Measuring the Contributions of Productivity and the Terms of Trade to Australian Economic Welfare

Erwin Diewert and Denis Lawrence

Paper presented to
Productivity Perspectives 2006, Hyatt Hotel, Canberra

23 March 2006

Meyrick Consulting Group Pty Ltd (trading as Meyrick and Associates)
ABN 60 113 345 743
6 Kurundi Place, Hawker, ACT 2614, AUSTRALIA
TEL +61 2 6278 3628 FAX +61 2 6278 5358
EMAIL denis@meyrick.com.au
WEB www.meyrick.com.au

AUSTRALIAN CAPITAL TERRITORY NEW SOUTH WALES VICTORIA

1 INTRODUCTION

Improvements in a country's terms of trade, as well as improvements in a country's productivity growth, raise domestic welfare. Whilst productivity growth raises domestic income, an increase in export prices relative to import prices allows a larger quantity of imports to be purchased for a given quantity of exports, thus raising the purchasing power of domestic income. The Industry Commission (1995) examined the impact of terms of trade changes on Australia's 'purchasing power' over the period 1968–69 to 1993–94 and found they had a small negative impact. Terms of trade changes reduced purchasing power by 0.1 per cent per annum on average while productivity growth increased it by 1.5 per cent per annum over the same period.

The recent resurgence in commodity prices has again focussed attention on the potential impact of the terms of trade on Australia's welfare. The Productivity Commission has engaged Meyrick and Associates to undertake a quantitative study of the relative impact of productivity and terms of trade changes on Australia's welfare over recent decades. This paper presents a summary of the methodology and findings of Diewert and Lawrence (2006).

Calculating the exact magnitude of each source of welfare gain is not straightforward. Diewert (1983), Diewert and Morrison (1986), Morrison and Diewert (1990) and Kohli (1990) (1991) (2003) (2004a) (2004b) developed a production theory methodology that enables one to obtain index number estimates of the contribution of each type of gain. In section 2, we summarise the adaptation of this methodology and how it can be used to measure the determinants of growth in an economy's real income. We show how this theoretical approach can be implemented in sections 2 and 3 assuming that the market sector of the economy can be represented by a translog GDP function. Section 4 implements the translog approach using Australian data for the years 1960–2004. The main determinants of growth in real income generated by the market sector of the economy are:

- Technical progress or improvements in Total Factor Productivity;
- Growth in domestic output prices or the prices of internationally traded goods and services relative to the price of consumption; and
- Growth in primary inputs.

However, GDP is a measure of productive potential, not welfare. For welfare measurement purposes, it is generally conceded that Net Domestic Product (NDP) is a better measure of output, since investment that just meets depreciation means that society is not made any better off from the viewpoint of sustainable final consumption possibilities (see, for example, Weitzman 1976, 1997 and Oulton 2002). Hence, in the second part of the report, we subtract depreciation from gross investment and use consumption plus sales to the government sector plus *net investment* plus the trade balance as our output concept. Thus, depreciation is treated as an intermediate input in this model of production. Section 5 explains this real net product approach and adapts the translog model to this new model of market sector real income generation. The translog deflated net product approach is then implemented using Australian data for the years 1960–2004.

Section 6 concludes by noting that the determinants of real net income growth in Australia are quite different from the corresponding determinants for real gross income in Australia: technical progress becomes much more important as a determinant and the role of capital deepening is diminished.

2 THE TRANSLOG GDP FUNCTION APPROACH

We assume that the market sector of the economy produces quantities of M (net)[1] outputs, $y \equiv [y_1,...,y_M]$, which are sold at the positive producer prices $P \equiv [P_1,...,P_M]$. We further assume that the market sector of the economy uses positive quantities of N primary inputs, $x \equiv [x_1,...,x_N]$ which are purchased at the positive primary input prices $W \equiv [W_1,...,W_N]$. In period t, we assume that there is a feasible set of output vectors y that can be produced by the market sector if the vector of primary inputs x is utilised by the market sector of the economy; denote this period t production possibilities set by S^t.

Given a vector of output prices P and a vector of available primary inputs x, we define *the period t market sector GDP function*, $g^t(P,x)$, as follows:[2]

(1) $g^t(P,x) \equiv \max_y \{P \cdot y : (y,x) \text{ belongs to } S^t\}$; $t = 0,1,2, \ldots$.

