A Quarterly Post-World War II Real GDP Series for New Zealand

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Abstract

There are no official quarterly real GDP estimates for New Zealand, for the period prior to 1977. We develop a seasonally adjusted series for 1947q2 to 2006q2, by linking quarterly observations from two recent official series to temporally disaggregated observations for an earlier time period. Annual real GDP series are disaggregated, using the information from two quarterly diffusion indexes, developed by Haywood and Campbell (1976). Three econometric models are used: the Chow and Lin (1971) model that disaggregates the *level* of GDP; and the Fernández (1981) and Litterman (1983) models that disaggregate changes in GDP. Statistical properties of the series are evaluated, and movements in the new series are benchmarked against qualitative research findings from New Zealand's post-WWII economic history. Our preferred quarterly series is based on results generated from the Chow-Lin model.

JEL Classification: C22, C82, E01, E32

Keywords: Quarterly real GDP series; temporal disaggregation; business cycles; New Zealand

1 Introduction

The performance of the post-World War II (WWII) New Zealand economy cannot be assessed effectively, without timely and accurate quarterly real GDP data that spans a sufficiently long time period. This is so, whether one's primary purpose is to establish classical business cycle turning points, evaluate competing theories of the business cycle, or assess the impacts of various government policies and external shocks.

At present, there are no official quarterly real GDP estimates for New Zealand, for the period prior to 1977. The current official chain-linked series of

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quarterly GDP goes back only to 1987. The span of time covered by this data includes only two completed classical business cycles and is thus inadequate for discriminating between various theories of the business cycle. In fact, it is not even sufficient to establish any stylized facts of the business cycle. There is a non-chain-linked series provided by Statistics New Zealand (SNZ) that covers the period 1977 to 1987 that allows researchers a little more leeway, but this span can still provide only four completed cycles.

Annual data on New Zealand GDP back to 1955 is available from SNZ, but annual data is of rather limited use when it comes to establishing classical business cycle turning points, stylized facts on the business cycle, and testing models of economic fluctuations. In addition to estimates available directly from SNZ there are a number of unofficial estimates of annual GDP covering more historical periods, including those of Lineham (1968), Hawke (1975), Easton (1990), and Rankin (1991).[1] Most of these estimates are for the period prior to WW II, and are therefore not directly relevant for this study. The exception is the series provided by Easton (1990), covering the period 1913/14 to 1976/77. For the immediate post-WWII period, the only indicators available on a quarterly basis for broadly-based economic activity movements are the diffusion indexes estimated by Haywood and Campbell (1976). These cover the period 1947 to 1974, and so the farthest we can potentially backcast quarterly GDP is to 1947.

The primary object of this paper is therefore to develop a quarterly seasonally adjusted real GDP series for New Zealand's post-WWII period, by linking recent official quarterly observations to temporally disaggregated observations for an earlier time period. The disaggregation is based on techniques that use seasonally adjusted indicator series which are available at a higher frequency and are related as closely as possible to the series of interest.

Temporal disaggregation is commonly resorted to by researchers when official statistical agencies are unable to provide data at a required frequency. The method has also been used by official statistical agencies themselves when direct estimation methods are unavailable.[2]

The remainder of the paper is as follows. Section 2 summarises the information available on economic activity in the New Zealand economy over the post-WWII era. Section 3 sets out the Chow and Lin (1971) and related methods for temporal disaggregation of the annual GDP data. Section 4 explains the splicing of the new quarterly estimates for the period 1947 to 1979, to official quarterly estimates for the period 1977 to 2006. Section 5 evaluates statistical properties of the series, and their relative usefulness for business cycle analysis and policy appraisal. Section 6 concludes. The quarterly seasonally adjusted

[1] Briggs (2003) provides a good summary of what each of these estimates involves and the estimates are available on Statistics New Zealand's long-term data series webpage (see http://www.stats.govt.nz/tables/ltds/default.htm).

[2] Proietti (2006, p 357) reports that " ... a large share of the Euro area quarterly gross domestic product is actually estimated by disaggregating annual data." Ciammola, Di Palma, and Marini (2005, p 6) cite Italy, France, and Belgium as specific examples. SNZ use temporal disaggregation rather differently. Where data from different sources are used for the Annual and Quarterly National Accounts, they use a 'benchmarking' process (see Bloem et al, 2001, pp 5-7), to ensure preliminary quarterly estimates are consistent with the annual growth rates.

data for our preferred series, based on results generated from the Chow-Lin model, are presented in Appendix Table A4.

2 The Data

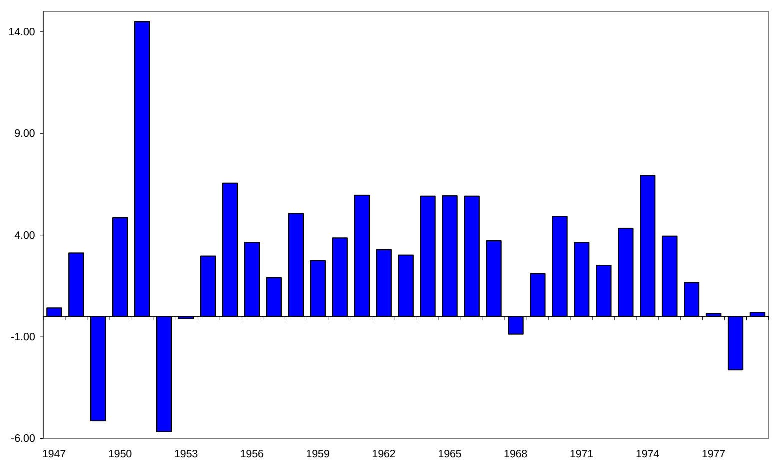
2.1 The Source GDP Data

Our new quarterly real GDP time series covers the post-WWII sample period, 1947q2 to 2006q2. Its construction has involved piecing together data from various sources, and scaling the linked series to a 1995/96 base.

We use SNZ's System of National Accounts series SNB, in 1991/92 prices, for the period 1977q2 to 1987q1. This seasonally adjusted series is not chain-linked. Their current series SNC, in 1995/96 prices, is chain-linked, and its seasonally adjusted observations are used for the period 1987q2 to 2006q2.

For the period 1947 to 1977, however, annual observations obtained from SNZ's long-term data series webpage, had to be the starting point. For 1947 to 1955, these observations are based on annual growth rates presented in Easton (1990), and for 1955 to 1977, the source is SNZ's annual SNB series (1991/92 base). Growth rates of the annual series are shown in Figure 1 for the years 1947 to 1979. Four periods involving negative economic growth can easily be detected: 1949, 1952-53, 1968, and 1977-79. Additionally, there is the unassociated 1957 period of slower economic growth, that could lead to our being able to uncover from quarterly series, further classical business cycle contractions.

