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Temporal Aggregation and Seasonal Adjustment

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INQUIRIES

The ABS welcomes comments on the research presented in this paper. For further information, please contact Mr Philip Carruthers, Analytical Services Branch, on Canberra (02) 6252 5307 or email <analytical.services@abs.gov.au>.

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TEMPORAL AGGREGATION AND SEASONAL ADJUSTMENT

Lisa Apted, Henry Chiem, Andrew Fitzgerald and Anthony Russo
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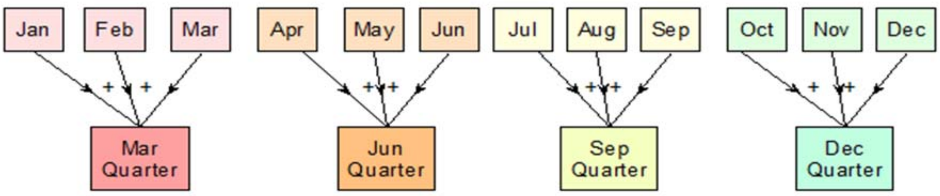
ABSTRACT

This paper describes an improved seasonal adjustment method for equivalent monthly and quarterly time series. Specifically, we assess the temporal aggregation method to calculate seasonally adjusted quarterly estimates. The appropriate trending method for such estimates is also outlined. Empirical analysis of the impacts of introducing this method is presented, the case study being Livestock and Meat Production (ABS cat. no. 7215.0). Seasonal adjustment quality was found to be improved, in terms of reduced residual seasonality, with similar or slightly better average revisions to the seasonally adjusted estimates.

1. INTRODUCTION

We consider temporal aggregate constructed by simply summing the monthly time series estimates across three periods to define the quarterly estimate as outlined in figure 1.1 below.

1.1 Temporal aggregation



Independent seasonal adjustment of equivalent monthly and quarterly original estimates leads to inconsistencies in seasonal adjustment outputs and is inefficient business practice. The temporal aggregation (TAG) method ensures consistency between monthly and quarterly seasonally adjusted estimates from the same original basis and improves productivity in the ABS statistical processes.

Monthly original time series are a richer source of information than their temporally derived quarterly counterparts. Hence calendar related effects are better estimated at the monthly level.

When considering the various dimensions of possible quality measures, the TAG method is, on balance, a superior seasonal adjustment procedure for equivalent original monthly and quarterly time series pairs.

The TAG method also ensures additivity of monthly and quarterly seasonally adjusted estimates.

In June 2008, the Time Series Analysis (TSA) section of the ABS presented their findings on the use of temporal aggregation to obtain quarterly time series from monthly seasonally adjusted series to the ABS Methodology Advisory Committee (MAC) – see Zhang and Apted (2008). The temporal aggregation (TAG) method was endorsed by the committee as being methodologically sound.

Since then additional empirical analysis, focussing on revision performance/impacts and the quality of seasonal adjustment has been conducted by TSA on Livestock and Meat Production time series, along with determination of appropriate trending procedures for temporally derived seasonally adjusted quarterly time series. Details of this post MAC work are included as Appendix A and Appendix B.

TSA sought EESG Methods Board approval for implementation of the TAG method for in scope time series in May 2012. The Board endorsed the method and its implementation for Livestock and Meat Production estimates.

The ABS time series software, SEASABS, now supports the TAG method, including consistent application of prior corrections for trend estimation across frequencies, diagnostics and quality checks of outputs. Trending aspects are considered in more detail in Section 2 and Appendix B.

2. BACKGROUND

There are two major drivers for the monthly and quarterly 'equivalent' original time series that exist within the ABS. Firstly, the requirements of Quarterly Australian National Accounts and secondly, demand from ABS major users. The quarterly original time series for these collections are derived through the temporal aggregation of monthly original time series.

Monthly original time series are a richer source of information than their temporally derived quarterly counterparts, and hence calendar related effects are better estimated at the monthly level (see Zhang *et al.*, 2005).

Seasonal adjustment is defined as the estimation and removal of systematic effects. Quarterly seasonally adjusted estimates based on monthly seasonally adjusted equivalents will hence have a more accurate estimate of the systematic behaviour removed. For example, the TAG method is the only reliable method for estimating and removing trading day effects from quarterly series.

For many of these series 'pairs', both the monthly and quarterly are directly (independently) seasonally adjusted. The non-linear nature of the seasonal adjustment process means that independently seasonally adjusted monthly-quarterly time series pairs will never be exactly consistent.

Further consistency issues from such independent seasonal adjustment can arise due to differences in the:

- estimation and application of trading day and other calendar related effects such as seasonal breaks, moving holidays, etc.;
- selection of seasonal filters and other X11 seasonal adjustment options; and
- application of trend related prior corrections such as large extremes and trend breaks.