In the present study our focus is on the income generated by the market sector or more

[1] If the mth commodity is an import (or other produced input) into the market sector of the economy, then the corresponding quantity y_m is indexed with a negative sign. We will follow Kohli (1978) (1991) and Woodland (1982) in assuming that imports flow through the domestic production sector and are "transformed" (perhaps only by adding transportation, wholesaling and retailing margins) by the domestic production sector.

[2] The function $g^t(P,x)$ will be linearly homogeneous and convex in the components of P and linearly homogeneous and concave in the components of x; see Diewert (1973) (1974; 136). Notation: $P \cdot y \equiv \sum_{m=1}^{M} P_m y_m$.

precisely, on *the real income generated by the market sector*, rather than GDP. However, since market sector GDP (the value of market sector production) is distributed to the factors of production used by the market sector, nominal market sector GDP will be equal to nominal market sector income; ie we have $g^t(P^t,x^t) = P^t \cdot y^t = W^t \cdot x^t$. As an approximate welfare measure that can be associated with market sector production, we will choose to measure the *real income generated by the market sector in period t*, r^t, in terms of the number of consumption bundles that the nominal income could purchase in period t; ie define ρ^t as follows:

$$\begin{aligned}(2)\ \rho^t &\equiv W^t \cdot x^t / P_C{}^t\,; \qquad\qquad t = 0,1,2,\ldots \\ &= w^t \cdot x^t \\ &= p^t \cdot y^t \\ &= g^t(p^t,x^t)\end{aligned}$$

where $P_C{}^t > 0$ is the *period t consumption expenditures deflator* and the market sector period t *real output price* p^t and *real input price* w^t vectors are defined as the corresponding nominal price vectors deflated by the consumption expenditures price index; ie we have the following definitions:

$$(3)\ p^t \equiv P^t/P_C{}^t\,;\ w^t \equiv W^t/P_C{}^t\,; \qquad\qquad t = 0,1,2,\ldots\ .$$

The first and last equality in (2) imply that period t real income, ρ^t, is equal to the period t GDP function, evaluated at the period t real output price vector p^t and the period t input vector x^t, $g^t(p^t,x^t)$. Thus, *the growth in real income over time can be explained by three main factors: t (Technical Progress or Total Factor Productivity growth), growth in real output prices and the growth of primary inputs*.

We now follow the example of Diewert and Morrison (1986; 663) and assume that the log of the period t (deflated) GDP function, $g^t(p,x)$, has the following translog functional form:[3]

$$\begin{aligned}(4)\ \ln g^t(p,x) \equiv\ & a_0{}^t + \sum_{m=1}^M a_m{}^t \ln p_m{}^t + (1/2) \sum_{m=1}^M \sum_{k=1}^M a_{mk} \ln p_m{}^t \ln p_k{}^t \\ & + \sum_{n=1}^N b_n{}^t \ln x_n{}^t + (1/2) \sum_{n=1}^N \sum_{j=1}^N b_{nj} \ln x_n{}^t \ln x_j{}^t + \sum_{m=1}^M \sum_{n=1}^N c_{mn} \ln p_m{}^t \ln x_n{}^t\,; \\ & \qquad\qquad t = 0,1,2,\ldots\ .\end{aligned}$$

Note that the coefficients for the quadratic terms are assumed to be constant over time. The

[3] This functional form was first suggested by Diewert (1974; 139) as a generalization of the translog functional form introduced by Christensen, Jorgenson and Lau (1971). Diewert (1974; 139) indicated that this functional form was flexible.

coefficients must satisfy the following restrictions in order for g^t to satisfy the linear homogeneity properties that we have assumed in section 2 above:[4]

(5) $\sum_{m=1}^{M} a_m^t = 1$ for t = 0,1,2, ...;
(6) $\sum_{n=1}^{N} b_n^t = 1$ for t = 0,1,2, ...;
(7) $a_{mk} = a_{km}$ for all k,m ;
(8) $b_{nj} = b_{jn}$ for all n,j ;
(9) $\sum_{k=1}^{M} a_{mk} = 0$ for m = 1,...,M ;
(10) $\sum_{j=1}^{N} b_{nj} = 0$ for n = 1,...,N ;
(11) $\sum_{n=1}^{N} c_{mn} = 0$ for m = 1,...,M ;
(12) $\sum_{m=1}^{M} c_{mn} = 0$ for n = 1,...,N .

