Sources of Growth and Output Gaps in New Zealand: New Methods and Evidence

by

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Abstract

We extend Fox, Kohli, and Warren (2002) by using alternative techniques to reexamine the sources of New Zealand's macroeconomic performance during the period 1984-2001. Specifically, a modified Diewert-Morrison decomposition is used to quantify the separate contributions from productivity growth and changes in factor utilization, the terms of trade and the trade balance to GDP growth. We also use a new Fisher-index decomposition to analyze the determinants of GDP growth. These techniques are adapted to identify sources of deviations of GDP from its trend. The results of these decompositions reveal that changes in domestic prices accounted for three-fifths of the growth of nominal GDP over the entire sample period. Capital accumulation and employment growth were wholly responsible for the real-output growth in this time frame. However, changes in total-factor productivity or in the terms of trade contributed importantly to changes in real net output and in an index of aggregate welfare in specific years. Finally, no one factor was primarily responsible for explaining changes in the nominal (or real) output gap over the whole period.

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1 Introduction

Much of the research on the macroeconomic performance of countries has focused on identifying the relative contributions of changes in input quantities and total-factor productivity on real-output growth [Young (1995)]. This line of inquiry has recently been extended to countries, such as New Zealand, which have undertaken sweeping economic reforms in the past two decades [Diewert and Lawrence (1999); Fox, Kohli and Warren (2002); Kohli (2003a)]. Two features of the New Zealand economy during this time period present special challenges, and opportunities, for any systematic attempt to account for annual fluctuations in aggregate performance. First, New Zealand experienced highly variable inflation rates, ranging from double-digit levels in the mid-1980s to virtual price stability since 1994. Consequently, a complete assessment of its macroeconomy must address changes in nominal, as well as real, Gross Domestic Product (GDP). Second, New Zealand is an increasingly open economy so that changes in its terms of trade must be incorporated into any sensible accounting of economic growth [Kohli (1990; 2003)].

In this paper, we extend the work of Fox, Kohli and Warren (2002) by using alternative techniques and new data to re-examine the sources of New Zealand's recent macroeconomic performance. We modify the framework established by Diewert and Morrison (1986) for decomposing GDP growth, and use it to quantify the separate contributions of changes in input quantities, total-factor productivity, the terms of trade, and domestic prices to the change in New Zealand's nominal (and real) output from 1983 to 2001. We also use a new Fisher-index decomposition to analyze the determinants of GDP growth. These techniques are adapted to identify sources of deviations of GDP from its trend, and to examine the factors associated with changes in an index of economic welfare.

We find that changes in domestic prices accounted for three-fifths of the growth in nominal GDP over the entire sample period, while capital accumulation and employment growth were the sole causes of real-output growth. In specific years, however, changes in total-factor productivity or in the terms of trade were the driving force behind changes in real GDP or in the aggregate welfare index. Finally, no one factor was primarily responsible for explaining changes in the nominal (or real) output gap over the whole period.

Section 2 describes the analytical framework used by Fox, Kohli and Warren (2002) to decompose output growth and the output gap into their contributing components. Section 3 describes the data and several implementations of the general framework. In particular, section 3.1 gives the results from the first method for decomposing GDP growth. Section 3.2 reports the decomposition of an estimate of the output gap using an adaptation of this same method. Section 3.3 describes how these results can be used to obtain estimates of changes and gaps in aggregate welfare. Section 3.4 presents the results from using an alternative method for decomposing growth and output gaps. Section 3.5 describes the use of a new Fisher-index decomposition for the same purposes. Section 4 provides a summary and presents some concluding remarks.

2 Theory

We model New Zealand as a trading economy with N_d domestic (nontraded) goods, N_x export goods, and N_m imported goods so that there are $N = N_d + N_x + N_m$ net outputs, or "netputs," denoted by $y \equiv (y_1, \ldots, y_N)^T$, where a T superscript denotes the transpose operator. If $y_n > 0$ (< 0), then the n^{th} netput is an output (input). We represent the (positive) price vector that corresponds to the (non-negative) net output vector y by $p \equiv (p_1, \ldots, p_N) \gg 0_N$.[1] The M primary inputs are $v \equiv (v_1, \ldots, v_M)^T \geq 0_M$, with corresponding price vector $w \equiv (w_1, \ldots, w_M)^T \gg 0_M$. GDP is denoted by $\pi = p \cdot y = w \cdot v$, using the notation $p \cdot y = \sum p_n y_n$ and $w \cdot v = \sum w_m v_m$. The term "GDP" hereafter refers to nominal output, unless otherwise indicated.

Now, suppose we have two observations on the GDP of a country, π^a and π^b. The ratio of the two observations is

$$\Gamma^{a,b} \equiv \pi^b / \pi^a = (p^b \cdot y^b)/(p^a \cdot y^a). \tag{1}$$

A productivity index between the two GDP values can be defined as:

$$R^{a,b} \equiv (\Gamma^{a,b}/P^{a,b})/V^{a,b}, \tag{2}$$

where $P^{a,b}$ is a price index for the netputs and $V^{a,b}$ is a primary-input quantity index, between states a and b. Hence, $\Gamma^{a,b}/P^{a,b}$ is an implicit netput quantity index.[2] The productivity measure in (2) is the part in the netput quantity index that cannot be explained by differences in primary-input utilisation; i.e., it is a total-factor-productivity (TFP) index. Equation (2) can be rearranged as follows:

$$\Gamma^{a,b} = R^{a,b} \cdot P^{a,b} \cdot V^{a,b}. \tag{3}$$

Therefore, the ratio of GDP observations in (1) can be decomposed into contributions from differences in productivity ($R^{a,b}$), prices ($P^{a,b}$) and primary inputs ($V^{a,b}$).

[1] The notation $p \gg 0_N$ means each component of p is positive, while $p > 0_N$ would mean $p \geq 0_N$ but $p \neq 0_N$.

[2] See Allen and Diewert (1981).

We define $P^{a,b}$ and $V^{a,b}$ in (3), respectively, as

$$P^{a,b} \equiv \exp\left[\sum_{n=1}^{N} \frac{1}{2}(s_n^a + s_n^b) \ln(p_n^b/p_n^a)\right], \tag{4}$$

which is a Törnqvist price index, where $s_n = (p_n y_n)/(p \cdot y)$ is the share of netput n in GDP, and

$$V^{a,b} \equiv \exp\left[\sum_{m=1}^{M} \frac{1}{2}(s_m^a + s_m^b) \ln(v_m^b/v_m^a)\right], \tag{5}$$

which is a Törnqvist quantity index, where $s_m = (w_m v_m)/(p \cdot y)$ is the GDP share of primary input m. Exploiting the log-additive nature of the Törnqvist-index formula, we can decompose the aggregate price index between GDP values π^a and π^b into a product of individual price differences:

$$P^{a,b} = \prod_{n=1}^{N} P_n^{a,b}, \tag{6}$$

where $P_n^{a,b}$ is the Törnqvist price index in (4) calculated for the n^{th} netput. Similarly, the primary-input index in (5) can be decomposed as follows:

$$V^{a,b} = \prod_{m=1}^{M} V_m^{a,b}, \tag{7}$$

where $V_m^{a,b}$ is the Törnqvist quantity index calculated for the m^{th} primary input. Therefore, equations (3), (6) and (7) yield a detailed decomposition of the difference (in ratio form) between π^a and π^b.

The use of the Törnqvist index for aggregating over goods can be justified from the axiomatic or "test" approach to index-number theory.[3] Diewert (1992) reports that only the Fisher Ideal index (Fisher, 1922) has more properties that are desirable of index numbers than does the Törnqvist index. However, Diewert (1978) showed that the Fisher and Törnqvist indexes approximate each other to the second order when they are evaluated at a point where prices and quantities are equal. Theil (1967) also provided a justification for the Törnqvist index using the stochastic approach to index numbers.

The other common framework for determining the desirability of an index-number formula is the "economic" approach (Diewert, 1976).

Consider the GDP function:

$$\pi(p, v) = \max_y \{p \cdot y : (y, v) \in \Psi\}, \tag{8}$$

[3] Moreover, a practical justification is its ability to perform the decompositions in (6) and (7).

where Ψ is the production possibility set. A GDP function (or a profit function) with constant returns to scale is (i) nonnegative, (ii) positively homogeneous of degree one in p, (iii) convex and continuous in p for every v, (iv) positively homogeneous of degree one in v, (v) nondecreasing in v for every fixed p, and (vi) concave and continuous in v for every fixed p.[4] If the log of π in (8) has the translog form (Christensen, Jorgenson and Lau, 1973; Diewert, 1974; Russell and Boyce, 1974), then the GDP function can be written as

$$\begin{aligned}\ln \pi^{\iota}(p,v) \equiv\; & \alpha_0^{\iota} + \sum_{n=1}^{N} \alpha_n^{\iota} \ln p_n + (1/2) \sum_{i=1}^{N}\sum_{j=1}^{N} \alpha_{ij} \ln p_i \ln p_j + \sum_{m=1}^{M} \beta_m^{\iota} \ln v_m \\ & + (1/2) \sum_{i=1}^{M}\sum_{j=1}^{M} \beta_{ij} \ln v_i \ln v_j + \sum_{n=1}^{N}\sum_{m=1}^{M} \gamma_{nm} \ln p_n \ln v_m, \end{aligned} \quad (9)$$

for $\iota = a, b$, where $\alpha_{ij} = \alpha_{ji}$ and $\beta_{ij} = \beta_{ji}$. To ensure that $\pi(p,v)$ is linearly homogeneous in p and v, we also require $\sum \alpha_n^{\iota} = 1$, $\sum \beta_m^{\iota} = 1$, $\sum \alpha_{ij} = 0$, $\sum \beta_{ij} = 0$, $\sum_n \gamma_{nm} = 0$, and $\sum_m \gamma_{nm} = 0$. The translog GDP function is flexible in the sense that it approximates an arbitrary, twice continuously differentiable function to the second order at a point (Diewert, 1974; p. 113).[5] We capture the difference between a and b's GDP in terms of productivity with the following index:

$$R^{a,b} \equiv \left[\frac{\pi^b(p^a, v^a)}{\pi^a(p^a, v^a)} \frac{\pi^b(p^b, v^b)}{\pi^a(p^b, v^b)} \right]^{1/2}, \quad (10)$$

where the first ratio in the brackets is an index of the productivity difference using the prices of GDP a as reference netput prices and the quantities of GDP a as reference primary-input quantities, while the second ratio is an index of productivity change which uses GDP b as reference netput prices and input quantities.