Figure 1. Growth Rate of Annual GDP
(year ending March, 1947 to 1979)



Source: Statistics New Zealand's long-term data series webpage (see http://www.stats.govt.nz/tables/ltds/default.htm).

2.2 The Related Quarterly Series

Two diffusion indices constructed by Haywood and Campbell (1976) provide the best information available on quarterly fluctuations in aggregate economic activity. For the period 1947q1 to 1974q4, from 63 seasonally adjusted time series indicators[3], they construct a weighted classical cycle index and a weighted amplitude adjusted index[4]. The weights are based on each series' relative economic significance, with consideration also being given to the importance of the sector to which each series belongs.

Construction of the weighted classical cycle is based on the direction series

$$s_{kt} = \begin{cases} 1, & z_{kt} > z_{k,t-1} \\ 0, & z_{kt} = z_{k,t-1} \\ -1, & z_{kt} < z_{k,t-1} \end{cases} \tag{1}$$

where z_{kt} is the value of the k^{th} time series indicator and $s_{k1} = 0$. The weighted classical cycle index is then defined as

$$x_t = \sum_{i=1}^{t} \sum_{k=1}^{K} a_k s_{kt}, \qquad \text{for } t = 1 \text{ to } T, \tag{2}$$

where a_k is the relative weight of the k^{th} indicator. The weighted amplitude adjusted classical index is defined in a similar manner, except for the adjustment for the relative amplitudes of the indicator series. The underlying indicators and the weights used by Haywood and Campbell (1976) are shown in Appendix Tables A1 to A3.

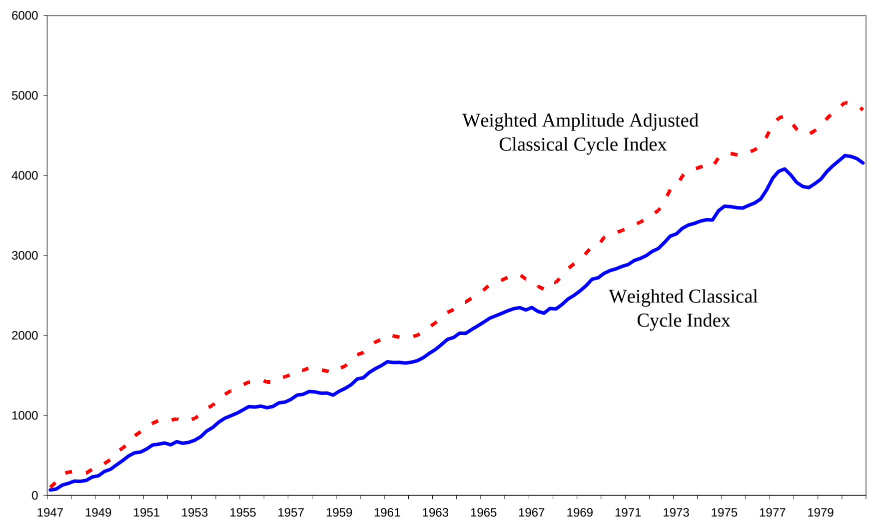
The diffusion indices of Haywood and Campbell (1976, Tables 13 and 14, p 22) end with 1974, and so leave us with a three year gap until the quarterly GDP series start. Fortunately, however, the New Zealand Institute of Economic Research (NZIER) updated the weighted static deviation cycle index of Haywood and Campbell (1976, Table 16, p 23) for a number of years, and presented the outcomes in its *Quarterly Predictions* through till 1979. The deviation cycle index is closely related to the classical cycle index, and so after further computation we were able to produce observations covering the next three years. The difference between the classical and deviation cycle indices is that the deviation cycle is the aggregation of a direction indicator of each indicator series. It takes on values of +1, 0, or −1, depending on whether a particular month's deviation cycle was above, the same, or below its trend value. As such, the deviation cycle measure is suitable for dating growth cycles rather than classical cycles. This deviation cycle series was successfully matched by Kay (1984) to the NZIER's surveyed *Business Opinion* measure of capacity utilization (CUBO), and in its extended form was used by Easton (1997), to date turning points in growth cycles in the New Zealand economy.

[3] For seasonal adjustment details, see Haywood and Campbell (1976, p 5, Chart A).

[4] The approach used for amplitude adjustment is similar to that of Shiskin (1961). Haywood and Campbell's computer programme also calculated deviation (or growth) cycles. Further details on their methodology are available in Haywood and Campbell (1976, ss 2, 3 and 4).

However, by assuming a trend consistent with the classical indices of Haywood and Campbell (HC), we were able to use the weighted static deviation cycle index to extend both the weighted classical index and the weighted amplitude adjusted classical index out to 1979q1. The assumed trend growth in both diffusion indices was 2.3 percent per annum, based on the average growth rate over the period 1947 to 1974. These extended classical indices are shown in Figure 2.

Figure 2. Extended Haywood and Campbell Diffusion Indices *(1947q1 to 1981q1)*



Source: Haywood and Campbell (1976), Easton (1997) and authors' calculations.

3 Temporal Disaggregation Methods

The problem we face is that for the period 1947 to 1977 we have only annual real GDP data, but would like quarterly data. The temporal disaggregation methods most commonly used are those of Chow and Lin (1971), Fernández (1981) and Litterman (1983)[5]. A key reason for their popularity for obtaining estimates of the desired high frequency data from low frequency data, is that they use relatively simple regression methods, dependent on a single autoregressive parameter In this section, we therefore explain briefly the key features of, and differences between, these methods, and present corresponding quarterly real GDP estimates.

[5] Proietti (2006) has investigated the potential use of state space methods for temporal disaggregation purposes. He also refers to, but did not evaluate the multivariate time series approaches of Harvey and Chung (2000) and Moauro and Savio (2005). None of these methods seems to have been widely used yet.

The method most often used is that of Chow-Lin. It can be used to generate any higher frequency estimates from lower frequency source data (subject to available higher frequency indicators), but from this point we restrict ourselves to considering the problem of moving from annual data to quarterly data.