In Diewert and Lawrence (2006) we give a detailed theoretical derivation of the approximate decomposition of real income growth going from period t−1 to t (γ^t) given by:

(13) $\gamma^t \approx \tau^t\, \alpha^t\, \beta^t$

where α^t measures the proportional change in the real income produced by the market sector that is induced by the change in real output prices going from period t−1 to t, using the technology that is available during period s and using the reference input quantities x and β^t measures the proportional change in the real income produced by the market sector that is induced by the change in input quantities used by the market sector going from period t−1 to t, using the technology that is available during period s and using the reference real output prices p.

Using the approximate equality (13), we can establish the following approximate relationship for the level of real income in period t, ρ^t, and the period t levels for technology, real output prices and input quantities:

(14) $\rho^t/\rho^0 \approx T^t\, A^t\, B^t$; t = 0,1,2, ...

Diewert and Morrison (1986; 663) showed that if g^{t-1} and g^t are defined by (4)-(12) above and there is competitive profit maximizing behaviour on the part of all market sector producers for all periods t, then (13) holds as an exact equality; ie we have

[4] There are additional restrictions on the parameters which are necessary to ensure that $g^t(p,x)$ is convex in p and concave in x.

(15) $\gamma^t = \tau^t\, \alpha^t\, \beta^t$; $t = 1,2, \ldots$.

In addition, Diewert and Morrison (1986; 663-665) showed that τ^t, α^t and β^t could be calculated using empirically observable price and quantity data for periods t–1 and t as follows:

(16) $\ln\alpha^t = \sum_{m=1}^{M} (1/2)[(p_m^{t-1}y_m^{t-1}/p^{t-1}\cdot y^{t-1}) + (p_m^t y_m^t/p^t\cdot y^t)] \ln(p_m^t/p_m^{t-1})$
$= \ln P_T(p^{t-1},p^t,y^{t-1},y^t)$;
(17) $\ln\beta^t = \sum_{n=1}^{N} (1/2)[(w_n^{t-1}x_n^{t-1}/w^{t-1}\cdot x^{t-1}) + (w_n^t x_n^t/w^t\cdot x^t)] \ln(x_n^t/x_n^{t-1})$
$= \ln Q_T(w^{t-1},w^t,x^{t-1},x^t)$;
(18) $\tau^t = \gamma^t/\alpha^t\, \beta^t$

where $P_T(p^{t-1},p^t,y^{t-1},y^t)$ is the Törnqvist (1936) and Törnqvist and Törnqvist (1937) output price index and $Q_T(w^{t-1},w^t,x^{t-1},x^t)$ is the Törnqvist input quantity index.

Since equations (15) now hold as exact identities under our present assumptions, equations (14), the cumulated counterparts to equations (13), will also hold as exact decompositions; ie under our present assumptions, we have

(19) $\rho^t/\rho^0 = T^t\, A^t\, B^t$; $t = 1,2, \ldots$.

We will implement the real income decompositions (15) and (19) in subsequent sections using Australian data for the years 1960–2004.

3 THE TRANSLOG GDP FUNCTION APPROACH AND CHANGES IN THE TERMS OF TRADE

For some purposes, it is convenient to decompose the aggregate period t contribution factor due to changes in all deflated output prices α^t into separate effects for each change in each output price. Similarly, it can sometimes be useful to decompose the aggregate period t contribution factor due to changes in all market sector primary input quantities β^t into separate effects for each change in each input quantity. In this section, we indicate how this can be done, making the same assumptions on the technology that were made in the previous section.