The TAG method for seasonal adjustment addresses all inconsistency issues above.

However, this does not address the trend estimates. The quarterly trend can be determined from the temporally derived quarterly seasonally adjusted series via either direct trending (smoothing of the seasonally adjusted estimates via a Henderson moving average) or indirect trending using temporal aggregation on the relevant monthly trend estimates.

Research and empirical results show direct trending of the temporally aggregated seasonally adjusted quarterly series is recommended over indirect trending, because this latter method can produce trend estimates that are less smooth. Monthly trend related prior corrections are effectively translated to quarterly prior corrections for direct trending. This is discussed in more detail in Appendix B.

The ABS recommends the TAG method for seasonal adjustment because it:

1. maintains or improves the quality of relevant quarterly seasonally adjusted estimates by better estimation and removal of calendar related effects;
2. imposes consistency between the seasonally adjusted estimates of monthly-quarterly time series pairs; and
3. improves the productivity of the ABS seasonal adjustment process.

Further, in combination with consistent application of trend related prior corrections across frequencies, the TAG method improves consistency between trend estimates of monthly-quarterly time series pairs.

3. PRACTICAL IMPACTS

Seasonally adjusted estimates

Estimation of monthly seasonally adjusted series does not change. Quarterly seasonally adjusted estimates will be derived as the temporal sum of their monthly seasonally adjusted counterparts.

Consistency of monthly and quarterly seasonally adjusted estimates

Introduction of the TAG method results in exact consistency between the seasonally adjusted estimates of equivalent original monthly and quarterly time series pairs.

Date of introduction

For greatest consistency benefits it is advisable to introduce the TAG method for seasonal adjustment as far back historically in a time series as is practical. For example, the TAG method will be introduced for Livestock and Meat Production quarterly series from the beginning of the corresponding monthly series, that is, from July 1979 or from the third quarter 1979 in quarterly terms. Quarterly seasonally adjusted estimates will hence be revised (see revision note below) to align exactly with the monthly series, beginning at this "date of introduction".

Revisions

The introduction of the TAG method will cause revisions to the quarterly seasonally adjusted and trend estimates from the date of introduction onward. For example, Livestock and Meat Production seasonally adjusted estimates (average absolute) revisions are in the order of 2%. See Section A.4 in Appendix A for details of these expected revisions to seasonally adjusted estimates upon implementation. Trend estimate revisions have not been calculated because they are expected to be of a similar nature and smaller order.

Combined factors

Direct decomposition (through independent seasonal adjustment) of a quarterly time series gives fine level components that contribute to the seasonal adjustment such as seasonal factors, moving holiday corrections and seasonal break corrections. Under the TAG method these are not available for multiplicative decomposition (refer to ABS, 2008) and only the derived combined factor (i.e. the ratio of the original estimate to the seasonally adjusted) is available.

Trend estimates

Estimation of monthly trend series does not change. For quarterly trend estimates, direct trending of the quarterly seasonally adjusted estimates is preferred to temporal aggregation of monthly trend estimates. Translation of prior corrections from the monthly series to the quarterly series is needed to produce ABS published trend estimates. This translation is automated within ABS time series systems according to the methods detailed in Appendix B.

Consistency of monthly and quarterly trend estimates

Consistency is increased between monthly and quarterly trend estimates by application of quarterly prior corrections that are automatically derived from monthly priors, via direct trending.

Quality assurance

The quality of seasonal adjustment will continue to be monitored for both the quarterly and monthly time series.

REFERENCES

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—— (2014) *Livestock Products, Australia,* cat. no. 7215.0, ABS, Canberra. < http://www.abs.gov.au/ausstats/abs@.nsf/mf/7215.0 >

Zhang, M.; Apted, L.; Hudson, J. and Outteridge, T. (2005) "Trading-Day Effect Estimation for Quarterly Time Series", Paper presented to the 55th Session of the International Statistical Institute, 5–12 April 2005, Sydney, Australia.

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APPENDIXES

A. SUMMARY OF EMPIRICAL ANALYSIS OF LIVESTOCK AND MEAT PRODUCTION SERIES

In summary, empirical analysis indicated that:

1. From a quality perspective there is little difference between independent adjustment and the TAG method. The TAG method performs better in terms of residual seasonality.
2. In terms of revision performance, on average, the TAG method provides similar or slightly better results to those of independent adjustment.
3. The actual revisions to quarterly seasonally adjusted estimates upon implementation, that is, when comparing what is published now to what will be published via the TAG method are, on average, in the order of 2%.

A.1 Background

Empirical analysis was carried out on 76 series from *Livestock Products, Australia* (cat. no. 7215.0), specifically the “Livestock slaughtered” and “Meat production” series. The monthly original time series for these groups are currently aggregated to derive the quarterly original estimates which are then independently seasonally adjusted along with the monthly series.