Let y be a $(4n \times 1)$ vector of the unknown quarterly series. Let X be a $(4n \times p)$ vector of related series. For the current application $p = 1$. Assume there exists a multiple regression of the form

$$y = X\beta + u \tag{3}$$

where u is a vector of disturbances such that $E[u] = 0$, $E[uu'] = V$. Let i be a (4×1) vector of ones so that $C = I_n \otimes\, i_4'$ is a $(n \times 4n)$ matrix converting quarterly into annual observations That is,

$$y_a = Cy \text{ and } X_a = CX. \tag{4}$$

An optimal (in the BLUE sense) estimator $\widehat{y}$ of y is given by

$$\widehat{y} = X\widehat{\beta} + VC'(CVC')^{-1}C(y_a - X_a\widehat{\beta}) \tag{5}$$

where

$$\widehat{\beta} = (X_a'(CVC')^{-1}X_a)^{-1}X_a'(CVC')^{-1}y_a. \tag{6}$$

A practical problem is that, in general, V is unknown and must be estimated. Chow-Lin assume a simple autoregressive structure for the disturbances of the form

$$u_t = \rho u_{t-1} + \varepsilon_t \tag{7}$$

where $E[\varepsilon_t] = 0$, $E[\varepsilon_t^2] = \sigma^2$. The resulting covariance matrix V has the Toeplitz form

$$V = \frac{\sigma^2}{1-\rho^2}\begin{bmatrix} 1 & \rho & \rho^2 & \cdots & \rho^{4n-1} \\ \rho & 1 & \rho & \cdots & \rho^{4n-2} \\ \rho^2 & \rho & 1 & \cdots \vdots & \rho^{4n-3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \rho^{4n-1} & \rho^{4n-2} & \rho^{4n-3} & \cdots & 1 \end{bmatrix} \tag{8}$$

and the covariance of the annual residuals is then given by $V_a = CVC'$. The first-order autocorrelation of the annual disturbances ρ_a is related to ρ in the following way

$$\rho_a = f(\rho) = \frac{\rho\,(\rho+1)\left(\rho^2+1\right)^2}{2\,(\rho+\rho^2+2)}. \tag{9}$$

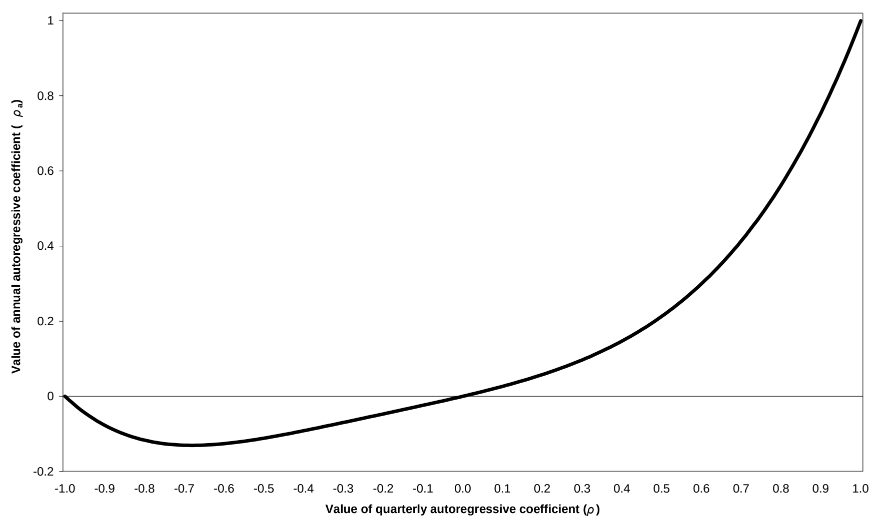
Figure 3 provides a plot of the function $f(\rho)$, and shows that for a given value of ρ_a we can obtain a unique value of ρ when $\rho_a > 0$. There is a range of small negative values of ρ_a for which there is not a unique value of ρ, and even more problematically for large negative values there is no solution to $\rho = f^{-1}(\rho_a)$ at all.

An iterative procedure can therefore be used to obtain an estimate of ρ. First regress y_a on X_a to get an estimate of $\widehat{u}_a^1$ and then regress $\widehat{u}_a^1$ on the first lag of $\widehat{u}_a^1$ to obtain an estimate $\widehat{\rho}_a^1$. Obtain an estimate of ρ using $\widehat{\rho}^1 = f^{-1}(\widehat{\rho}_a^1)$. Take this estimate and form a set of annual regression residuals using

$$\widehat{u}_a^2 = y_a - X_a \left[(X_a'(CV_1C')^{-1}X_a)^{-1}X_a'(CV_1C')^{-1}y_a \right] \tag{10}$$

where V_1 is the Toeplitz matrix based on the estimate $\widehat{\rho}^1$. From these residuals compute a new estimate $\widehat{\rho}_a^2$ and thus a new $\widehat{\rho}^2$ is obtained via the inverse function of $f(\rho)$. Continue until convergence is achieved. Plugging these final estimates into (5) yields the best linear unbiased estimate of quarterly real GDP.

Figure 3. Annual AR coefficient as function of the quarterly AR coefficient using the Chow-Lin model



As long as the first order autocorrelation coefficient is positive the iterative procedure will converge. It is important to verify this condition before trying to apply the Chow-Lin procedure. It is also important to verify that the Chow-Lin regression model (3) forms a cointegrating relationship when the underlying data contain stochastic trends.

We estimate the Chow-Lin regression over the period 1947q2 to 1979q1. Strictly speaking we need to estimate the regression only over the period 1947q2 to 1977q1, since we have quarterly GDP data starting from 1977q2. However joining the Chow-Lin estimates at 1977 is problematic for two reasons: (i) SNZ quarterly and annual series do not match for this year; and (ii) the SNZ growth estimates for this year are in dispute.[6] Thus in order to splice our new quarterly

[6] The Statistics New Zealand production-based real GDP series SNBA.2SAZAT reports annual growth of -2.6 percent for the year ending 31 March 1978. The series was discontinued

estimates to the existing quarterly estimates without any awkward discontinuities we use the sample up to 1979q1 for the Chow-Lin regression.

We consider the two cases: (i) the related series is the HC weighted classical diffusion index (denoted unadjusted); and (ii) the related series is the HC weighted amplitude adjusted classical diffusion index (denoted adjusted). Table 1 reports the estimated values of the autoregressive coefficient (for both annual and quarterly data) and a residual based test of cointegration, using the augmented Dickey Fuller (ADF) statistic. In the first case, the necessary conditions that the autoregressive coefficient is positive, and the Chow-Lin regression is cointegrated, are satisfied. However, in the second case, while the autoregressive coefficient is positive, it is so close to the unit root value of one that the cointegration condition is violated. For the Chow-Lin regression method, the amplitude adjusted series can therefore be rejected in favour of the series without adjustment.

