Give me a break? New Zealand visitor arrivals and the effects of 9/11

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Abstract

We analyse monthly short-term visitor arrival time series for New Zealand, to assess the effect of the 11 September 2001 terrorist attacks on the number of visitors to New Zealand. Somewhat misleading reports from the media concerning these data are highlighted. We demonstrate that while some historical events have had a marked structural effect on trends in visitor arrivals to New Zealand, 9/11 was not one of these. Our conclusions are drawn on the basis of an initial nonparametric analysis, followed by a new iterative approach to fitting parametric structural break models, motivated by iterative methods for seasonal data. Our new approach has potential applications for model-based seasonal adjustment, in addition to the dating of structural changes.

Key words: Break dates; Causation; Endogenous dating of structural changes; Iterative fitting; Multiple breaks; Nonparametric estimation; Seasonality; Seasonal adjustment; Terrorism effects; Trend extraction.

1 Introduction

There seems little doubt that the terrorist attacks of 11 September 2001 have had a pronounced influence on world events since that time. For example, see US Department of State (2004), for a summary of 100 editorial opinions from media in 57 countries around the world, commenting on the three years following September 2001. Those terrorist events and their subsequent effects have been used to explain apparent movements in many time series, and in this paper we focus on a particular example: the number of short term visitor arrivals to New Zealand.

As we shall illustrate, in fact there is actually little to suggest that the September 11 incidents had much effect on New Zealand visitor arrivals, when viewed in the context of 'normal' historically observed movements. In contrast, we identify some other historical events which do appear to have affected visitor arrivals to New Zealand quite markedly.

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We also illustrate features of the arrivals data which highlight the importance of graphical displays when examining time series.

In Section 2 we highlight some reports from the media concerning these arrivals data, which motivated the need to look at claims of movements in a context of either structural or irregular change, allowing for observed stochastic variation. Section 3 presents an exploratory data analysis of New Zealand visitor arrivals and a discussion of some apparent sources of variability in the data. Section 4 presents a parametric model that allows separate structural changes in the trend and seasonal components. We use a new iterative fitting procedure, motivated by the classical Macaulay cycle method for the decomposition of seasonal data. Finally in Section 5 we give some concluding comments.

2 Motivation: the reported effects of 9/11 on short-term visitor arrivals to New Zealand

As an illustration of the perceived effects of the 9/11 incidents on New Zealand short-term visitor arrivals, we quote some short passages from The Dominion Post, one of New Zealand's widely read daily newspapers. All the quotes appeared around the first anniversary of 9/11. Much of the reported analysis was conducted by specialists within the tourism industry or the government and not by Dominion Post reporters. Article headlines are in bold, and our first example appeared as the lead story on the front page:

> **Sept 11 costs Kiwis $1 billion**
> The main costs incurred *as a direct result of the attacks* include: $64 million in lost income from tourists.
>
> (The Dominion Post, 7 September 2002, our emphasis)

A second example concerns a supposedly-causal link from the effects of the September 11 events to changes in arrivals numbers:

> **September 11 hits tourist numbers**
> Uncertainty about travelling on September 11 contributed to a 3 per cent drop in visitor arrivals *in August compared with the same month last year.* Visitors from New Zealand's biggest market, Australia, dropped 12 per cent while Japanese tourist numbers fell 6 per cent. Tourism Holdings general manager Shaun Murray said, "[w]e are *very sure* that speculation that people were wary of travelling around the time of 11 September was in fact quite correct." Tourism New Zealand chief executive George Hickton agreed.
>
> (The Dominion Post, 21 September 2002, our emphasis)

As just noted, comparisons are often made with the 'equivalent' period from the preceding year. Such comparisons may not always reflect observed features of the data though. For example, the previous year may have been 'high', rather than 'normal'; should a decrease then be viewed pessimistically?

The 9/11 incidents have also been used to account for forecast errors, although such errors occur every year:

> Tourism Ministry figures show there were 26,000, or 1.4 per cent, fewer tourists in total last year *than forecast*, and much of the shortfall *can be attributed to September 11.*
>
> (The Dominion Post, 7 September 2002, our emphasis)

In fact, the number of visitor arrivals from 1 September 2001 to 31 August 2002 was 1,959,886, an increase of 42,102 (or 2.2%) on the previous year. The wish to explain precisely why a forecast of a stochastic series was wrong is a failure to acknowledge naturally occurring variability: any forecast will be wrong, but a sensible quantification of the likely size of the error is a more realistic goal.

Explanations for variations in seasonality or trend that attribute movements to any one cause, such as the 9/11 incidents noted above, are almost always too simplistic. For monthly data, the 'equivalent' period from the preceding year often means 'same month'. Yet such a simple comparison ignores known calendar effects like Easter – e.g., Zhang, McLaren and Leung (2001) discuss an approach for an Australian Easter effect. Another more obscure 'calendar effect' in these data is a trans-Tasman rugby effect, identified in Haywood and Randal (2004) and due to changes in the month in which New Zealand's All Blacks hosted the Australian Wallabies for a rugby test match. The All Blacks' home game was in August 2001, but moved to July in 2002. The net result was to observe an increase from 2001 to 2002 in visitors from Australia in July but a corresponding decrease in August. Attribution of the observed August 2001 to 2002 decrease in visitors from Australia to a 9/11 effect, as made above, is clearly not the whole story. Neither is a trans-Tasman rugby effect, but there is more than one reason for the observed movements.

Our aim here is not to provide reasons for all changes in arrival numbers, from all source countries. Rather, we hope to illustrate that appreciation of stochastic variation is necessary in order to view apparent movements in an appropriate context; that is structural (longer-term) or not.

3 EDA of short-term visitor arrivals to New Zealand

The economic importance of tourism to New Zealand has recently increased considerably. As Pearce (2001) notes in his review article, international visitor arrivals increased by 65% over the period 1990 to 1999 while foreign exchange earnings increased by 120% (in current terms). More recently, for the year ended March 2004 tourism expenditure was $17.2 billion (Statistics New Zealand 2005). In that year, the tourism industry made a value added contribution to GDP of 9.4%, split between direct (4.9%) and indirect (4.5%) contributions, and 102,700 people (FTE) had work that was directly engaged in tourism: 5.9% of the total employed workforce. Also in that year, tourism's 18.5% contribution to exports was greater than that of dairy products (14.3%), which in turn was greater than the contributions from meat and meat products, wood and wood products, and seafood. The same ranking of industries was also seen in 2003. So tourism is now one of the most important industries in New Zealand.

The short-term New Zealand visitor arrival series is one direct and easily recorded measurement of the international tourist contribution to the New Zealand economy; see Statistics New Zealand (2005) for a breakdown of recent expenditure by domestic and international tourists. On a monthly basis, Statistics New Zealand releases official monthly totals, and these are commonly reported in the media, often with comparisons to the same month one year ago.