Diewert and Morrison (1986) demonstrated a relationship between the translog functional form and the Törnqvist (1936) index formula, which they proposed for decomposing the growth in domestic product for a trading economy.[6] Specifically, Diewert and Morrison (1986) considered the case where $a = t-1$ and $b = t$, with $t = 1, \ldots, T$ indexing time. In this formulation, the GDP ratio in equation (1) is an index of GDP growth between periods $t-1$ and t. Diewert and Morrison (1986) showed that if the GDP function is translog as defined by (9), and there is competitive, profit-maximising behaviour, then the productivity index in (10) is a Törnqvist implicit output-quantity index divided by the primary-input-

[4]See Diewert (1973) for proofs.

[5]Note that only the second-order terms in (9) are restricted to be constant across firms.

[6]For further details of the GDP approach, see Kohli (1990; 1991) and Fox and Kohli (1998).

quantity index between a and b; i.e., (10) is equal to (2) so that

$$R^{t-1,t} \equiv \left[\frac{\pi^t(p^{t-1},v^{t-1})}{\pi^{t-1}(p^{t-1},v^{t-1})}\frac{\pi^t(p^t,v^t)}{\pi^{t-1}(p^t,v^t)}\right]^{1/2}$$
$$= (\Gamma^{t-1,t}/P^{t-1,t})/V^{t-1,t}, \quad (11)$$

where $\Gamma^{t-1,t}$ is defined as in (1), and $P^{t-1,t}$ and $V^{t-1,t}$ are defined as in (4) and (5), respectively. Equation (11) can then be rearranged as in (3) to give a decomposition of the growth in GDP.

The concept of the output gap is central to the measurement of aggregate excess demand or supply and, therefore, to the formulation of macroeconomic policy. The output gap is defined as the difference between potential and actual output. Fox and Warren (2001) interpreted a as potential GDP and b as actual GDP. With this interpretation, (1) is the ratio of actual GDP to potential GDP, or a ratio measure of the output gap. As is the case for GDP growth, it is possible to decompose the output gap into various contributing factors. In this case, the productivity index corresponding to (11) is

$$R^{t} \equiv \left[\frac{\tilde{\pi}^t(\bar{p}^{t},\bar{v}^{t})}{\bar{\pi}^{t}(\bar{p}^{t},\bar{v}^{t})}\frac{\tilde{\pi}^t(\tilde{p}^t,\tilde{v}^t)}{\bar{\pi}^{t}(\tilde{p}^t,\tilde{v}^t)}\right]^{1/2}$$
$$= (\Gamma^{t}/P^{t})/V^{t}, \quad (12)$$

where a bar over a variable denotes a potential value while a tilde denotes an actual value, Γ^t is defined as in (1), and P^t and V^t are defined as in (6) and (7), respectively. However, Γ^t, P^t and V^t are now indexes for comparing values in the same period t rather than across periods. Equation (12) can then be rearranged as in (3) to give a decomposition of the GDP gap.

3 Results

We use annual data from 1983 to 2001 for New Zealand on net outputs of (private and government) domestic expenditure (E), exports (X), and imports (M). The latter is defined as a negative output, in line with the standard definition of GDP. This treatment recognises that finished imports are intermediate inputs into production, since value is added domestically through activities such as transportation, marketing and retailing. Domestic expenditure E is an aggregate of private consumption, private investment, and government consumption.

The sum of the net outputs comprises aggregate GDP. The exogenously determined inputs are labour (L) and capital (K). Hence, we define $n\epsilon(E, X, M)$ and $m\epsilon(L, K)$.[7] The price and quantity data are plotted in Figures 1 and 2, respectively.

An important point to note in matching data with calendar years is that New Zealand's accounting year ends on 31 March. Statistics New Zealand labels the data according to the year in which the accounting period ends. Hence, the year from 1 April 1983 to 31 March 1984 is labelled 1984 by Statistics New Zealand. However, international agencies (e.g. OECD) label the data according to the year in which the accounting year begins. Hence, the year from 1 April 1983 to 31 March 1984 is labelled 1983 by the OECD.

The data necessarily differ from those used by Fox, Kohli and Warren (2002) in two important respects. First, their data only went up to 1996. Second, Statistics New Zealand changed to a chained Laspeyres index formula for constructing GDP aggregates in 2000. The output data were provided directly from Statistics New Zealand.

Since Fox, Kohli and Warren (2002) used data from the OECD and this paper uses data from Statistics New Zealand, some care has to be taken in comparing results. The results in this paper are more directly comparable with those of Diewert and Lawrence (1999), who also used Statistics New Zealand data, so that our labelling of years is the same as theirs.

3.1 Index-Number Decomposition of GDP Growth

This section uses the index-number decomposition method of Diewert and Morrison (1986), as extended by Kohli (1990). This method was applied by Fox and Kohli (1998) to Australian data, and by Diewert and Lawrence (1999) to New Zealand data. Although Diewert and Lawrence (1999) used raw data from Statistics New Zealand, they constructed their own aggregates. The current study uses official aggregates, leading to somewhat different results. Moreover, Diewert and Lawrence (1999) did not consider the alternative approach of section 3.4 below, nor did they perform the output-gap decompositions of section 3.2. Also, their results end in 1998, whereas our sample continues until 2001.

The decomposition of GDP growth, from (11), (6) and (7), is

$$\Gamma^{t-1,t} = R^{t-1,t} \cdot A^{t-1,t} \cdot P_E^{t-1,t} \cdot V_L^{t-1,t} \cdot V_K^{t-1,t}, \tag{13}$$

where, using (6),

$$A^{t-1,t} = \exp\left[\frac{1}{2}(s_M^{t-1} + s_M^t)\ln(p_M^t/p_M^{t-1}) + \frac{1}{2}(s_X^{t-1} + s_X^t)\ln(p_X^t/p_X^{t-1})\right] \tag{14}$$

[7]See the Appendix A for details of the construction of the data set.

is a Törnqvist index of the contribution of changes in the terms of trade to GDP growth. Hence, GDP growth is decomposed into contributions from changes in total-factor productivity ($R^{t-1,t}$), the terms of trade ($A^{t-1,t}$), domestic prices ($P_E^{t-1,t}$), labour utilisation ($V_L^{t-1,t}$), and capital utilisation ($V_K^{t-1,t}$).

Table 1 and Figure 3 present the results of decomposing New Zealand's GDP growth into the various contributing factors, using the index-number formula given in equation (13). To obtain growth rates in percentage terms, we subtract one from the tabulated index value and multiply by one hundred. The geometric means of each variable, for the entire 1983-2001 period and for the pre- and post-1991 sub-periods, are shown at the bottom of the appropriate column.

For the whole period, we find that nominal GDP (NGDP) grew at an average annual rate of 7.2 per cent. Column 2 reveals that increases in domestic prices account for approximately three-fifths of the growth in nominal GDP. The average growth rate of real net output, calculated by dividing the index of nominal GDP growth by the contribution of domestic-price changes ($P_E^{t-1,t}$), was 2.7 per cent per annum.

The factor which contributed most importantly to the growth in real net output is capital accumulation, accounting for about 1.6 per cent annually (or approximately three-fifths of the average real growth rate). The next-most important contributor is the growth in employment, which explains about two-fifths of the growth in real net output. We note that changes in the terms of trade during the 1984-2001 period contributed only modestly (about 0.2 per cent) to the average growth in real net output, and almost exactly offset the reduction in real growth associated with changes in total-factor productivity.