Several measures were calculated to assess the performance of temporally derived quarterly seasonally adjusted series compared to the directly seasonally adjusted series. The first set of measures assessed the revision performance of the two methodologies while the second evaluated the quality of seasonal adjustment. The data span considered was September quarter 1979 to September quarter 2008 inclusive.

It is known from previous work that the estimation and removal of calendar related effects and outliers are more accurate for monthly time series than quarterly series. Following the Methodology Advisory Committee paper method (Zhang and Apted, 2008), these effects were corrected before performance measures were calculated to ascertain whether the seasonal adjustment process favours the TAG method or the direct method.

For actual revisions (revisional impact upon implementation), quarterly seasonally adjusted estimates as published using independent seasonal adjustment were compared with those produced via the TAG method using monthly published seasonally adjusted estimates. The data span considered was the September quarter 1979 to the September quarter 2011 inclusive.

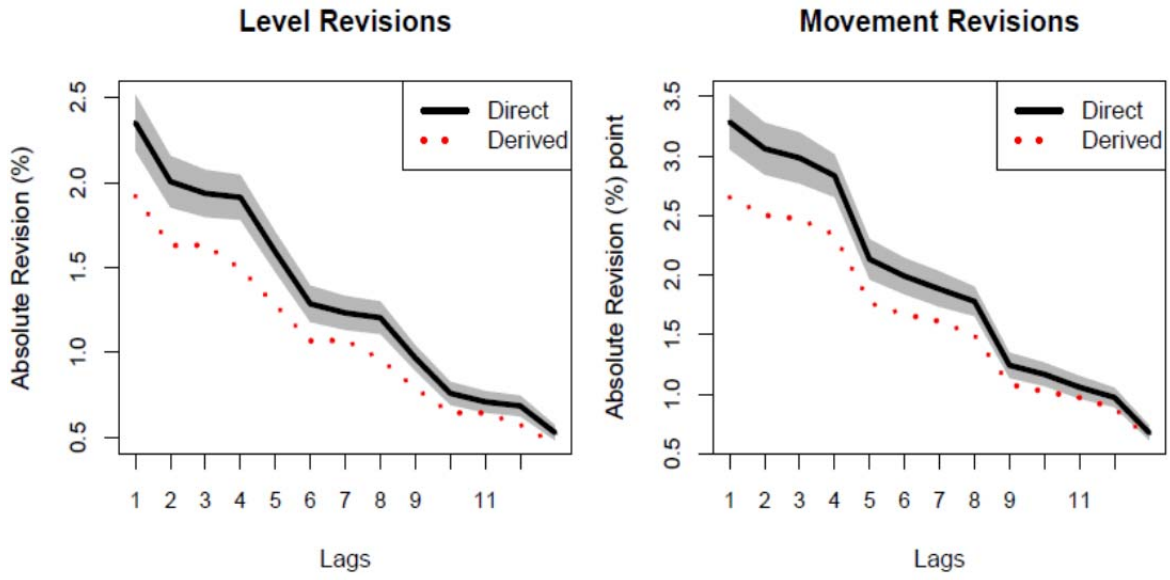
Revisions are expected to be relatively large for monthly-quarterly series pairs where the independent seasonal adjustment is not aligned well. For example, the pairs have inconsistent prior corrections. This is one of the issues the TAG method remedies. In contrast, where monthly-quarterly series pairs align well, for example, have no prior corrections or corresponding prior corrections, revisions are much smaller. Examples of these two scenarios are discussed in Section A.4.