We analyse 25 complete years of monthly data from January 1980 to December 2004, looking at the total short-term arrivals and also those from the most important countries of origin, ranked by current proportion of the total: Australia, UK, USA, Japan, Korea, China, Germany. In the rest of this section we present some exploratory data analysis (EDA), which investigates the main features of the arrivals data and highlights some of the apparent sources of variability. A "U"-shaped seasonal pattern is common (see Figure 1), with visitor numbers reaching a local maximum in the summer months December to February, and a local minimum in the winter months June and July.

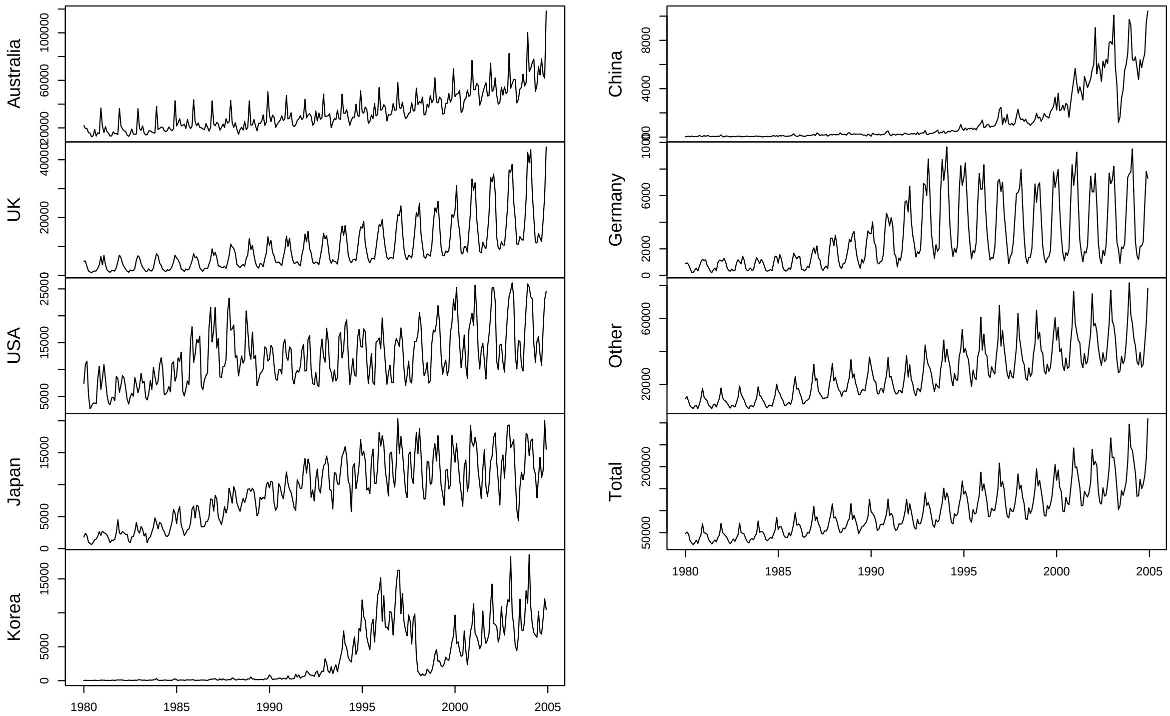

Figure 1. Monthly short term visitor arrivals to New Zealand, by origin, from January 1980 to December 2004. The vertical scales are not equal.

Several prominent features are evident in Figure 1. Australian and UK arrivals appear to be growing at a relatively steady rate. In contrast, a large downturn in arrivals from the USA is evident in the late 1980s, a period which immediately followed the stock market crash of October 1987. The trend in Japanese arrivals levels off over the last 15 years. Arrivals from Germany show a clear change from exponential growth prior to the early 1990s to a more stable pattern in recent times. Arrivals from China contain perhaps the most visible short term effect in these series, which is due to the SARS epidemic that virtually eliminated international travel by Chinese nationals during May and June 2003. Some other series, including Other and Total arrivals, show a SARS effect similar to but less prominent than that seen in the Chinese arrivals. The effect of the Asian financial crisis of 1997 is evident especially in the Korean data, with visitor numbers dramatically reduced just after this event. One of the more obvious shifts in the aggregate 'Total' series appears to be linked to the Korean downturn, and can be attributed to the Asian financial crisis.

The Asian financial crisis of 1997-1998 markedly affected stock markets and exchange rates in nine East Asian countries: Hong Kong, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand. See Kaminsky and Schmukler (1999) for a chronology of the crisis, from the official onset marked by the devaluation of the Thai baht on 2 July 1997 up to the resignation of Indonesian President Suharto in May 1998. Kaminsky and Schmukler (1999) suggest the presence of important contagion effects in those markets, based on an analysis of identified market jitters. More recent analysis by Dungey, Fry and Martin (2004) suggests, however, that increased exchange rate volatility observed in Australia and New Zealand around that time was not due to contagion, or unanticipated factors, from Asian countries but rather to common (anticipated) world factors. As Dungey, Fry and Martin (2004) note, the most obvious anticipated linkages between markets are via economic fundamentals, such as trade linkages. This is one context in which changes in short term visitor arrivals to New Zealand from Asian countries around 1997-1998 can be viewed, since tourism has become such an important sector of the New Zealand economy, as noted above. In particular, Korea is one of the five source countries with the largest current proportion of visitors to New Zealand (Table 1). A large decline in visitors from Korea, starting in late 1997 and continuing throughout 1998, is evident in Figure 1.

	Min	LQ	Median	UQ	Max	80-04	80-84	00-04
Australia	21.8	30.0	35.9	41.6	58.8	33.8	44.9	33.3
UK	3.4	6.3	8.0	10.6	18.3	9.8	7.6	11.8
USA	6.3	10.3	13.0	16.3	29.4	12.4	16.7	10.0
Japan	2.8	7.1	9.1	11.0	17.8	9.2	5.9	7.8
Korea	0.0	0.2	1.0	4.3	10.5	3.4	0.2	4.8
China	0.0	0.2	0.4	1.2	4.7	1.4	0.1	3.1
Germany	0.8	1.5	2.2	3.4	7.5	2.9	1.8	2.6
Other	17.9	23.4	26.1	28.6	34.3	27.0	22.8	26.7

Table 1. Summary statistics for the monthly proportion of visitors to New Zealand, by origin. The final three columns give proportions of the Total for the entire 25 year sample period, and the five-year periods 1980-1984 and 2000-2004, respectively.

Table 1 shows that Australia is by far the biggest single source of visitors to New Zealand, accounting for almost exactly one-third of visitors in the 2000-2004 five year period and slightly more over the entire data period. The maximum proportion in a month from Australia was 58.8% in June 1985, and the minimum was 21.8% in February 1997.