Table 1. Chow-Lin Regression Results
(sample period 1947q2 to 1979q1)

Statistic	Unadjusted	Adjusted
β_0	5.575	6.411
β_1	3.109	2.282
ρ_a	0.869	0.968
ρ	0.949	0.988
ADF Test	−4.844	−2.116

Notes: The 5% critical values for the cointegration test is −3.385 from MacKinnon(1991). The results, for when the HC weighted classical diffusion index is used as the related series, are shown in the column labelled unadjusted. Results for when the HC weighted amplitude adjusted classical diffusion index is used as the related series, are shown in the column labelled adjusted.

in June 2000. An earlier series SNBA.SX9 (discontinued in March 1985) shows annual growth of -3.5 percent. Brian Easton suggests that even the -2.6 percent figure appears implausibly low, given other macroeconomic and sectoral data. (See "The 1977/78 Downturn in the New Zealand Economy" http://www.eastonbh.ac.nz/?p=776.) In personal communication, Brian Easton has advised us that the exaggerated contraction is due to the adoption of a new inventory series with no overlap between surveys. The problem is even worse when one examines the quarterly data. The official real GDP index (SNBQ.SY299) records growth rates for September 1977, December 1977 and March 1978 as -2.1 -4.3, and 0.0 percent, respectively. Such a substantial decline in output would surely have been noticed at the time as a particularly major contraction, and have been widely commented on. Having the underlying surveys change and a new quarterly series start during a significant contraction makes unravelling the truth of the matter impossible. So, given that the negative quarterly official statistics for the second half of 1977 are almost certainly implausibly low, we have not including those observations in our series. Instead we have used the estimates from the Chow-Lin procedure based on the annual data and the Haywood and Campbell related indicators. This still leaves a large contraction for the March 1978 year consistent with the official annual data. In generating our new quarterly GDP estimates we believe it is important to stay as close as possible to official statistics, while at the same time recommending caution to potential users, who may if they wish apply their own adjustments. For example, Brian Easton has guessed the annual March 1978 contraction to be more like 1 to 1.5 percent.

When the cointegration condition fails, alternative methods proposed by Fernández (1981) and Litterman (1983) are considered potentially more suitable. The salient characteristic of the Fernández-Litterman methods involves temporal disaggregation of the annual *changes* into quarterly *changes*. Thus we have the regression model

$$\Delta y = \Delta X \beta + u \tag{11}$$

where Δ denotes the first difference operator and we have the following formulation for the disturbance terms

$$u_t = u_{t-1} + e_t \tag{12}$$

where

$$e_t = \psi e_{t-1} + \varepsilon_t. \tag{13}$$

The Fernández model is the special case when $\psi = 0$. Under this assumption the resulting covariance matrix V has the form $(D'D)^{-1}$ where the $4n \times 4n$ matrix D is given by

$$\begin{bmatrix} 1 & 0 & 0 & \cdots & 0 & 0 \\ -1 & 1 & 0 & \cdots & 0 & 0 \\ 0 & -1 & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & -1 & 1 \end{bmatrix}. \tag{14}$$

Plugging the above formula into (5) yields the Fernández estimate of quarterly real GDP. We estimate the Fernández regression over the period 1947q2 to 1979q1. Again we consider the two cases: (i) the related series is the HC weighted classical diffusion index (denoted unadjusted); and (ii) the related series is the HC weighted amplitude adjusted classical diffusion index (denoted adjusted). Table 2 reports the estimated values of the autoregressive coefficient (for both annual and quarterly data). Given that the value of ρ was set to unity, the tests for cointegration between the estimated quarterly series and the related series are rejected.

Table 2. Fernández Regression Results
(sample period 1947q2 to 1979q1)

Statistic	Unadjusted	Adjusted
β_0	6.518	6.360
β_1	2.015	1.805
ρ_a	$--$	$--$
ρ	$--$	$--$
ADF Test	−1.290	−1.228

Notes: See Table 1.

Finally, the Litterman (1983) method of temporally disaggregation is also a possible option. The Litterman model adds the problem of estimating the parameter ψ. In this case the resulting covariance matrix V has the form $(D'H'HD)^{-1}$ where the $4n \times 4n$ matrix H is given by

$$\begin{bmatrix} 1 & 0 & 0 & \cdots & 0 & 0 \\ -\psi & 1 & 0 & \cdots & 0 & 0 \\ 0 & -\psi & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & -\psi & 1 \end{bmatrix}. \tag{15}$$

The first-order annual serial correlation coefficient, ψ_a, is related to the quarterly coefficient, ψ. To calculate this relationship one sets ψ_a equal to the ratio of the off-diagonal element to the diagonal element of the matrix $QH^{-1}H^{-1\prime}Q'$ (Silver, 1986), where $Q = \Delta C D^{-1}$ and the $n \times n$ matrix Δ is given by

$$\begin{bmatrix} 1 & 0 & 0 & \cdots & 0 & 0 \\ -1 & 1 & 0 & \cdots & 0 & 0 \\ 0 & -1 & 1 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & -1 & 1 \end{bmatrix}. \tag{16}$$

Plugging this formula for V, together with the final estimate of ψ, into (5) yields the Litterman estimate of quarterly real GDP. We estimate the Litterman regression over the period 1947q2 to 1979q1, again using both the unadjusted and adjusted related series of HC. The estimated coefficient for the regression using the unadjusted or the adjusted related series are broadly similar. As with the Fernández regression the estimated quarterly GDP series is not cointegrated with the related series.

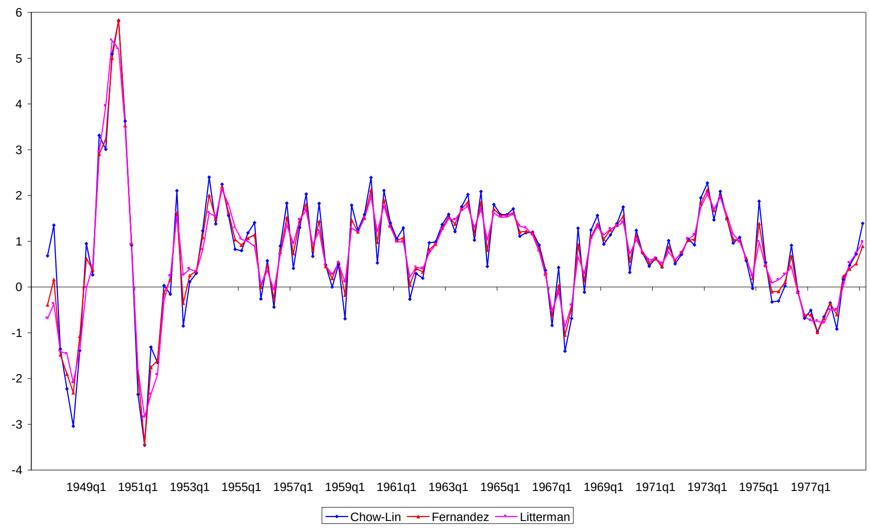
Table 3. Litterman Regression Results
(sample period 1947q2 to 1979q1)

Statistic	Unadjusted	Adjusted
β_0	6.624	6.503
β_1	1.321	1.279
ψ_a	0.633	0.633
ψ	0.950	0.950
ADF Test	−0.956	−0.935

Notes: See Table 1.