A.2 Revision performance of the temporal aggregation method

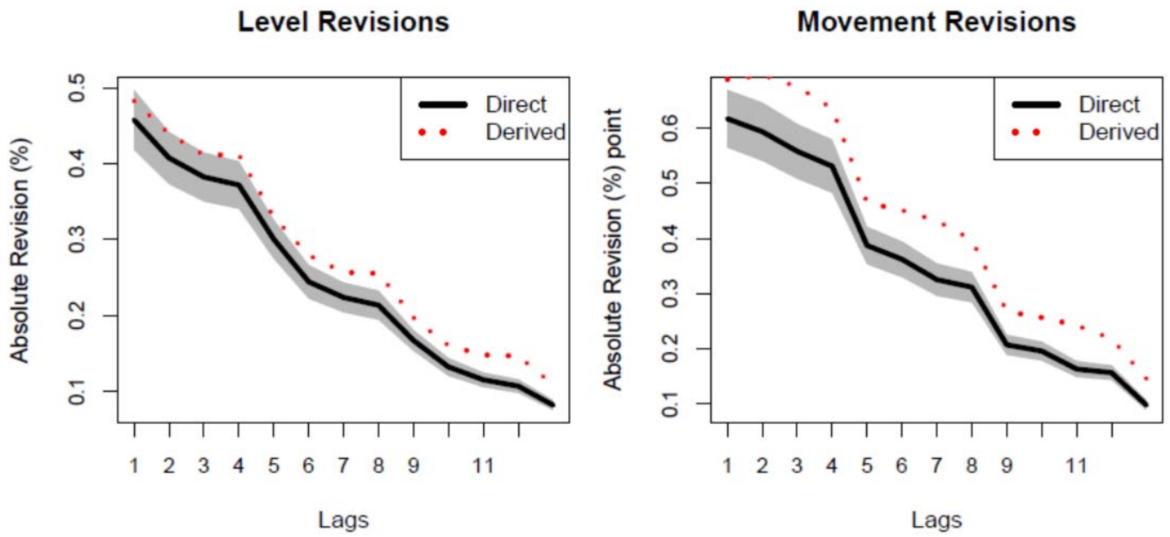
To assess revision performance, average mean absolute percentage revisions were calculated for the seasonally adjusted estimates of both the temporally derived and the directly adjusted quarterly series at different lags. These results show no overall increase in revisions to the TAG quarterly series. Prior corrections for Easter proximity and seasonal breaks are currently inconsistent in many monthly/quarterly series pairs for this collection. While TAG in production will correct such inconsistencies, for this empirical study all such prior corrections were deactivated for the purpose of allowing an informative comparison between methods.

Figures A.1 and A.2 depict the revision performance of two series for illustrative purposes. In each graph the shadowed area shows the mean absolute revisions of the direct method that is plus or minus one standard error; included to give an indication of the certainty relating to these mean revision estimates. Figure A.1 for Australia-level calf slaughterings, indicates that the TAG method leads to lower level and movement revisions at each lag compared to the direct method. Figure A.2 for Australia-level pig slaughterings, on the other hand, depicts a series where the direct method produces lower revisions at certain lags. Note that these revision simulations were based on the airline ARIMA model of order (0,1,1)(0,1,1) which was an acceptable fit in the vast majority of cases.