We first model the effects of a change in a single (deflated) output price, say p_m, going from period t–1 to t. We can do this for changes in all (deflated) output prices using the following

Laspeyres type measure α_{Lm}^t that chooses the period t–1 reference technology and holds constant other output prices at their period t–1 levels and holds inputs constant at their period t–1 levels x^{t-1} and a *Paasche type measure* α_{Pm}^t that chooses the period t reference technology and reference input vector x^t and holds constant other output prices at their period t levels:

$$(20)\ \alpha_{Lm}^t \equiv g^{t-1}(p_1^{t-1},...,p_{m-1}^{t-1},p_m^t,p_{m+1}^{t-1},..., p_M^{t-1},x^{t-1})/g^{t-1}(p^{t-1},x^{t-1})\ ; \qquad m = 1,...,M;\ t = 1,2, ... ;$$

$$(21)\ \alpha_{Pm}^t \equiv g^t(p^t,x^t)/g^t(p_1^t,...,p_{m-1}^t,p_m^{t-1},p_{m+1}^t,..., p_M^t,x^t)\ ; \qquad m = 1,...,M;\ t = 1,2, ...$$

Since both measures of real output price change are equally valid, it is natural to average them to obtain an *overall measure of the effects on real income of the change in the real price of output m*:

$$(22)\ \alpha_m^t \equiv [\alpha_{Lm}^t\,\alpha_{Pm}^t]^{1/2}\ ; \qquad m = 1,...,M\ ;\ t = 1,2, ...$$

Under the assumption that the deflated GDP functions $g^t(p,x)$ have the translog functional forms as defined by (4)-(12) in the previous section, the arguments of Diewert and Morrison (1986; 666) can be adapted to give us the following result:

$$(23)\ \ln\alpha_m^t = (1/2)[(p_m^{t-1}y_m^{t-1}/p^{t-1}\cdot y^{t-1}) + (p_m^t y_m^t/p^t\cdot y^t)]\ \ln(p_m^t/p_m^{t-1})\ ; \qquad m = 1,...,M\ ;\ t = 1,2, ...$$

Note that $\ln\alpha_m^t$ is equal to the mth term in the summation of the terms on the right hand side of (16). This observation means that we have the following exact decomposition of the period t aggregate real output price contribution factor α^t into a product of separate price contribution factors; ie we have under present assumptions:

$$(24)\ \alpha^t = \alpha_1^t\alpha_2^t...\ \alpha_M^t\ ; \qquad t = 1,2, ...$$

The above decomposition is useful for analysing how real changes in the price of exports (ie a change in the price of exports relative to the price of domestic consumption) and in the price of imports impact on the real income generated by the market sector. In the empirical illustration which follows later, we let M equal three. The three net outputs are:

- Domestic sales (C+I+G);

- Exports (X) and
- Imports (M).

Since commodities 1 and 2 are outputs, y_1 and y_2 will be positive but since commodity 3 is an input into the market sector, y_3 will be negative. Hence an increase in the real price of exports will *increase* real income but an increase in the real price of imports will *decrease* the real income generated by the market sector, as is evident by looking at the contribution terms defined by (23) for m = 2 (where $y_m^t > 0$) and for m = 3 (where $y_m^t < 0$).

As mentioned above, it is also useful to have a decomposition of the aggregate contribution of input growth to the growth of real income into separate contributions for each important class of primary input that is used by the market sector. We now model the effects of a change in a single input quantity, say x_n, going from period t–1 to t. We can do this for changes in input n using the following *Laspeyres type measure* β_{Ln}^t that chooses the period t–1 reference technology and holds constant other input quantities at their period t–1 levels and holds real output prices at their period t–1 levels p^{t-1} and a *Paasche type measure* β_{Pn}^t that chooses the period t reference technology and reference real output price vector p^t and holds constant other input quantities at their period t levels:

$$(25)\ \beta_{Ln}^t \equiv g^{t-1}(p^{t-1},x_1^{t-1},...,x_{n-1}^{t-1},x_n^t,x_{n+1}^{t-1},..., x_N^{t-1})/g^{t-1}(p^{t-1},x^{t-1})\ ; \qquad n = 1,...,N;\ t = 1,2, ... ;$$

$$(26)\ \beta_{Pn}^t \equiv g^t(p^t,x^t)/g^t(p^t,x_1^t,...,x_{n-1}^t,x_n^{t-1},x_{n+1}^t,..., p_N^t)\ ; \qquad m = 1,...,M;\ t = 1,2, ...$$

Since both measures of input change are equally valid, as usual, we average them to obtain *an overall measure of the effects on real income of the change in the quantity of input n*:

$$(27)\ \beta_n^t \equiv [\beta_{Pn}^t\, \beta_{Pn}^t]^{1/2}\ ; \qquad n = 1,...,N\ ;\ t = 1,2, ...$$