An Australian influence is notable in the total arrivals, because as the nearest neighbour to a geographically isolated country, arrivals from Australia exhibit variation not seen in the remaining data. As seen in Figure 1, the Australian data has a regular seasonal pattern which is quite different from that of any other country. Closer analysis indicates four peaks per year (after 1987) aligned with the Australian school holidays, one of which typically encompasses the Easter festival. An Easter effect is apparent in both the 1996-1998 and 2001-2003 periods, during which Easter alternated between April and March. As Figure 2 shows, in 1997 and 2002 when Easter was in March, March arrivals were high and April arrivals low. As a proportion of the total annual arrivals from

Australia, the average arrivals in March and April over the years 1996-2003 were 8.72% and 8.77%, when 1997 and 2002 are excluded. In contrast, March figures rose to 9.62% in 1997 and 9.83% in 2002, while for April the rates dropped to 7.57% in 1997 and 7.48% in 2002. Year to year comparisons of monthly arrivals for the Australian series are thus affected by these Easter movements. Since Australia is such a large contributor to total arrivals, this also feeds into year to year comparisons of monthly totals.

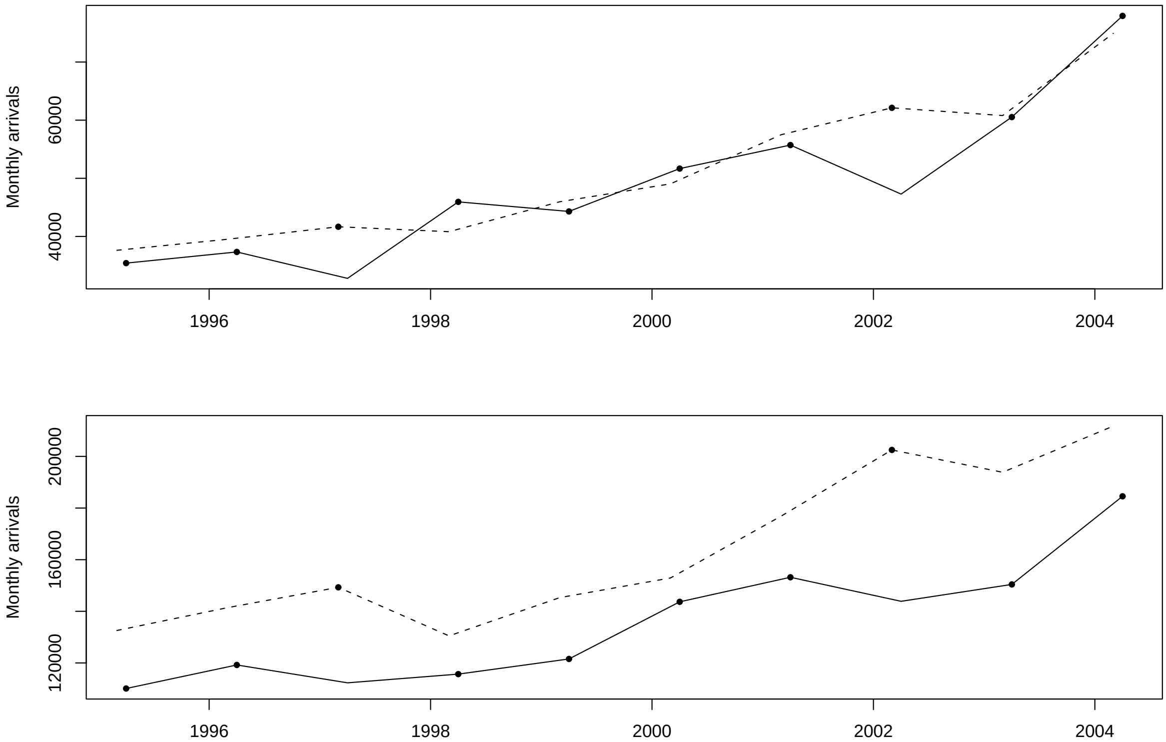

Figure 2. The March (dashed lines) and April (solid lines) monthly arrivals from Australia (top) and from all origins (bottom), for 1995 to 2004 inclusive. The location of the Easter festival (in March or April) is shown using black dots.

The arrivals data can be decomposed into unobserved components: a trend, representing the general level of the series; a seasonal, encapsulating regular deviation from the trend on a within-year basis; and an irregular, which is the residual, or unexplained variation in the data. One way of estimating these components is to use a robust, non-parametric technique such as STL (Cleveland, Cleveland, McRae and Terpenning 1990). This procedure consists of an iterated cycle in which the data is detrended, then the seasonal is updated from the resulting detrended seasonal-subseries, after which the trend estimate is updated. At each iteration, robustness weights are formed based on the estimated irregular component; these are used to down-weight outlying observations in subsequent calculations.

A typical STL decomposition is shown in Figure 3 for the natural logarithm of the Total arrivals. The log transformation is commonly used to stabilise a seasonal pattern which increases with the level of the series, and effectively transforms a multiplicative decomposition into an additive one. The plot shows an evolving seasonal pattern, an upward trend with several changes in slope, and a relatively small irregular component. A vertical line is added to indicate September 2001. There is no obvious (structural) change in the trend at or about this month, although there is a reduction in the slope of the trend nearer the start of 2001, which we discuss further in Section 5 below. More prominent is a cluster of negative irregulars immediately following 9/11, the largest of which is the third largest negative irregular in the sample period. Jointly though, these irregulars are smaller and less persistent than those occurring at the time of the SARS outbreak in 2003. Our exploratory analysis with STL thus suggests that while the events of 9/11 may have had a moderate short-term (irregular) effect, there is nothing to suggest that a longer-term (structural) effect occurred. We investigate this hypothesis more formally in Section 4.