The Chow-Lin, Fernández, and Litterman-based quarterly real GDP growth rate estimates, for the unadjusted HC diffusion index, are presented in Figure 4. Visual inspection reveals the differences to be almost imperceptible. The only visible difference is that the amplitudes of the Chow-Lin series are a fraction higher. Overall, therefore, including when viewed in the context of the annual growth rates presented in Figure 1, the temporally disaggregated series from all three methods seem to provide potentially valuable quarterly real GDP information.

Figure 4. Quarterly real GDP Growth Estimates, from Chow-Lin, Fernández and Litterman Methods
(1947q2 to 1979q1, unadjusted HC series)



4 Splicing the Data

One final computation remains. That is to combine the temporally disaggregated and official quarterly GDP series, to make a complete time series. The estimated GDP observations for the period 1947q2 to 1979q1, and the SNB series for the period 1979q2 to 1987q1 are converted into 1995/96 prices, so as to match the base year for the 1987q2 to 2006q2 SNC series.

The resulting quarterly series, covering the period 1947q2 to 2006q2, can be subdivided into four periods of potentially distinct quality and consistency. Issues involving credibility of the data for 1977, and the extent to which the annual and quarterly observations match for that year, were summarised in section 2 above, and results from testing for structural breaks (whether from a key economic event or due to different methods of series construction) are presented below in section 5.

The first period, 1947q2 to 1954q1, potentially has the lowest quality data, being generated from temporally disaggregated unofficial annual estimates. This period also suffers from some very volatile fluctuations, associated with the conversion of economic production from wartime to peacetime mode. It followed World War II, and included the Korean War and associated wool boom, and the food rationing system still in place in the United Kingdom. At the time, the UK was still New Zealand's major export destination.

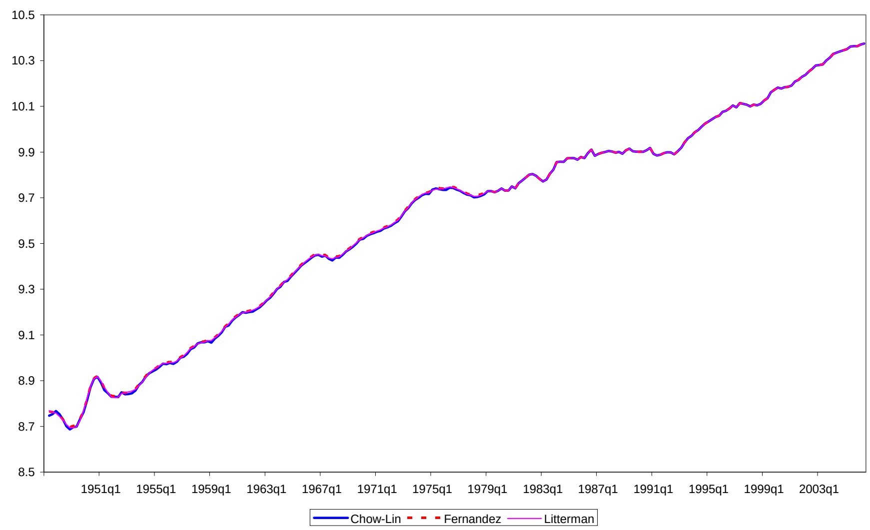
The second period, 1954q2 to 1979q1, has data of somewhat of higher quality, in the sense that the annual data is based on official statistics. However, the quarterly track still contains an unknown degree of estimation error. The closer the Haywood and Campbell diffusion index is to what actually transpired, the smaller this estimation error would be.

The quality of the third period data, from 1979q2 to 1987q1, is likely to be better still, since we no longer need to rely on a related indicator to assist with estimating the quarterly track for GDP, and we can use the non-chain-linked series available from SNZ. Finally, the fourth period 1987q2 to 2006q2 will have the highest quality data, since it is the current series of chain-linked data with SNZ preferred status.

The real GDP series for 1947q2 to 2006q2, based on the Chow-Lin unadjusted HC series estimates[7], and the corresponding Fernández- and Litterman-based estimates, are presented in Figure 5. Visually, there are no detectable differences between these natural log series.

But before proceeding to express preference for a Chow-Lin, Fernández, or Litterman-based series, whether for the purposes of business cycle analysis or the dating of classical business cycle turning points, we examine the series' key statistical properties, and test for any structural breaks.

Figure 5. Quarterly real GDP Estimates,
from Chow-Lin, Fernández, and Litterman Methods
(1947q2 to 2006q2, natural logs)



Source: SNZ from 1979q2 to 2006q2, and estimates based on Chow-Lin, Fernández, and Litterman regressions for the period 1947q2 to 1979q1.

[7] Recall, from the cointegration test results presented in Table 1, that for the Chow-Lin method, the amplitude adjusted series could be rejected in favour of the series without adjustment.

5 Series Evaluation

5.1 Unit Root and Cointegration Tests

Each of the four GDP series show strong trending behaviour. Unit root tests reported in Table 4 indicate that at the 5 percent significance level the hypothesis of a unit root in the level of GDP cannot be rejected, implying there is a stochastic trend in the data. The hypothesis of a unit root is rejected at the 5 percent level for the first difference of the series, implying all four series are integrated of order one.

Table 4. Unit Root Tests for Logarithms of GDP
(Sample 1947q2 to 2006q2)

Estimation method	Related Series	Levels	First difference
Chow-Lin	Unadjusted	−1.860	−8.767
Chow-Lin	Adjusted	−1.333	−5.088
Fernández	Unadjusted	−1.927	−5.221
Fernández	Adjusted	−1.302	−4.672
Litterman	Unadjusted	−0.628	−7.406
Litterman	Adjusted	−0.665	−7.424

Note: The 5 percent critical value is −3.429 (MacKinnion, 1991). The hypothesis of a unit root was tested against the alternative of a trend stationary process. The lag length for the unit root test was determined using the Akaike information criterion with a maximum lag of 14.

Whatever estimation method or related series are used we would expect that over a long enough span of data our estimated GDP series should inform us about the long run trends in the data. That is, each of the estimated series should be cointegrated with each other. Table 5 reports the Johansen trace statistics for cointegration statistics, and the results indicate that there are five cointegrating equations at the 0.05 level. The five estimated cointegrating vectors are $(1, -1)$ up to three decimal places. Thus, the most basic requirement from our estimation methods, is that we obtain consistent results on the long run trends in the data.

Next we compare the correlations of the growth rates (reported in Table 6) to see if different methods of disaggregating the annual data might produce different first difference growth cycles. We observe very high correlations between growth rates irrespective of which estimation method or which related series is used.