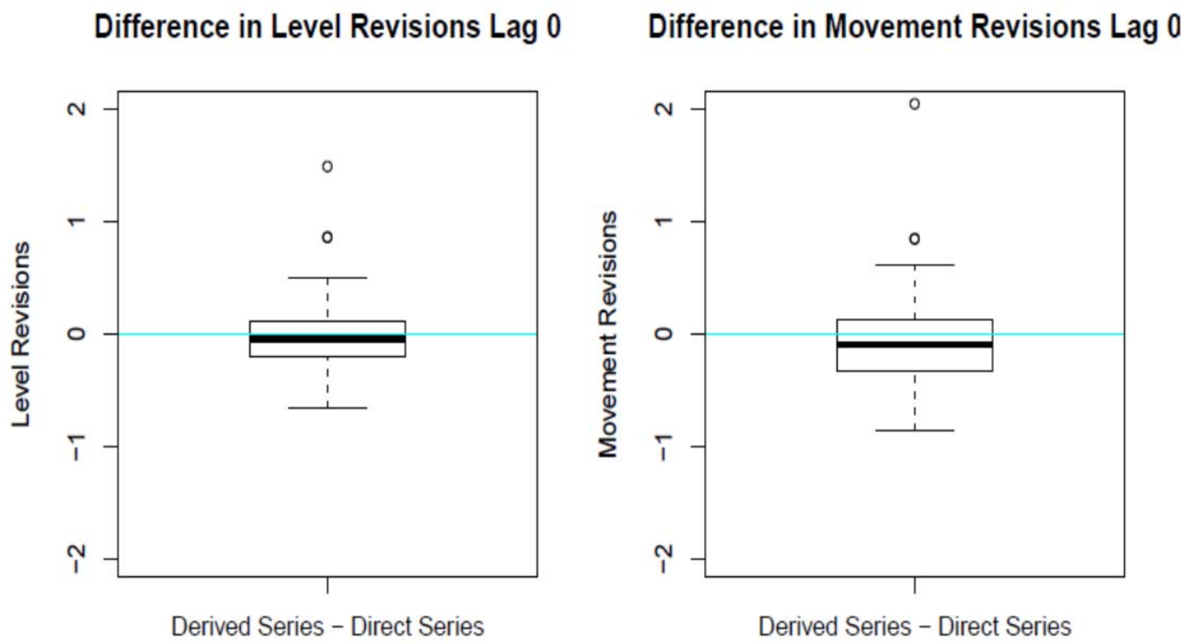
A.1 Calf slaughterings, Australia



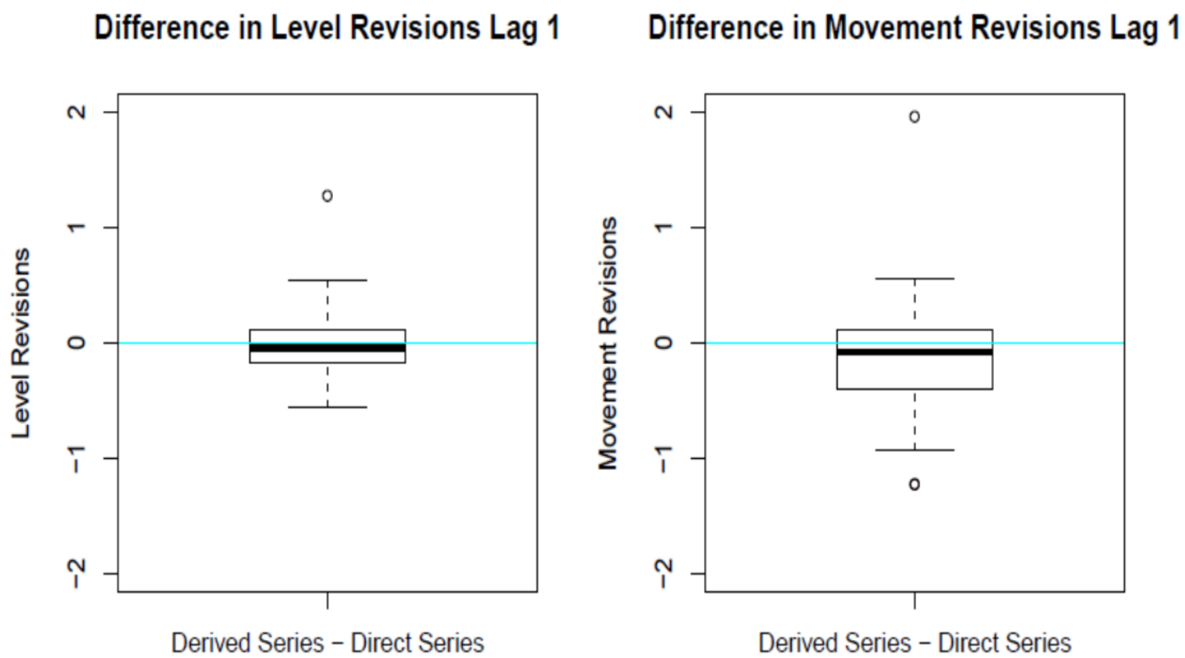
A.2 Pig slaughterings, Australia



A.3 Average Absolute Percentage Level and Movement Revisions at Lag 0



A.4 Average Absolute Percentage Level and Movement Revisions at Lag 1



Figures A.3 and A.4 summarise via box plots the difference in average absolute percentage level and movement revisions at lag 0 and 1, over the 76 Livestock Products series. For example, for each of the 76 *Livestock Products* series ('Livestock slaughtered' and 'Meat produced', by state), we calculate mean lag 0 revisions for derived series and subtract mean lag 0 revisions for direct series. These 76 differences for level revisions are presented on the left box plot in figure A.3 and those for movement revisions on the right box plot in figure A.3.

If using the TAG method to derive seasonally adjusted estimates reduced revisions in all 76 series, we would expect all of the box plot to be below zero. In fact, the box plot indicates that for some series the change in method improves revisions, and for some increases them. Overall the effect on the 76 series is centred around (slightly below) zero and pretty symmetric, indicating that the TAG method and the direct method perform similarly (or the TAG method better) at the most significant lags 0 and 1.

A.3 Quality assessment of the temporally derived method

Evaluation of the quality of seasonal adjustment was based on the residual seasonality, volatility and the smoothness of the quarterly seasonally adjusted estimates.

The residual seasonality of the seasonally adjusted quarterly series was assessed using the F-test from a simple Analysis of Variance on the residuals of seasonally adjusted and trend estimates. The lower the probability or 'p-value' the stronger the evidence of the presence of residual seasonality.

The volatility of the seasonally adjusted quarterly series was assessed using their average absolute percentage change (AAPC).