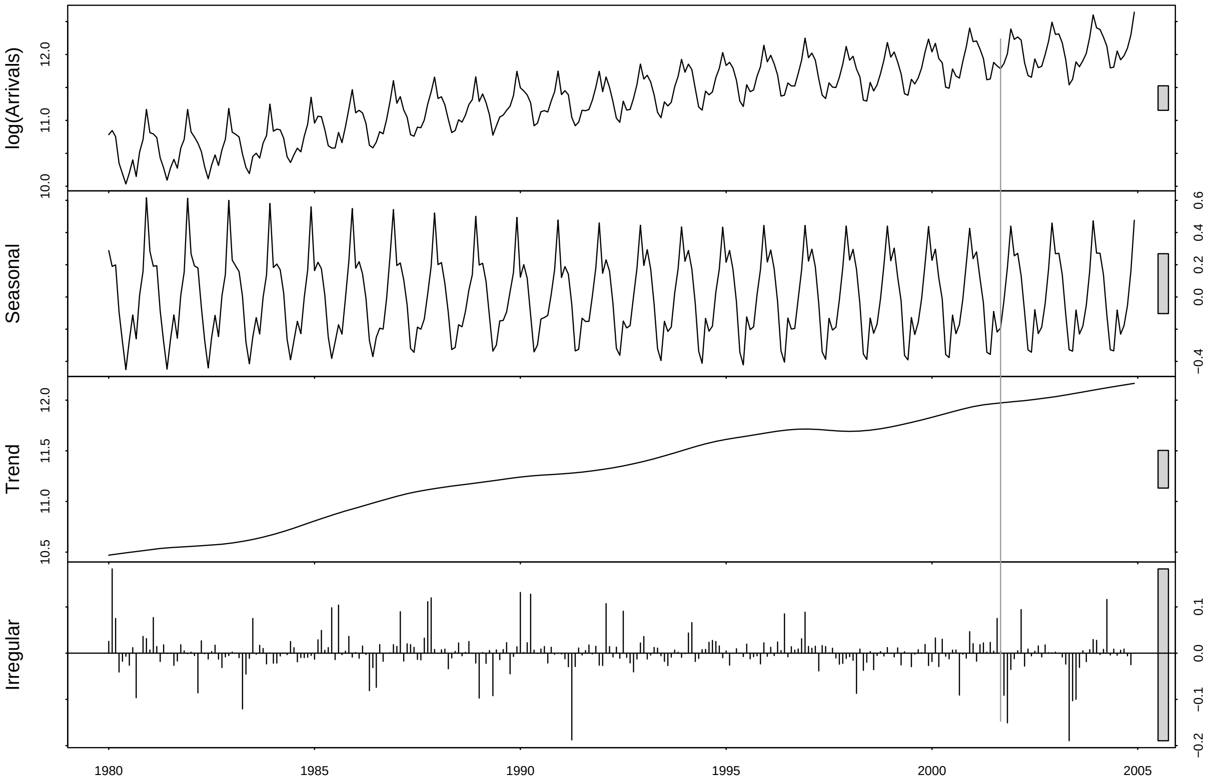

Figure 3. The STL decomposition of the log aggregate monthly visitor arrivals to New Zealand from January 1980 to December 2004. The vertical grey line is at September 2001, and the solid bars on the right hand side of the plot are all the same height, to aid comparisons.

A relevant confounding effect is the collapse of Ansett Australia, which occurred just three days after the terrorist attacks of 9/11; hence it is impossible to separate these two effects with monthly data. The termination of flights by Ansett Australia and Ansett International on 14 September 2001 certainly affected capacity and timing of arrivals to New Zealand. In addition, in the following week, strike action targetted at Air New Zealand occurred at Melbourne and Perth airports (Air New Zealand had acquired control of Ansett Australia during the year preceding its collapse). Those strikes required the cancellation of all Air New Zealand trans-Tasman flights operating from Melbourne and Perth. So considerable limitations were imposed on arrivals from Australia during September 2001, for reasons other than the 9/11 events. This would have noticeably influenced Total arrivals too, due to the large number of visitors from Australia.

4 Modelling the arrivals using structural breaks

The seasonal variation of the arrivals typically increases with the level of the series (Figure 1). This suggests a log transformation, which has the additional benefit that changes in the log series are approximately equal to percentage changes in the original number of arrivals, provided that change is small. Percentage changes are often reported for tourism data and thus a tourism industry perspective is one motivation for analysis using logged data. However the log transformation is not appropriate for all these series, and instead we estimate a power transformation, identified using the robust spread-vs-level plots described in Hoaglin, Mosteller and Tukey (1983). For each individual series we calculate the median and interquartile range (IQR) of the monthly arrivals for each of the 25 calendar years, then regress log IQR on log median. The appropriate transformation is $x^{1-\text{slope}}$, and the transformed series are shown in Figure 4, with the estimated powers. Confidence intervals for the slopes in these regressions support the use of logs only in the case of the UK, USA and Total arrivals (i.e. a power of zero, or a slope of one). In the case of Germany the estimated power is negative, so $-x^{1-\text{slope}}$ is used to preserve order in the transformed arrivals. Even though we lose the interpretability of proportionate changes that a log transformation would give, we believe that constancy of seasonal variation is particularly important for the break-dating procedure that we introduce next. Thus all further analysis is conducted on the power transformed data.

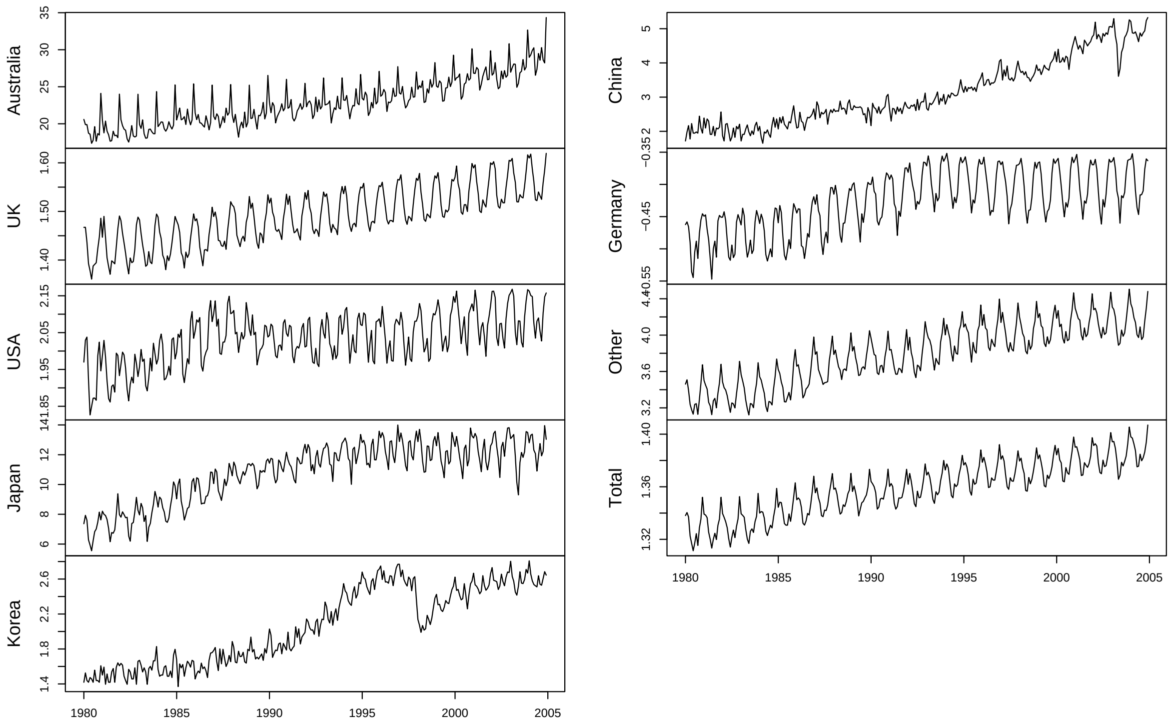

Figure 4. Power transformed monthly short term visitor arrivals to New Zealand, by origin, from January 1980 to December 2004. The power transformations are: Australia 0.3, UK 0.05, USA 0.08, Japan 0.27, Korea 0.11, China 0.18, Germany -0.11, Other 0.13, and Total 0.03.