Table 5. Johansen Cointegration Test
(Sample 1947q2 to 1977q1)

Hypothesized Number of Cointegrating Equations	Trace Statistic	5% Critical Value
None*	410.0	95.8
At most 1*	248.6	69.8
At most 2*	163.9	47.9
At most 3*	92.9	29.8
At most 4*	33.0	15.5
At most 5	0.3	3.8

Notes: The lag length for the cointegration test was 5, and was determined by using the Akaike information criterion with a maximum lag of 6. The model assumed a linear deterministic trend. * denotes significant at the 5% level.

Table 6. Correlation of Growth Rates
(*Sample 1947q2 to 1977q1*)

Series	Chow-Lin		Fernández		Litterman	
	(unadj)	(adj)	(unadj)	(adj)	(unadj)	(adj)
Chow-Lin(unadj)	1	0.964	0.981	0.965	0.945	0.942
Chow-Lin(adj)		1	0.953	0.996	0.934	0.971
Fernández(unadj)			1	0.970	0.985	0.970
Fernández(adj)				1	0.958	0.985
Litterman(unadj)					1	0.984
Litterman(adj)						1

Both the cointegration test for the levels data, and the correlations of the growth rates, demonstrate that the choice of diffusion index used to convert annual series into quarterly series is largely immaterial. Therefore, for the remainder of the paper, we will report only the results generated from HC's weighted classical cycle index. Results using the weighted amplitude adjusted classical cycle index are almost identical.

5.2 Statistical Properties

In order to help establish the relative merits of the Chow-Lin, Fernández and Litterman-based real GDP series, we summarize their stylized statistical facts. Tables 7 to 9 report statistics that summarize the series' properties in terms of growth, volatility, normality, and persistence. One concern potential users may have with the splicing of data generated by different methods is that the splicing may induce unsatisfactory properties in the series. To check this, we also examine properties for the four sub-periods referred to above, corresponding approximately to the relative quality of the data sub-period observations. Recall that these are as follows: period I, 1947q2 to 1954q1; period II, 1954q2 to 1977q1;

period III, 1977q2 to 1987q1; and period IV, 1987q2 to 2006q2. Naturally, the 'Full' period is 1947q2 to 2006q2.

For all three series, period II is the high growth period with a mean growth rate of about 0.9 percent per quarter (about 3.6 percent per year) while the low growth period is period III with a mean growth rate of approximately 0.4 percent per quarter (about 1.6 percent per year).

Period I was a time of extreme fluctuations in economic activity, with standard deviations about twice the size of those for the sample as a whole. The relatively benign periods for fluctuations in economic activity were periods II and IV. Of more interest, is the volatility in the usual business cycle frequency (6 quarters to 32 quarters) which can be measured using the integrated normalized spectrum (see for example Ahmed, Levin and Wilson (2004)). The integrated normalized spectrum for any band of frequencies can be estimated using

$$H(\omega_1, \omega_2) = \left[\frac{\omega_2 - \omega_1}{\pi} \widehat{\Gamma}(0) + \frac{2}{\pi} \sum_{j=1}^{T-1} \widehat{\Gamma}(j) \frac{\sin(\omega_2 j) - \sin(\omega_1 j)}{j} \right] / \sigma^2 \qquad (17)$$

where $\widehat{\Gamma}(j)$ represents the j^{th}-order sample autocovariance and $\omega_1 = \pi/16$ and $\omega_2 = \pi/3$ which corresponds to cycles of 6 to 32 quarters. The integrated normalized spectrum tells us that, for business cycle frequencies, the volatility is similar for the 3 sub-periods II to IV, and for the Full period. The fact that the integrated normalized spectrum is higher in period I should be treated with some caution, given that it is only 28 quarters long.

Table 7. Stylized Facts for GDP Growth
(annual data converted to quarterly using the Chow-Lin Model)

Statistic	Sample Period				
	Period I	Period II	Period III	Period IV	Full
Mean	0.548	0.909	0.403	0.628	0.690
Median	0.299	1.001	0.198	0.650	0.772
Std. Dev.	2.348	0.809	1.248	0.869	1.184
Skewness	0.384	−0.475	0.109	−0.655	−0.013
Kurtosis	2.661	2.766	3.002	4.239	5.566
Jarque-Bera	0.796	3.668	0.079	10.421	64.773
Half-life	2.941	0.711	0.372	0.535	0.918
$H(\omega_1, \omega_2)$	0.831	0.448	0.413	0.338	0.406

Notes: The sample periods are: period I, 1947q2 to 1954q1; period II, 1954q2 to 1977q1; period III, 1977q2 to 1987q1; and period IV, 1987q2 to 2006q2. The Full period is 1947q2 to 2006q2. The Jarque-Bera statistic provides a test of normality which has a χ^2-distribution with 2 degrees of freedom and thus a 5% critical value of 5.991. The half-life is the length of time (in quarters) it takes for a shock to GDP growth to dissipate by half. The integrated normalized spectrum ($H(\omega_1, \omega_2)$) provides the fraction of variance attributable to the business cycle frequency range 6 quarters to 32 quarters.

The Jarque-Bera test for normality is clearly rejected for the full sample with strong evidence of excess kurtosis. However, growth rates appear to follow a normal distribution in each sub-period, except for period IV. The rejection of normality seems to be due to the mixture of normals with different standard deviations, rather than being drawn from a distribution with fat-tails.

Finally, we can examine the persistence of the innovation to growth using a measure of the half-life, which is the length of time (in quarters) it takes for a shock to GDP growth to dissipate by half, and is given by the formula $|\ln(0.5)/\ln(\alpha)|$,where α is the parameter in an autoregressive model of order one. A median-unbiased estimate of α was computed using the procedure of Andrews (1993*a*). In general, the degree of persistence is small, with shocks dissipating by about half each quarter. The exception is period I which shows more persistence. However, again we need to be cautious about reading too much into this result given the small sample size of this sub-period.

The stylized facts for the Chow-Lin, Fernández and Litterman-based growth rate series are generally consistent across sub-periods. To this point, then, there is no compelling evidence to prefer one model over the other.

However, there are somewhat greater differences for period I, foreshadowed above in section 4 as having potentially problematic observations associated with post-WWII exceptional events. This further suggests that considerable caution should be exercised if observations from the beginning of the Full sample are to be used. In fact, we recommend that for most statistical purposes the sample should be restricted to the period 1954q2 to 2006q2 because of the special feature imposed on the data by the changes in economic production following WWII and the Korean War. Treating these New Zealand data observations in this way would be not be unusual, as in their macroeconomic time series study of business cycle fluctuations in the US, Stock and Watson (1999) restricted their statistical analysis to the period 1953q1 to 1996q4, for these very reasons.