Under the assumption that the deflated GDP functions $g^t(p,x)$ have the translog functional forms as defined by (4)-(12) in the previous section, the arguments of Diewert and Morrison (1986; 667) can be adapted to give us the following result:

$$(28)\ \ln\beta_n^t = (1/2)[(w_n^{t-1}x_n^{t-1}/w^{t-1}\cdot x^{t-1}) + (w_n^t x_n^t/w^t\cdot x^t)]\ \ln(x_n^t/x_n^{t-1})\ ; \qquad n = 1,...,N\ ;\ t = 1,2, ...$$

Note that $\ln\beta_n^t$ is equal to the nth term in the summation of the terms on the right hand side of

(17). This observation means that we have the following exact decomposition of the period t aggregate input growth contribution factor β^t into a product of separate input quantity contribution factors; ie we have under present assumptions:

(29) $\beta^t = \beta_1{}^t\beta_2{}^t... \beta_N{}^t$; $t = 1,2, ...$.

4 DEFLATED GDP TRANSLOG APPROACH FOR AUSTRALIA

It is not an easy task to obtain consistent data on the outputs produced and the inputs used by the market sector of an economy. In this report we use a modified version of the Australian database developed by Diewert and Lawrence (2005).

The Diewert Lawrence (D–L) total factor productivity (TFP) database was constructed for the Department of Communications, Information Technology and the Arts (DCITA). The modified version used here contains value, price and quantity information on a total of 32 output and input categories. These are made up of an aggregate consumer commodity, one government consumption commodity, 10 investment commodities, 3 inventory change commodities, one export commodity, one import commodity, labour input, 9 capital stocks and 3 inventory stocks and 2 land stocks. Data on these variables cover the 45 year period from 1959–60 to 2003–04.

The main differences between the D–L database and that used by the Australian Bureau of Statistics in producing its multifactor productivity (MFP) estimates are the following:[5]

- Broader coverage of the economy – D–L include 16 of the 17 major industrial sectors whereas the ABS 'market sector' only covers 12 of the 17 sectors. D–L exclude Government Administration and Defence whereas the ABS also excludes Health, Education, Business and Property Services and Personal services. With the changing composition of the economy, the private sector in Australia accounts for significant proportions of Health, Education and Personal Services output and nearly all of the relatively large Business and Property Services sector's output. The D–L approach of measuring output from sources of final demand enables them to cover more of the desired market–oriented parts of the economy than the ABS sectoral value added approach where measurement problems are more problematic.
- Diewert and Lawrence built up an output measure from final consumption

[5] Diewert and Lawrence (2005) acknowledge the full cooperation of the ABS in constructing their database.

components rather than sectoral gross value added. This final demand approach allows a more accurate output measure to be used as interindustry flows of intermediates are netted out and more accurate records are available for final demand consumption components as compared to the estimates for business gross outputs and intermediate input usage.

- Diewert and Lawrence expressed both outputs and inputs in terms of producer prices. From the viewpoint of production theory (which is the theoretical basis for making productivity comparisons), the appropriate prices are the prices that producers face, which should not include final demand tax wedges. However, some commodity taxes (such as property taxes and tariffs on imports) fall on inputs to the production sector and so these taxes should be included in producer prices for productivity purposes. Subsidies also create problems in trying to determine what the 'correct' producer prices are for subsidised outputs.
- Diewert and Lawrence attempted to construct consistent capital and inventory input series and attempted to measure inventory change in a consistent manner.[6] The US Bureau of Labor Statistics methodology currently used by the ABS for forming stocks and flows is not completely consistent. Diewert and Lawrence used instead the Jorgenson[7] geometric depreciation approach which is consistent. They also smoothed the depreciation rates used by the ABS and pushed back the ABS estimates for some capital stocks that start at substantial nonzero values part way through the time period.

A more extensive discussion of the D–L database can be found in Appendix A of this report, which reproduces Appendix A of Diewert and Lawrence (2005) but also includes the data modifications made for this study. Diewert and Lawrence (2005) used an exogenous real interest rate in their user costs of capital stock components and, hence, their data did not balance; ie the value of inputs was not identically equal to the value of outputs for each year. But the methodology developed in the previous sections assumes that the value of market sector outputs is equal to the value of market sector primary inputs in each period. Hence, the modified version of the Diewert Lawrence database used in this report contains a balancing real rate of return calculated for each year that makes the value of inputs equal to the value of outputs. The balancing real rate of return ranged between a high of 6.8 per cent in 1964 to a low of –0.1 per cent in 1975 and averaged about 3 per cent.[8] The present version of the database also has a more accurate treatment of capital taxes.