The annual growth in real economic activity over the sample period was highly volatile, with increases in excess of 5 per cent in 1983, 1994, and 1995 and reductions of 1.5 per cent and 2.2 per cent in the recession years of 1991 and 1992, respectively. Examining the sub-period means, we note that the rate of growth in real net output increased starting in 1993 by about 1.5 per cent per year compared to earlier years. This rise in the real growth rate can be attributed entirely to an increase in the growth of total-factor productivity; differences between the two sub-periods in rates of capital accumulation and in employment growth and changes in the terms of trade were negligible.[8]

[8]Table 1 can be compared with Table 3.5 of Diewert and Lawrence (1999). Our estimates of productivity contributions are lower than theirs, which can be attributed to differences in the data used. It can be noted that our results do not have the 11% decline in TFP for 1980, nor the 14% increase in TFP for 1984 that are reported by Diewert and Lawrence. Neither of these results are evident in their Table 4.4, which reports TFP growth using both official production-based and expenditure-based GDP data. Hence, there appears to be considerable variability in their productivity index in Table 3.5 that is not apparent elsewhere in their

The cumulative contributions of these various factors to the growth in real net output over the sample period are plotted in Figure 4. The bottom curve indicates the contribution of employment growth to the change in real net output. The next curve up is obtained by adding vertically the contribution of capital accumulation to the first curve. The contributions from changes in the terms of trade and from TFP growth are then added, in sequence, to give the solid curve, which illustrates the time path of real net output presented in the last column of Table 1.

3.2 Decomposition of the GDP Gap

A reduction in the rate and variability of inflation has been an important goal of the recent economic reforms in New Zealand. This focus led New Zealand's Parliament to establish an explicit inflation target for the Reserve Bank (Evans, et al., 1996; pp. 1863-66). The inflation rate is determined by the difference between potential and actual GDP (the GDP gap), along with expected inflation. Implementation of a monetary policy that is appropriate for a specific inflation mandate requires, therefore, an accurate estimate of the GDP gap. Understanding the driving forces behind changes in the gap will then provide a basis for devising appropriate policy responses to economy-wide shocks to potential or actual GDP. Hence, we use the method proposed in section 2, and the formula in equation (12), to decompose the GDP gap into various contributing factors.

We construct for each variable a series representing its long-run trend. To accomplish this task, we employ the flexible Super Smoother technique, developed by Friedman (1984), which uses data-dependent methods to estimate the appropriate degree of smoothness in the underlying time series.[9] Consistent with our model of production, we perform the smoothing at the component level, rather than at the aggregate (real) GDP level. The results from smoothing the prices and quantities are represented in Figures 1 and 2 by the smooth solid lines.[10] The decomposition of the output gap, from (12), (6) and (7), is

$$\Gamma^t = R^t \cdot A^t \cdot P_E^t \cdot V_L^t \cdot V_K^t, \tag{15}$$

where, for example, A^t is a Törnqvist index of the contribution to deviations of actual GDP from potential GDP associated with deviations of import and export prices from their "potential" values in period t. Hence, the output gap is decomposed into the contributions

report, nor in the literature.

[9]For more on the Super Smoother, see Appendix B.

[10]The original data and the smoothed series are available from the authors on request.

of the deviations of changes in productivity (R^t), the terms of trade (A^t), domestic prices (P_E^t), labour utilisation (V_L^t), and capital utilisation (V_K^t) from their respective trend values.

Table 2 contains the results of decomposing changes in the output gap into the various contributing factors described by equation (15). Figure 5 plots the time series for each of these factors, as reported in the table, along with providing a plot of the nominal output gap (solid line) and the "real gap" (Γ^t/P_E^t) (dashed line). The first column of Table 2 gives potential (nominal) GDP, which was constructed by smoothing actual (nominal) GDP reported in column 2. Column 3 shows the index for the nominal GDP gap, calculated as the ratio of column 2 to column 1. This ratio can be transformed into percentage deviations of actual from potential GDP by subtracting one and multiplying by one hundred. For example, in the recession year of 1992, the nominal gap is 0.970 so (0.970 - 1) x 100 = -3.0 per cent is the percentage shortfall of actual from potential nominal output. Column 5 contains annual estimates of the contribution to the nominal (and real) GDP gap of deviations of total-factor productivity $R^{1992} = 0.980 < 1$, so the TFP gap provides two-thirds of the explanation for the 3 per cent negative output gap experienced that year. The annual contributions of deviations in the terms of trade from its long-run trend are listed in column 6; for 1992, this effect is -0.9 per cent and accounts for the remaining one-third of the 3 per cent nominal-output shortfall. Columns 7 and 8 report the effects of deviations of the input quantities (labour and capital, respectively) from their long-run trends. The effects of trend deviations in both labour and capital are negligible over the entire (1983-2001) sample period. Finally, column 9 presents annual estimates of the gap in real output, which is slightly less (0.1 per cent) than the nominal-output gap because deviations of domestic prices from their long-run trend widened the nominal gap by a correspondingly small amount.

Over the period from 1983 to 2001 and for each of the two sub-periods, no one factor contributed heavily to changes in the nominal (or real) output gap. The small (0.2 percent) average deviation of TFP below its trend was offset by an equally small positive deviation of employment from trend. Once again, however, the stable sample means obscure considerable annual volatility in the GDP gaps and the various contributing factors. Deviations of domestic prices from their long-run trend played a substantial role in the shortfall of nominal output from its potential in 1984 and 1985, as well as in understanding the positive nominal-output gaps that occurred in 1987 and 1988. On the other hand, the negative GDP gaps of the 1992 and 1993 recession years were largely driven by below-trend levels of total-factor productivity and labour utilization.

3.3 Changes in Welfare

In this section, we use the results from the index-number approach to decomposing output growth to construct an index of the annual change in welfare arising from total-factor-productivity growth and changes in the terms of trade. We also derive an index of the welfare gap associated with deviations of TFP and the terms of trade from their respective long-run trends.

Productivity growth improves welfare by allowing more output to be produced with the same quantity of inputs. Improvements in the terms of trade also improve welfare because they allow the production of non-traded goods to be increased without changing the trade balance. Accordingly, Diewert and Morrison (1986) proposed the following welfare-change index $W^{t-1,t}$ between periods $t-1$ and t,

$$W^{t-1,t} \equiv R^{t-1,t} \cdot A^{t-1,t}. \tag{16}$$

Following Fox and Warren (2001), we also construct a "welfare-gap index" by taking the product of the productivity-gap and terms-of-trade-gap indexes:

$$W^{t} \equiv R^{t} \cdot A^{t}. \tag{17}$$

We interpret terms-of-trade changes over time as a type of productivity change which affects welfare in the same way as a change in TFP. The welfare gap tells us by how much welfare could have been improved (or reduced) if productivity growth and changes in the terms of trade were at their long-run trend levels, holding constant changes in factor endowments and the prices of non-traded goods. Note that the definitions of changes in aggregate welfare in (16) and (17) capture only the effects of productivity and terms-of-trade changes, and hence exclude, for example, the consequences of changes in job security, income inequality, and the quality of services provided. However, the welfare index does measure the effects of two primary sources of aggregate welfare change. Using equation (16), we calculate the welfare effects of productivity and terms-of-trade changes over time, holding domestic inputs fixed, using the index-number approach of 3.1. Similarly, we use equation (17) to calculate the welfare gap for each year. The results are given in Table 3.

Geometric-mean values of the annual change in welfare and in the welfare gap, for the entire period and the two sub-periods 1983-91 and 1992-2001, are provided at the bottom of this table. These summary statistics reveal that there was very little change in (average) welfare or in the welfare gap over the whole time frame and, moreover, no quantitatively important difference between the pre- and post-1992 periods. However, a comparison of sub-period means masks considerable annual variation in both welfare indices. For example, there was an 8.5-percent reduction in welfare in 1986 and a 3-percent decrease in both 1991 and 1992, reflecting corresponding declines in total-factor productivity in those years. On the other hand, the welfare index rose substantially in 1989 and 1994, with improvements in both TFP and the terms of trade contributing equally to the earlier increase and the 1994 gain driven entirely by a rise in TFP.

Noteworthy shortfalls of actual welfare from its trend (or potential welfare) occurred in 1986-87 and 1992-93. Deviations of TFP growth from trend were exclusively responsible for the negative welfare gaps in the earlier years. However, deterioration in the terms of trade relative to trend values was also a contributing factor in the departure of measured welfare from its potential. In contrast, the welfare gap was substantially positive in 1985, 1989, and 1990. Above-average TFP growth was exclusively responsible for this situation in 1985, while a favorable trend-deviation of the terms of trade can be credited in the latter two years.

3.4 An Alternative Decomposition Method

There is a problem with interpreting $A^{t-1,t}$ (or A^t) as a terms-of-trade effect, because it is not homogeneous of degree zero in prices. This means that a proportional increase in export and import prices will lead to a change in $A^{t-1,t}$ unless trade is balanced, so that the shares of exports and imports sum to zero on average over both periods.

The issue, then, is how to split up, for example, $P^{t-1,t}$ in (13) if $P^{t-1,t} = P_E^{t-1,t} \cdot A^{t-1,t}$ is not favoured. Kohli (2003) has suggested the following decomposition:

$$P^{t-1,t} = P_S^{t-1,t} \cdot G^{t-1,t} \cdot H^{t-1,t} \tag{18}$$

where the change in the domestic price index is

$$P_S^{t-1,t} = \frac{p_E^t}{p_E^{t-1}}, \tag{19}$$

the (inverse of the) terms-of-trade effect is:

$$G^{t-1,t} = \exp\left[\frac{1}{2}(s_M^{t-1} + s_M^t)\ln\frac{g^t}{g^{t-1}}\right], \tag{20}$$

with $g^t \equiv p_M^t/p_X^t$, and the change in the trade-balance is given by:

$$H^{t-1,t} = \exp\left[\frac{1}{2}(s_B^{t-1} + s_B^t)\ln\frac{h^t}{h^{t-1}}\right], \tag{21}$$

where $h^t \equiv p_X^t/p_E^t$ and $s_B^t = s_X^t + s_M^t$. Figure 6 plots the relative prices g^t and h^t, where the lines represent the corresponding smoothed series. Note that the domestic-price-change *contribution* to nominal GDP growth, $P_E^{t-1,t}$, is not the same as the rate of growth of domestic prices, $P_S^{t-1,t}$.