Table 8. Stylized Facts for GDP Growth
(annual data converted to quarterly using the Fernández Model)

Statistic	Sample Period				
	Period I	Period II	Period III	Period IV	Full
Mean	0.489	0.910	0.391	0.628	0.682
Median	0.250	1.017	0.230	0.650	0.762
Std. Dev.	2.229	0.696	1.233	0.869	1.128
Skewness	0.603	−0.511	0.144	−0.655	0.081
Kurtosis	2.981	2.841	3.129	4.239	6.012
Jarque-Bera	1.635	4.094	0.167	10.421	89.487
Half-life	4.977	1.609	0.365	0.535	1.125
$H(\omega_1, \omega_2)$	0.880	0.607	0.405	0.338	0.453

Notes: refer to Table 7 notes.

Table 9. Stylized Facts for GDP Growth
(annual data converted to quarterly using the Litterman Model)

Statistic	Sample Period				
	Period I	Period II	Period III	Period IV	Full
Mean	0.464	0.911	0.399	0.628	0.681
Median	0.258	0.992	0.193	0.650	0.749
Std. Dev.	2.220	0.655	1.233	0.869	1.117
Skewness	0.692	−0.546	0.135	−0.655	0.124
Kurtosis	2.781	2.925	3.109	4.239	5.737
Jarque-Bera	2.206	4.596	0.141	10.421	73.739
Half-life	9.551	3.493	0.391	0.535	1.125
$H(\omega_1, \omega_2)$	0.901	0.701	0.414	0.338	0.485

Notes: refer to Table 7 notes.

5.3 Structural Breaks

To assess whether our splicing procedure has introduced any change in the growth rate or variance of the resulting series we apply the tests of Andrews (1993*b*) and Andrews and Ploberger (1994).

We test for a structural break in GDP growth using the regression

$$\Delta y_t = \mu + \varepsilon_t. \tag{18}$$

We also test for a structural break in the residual variance using the regression

$$\widehat{\varepsilon}_t^2 = \kappa + \nu_t. \tag{19}$$

Table 10. Tests for Structural Change
(sample period 1947q2 to 2006q2)

Estimation method	Exp	Ave	Sup	Estimated Break
		GDP growth		
Chow-Lin	2.671	2.017	9.753	1991q1
Fernández	2.709	2.172	10.799	1991q1
Litterman	2.665	2.181	11.025	1991q1
		GDP variance		
Chow-Lin	12.226	29.614	70.488	1952q3
Fernández	10.060	27.601	67.206	1952q3
Litterman	10.803	32.196	76.678	1952q3

Notes: Exp, Ave and Sup refer to the exponential, average and supremum test statistics of Andrews and Ploberger (1994) and Andrews (1993b). The 5 percent critical values are 2.06 (Exp), 2.88 (Ave), and 8.85 (Sup).

The break dates reported in Table 10 are identical for the three models. There is no clear evidence of breaks attributable to the splicing of official series which have been compiled differently (which would be at 1987q1 and 1987q2), or to the splicing of temporally disaggregated and official series (which would be between 1977q1 and 1979q1). The break dates of 1952q3 and 1991q1 coincide with material changes in economic activity, rather than with series-splicing or with chain-linked versus non-chain-linked methodologies.

5.4 Link to New Zealand's Post-WWII Economic History

For the Chow-Lin, Fernández and Litterman-based series, the cointegration vector presented in section 5.1 has shown that the long run trends in the Full sample series are consistent. The corresponding correlation of *growth rates* for their unadjusted series is also high, at 94.5 per cent or better.

Breaking the data by sub-periods reveals the biggest difference across time occurs in the variance of the growth rate over the immediate post-WWII period to 1954q1. This provides further support to our recommendation in section 5.3 that, for most statistical purposes, the Full sample should be either restricted to the period 1954q2 to 2006q2, or the earliest observations treated with considerable caution. It is also consistent with the finding in section 5.3 of a structural break in all three series, at 1952q3.

But what of the relative merits of the Chow-Lin, Fernández and Litterman-based *levels of GDP series*, for the purposes say of dating classical business cycle turning points?[8] Visual inspection of Figure 5 suggests, as expected from the series' common official data components, that they can clearly identify the contractions of the early 1980s and 1990s, and the contraction associated with the Asian financial crisis and summer drought period of 1997-98. It is also the case that the series appear to behave very similarly for contractions around the 'Black Budget' of 1958, and the exchange rate crisis 1966-67. A possible quibble, though, is that the slightly different amplitudes of the cycles have the potential to identify slightly different short periods of negative growth. Such minor differences could make the dating of any associated growth or classical business cycle turning points sensitive to which method has been employed to disaggregate the GDP series.

Overall, there is very little difference in the temporally disaggregated observations estimated from the three methods. However, on balance, we prefer to use the Chow-Lin-based series for most purposes. This preference is based on the fact that the cointegration test cannot be rejected for the Chow-Lin regression, implying there is minor specification error in the Fernández and Litterman regressions.

[8] A new 'benchmark' set of Classical business cycle turning points, for the period 1947q2 to 2006q2, and reference to the associated key events in New Zealand's economic history, are reported in Hall and McDermott (2007).

6 Conclusion

We have developed a new quarterly seasonally adjusted real GDP series for post-WWII New Zealand, spanning the period 1947q2 to 2006q2. It contains two short periods of observations, which will remain somewhat controversial, namely 1947q2 to 1953q3, and 1977. Despite this, we believe this new series for a considerably longer period than has previously been available, will be valuable for a range of purposes. These include the identification of classical business cycle turning points, the establishment of a more robust set of business cycle characteristics, and assistance with assessing the impacts of various government policies and external shocks.

Our series were developed by linking quarterly observations from two recent official series to temporally disaggregated observations for an earlier time period. Annual official and non-official real GDP series were disaggregated using the information from two quarterly diffusion indexes developed by Haywood and Campbell. Three econometric methods were used: the Chow-Lin model that disaggregates the level of GDP; and the Fernández and Litterman methods that disaggregate the change in GDP.

Statistical properties of the series were evaluated, and movements in the new series checked against qualitative findings from New Zealand's post-WWII economic history.

Consistent results were obtained for the long run trends in all three series, and this suggests any one of the series could be used for measuring economic growth, or testing growth theories. However, when it comes to measuring business cycle fluctuations, results associated with the early post-War and 1977 periods might be somewhat sensitive to which series is used. The quarterly observations prior to 1954 reflect the special nature of the fluctuations in that period, and the probability of these being repeated in the near future may not be high. So, most users would be wise to discard from their sample the quarterly observations prior to 1954. We have done this when estimating Markov-switching growth models for post-War New Zealand, but for dating classical business cycle turning points we have preferred the Full sample quarterly series based on results generated from the Chow-Lin model.