We now consider modelling the transformed visitor arrivals series using a piecewise linear trend, with a superimposed piecewise constant seasonal pattern. Bai and Perron (1998, 2003) present a methodology for fitting a regression model with structural breaks, in which the break points, i.e. the time at which the parameters change, are determined optimally. In short, the optimal positions of m break points are determined by minimising the residual sum of squares, for each positive integer $m \leq m_{\max}$. The optimal number of break points ($0 \leq m^* \leq m_{\max}$) may then be determined by, for example, minimising an information criterion such as BIC. Given a sample of T observations, the selected break points are estimated consistently, with rate T convergence of the estimated break fractions (that is, the proportion of the data span at which the break points occur).

The maximum number of break points is determined by the number of observations relative to the number of parameters in the model. In general, for a model with m breaks and q parameters, at least q observations are needed between each pair of break points, requiring at least $T \geq (m+1)q$ observations in total. Clearly if the model has many parameters, fewer break points can be estimated from a given sequence of observations. In the case of the transformed arrivals data, the linear time trend requires two parameters, and the dummy seasonal an additional $s - 1 = 11$. Figure 4 indicates that for most series a linear time trend would need breaks. Further, while the seasonal patterns generally have constant variation over the length of the series, due to the power transformations, we do not wish to preclude seasonal changes during the data period. The parameter-rich trend-plus-seasonal (complete) model would severely limit our ability to estimate a fitted model which would appropriately fit the data, since the large number of seasonal dummies (and the relatively stable seasonal patterns) would reduce the possible number of break points. In some cases, that reduction may be to below the optimal number required, especially if selected by a penalised likelihood criterion such as BIC, as we do.

To address this concern we estimate the trend and seasonal components separately, using a new iterative approach motivated by the Macaulay cycle seasonal decomposition method and the iterative technique of STL. This allows more flexible structural break estimation than directly fitting a complete model. We assume that data can be decomposed into a piecewise linear time trend and a piecewise constant seasonal pattern. Each component is then estimated using the methodology of Bai and Perron (1998, 2003), implemented in R using the package of Zeileis, Kleiber, Krämer and Hornik (2003).

We estimate the trend of the transformed visitor arrivals data using a piecewise linear regression model

$$Y_t = \alpha_j + \beta_j t + \epsilon_t \qquad t = T_{j-1} + 1, \ldots, T_j$$

for $j = 1, \ldots, m+1$, with Y_t the deseasonalised, transformed monthly arrival series, ϵ_t a zero-mean disturbance and T_j, $j = 1, \ldots, m$ the unknown trend break points. We use the convention that $T_0 = 0$ and $T_{m+1} = T$ (Bai and Perron 1998). Once the trend has been estimated, we estimate the seasonal component as a piecewise constant function,

$$W_t = \delta_{0,j} + \sum_{i=1}^{11} \delta_{i,j} D_{i,t} + \nu_t \qquad t = T'_{j-1} + 1, \ldots, T'_j$$

for $j = 1, \ldots, m' + 1$, with W_t the detrended, transformed monthly arrival series, $D_{i,t}$ seasonal dummies, ν_t a zero-mean disturbance and T'_j, $j = 1, \ldots, m'$ the unknown seasonal break points. As before, we take $T'_0 = 0$ and $T'_{m'+1} = T$. The $\delta_{i,j}$ are adjusted so that they add to zero within each seasonal regime (between seasonal breaks), to prevent any change in trend appearing in the seasonal component as a result of a seasonal break happening 'mid-year'. That is,

$$\sum_{i=0}^{11} \delta_{i,j} = 0 \qquad \text{for all } j.$$

This estimation process is then iterated to convergence; three iterations were sufficient to ensure convergence of the estimated break points in all cases but 'Other' and Total, which each required four. We are thus able to estimate a trend which, due to its parsimonious representation, is able to react to obvious shifts in the general movement of the data. If required, we are able to identify important changes in the seasonal pattern separately. We note it is unlikely that many seasonal breaks would be needed in general, following use of our power transformations, since the amplitude of variation around the trend is stabilised by that approach.

The estimated trend break points are shown in Table 2 along with estimated confidence intervals. The confidence intervals have been formed with heteroscedasticity and autocorrelation consistent estimates of the covariance matrix (Andrews 1991). Note the intervals are not symmetric about the estimated breaks, indicating that movement of the break date within the interval is often possible in one direction, but not in the other.

Australia			China		
1984(5)	1985(1)	1985(2)	1984(7)	1984(8)	1985(1)
1989(3)	1989(4)	1990(5)	1988(10)	1989(7)	1989(9)
1997(10)	1997(12)	1998(1)	1997(1)	2000(11)	2000(12)
2001(1)	2001(10)	2001(11)	Germany		
UK			1986(6)	1986(7)	1986(11)
1985(10)	1986(1)	1986(4)	1994(5)	1994(6)	1994(7)
1990(7)	1990(8)	1996(5)	1999(6)	1999(8)	2000(11)
USA			Other		
1982(12)	1983(3)	1986(12)	1983(1)	1983(3)	1983(4)
1988(9)	1988(10)	1990(1)	1985(6)	1986(8)	1986(9)
1998(6)	1998(8)	2001(6)	1990(7)	1990(10)	1990(12)
Japan			1992(11)	1994(1)	1994(3)
1987(3)	1987(6)	1987(8)	1997(3)	1997(6)	1997(8)
1996(2)	1996(8)	1996(10)	2001(4)	2001(7)	2001(9)
Korea			Total		
1982(8)	1983(12)	1984(4)	1982(12)	1983(1)	1983(3)
1990(9)	1990(10)	1990(11)	1987(10)	1987(12)	1988(4)
1994(9)	1994(11)	1994(12)	1989(8)	1990(12)	1991(4)
1997(10)	1997(11)	1997(12)	1997(1)	1997(3)	1997(6)
2000(10)	2000(11)	2001(1)			

Table 2. Estimated trend break points for the transformed monthly visitor arrivals to New Zealand, by origin, from January 1980 to December 2004. The middle column gives the estimated break points, while the first and third columns give the lower and upper 95% confidence limits respectively, estimated using a HAC estimate of the covariance matrix.

The estimated parametric trends and break points (with 95% confidence intervals) are shown in Figure 5, along with nonparametric trends estimated by STL. September 2001 is included in only two confidence intervals, indicating the possibility that the terrorist events of 9/11 may be linked to a structural break in the trend of arrivals for those two origins: Australia and Other. 'Other' is difficult to interpret of course, given its composite nature. In the case of Australia, a break is estimated in the month following 9/11. This results in an increased trend slope but a decreased intercept. We cannot attribute this initial fall solely to the 9/11 terrorist events, due to the 'Ansett effects' already noted in Section 3. The limit on passenger numbers due to those other effects is a plausible explanation for a decrease in intercept, while the subsequent increase in the rate of arrivals from New Zealand's nearest neighbour is unlikely to have any causal links from the terrorist events of September 2001.