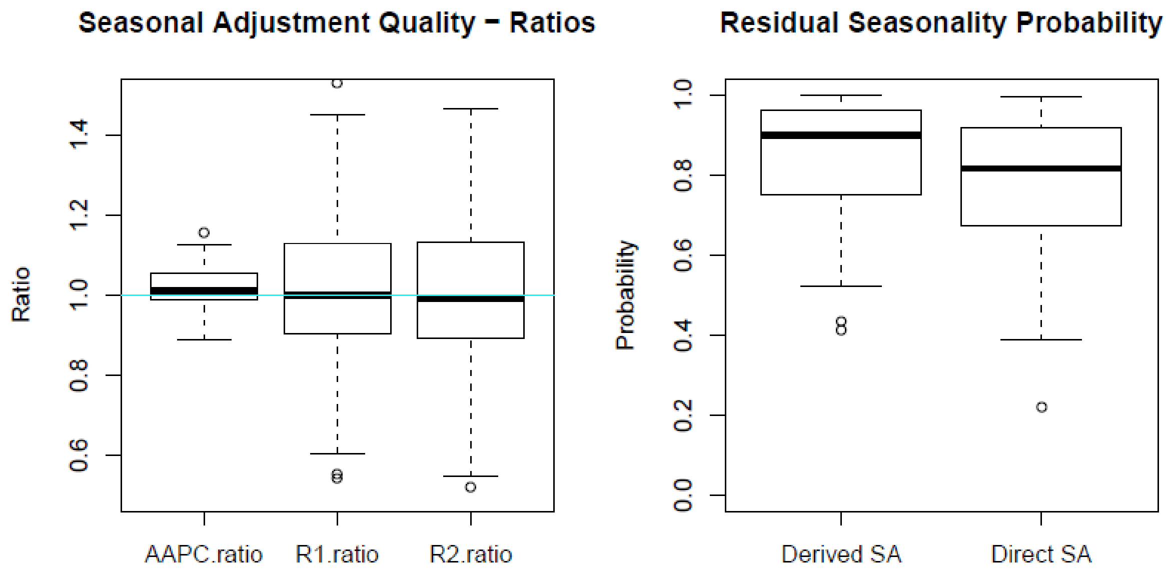
The smoothness of the seasonally adjusted series was measured in two ways. The R1 measure: the mean of the squares of the first differences of the seasonally adjusted series and the R2 measure: the mean of the squares of the additive residual-irregulars (the seasonally adjusted estimates minus the trend estimates). The lower the R1 value, the smoother, and hence, 'better' the seasonal adjustment. Similarly, a lower R2 value indicates a smoother seasonal adjustment.

Ratios of the temporally derived volatility and smoothness measures over their direct equivalents were used to determine method performance. That is, ratios less than one indicate that the TAG method is of higher quality.

Figure A.5 depicts the quality of seasonal adjustment comparison of the 76 temporally derived and directly adjusted Agriculture quarterly series. The left box plot in figure A.5 depicts an AAPC ratio almost centred around unity and largely symmetrical indicating comparable volatility for both methods; and R1 and R2 ratios that are less than 1, indicating that the TAG method results in smoother seasonally adjusted series when compared to the direct method. The right box plot of figure A.5 depicts a distribution of residual seasonality p-values that is generally higher in the case of derived seasonal adjustment, indicating less evidence of residual seasonality when using the TAG method.

Overall these box plots indicate that from a quality perspective there is little difference between the direct and TAG methods.

A.5 Quality of Seasonal Adjustment



A.4 Actual revisions between independent adjustment of quarterly time series and temporal aggregation method

To quantify actual revisions, average mean absolute percentage revisions were calculated for the seasonally adjusted estimates of both the temporally derived and the directly adjusted quarterly.

Unlike the previous section, prior corrections used in production were kept in place so these revisions were as indicative of actual revisions as possible.

Actual revisions have been summarised in table A.6. These indicate that in some instances there is very little difference between direct adjustment and the TAG method, for example at the Australian level revisions are less than 1% for all Livestock and Meat Production time series. This is further illustrated in figures A.7 and A.8.

Figure A.7 illustrates the temporally derived and directly adjusted livestock slaughtered bulls, bullocks and steers at the Australian level. The average absolute percentage change is 3.70 for directly adjusted and 4.01 for temporally derived respectively.

A.6 Livestock and Meat Production time series – mean absolute percentage difference between temporally aggregated and directly adjusted seasonally adjusted quarterly estimates

Group	*Absolute % difference*	*Group*	*Absolute % difference*
Livestock slaughtered ('000)		Meat produced (tonnes)	
New South Wales	1.31	New South Wales	1.34
Victoria	1.45	Victoria	1.45
Queensland	1.36	Queensland	1.51
South Australia	2.03	South Australia	1.88
Western Australia	1.81	Western Australia	1.80
Tasmania	2.60	Tasmania	3.07
Australia	0.94	Australia	0.96
Bulls, bullocks and steers	1.27	Beef	1.21
Cows and heifers	1.45	Veal	3.25
Cattle (excl. calves)	1.11	Mutton	2.03
Calves	2.95	Lamb	1.89
Sheep	1.97	Pig meat	0.98
Lambs	1.84		
Pigs	0.93	Total meat	0.94
All series	1.64	All series	1.72