The quarterly seasonally adjusted data for this preferred series are presented in Appendix Table A4.

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7 Appendix

Table A1. Employment and Production Indicators

Haywood and Campbell Indicators	
Indicator	*Weights*
Index of effective weekly wage rate, adult males	4
Real net salary and wage payments	9
Labour placements $\times -1$	3
Notified vacancies	9
Registered unemployed $\times -1$	9
Employment in industry, female	5
Employment in industry, male	5
Employment in industry, total	10
Industrial disputes, working days lost	1
Meat production	2
Gas production	3
Electricity generation	5
Production of cheese	2
Production of butter	2
Electric ranges	4
Washing machines	4
Refrigerators	4
Paper	3
Plywood production, 3/16 in. basis	3
Chemical fertilisers, total make	4
Cement	4
Passenger cars assembled	5
Trucks, vans and buses assembled	6
Beer production	1
RNBZ volume of domestic manufacturing production index	10

Source: Haywood and Campbell (1976, Table 1, p 6).

Table A2. Investment, External, Transport, and Domestic Trade Indicators

Haywood and Campbell Indicators	
Indicator	*Weights*
Building permits issued	9
Wholesale turnover of machinery	6
Manufacturers' stocks, including primary processing	3
Manufacturers' stocks, excluding primary processing	9
Terms of trade	5
Exports, total f.o.b.	8
Imports, total c.d.v.	8
Surveyed import orders	6
Surveyed import payments	6
Current account balance	8
Government railways, net ton-miles run	2
Government railways, passenger journeys, motor	2
Government railways, passenger journeys, railway	2
Civil aviation, freight tonne-kilometres	2
Civil aviation, passenger kilometres, domestic	2
Motor vehicles licensed	4
Wholesale automobile sales	4
Wholesale trade turnover, all groups	8
Real retail trade turnover, all groups	9
Value of goods sold on hire-purchase	7
T.A.B. turnover	3
Sales tax collected	3

Source: Haywood and Campbell (1976, Table 1, pp 6-7).

Table A3. Finance and Other Indicators

Haywood and Campbell Indicators	
Indicator	*Weights*
Trading bank debits	8
Trading bank velocity of circulation	3
Volume of money	6
Money supply, demand deposits and selected liquid assets	8
Overseas assets of the New Zealand banking system	4
Average rate of return on new mortgages	3
Dividend yields on market prices of company shares $\times -1$	3
Reserve Bank share price index	5
Average yield on Government securities, long-term $\times -1$	3
New mortgages registered, number	4
Land transfers, urban, number	3
Land transfers, rural, number	3
Trading bank new lending	6
Bankruptcies	5
RBNZ real domestic expenditure	7
RBNZ real aggregate expenditure	10

Source: Haywood and Campbell (1976, Table 1, p 7).

Table A4. Quarterly real GDP Estimates, 1947q2 - 2006q2

(seasonally adjusted, 1995-96 prices)

16448.85

Year	Mar	Jun	Sep	Dec
1947		6289.90	6332.77	6418.83
1948	6332.35	6192.94	6007.33	5924.46
1949	5980.92	5996.65	6198.66	6388.01
1950	6721.52	7124.77	7387.85	7455.79
1951	7282.94	7035.60	6943.73	6830.15
1952	6832.40	6821.59	6966.67	6907.54
1953	6915.41	6936.14	7021.77	7192.31
1954	7292.07	7457.53	7574.79	7637.38
1955	7698.41	7790.12	7900.36	7879.81
1956	7925.11	7890.44	7961.45	8108.67
1957	8141.63	8248.17	8417.55	8474.20
1958	8630.23	8671.89	8671.87	8714.46
1959	8654.22	8810.38	8920.92	9063.44
1960	9282.72	9331.52	9530.36	9664.69
1961	9767.16	9894.22	9867.84	9896.70
1962	9915.63	10011.81	10111.11	10250.03
1963	10414.07	10540.71	10727.01	10946.21
1964	11058.71	11291.82	11342.71	11549.24
1965	11733.62	11920.61	12125.99	12261.22
1966	12407.69	12557.40	12673.00	12719.31
1967	12613.00	12666.70	12490.17	12404.72
1968	12564.96	12550.54	12707.61	12907.96
1969	13029.26	13178.57	13362.32	13598.18
1970	13641.63	13811.45	13914.60	13977.88
1971	14066.80	14127.66	14271.88	14344.40
1972	14446.46	14598.83	14733.40	15023.55
1973	15369.13	15596.16	15925.58	16165.92
1974	16322.14	16500.30	16595.26	16589.96
1975	16903.83	16994.49	16938.69	16887.06
1976	16890.67	17044.91	17027.33	16911.17
1977	16825.28	16661.41	16552.66	16495.24
1978	16344.19	16371.80	16448.85	16568.02
1979	16800.00	16802.00	16714.00	16826.00
1980	16999.00	16830.00	16842.00	17150.00
1981	17001.00	17405.00	17598.00	17825.00
1982	18057.00	18098.00	17957.00	17727.00
1983	17520.00	17666.00	18129.00	18435.00
1984	19086.00	19109.00	19094.00	19382.00
1985	19413.00	19416.00	19277.00	19494.00

Table A4. Quarterly real GDP Estimates, 1947q2 - 2006q2 (cont.)
(seasonally adjusted, 1995-96 prices)

Year	Mar	Jun	Sep	Dec
1986	19412.00	19839.00	20147.00	19607.00
1987	19765.00	19857.00	19933.00	20030.00
1988	19969.00	19871.00	19952.00	19789.00
1989	20077.00	20226.00	20000.00	19965.00
1990	19953.00	19947.00	20089.00	20293.00
1991	19778.00	19634.00	19692.00	19835.00
1992	19906.00	19901.00	19733.00	19997.00
1993	20312.00	20774.00	21181.00	21399.00
1994	21734.00	21967.00	22293.00	22586.00
1995	22779.00	23019.00	23237.00	23361.00
1996	23762.00	23872.00	24108.00	24431.00
1997	24237.00	24691.00	24602.00	24517.00
1998	24325.00	24527.00	24457.00	24600.00
1999	24962.00	25231.00	25898.00	26151.00
2000	26428.00	26307.00	26470.00	26513.00
2001	26664.00	27146.00	27323.00	27696.00
2002	27923.00	28355.00	28676.00	29100.00
2003	29166.00	29233.00	29743.00	30112.00
2004	30606.00	30785.00	30961.00	31105.00
2005	31262.00	31613.00	31676.00	31660.00
2006	31898.00	32047.00		

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