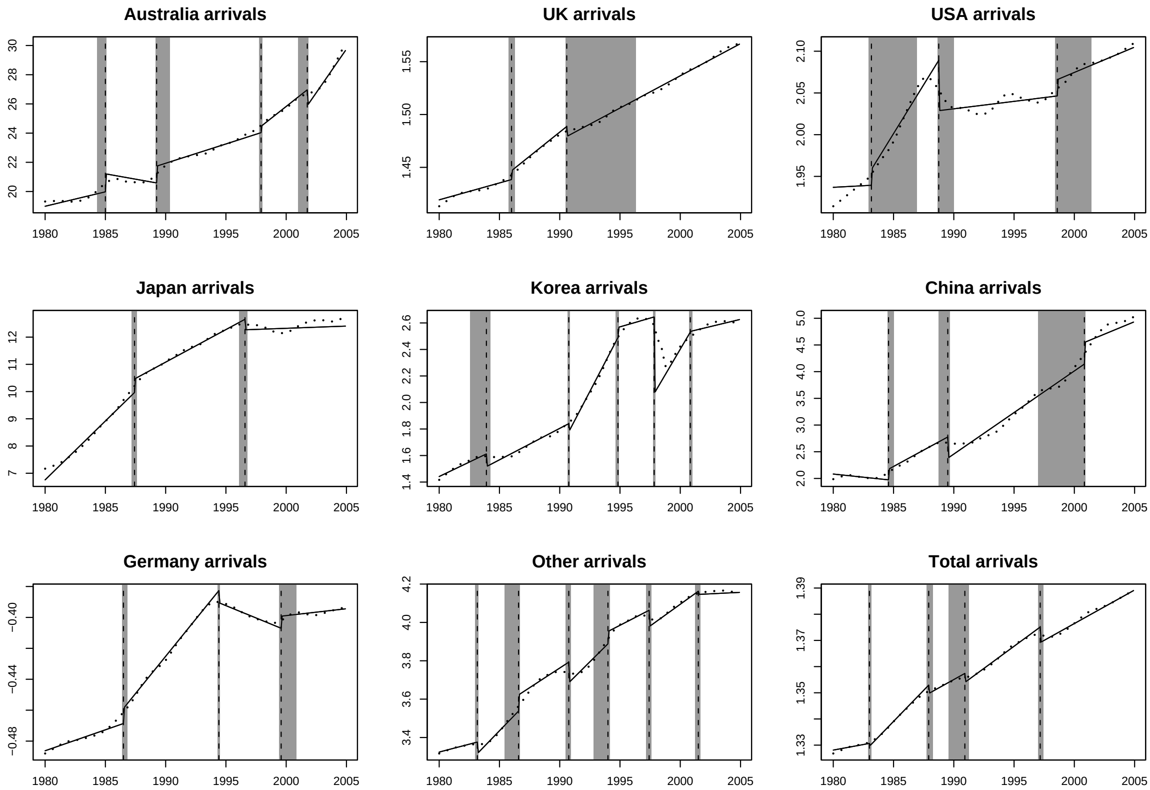

Figure 5. Estimated trends and trend break points for the transformed monthly visitor arrivals to New Zealand, by origin, from January 1980 to December 2004. The solid line is the piecewise linear time trend, while the dotted line is the estimated STL trend. The vertical dashed lines and grey regions respectively indicate the fitted break points and their 95% confidence intervals, estimated using a HAC estimate of the covariance matrix.

Focusing on Figure 5 more generally, we note that it is often difficult to distinguish between the two alternative trend estimates. In particular, the iterative parametric method achieves similar flexibility in its trend estimate to the nonparametric technique, with the latter essentially fitting linear time trends at each point in the series using only a local window of observations to estimate parameters. The break point technology allows instantaneous changes in the trend however, unlike the STL technique. In effect, STL is requiring an 'innovational outlier' approach to any structural changes in the data, while our parametric procedure models the changes directly and permits an 'additive outlier' approach. (In a long series of papers with various coauthors, Perron has popularised the use of these 'outlier' terms, to describe an approach which he attributes to the intervention analysis work of Box and Tiao (1975).) An obvious contrast between the two approaches is seen in the Korean data at the time of the Asian financial crisis. The parametric break point is dated at November 1997, which corresponds exactly to the month that the financial crisis first affected Korea (Kaminsky and Schmukler 1999). However STL spreads the downward impact of the crisis over a number of months, in contrast to the observed behaviour.

Table 3 gives the estimated seasonal break points for the transformed arrivals, estimated using detrended data; the estimated seasonal components are shown in Figure 6. Korea, China, Germany and Other have no estimated seasonal break points. As the power transformations have effectively stabilised the seasonal variation, any changes in the seasonal patterns more likely reflect behavioural changes in the time of year when visitors arrive. For example, in Australia's seasonal pattern the peaks have moved, reflecting a shift from a three-term school year to a four-term year in New South Wales in 1987 (NSW Department of Education 1985). The placement of the seasonal break point coincides exactly with the final month under the old three term system, with the first holiday in the new sequence occuring in July 1987. The UK data show a shift in arrivals from the second half of the year to the first and a shift in the peak arrivals from December to February. The USA and Japanese arrivals have had relatively complex changes, while the Total series has seen most change in the winter months.

Origin	Point estimate and 95% CI		
Australia	1987(1)	1987(6)	1987(9)
UK	1985(11)	1986(6)	1987(9)
USA	1995(1)	1995(4)	1995(12)
Japan	1987(10)	1988(6)	1988(12)
Total	1987(3)	1987(7)	1988(1)

Table 3. Estimated seasonal break points for the transformed monthly visitor arrivals to New Zealand, by origin, from January 1980 to December 2004. The middle column gives the estimated break points, while the first and third columns give the lower and upper 95% confidence limits respectively, estimated using a HAC estimate of the covariance matrix. Korea, China, Germany and Other have no estimated seasonal break points.