Nominal GDP growth can be decomposed as follows:

$$\Gamma^{t-1,t} = R^{t-1,t} \cdot P_S^{t-1,t} \cdot G^{t-1,t} \cdot H^{t-1,t} \cdot X_L^{t-1,t} \cdot X_K^{t-1,t}. \tag{22}$$

Real value added is

$$\Gamma^{t-1,t}/P_S^{t-1,t} = R^{t-1,t} \cdot G^{t-1,t} \cdot H^{t-1,t} \cdot X_L^{t-1,t} \cdot X_K^{t-1,t}, \tag{23}$$

and (Törnqvist) real GDP is,

$$\begin{aligned} \Gamma^{t-1,t}/(P_S^{t-1,t} \cdot G^{t-1,t} \cdot H^{t-1,t}) &= \Gamma^{t-1,t}/P^{t-1,t} \\ &= R^{t-1,t} \cdot X_L^{t-1,t} \cdot X_K^{t-1,t}. \end{aligned} \tag{24}$$

Table 4 and Figure 7 report the results of this alternative decomposition of the change in nominal GDP. The series labelled “Real VA” and “Real GDP” correspond, respectively, to the decompositions in equations (23) and (24) and, therefore, differ because of changes in the terms of trade or the trade balance.[11] For the entire 1983-2001 period, we find that the growth in real value added was higher than the growth in real GDP, a difference that is due entirely to improvements in the terms of trade during these years. The discrepancy between the two measures of real output was larger between 1984 and 1992 than between 1993 and 2001, again solely because of differential changes in the terms of trade between the two sub-periods. Indeed, the contribution of changes in the balance of trade to explaining the difference between real value added and real GDP is negligible, on average, over the entire period of observation and in both sub-periods. The annual change in the trade balance exceeds 0.1 percent in only two of the eighteen years.

Nevertheless, the relatively small average differences in the two measures of the growth in economy-wide real output masks noteworthy discrepancies in calculated growth rates for particular years, when there were large changes in the terms of trade. For example, in both 1987 and 1988 the growth in real value added exceeded the growth in real GDP by more than 2 per cent because of the substantial improvements in the terms of trade in those two years.

Table 5 and Figure 8 report the results from the alternative output-gap decomposition that correspond to the growth decompositions of equations (22)—(24). A comparison of

[11] Real VA is the same as $\tilde{Y}_{t,t-1}$ in Table 4 of Kohli (2003a).

the "Real VA Gap" and the "Real GDP Gap" reveals that there are substantial differences which are driven (mainly) by deviations in the terms of trade from its long-run trend. For example, the real GDP gap for 1986 indicates that real output was above its long-run trend. In contrast, if the negative impacts of the terms of trade and the balance of trade are taken into account, as in real value added, then real output was 15% below its trend. This suggests that these different concepts of output can have significantly different implications for the conduct of monetary policy.

3.5 Fisher versus Törnqvist Decompositions

The decompositions performed thus far depend on the Törnqvist index, using its characterisation as a weighted geometric mean. It is natural to consider if there are other superlative index numbers which can be similarly decomposed. In particular, the Fisher index has a stronger justification from the axiomatic approach to assessing index numbers, and has a similar justification as the Törnqvist index from the economic approach to index numbers. Its recent adoption by statistical agencies (for example, the U.S. Bureau of Labor Statistics) for various series (e.g., GDP) has lead to increasing interest in possible methods of achieving a decomposition similar to that for the Törnqvist index (Reinsdorf, Diewert and Ehemann, 2000; Kohli, 2002; Balk, 2002).

Kohli (2002), building on the work of Reinsdorf, Diewert and Ehemann (2000), found that a particular expression for a Fisher quantity index follows naturally from taking the geometric mean of the Laspeyres and Paasche price indexes, expressed in terms of share-weighted sums. For example, using the notation of section 2, we can write a Fisher output-price index as follows:

$$P_F^{a,b} = \exp\left[\sum_{m=1}^{M} \frac{1}{2}(\sigma_L^{a,b} + \sigma_P^{a,b}) \ln(p_n^b/p_n^a)\right], \tag{25}$$

with

$$\sigma_L^{a,b} \equiv \frac{s_n^a \cdot m(p_n^b/p_n^a, P_L^{a,b})}{\sum_{n=1}^N s_n^a \cdot m(p_n^b/p_n^a, P_L^{a,b})} \tag{26}$$

and

$$\sigma_P^{a,b} \equiv \frac{s_n^b \cdot m(p_n^a/p_n^b, 1/P_P^{a,b})}{\sum_{n=1}^N s_n^b \cdot m(p_n^a/p_n^b, 1/P_P^{a,b})} \tag{27}$$

where $P_L^{a,}$ and $P_P^{a,}$ are the standard Laspeyres and Paasche price indexes, respectively, and $m(x, y)$ denotes the logarithmic mean of x and y, $m(x, y) = (a-b)/(\ln a - \ln b)$, $m(x, x) = x$, for $x, y > 0$. We can easily verify that $P_F^{a,b}$ has the same form as equation (4), the only difference arising from the weights on the relative prices. From these expressions, we see that the indexes will approximate each other quite closely as long as relative prices do not change too much in going from a to b (Kohli, 2002).

From (25), we can write the Fisher price index as

$$P_F^{a,b} = \prod_{n=1}^{N} P_{F,n}^{a,b}, \tag{28}$$

where $P_{F,n}^{a,b}$ is the Fisher price index in (25) calculated for the n^{th} netput. This expression can be compared with the corresponding expression for the Törnqvist index in equation (6). Hence, the Fisher index also can be written as the product of its components, making it possible to decompose it in the various ways proposed for the Törnqvist index. The only difference is that each of the components in the Törnqvist case can be given a justification from the economic approach to index numbers, while for the Fisher index we can find a justification only for the aggregate index, $P_F^{a,b}$, from the economic approach (Diewert, 1992).

Applying the Fisher-index method to the current data set yielded results that are almost identical for each of the components in both the growth and output-gap decompositions. These findings are reassuring, and act as a "test" of the robustness of the results. The Törnqvist index fails to satisfy some of the desirable axioms that the Fisher index satisfies, yet the empirical results are essentially identical. This suggests that, at least in the present context, one can interpret the results as being generated either from a Törnqvist index, which is superior in terms of an economic justification, or from a Fisher index, which is superior in terms of the axiomatic approach to index numbers.

4 Concluding Remarks

We have used new data and alternative index-number techniques to decompose estimates of GDP growth, real value-added growth, the output gap, and aggregate welfare for the New Zealand economy into various contributing factors. Our approach allows for a more detailed examination of the sources of variations in these indices of macroeconomic performance than is possible from the traditional growth-accounting framework.

Over the 1983-2001 period under study, nominal GDP grew at an average rate of 7.2 per cent per year. Increases in domestic prices were responsible for about sixty percent of this growth, so real net (of domestic prices) output grew at an average rate of around 2.7 per cent. The factor which contributed most heavily to real-net-output growth was capital accumulation, accounting for approximately three-fifths, or 1.6 percent. This was followed by the growth in employment, which explained the remaining two-fifths of the real growth rate. The contributions of changes in the terms of trade and in total-factor productivity were, on average, small and roughly offsetting (+/-0.2 percent per year).

There is no single factor that explains changes in the nominal or real output gap over the entire sample period. In some years, the deviation of domestic prices from long-run trend was most responsible for the shortfall of output from its potential, but in other years (e.g., 1992 and 1993), the negative GDP gap was driven by deviations of total-factor productivity and employment from their long-run trends. There was virtually no change in the index of aggregate welfare during this period, although there were instances of considerable variation from year to year that were associated with changes in total-factor productivity or a combination of TFP and terms-of-trade changes.

Our findings largely confirm the results reported by Fox, Kohli and Warren (2002), using different data and alternative methods of index-number decomposition. The robustness of our conclusions to differences in the sample period examined, GDP data used, and decomposition techniques employed increases the confidence we place in the specific results we obtained. More importantly, we have illustrated how various techniques for decomposing nominal and real output are capable of providing additional insights into the recent performance of the New Zealand economy.

Appendix A: Data Description

We use annual data for New Zealand over the period 1983-2001. The output data are the same as used by Kohli (2003a). For the inputs, recent data was obtained from the Statistics New Zealand website on the total number of people employed and average weekly paid hours. These were used to construct a labor quantity index (by multiplying them together) which was then spliced with earlier data used by Fox, Kohli and Warren (2002). The capital stock data were obtained with the same approach as Fox, Kohli and Warren (2002) and Fox and Kohli (1998), using the 1960-1967 growth rate and a 5% depreciation rate to obtain a 1967 initial value, and accumulating the investment series thereafter. Note that we have not used the official Statistics New Zealand capital stock series. This is because our preferred approach to measuring the capital stock facilitates international comparisons, as capital stock series for other countries can be constructed using the identical approach; see e.g., Kohli (2003b) and Fox and Diewert (1999).