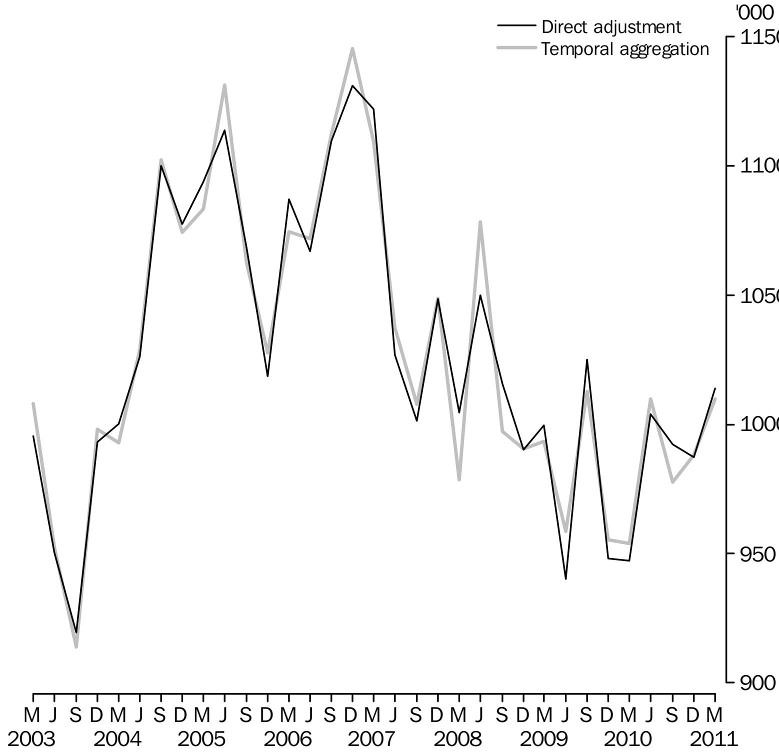
In comparison, the magnitudes of revisions for series at state level are much higher.

Figure A.7 shows the discrepancy between the direct adjustment and temporal aggregation. The maximum absolute difference in percentage terms is approximately 2.8%, whilst the mean absolute percentage difference between the two series is only 0.81%. This demonstrates that the series never differ greatly from one another. It may be worth noting in passing that the differences are usually more exaggerated at turning points in the series (for example, the March and June quarters of 2008). No evidence of a change of level or bias in the TAG method was detected, with the average difference between the two series being only 0.03%.

The situation for the lower level (Western Australia) series is similar to that of the Australia level series in terms of the differences of the two series (see figure A.8). However, these differences tend to be larger in percentage terms, as this series is in a relative sense, more volatile. Notwithstanding, one would expect such a result for a lower level series. Specifically, the maximum absolute percentage difference between the two methods is 15.95%, whilst the average absolute difference is 2.40%.

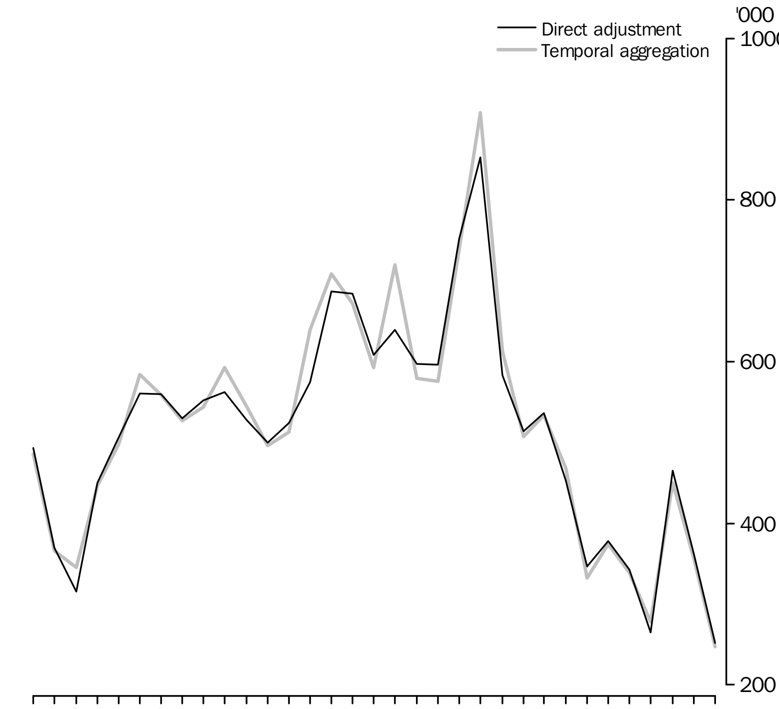
A.7 Comparison of seasonally adjusted estimates, direct adjustment vs temporal aggregation

LIVESTOCK SLAUGHTERED, Bulls, bullocks and steers—Australia



A.8 Comparison of seasonally adjusted estimates, direct adjustment vs temporal aggregation

LIVESTOCK SLAUGHTERED, Sheep—Western Australia



B. DETERMINING TREND PRIOR CORRECTION FOR QUARTERLY TEMPORAL AGGREGATES FROM THEIR MONTHLY EQUIVALENTS

Construction of a trend for temporally aggregated seasonally adjusted series was considered for two options:

1. Indirect trending, whereby the trend series is constructed by temporal aggregation, that is, summing the monthly trend series to obtain the quarterly trend series.