To conclude this section, we compare the trend estimates obtained from our new iterated approach to the trends obtained fitting a complete structural break model (with 13 parameters within each regime), and using STL. In the 13-parameter case, the constant term in the estimated time-trend (with breaks) is corrected so that the seasonal component adds to zero. In Figure 7 we present trends for the Korean arrivals and those from 'Other' origins. We also show sample autocorrelation functions for the three sets of residuals. The trends are all similar, but the agreement is closest for the iterated approach and STL. Some differences are evident particularly at the end of the series though, which would be important for prediction. The iterated technique estimates the well-motivated break point in the Korean data accurately, matching the onset of the Asian financial crisis precisely (November 1997) and with a narrow 95% confidence interval of October 1997 to December 1997. For 'Other' arrivals, the number of parameters required for the complete model clearly restricts the estimated number of breaks, leading to greater departures from the STL trend than achieved by iteration. The irregular components also favour

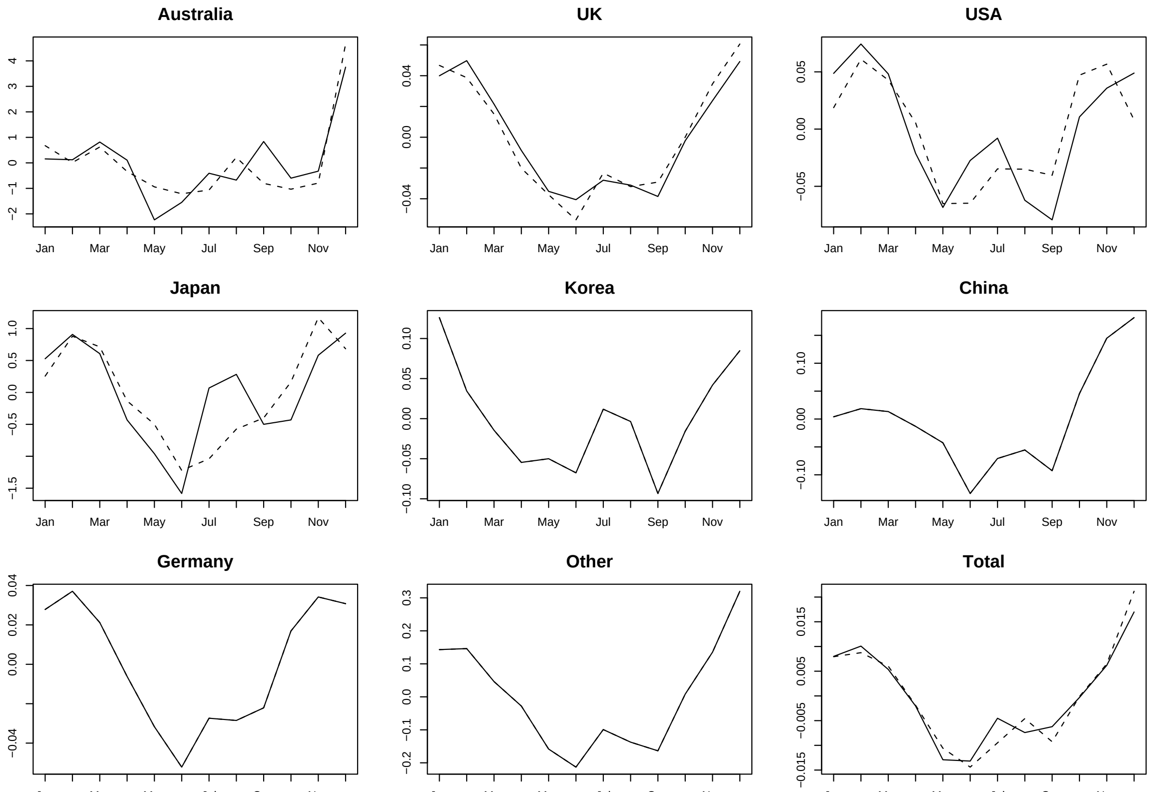

Figure 6. The estimated seasonal components for visitors to New Zealand by origin. The solid line is the final estimated seasonal component; it is the only estimate in four of the nine cases, where no seasonal breaks were detected. The five dashed lines are the seasonal components prior to the seasonal break points listed in Table 3.

the iterated approach, including over STL, as the residuals for the other approaches are highly autocorrelated, especially at low lags. In contrast, the residuals of the iterated method exhibit far less autocorrelation, indicating a better overall decomposition.

5 Discussion

The growth in the number of visitor arrivals to New Zealand was lower than expected in late 2001 (e.g., by the New Zealand Ministry of Tourism, as noted in Section 2), yet there is no conclusive evidence to attribute this forecast error solely to the terrorist events of 9/11. The termination of flights by Ansett Australia on 14 September 2001 certainly affected capacity and timing of arrivals from Australia to New Zealand, and that would have affected Total arrivals in September 2001 somewhat as well. Indeed Australia is the only (individual) country of origin with a structural change in trend identified relatively close to 9/11. The subsequent rate of Australian arrivals to New Zealand in fact shows an *increase*, following an initial drop which is plausibly explained by the Ansett effect; see Table 2 and Figure 5.

A further plausible cause for the lower than forecast number of visitors is the US recession dated March 2001 (Hall *et al.* 2001), along with the world wide flow-on effects from a slow down in the US economy. The recession predates 9/11 by six months but that is consistent with observed features of the data. In particular, as seen in Figure 8,