The shares of labour and capital for the most recent years were also obtained from the Statistics New Zealand website. The value of labour and the value of capital were obtained by multiplying nominal GDP by these shares. This ensures that the GDP identity holds, but means that the values are larger than those appearing in the national accounts (because of indirect taxes and subsidies). However, this discrepancy does not matter since, on the input side, one only needs the quantity indexes and the shares.

Appendix B: The Super Smoother

Using the Super Smoother technique the smooth function, $S_{t,t-1}$, is built pointwise as follows.

1. The k nearest neighbours to some point R^0 define the "span". Observations which lie within this span are said to be within a neighbourhood, $N(R^0)$, of R^0. The choice of the span is discussed below.

2. The largest distance between R^0 and another point in $N(R^0)$ is calculated:

$$\Delta R^0 = max_{N(R^0)} |R^0 - R^i|. \tag{29}$$

3. A tri-cube weight function is used to assign weights to each point in $N(R^0)$:

$$W\left(\frac{|R^0 - R^i|}{\Delta R^0}\right) \tag{30}$$

where

$$W(u) = \begin{cases} (1-u^3)^3 & \text{for } 0 \leq u < 1 \\ 0 & \text{otherwise.} \end{cases} \tag{31}$$

4. Using these weights, the weighted least squares fit of R^0 on $N(R^0)$ is calculated, and the fitted value is taken to be S^0.

5. This procedure is repeated for each observation.

For a fixed span, the above describes locally weighted regression smoothing. A constant span may be inappropriately restrictive. Super Smoother chooses the span for each observation based on the cross-validation criterion:

$$CV(k) = (1/k)\sum_{i=1}^{k}[R^i - S^{-i}(R^i|k)]^2, \tag{32}$$

where S^{-i} denotes the smoothed value of R^i calculated by dropping R^i and using the R_j in the neighbourhood $N(R^0)$ of span k as predictors of R^i. The span which minimizes $CV(k)$ is selected for each R^i.

Super Smoother comes as a option in statistical packages such as S-PLUS (Statistical Sciences, 1995).

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Table 1: Decomposition of GDP Growth

Year	NGDP	Domestic Prices	TFP	Terms of Trade	Labour	Capital	Real Net Output
1984	1.109	1.054	1.021	0.995	1.018	1.018	1.053
1985	1.134	1.092	1.008	0.989	1.024	1.018	1.039
1986	1.150	1.152	0.916	0.999	1.068	1.022	0.998
1987	1.198	1.145	0.997	1.018	1.013	1.017	1.046
1988	1.126	1.092	0.996	1.022	0.997	1.015	1.031
1989	1.086	1.051	1.016	1.015	0.988	1.014	1.033
1990	1.057	1.046	0.998	1.009	0.990	1.013	1.010
1991	1.018	1.033	0.983	0.985	0.999	1.018	0.985
1992	0.997	1.020	0.979	0.992	0.994	1.013	0.978
1993	1.032	1.017	0.996	1.004	1.010	1.005	1.015
1994	1.082	1.010	1.038	1.007	1.017	1.007	1.071
1995	1.070	1.012	1.010	1.004	1.028	1.014	1.057
1996	1.065	1.024	0.997	1.002	1.023	1.018	1.040
1997	1.046	1.012	1.000	1.003	1.011	1.020	1.034
1998	1.033	1.008	1.011	0.996	0.997	1.020	1.025
1999	1.008	1.012	0.983	0.998	0.996	1.018	0.996
2000	1.048	1.004	1.024	0.998	1.008	1.014	1.044
2001	1.058	1.027	0.998	1.008	1.006	1.018	1.031
Geometric Means							
1984-01	1.072	1.044	0.998	1.002	1.010	1.016	1.027
1984-92	1.095	1.075	0.990	1.003	1.010	1.016	1.019
1993-01	1.049	1.014	1.006	1.002	1.011	1.015	1.034

Table 2: Decomposition of the Output Gap

Year	Potential GDP	Actual GDP	Nominal Gap	Domestic Prices	Productivity	Terms of Trade	Labour	Capital	Real Gap
1983	32609	32100	0.984	0.997	0.970	1.011	1.005	1.001	0.987
1984	37545	35613	0.949	0.942	1.013	1.001	0.994	0.999	1.006
1985	42705	40395	0.946	0.933	1.042	0.986	0.989	0.998	1.014
1986	48226	46462	0.963	0.978	0.973	0.980	1.032	1.002	0.985
1987	53995	55666	1.031	1.027	0.982	0.991	1.030	1.002	1.004
1988	59560	62657	1.052	1.039	0.988	1.006	1.018	1.002	1.012
1989	64510	68018	1.054	1.026	1.011	1.013	1.003	1.001	1.028
1990	68678	71865	1.046	1.022	1.014	1.018	0.993	1.000	1.024
1991	72126	73152	1.014	1.018	0.999	1.001	0.992	1.005	0.996
1992	75206	72937	0.970	1.010	0.980	0.991	0.983	1.005	0.960
1993	78542	75245	0.958	1.006	0.974	0.994	0.985	0.998	0.952
1994	82357	81388	0.988	0.999	1.007	1.000	0.990	0.993	0.989
1995	86454	87053	1.007	0.996	1.012	1.003	1.004	0.992	1.011
1996	90782	92679	1.021	1.006	1.003	1.003	1.014	0.995	1.015
1997	95110	96909	1.019	1.004	0.998	1.004	1.014	0.998	1.014
1998	99158	100075	1.009	1.000	1.005	1.000	1.004	1.001	1.010
1999	102860	100835	0.980	0.999	0.987	0.998	0.995	1.002	0.981
2000	106482	105687	0.993	0.990	1.008	0.996	1.000	0.999	1.003
2001	110151	111861	1.016	1.004	1.005	1.004	1.002	1.000	1.012
Means									
1983-01	74056	74242	0.999	0.999	0.998	1.000	1.002	1.000	1.000
1983-92	55516	55887	1.000	0.999	0.997	1.000	1.004	1.001	1.002
1993-01	94655	94637	0.999	1.000	1.000	1.000	1.001	0.997	0.998

Note: The arithmetic mean is used to average over the GDP values, while the geometric mean is used to average over the indexes. The GDP values are in millions of New Zealand dollars.

Table 3: Welfare Indexes

Year	Welfare Change	Welfare Gap
1983		0.981
1984	1.016	1.014
1985	0.996	1.027
1986	0.915	0.953
1987	1.015	0.973
1988	1.018	0.993
1989	1.031	1.025
1990	1.007	1.031
1991	0.969	1.000
1992	0.971	0.971
1993	1.000	0.968
1994	1.045	1.006
1995	1.015	1.015
1996	0.999	1.007
1997	1.002	1.002
1998	1.007	1.005
1999	0.981	0.985
2000	1.021	1.005
2001	1.006	1.009
Geometric Means		
1983-01	1.000	0.998
1983-91	0.992	0.996
1992-01	1.008	1.000

Table 4: Decomposition of GDP Growth: Alternative Approach

Year	NGDP	Domestic Prices (P_s)	Real VA	Real GDP	Terms of Trade (G)	Balance of Trade (H)
1984	1.109	1.053	1.054	1.058	0.996	1.000
1985	1.134	1.090	1.041	1.050	0.992	0.999
1986	1.150	1.147	1.003	1.000	1.000	1.003
1987	1.198	1.143	1.048	1.027	1.019	1.002
1988	1.126	1.093	1.030	1.008	1.022	1.000
1989	1.086	1.052	1.032	1.018	1.014	1.000
1990	1.057	1.047	1.009	1.001	1.008	1.001
1991	1.018	1.033	0.985	1.000	0.985	1.000
1992	0.997	1.020	0.977	0.986	0.992	0.999
1993	1.032	1.017	1.014	1.010	1.002	1.001
1994	1.082	1.010	1.070	1.063	1.007	0.999
1995	1.070	1.012	1.057	1.053	1.005	0.999
1996	1.065	1.024	1.040	1.038	1.002	0.999
1997	1.046	1.012	1.033	1.031	1.003	1.000
1998	1.033	1.008	1.025	1.028	0.996	1.000
1999	1.008	1.012	0.996	0.998	0.998	1.000
2000	1.048	1.004	1.044	1.047	0.998	1.000
2001	1.058	1.027	1.031	1.023	1.008	1.000
Geometric Means						
1984-01	1.072	1.044	1.027	1.024	1.003	1.000
1984-92	1.095	1.075	1.020	1.016	1.003	1.000
1993-01	1.049	1.014	1.034	1.032	1.002	1.000

Table 5: Decomposition of the Output Gap: Alternative Approach

Year	Nominal Gap	Domestic Prices	Real VA Gap	Real GDP Gap	Terms of Trade	Balance of Trade
1983	0.984	0.997	0.987	0.978	1.009	1.001
1984	0.949	0.944	1.005	1.005	1.000	1.000
1985	0.946	0.934	1.013	1.028	0.988	0.998
1986	0.963	0.978	0.985	1.003	0.982	0.999
1987	1.031	1.027	1.004	1.011	0.993	1.000
1988	1.052	1.039	1.012	1.005	1.007	0.999
1989	1.054	1.026	1.027	1.014	1.014	0.999
1990	1.046	1.022	1.023	1.005	1.018	1.000
1991	1.014	1.018	0.996	0.996	1.001	1.000
1992	0.970	1.011	0.960	0.968	0.992	0.999
1993	0.958	1.006	0.952	0.958	0.993	1.001
1994	0.988	0.999	0.989	0.989	0.999	1.000
1995	1.007	0.996	1.011	1.008	1.003	1.000
1996	1.021	1.006	1.015	1.012	1.003	1.000
1997	1.019	1.004	1.014	1.010	1.004	1.000
1998	1.009	1.000	1.010	1.010	1.000	1.000
1999	0.980	0.999	0.981	0.985	0.997	1.000
2000	0.993	0.990	1.003	1.009	0.994	1.000
2001	1.016	1.004	1.012	1.011	1.001	1.000
Means						
1983-01	0.999	1.000	1.000	1.000	1.000	1.000
1983-92	1.000	0.999	1.001	1.001	1.000	1.000
1993-01	0.999	1.000	0.998	0.999	0.999	1.000