2. Direct trending, whereby the trend is constructed by directly applying a Henderson filter to the temporally aggregated seasonally adjusted series in a manner consistent with the current ABS trend for all directly adjusted series in the ABS.

Option 2 was found preferable for the following reasons:

- An indirect trend does not closely approximate the 7-term Henderson filter seen as appropriate for trending quarterly series for publication. Two time series with identical seasonally adjusted series will have drastically different trends depending upon whether they are directly adjusted or temporally aggregated.

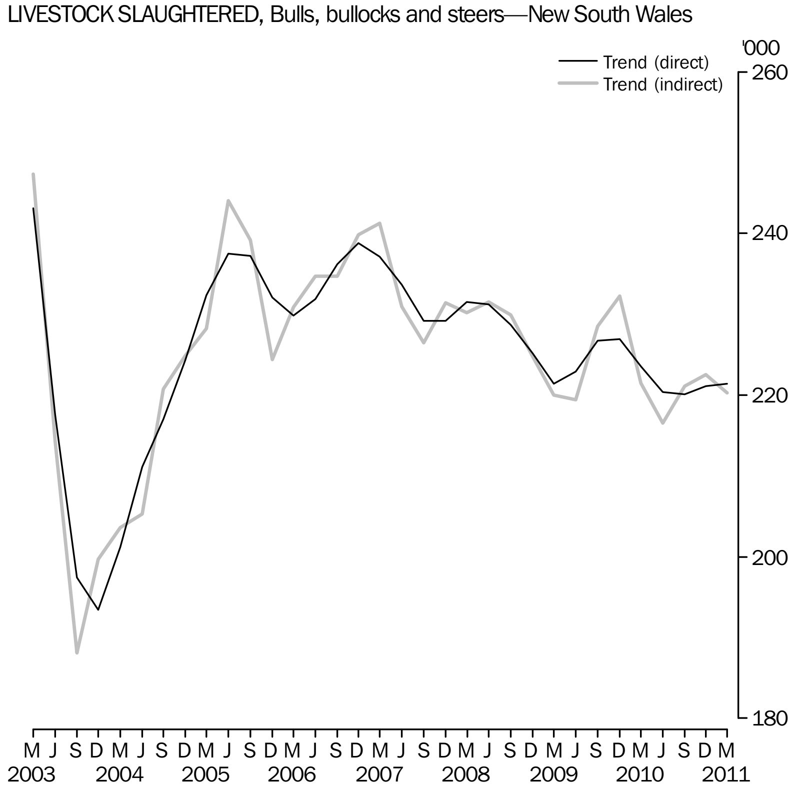
- An indirect trend does not result in a well-defined filter. The effective quarterly weights are not fixed and invariant between series and hence by any single criterion of ‘good behaviour’ for a trend, it is likely to be the case that series exist that will fail this criterion when indirectly trended.

- The derived gain of the temporally aggregated monthly 13-term filter shows that cycles of higher frequencies remain less dampened, compared to those of the direct 7-term quarterly filter. That is, under indirect trending, insufficient smoothing of the seasonally adjusted estimates is expected.

Empirical results further support direct trending. The example in figure B.1 shows *Bulls Slaughtered* in New South Wales with an indirect trend which does not have an adequate degree of smoothing.

Direct trending, requires that certain prior corrections, specifically large extremes, trend breaks and non-seasonal additive outliers, be translated from the monthly to the quarterly series.

B.1 Example of a temporally aggregated indirect trend



This functionality has been built into the ABS time series software based on investigated methodology which was successfully peer reviewed. The method of translation is consistent with the condition that the derived 'smoothed seasonally adjusted' – the series upon which a Henderson filter is applied to derive the publication trend – has its structure preserved by temporal aggregation. Formally, what we mean by this is simply that the following condition be satisfied:

$$TAG\left(\widetilde{SSA}_m\right) = \widetilde{SSA}_q$$

where $\widetilde{SSA}_m$ is the monthly smoothed seasonally adjusted series and $\widetilde{SSA}_q$ is the quarterly smoothed seasonally adjusted series.

Each series is derived by applying the respective monthly or quarterly prior correction factors. The above condition, then, is to say that applying all monthly trending priors to the monthly seasonally adjusted, then aggregating, yields the same series as would result from aggregating the seasonally adjusted and then applying translated quarterly priors.

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