [www.bankofengland.co.uk/mfsd/artfeb03sa.doc](http://www.bankofengland.co.uk/mfsd/artfeb03sa.doc).
9. Up to date documentation of the X-12-ARIMA program, and the program itself, are on the US Census Bureau's website ([www.census.gov/srd/www/x12a](http://www.census.gov/srd/www/x12a)).

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<sup>16</sup> These references are listed in date order. Other references to the Bank's previous seasonal adjustment work can be found in 'Further references on monetary and banking statistics' in Part 2 of the Bank's annual *Statistical Abstract*. See the immediately preceding footnote.