Figure 1: Prices

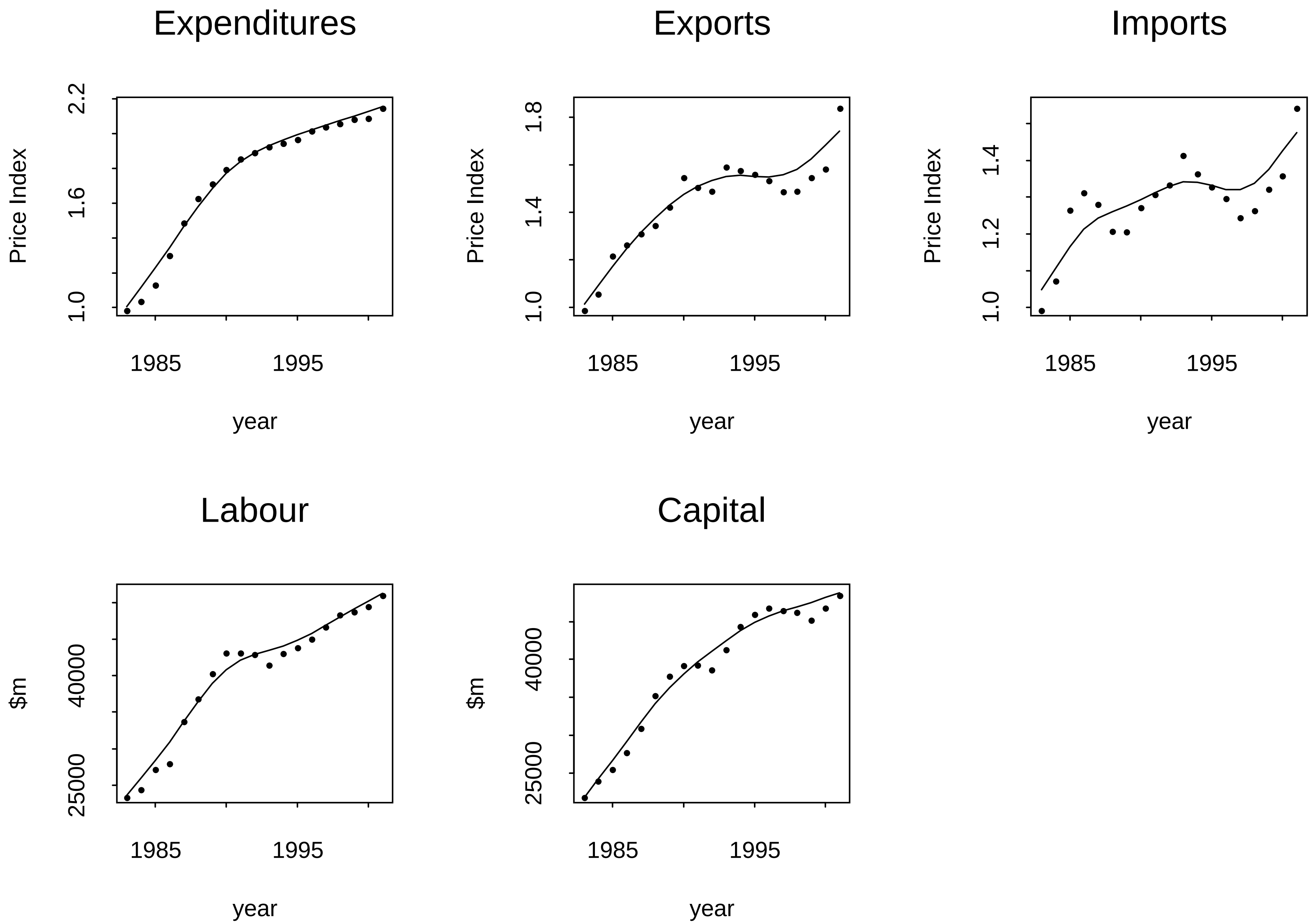

Figure 2: Quantities

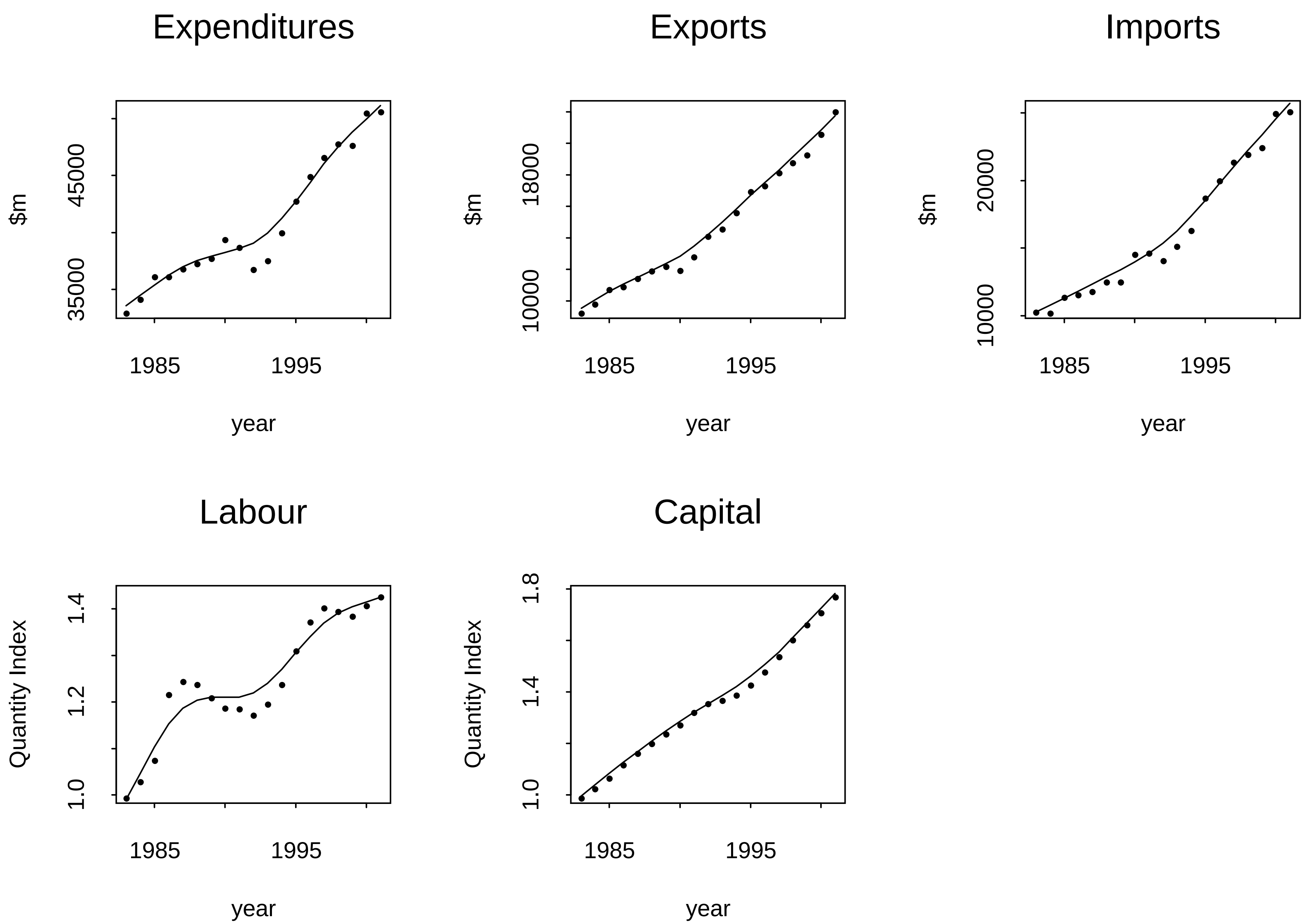

Figure 3: Decomposing Output Growth, Contributions from Different Sources

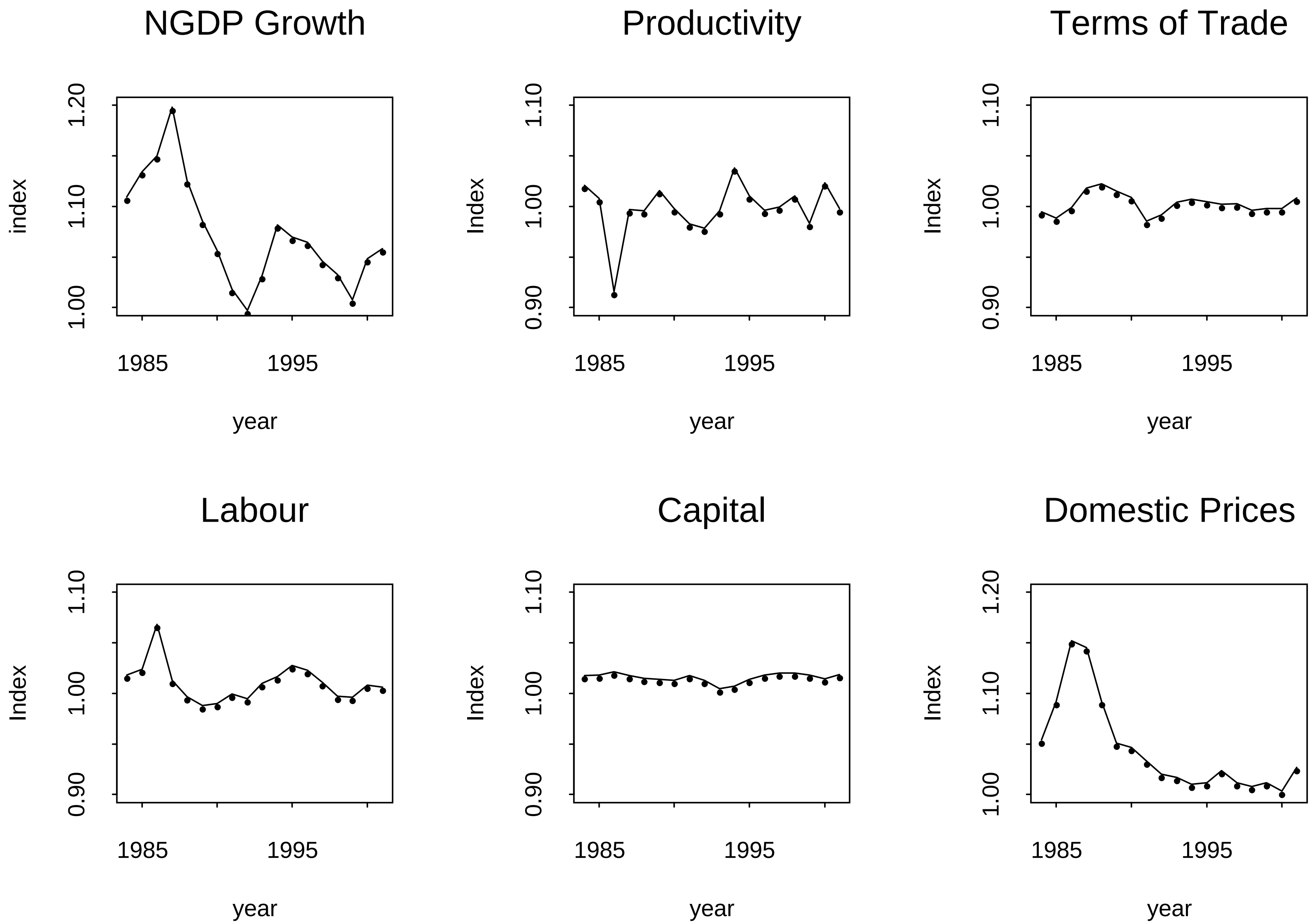