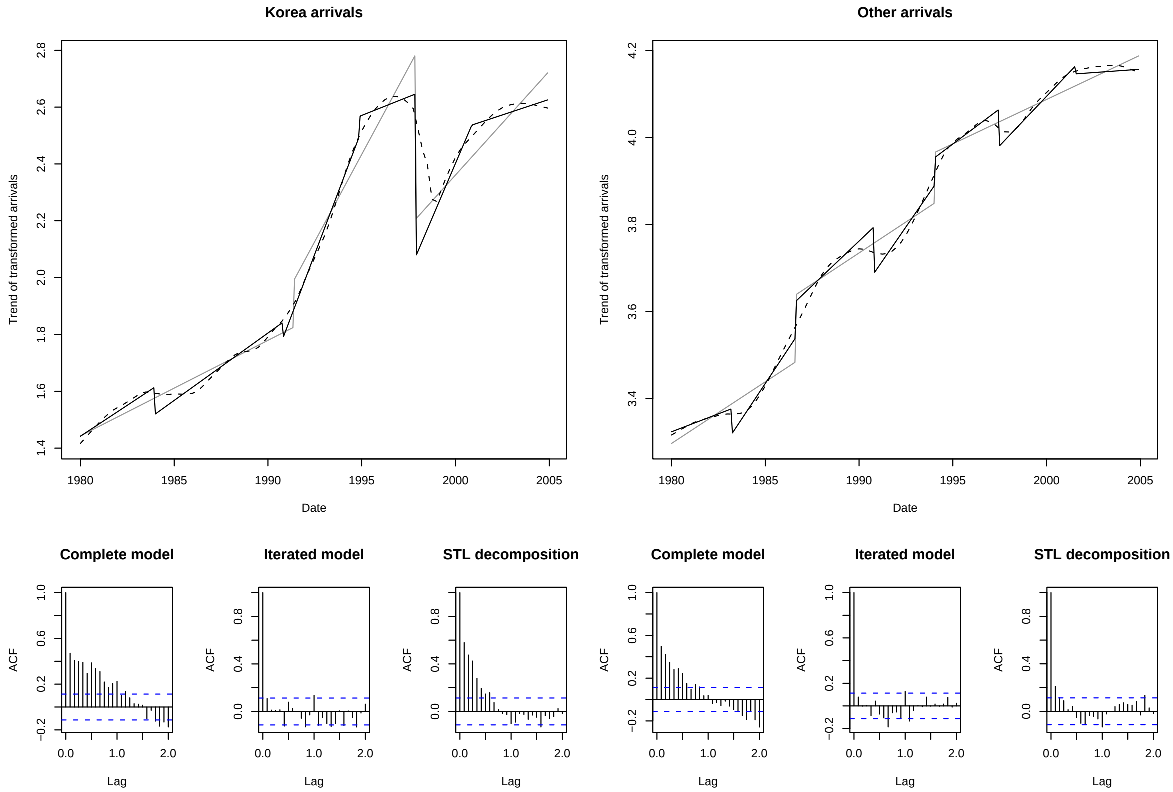

Figure 7. Trend estimates for the Korean arrivals and those from 'Other' origins. The trend estimates are based on the complete model (grey), the new iterated approach (black) and STL (dashed). Also shown are sample autocorrelation functions for the residuals from the three methods.

March 2001 corresponds exactly to the minimum in the second difference of an STL trend of Total monthly (log) arrivals, indicating a maximum decrease in the slope at that time. It is possible that the slow down seen in the 'Other' (composite) arrivals series, dated July 2001, may be due in part to the flow-on effects from this US recession.

It seems quite clear that the events of 9/11 did not have much influence on the longer-term numbers of visitors to New Zealand, and especially not a negative influence. In contrast our analysis identifies other events which have had marked structural effects on the trends in these data, especially from certain countries of origin. In particular, the stock market crash of October 1987 preceded a dramatic decline in arrivals from the USA, followed by a sustained period of only moderate growth. In turn, both the intercept and slope of Total arrivals decreased in December 1987. Similarly, the Asian financial crisis of 1997-1998 precipitated a massive drop in arrivals from Korea, with the intercept and slope of Total arrivals again both decreasing in 1997. The SARS epidemic affected arrivals from China in a different way, with a very short-lived but large reduction, which we class as temporary and not structural. The overall effects of 9/11 might also be seen as temporary and negative, but of a smaller magnitude than those associated with SARS.

Estimation of structural breaks was facilitated by a new implementation of Bai and Perron's (1998, 2003) work. Use of an iterative approach to estimate the trend and seasonal components separately enabled us to locate structural breaks in the data, and to attribute these to either changes in the trend or the seasonal pattern. Estimating these components simultaneously did not achieve the same flexibility in the estimated components, nor in the location of the break points. The agreement between the estimated

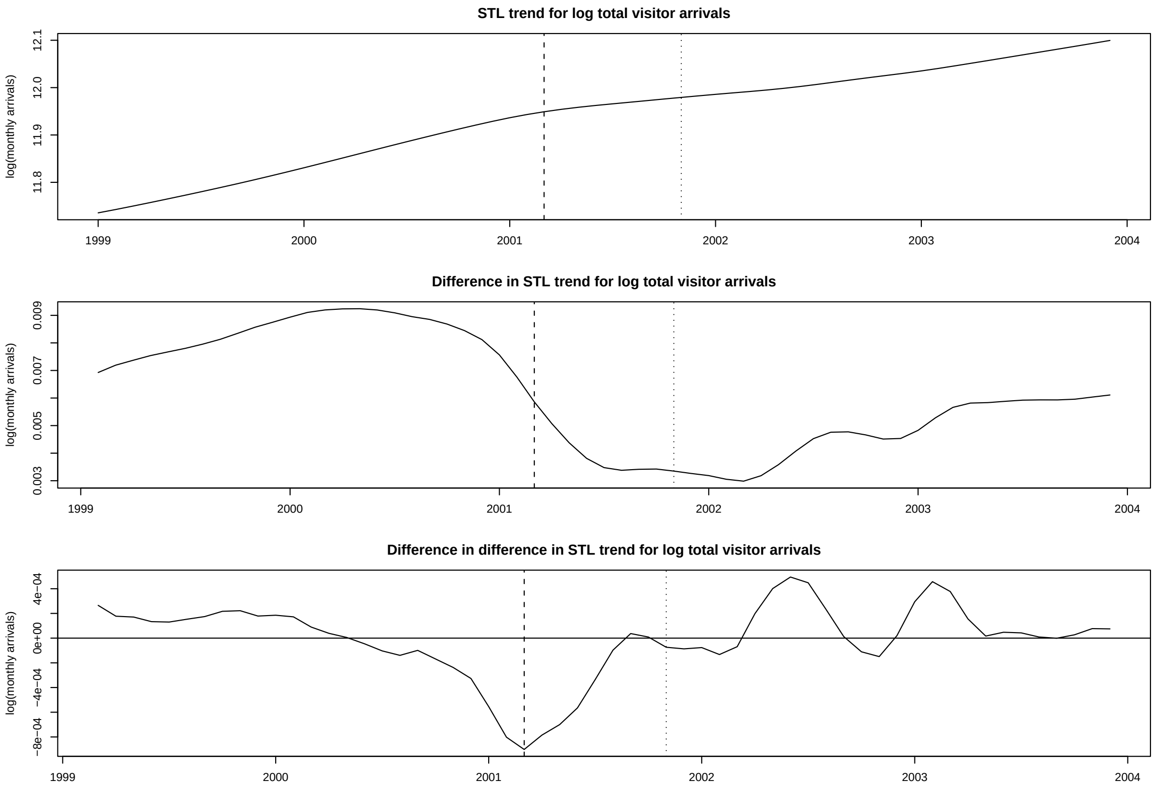

Figure 8. A trend estimate of the total monthly (log) visitors to New Zealand from any origin, with its first and second differences. The vertical lines are at March and November 2001, which are the recorded dates of the beginning and end of a US recession.

parametric trends from the iterated approach and the nonparametric STL trends is especially pleasing, as is the lack of residual structure around those parametric trends when compared to other trend estimates.

Finally, we note that our approach may be fruitful for model-based seasonal adjustment; something that is still extremely rare in the production of official statistics around the world. One major reason for this somewhat surprising rarity is a lack of appropriate flexibility in the evolution of model-based trends and seasonal components; see Bruce and Jurke (1996). Our parametric trends have similar flexibility to those of STL and our power transformation approach ensures that seasonal patterns do not change simply due to amplitude variation. Hence there is a real possibility that a seasonal-trend decomposition obtained from this approach may be a viable competitor to that achieved using X-12-ARIMA, but with the obvious advantages of model-based standard errors and forecast functions obtained with appropriate prediction intervals. A more detailed comparison to support this suggestion is the subject of a further paper.

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