Figure 4: Real Net Output

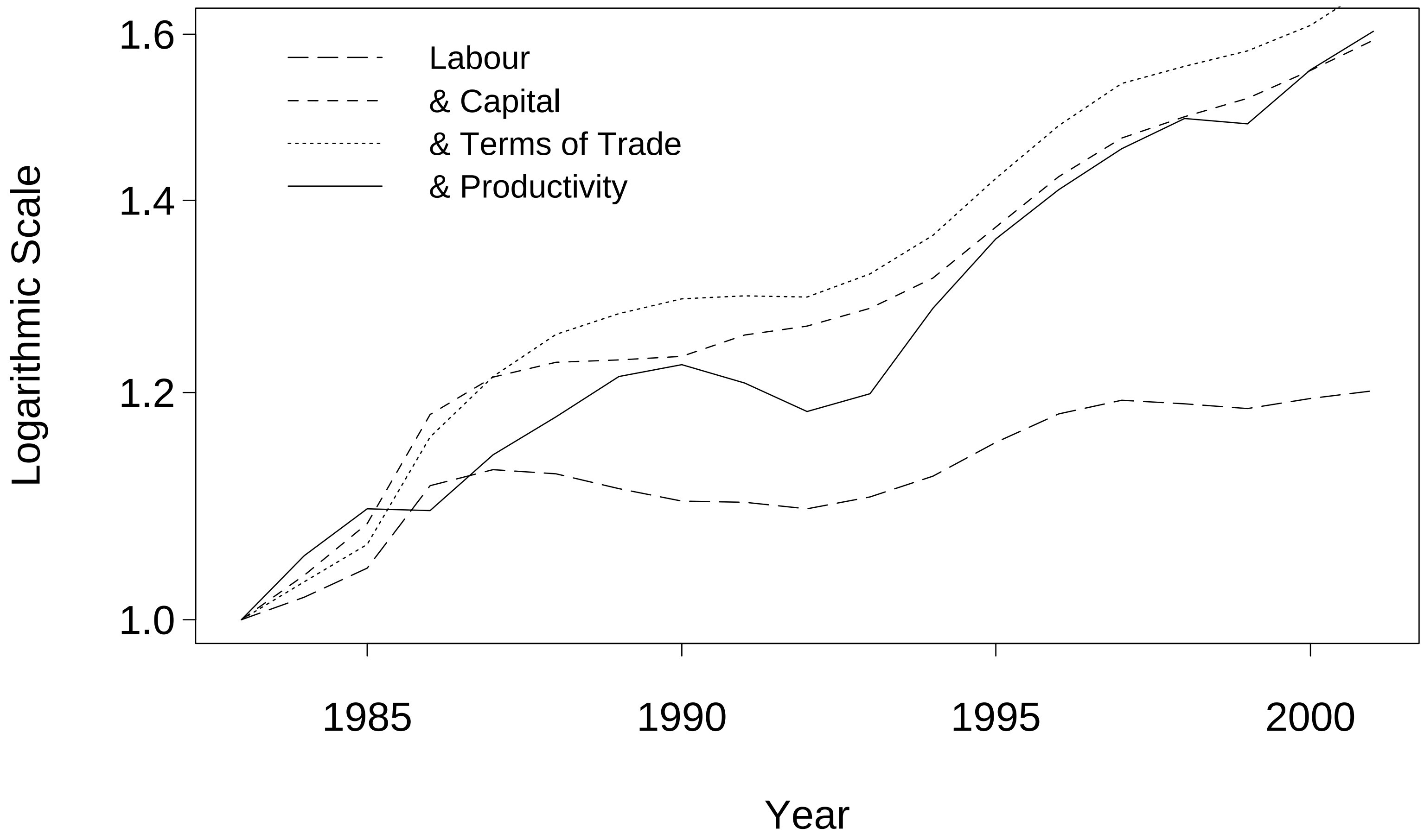

Figure 5: Decomposing the Output Gap, Contributions from Different Sources

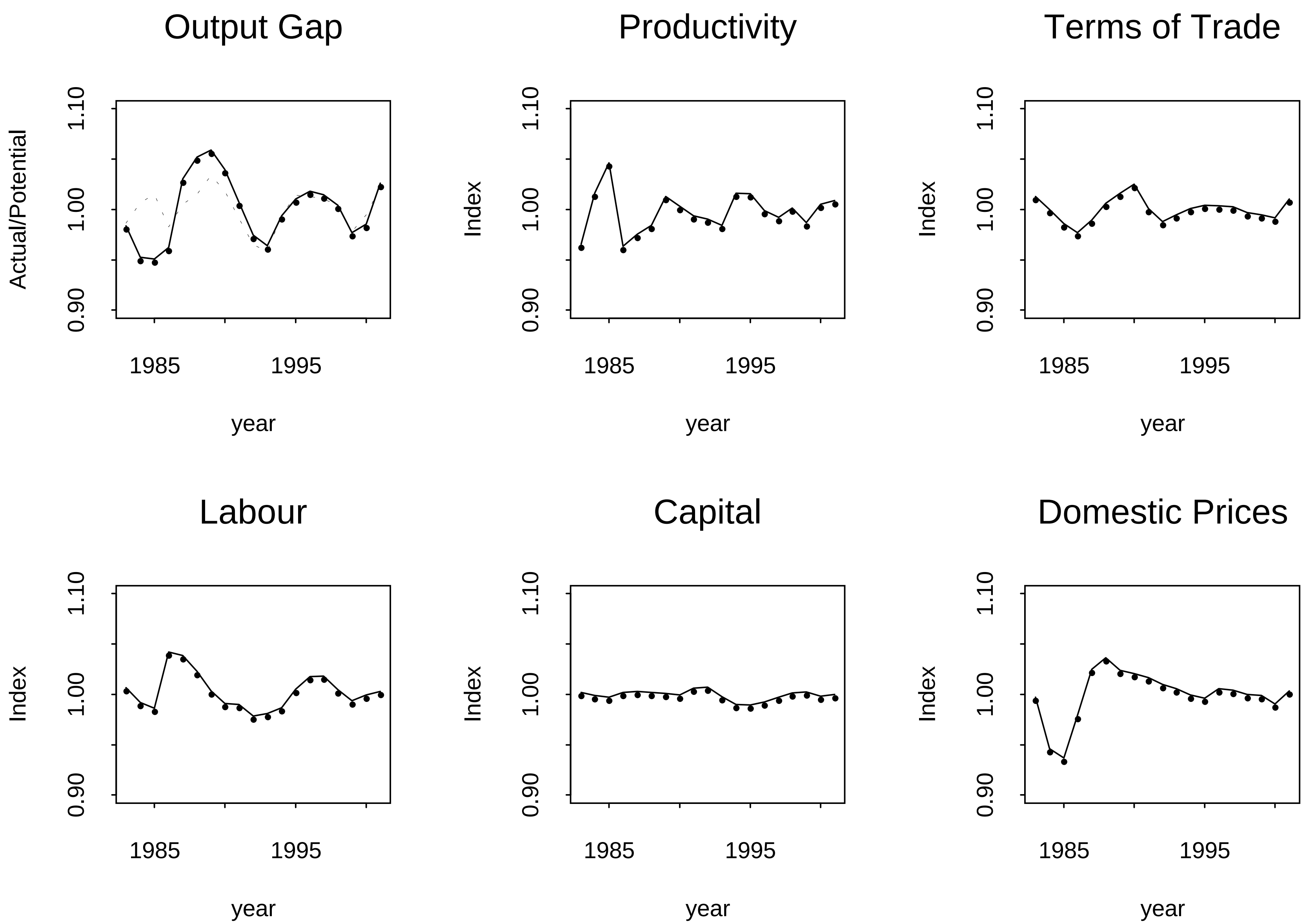

Figure 6: Relative Prices

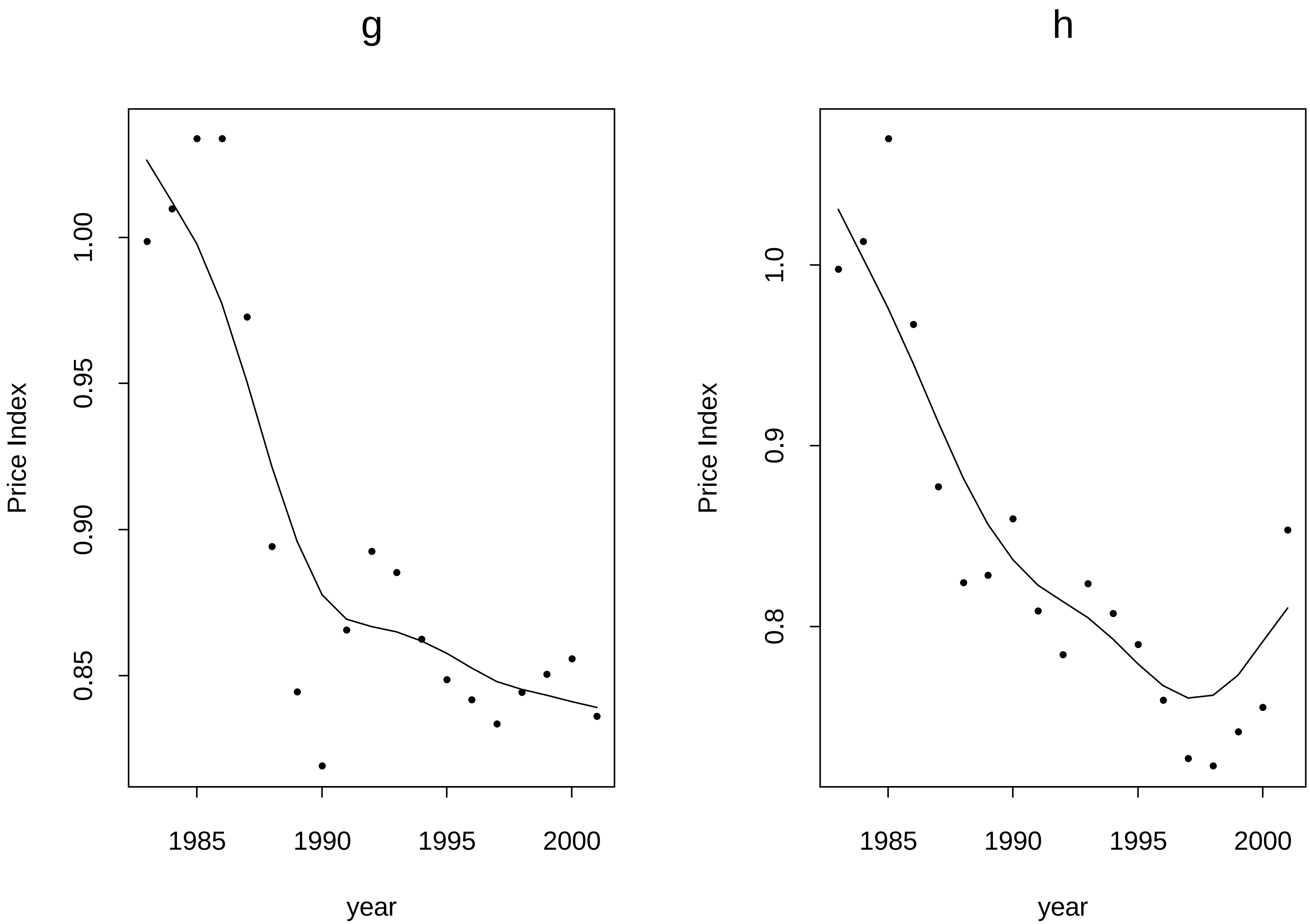

Figure 7: Decomposing Real Value-Added Growth, Contributions from Different Sources

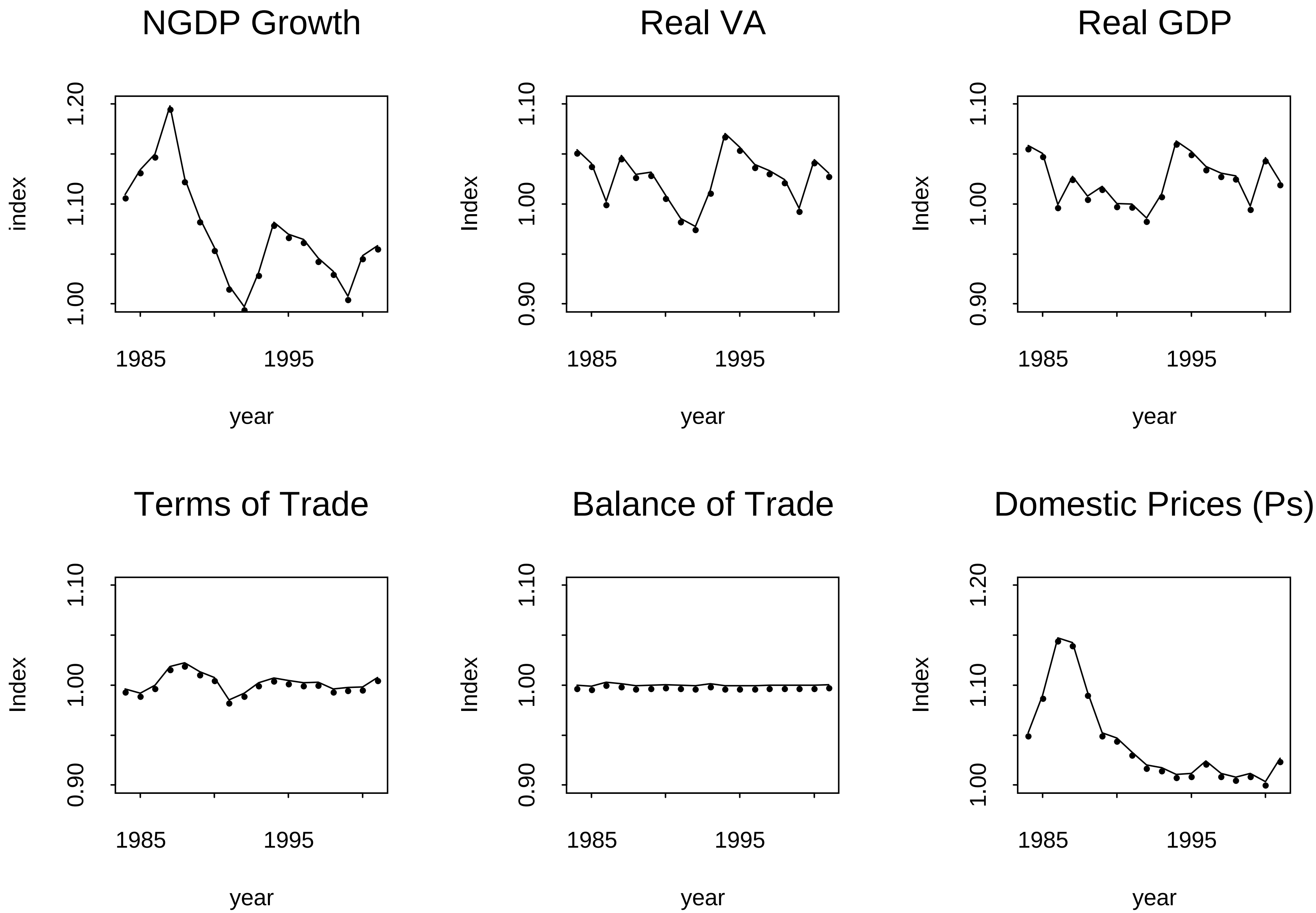

Figure 8: Decomposing the Real Value-Added Gap, Contributions from Different Sources