[6] They used the inventory methodology developed by Diewert and Smith (1994) and Diewert (2005).

[7] See Jorgenson and Griliches (1967) (1972) and Jorgenson (1989) (1996a) (1996b).

[8] The balancing real rate was negative for only one year and when capital taxes were added to the user costs, all user costs were positive. However, it should be mentioned that the user costs were constructed by setting the anticipated rates of asset inflation equal to the anticipated general inflation rate. This has the effect of eliminating the negative user cost problem but it is not an entirely satisfactory solution.

Table 1: **Decomposition of Market Sector Real Income Growth into Translog Productivity, Real Output Price Change and Input Quantity Contributions Factors**

Year	γ^t	τ^t	$\alpha_D{}^t$	$\alpha_X{}^t$	$\alpha_M{}^t$	$\beta_L{}^t$	$\beta_K{}^t$	$\alpha_T{}^t$
1961	1.0058	0.9680	0.9977	0.9874	1.0056	1.0325	1.0159	0.9929
1962	1.0839	1.0545	1.0067	0.9996	1.0027	1.0027	1.0159	1.0023
1963	1.0292	0.9953	0.9979	1.0033	0.9998	1.0174	1.0154	1.0032
1964	1.1369	1.0802	1.0023	1.0137	1.0042	1.0148	1.0166	1.0179
1965	0.9861	0.9602	1.0006	0.9882	1.0039	1.0157	1.0186	0.9921
1966	1.0356	0.9991	0.9969	0.9974	1.0039	1.0220	1.0161	1.0012
1967	1.0899	1.0553	1.0047	0.9954	1.0045	1.0122	1.0157	0.9999
1968	1.1174	1.0954	0.9958	0.9909	1.0029	1.0138	1.0167	0.9938
1969	1.0139	0.9782	0.9988	0.9996	1.0045	1.0123	1.0210	1.0041
1970	1.0667	1.0312	1.0002	1.0018	1.0004	1.0151	1.0167	1.0022
1971	1.0380	1.0069	1.0017	0.9857	1.0028	1.0261	1.0147	0.9885
1972	0.9915	0.9700	1.0063	0.9964	0.9922	1.0142	1.0132	0.9886
1973	1.1019	1.0493	0.9972	1.0249	1.0063	1.0110	1.0099	1.0314
1974	1.0627	1.0133	1.0008	1.0126	1.0036	1.0216	1.0095	1.0162
1975	0.9937	0.9431	1.0258	0.9971	0.9824	1.0361	1.0121	0.9796
1976	1.0479	1.0616	1.0026	0.9864	1.0034	0.9887	1.0062	0.9897
1977	1.0075	1.0196	1.0003	1.0007	0.9924	0.9882	1.0066	0.9931
1978	1.0259	1.0326	0.9964	0.9908	0.9932	1.0075	1.0058	0.9840
1979	1.0312	1.0133	0.9898	1.0049	0.9954	1.0213	1.0066	1.0002
1980	1.0379	1.0129	0.9962	1.0219	0.9861	1.0117	1.0090	1.0077
1981	1.0393	1.0131	1.0024	0.9958	1.0031	1.0167	1.0078	0.9989
1982	1.0005	0.9841	1.0101	0.9869	1.0135	0.9964	1.0100	1.0002
1983	1.0363	1.0555	0.9998	0.9956	1.0027	0.9738	1.0102	0.9982
1984	1.0297	1.0171	0.9895	0.9961	1.0094	1.0092	1.0083	1.0054
1985	1.0216	0.9866	0.9969	1.0035	0.9924	1.0343	1.0085	0.9958
1986	1.0200	1.0089	1.0000	0.9932	0.9828	1.0263	1.0093	0.9761
1987	1.0381	1.0289	0.9923	0.9879	1.0005	1.0185	1.0100	0.9884
1988	1.0516	1.0168	0.9823	0.9987	1.0201	1.0230	1.0104	1.0187
1989	1.0546	0.9946	0.9898	0.9986	1.0350	1.0243	1.0118	1.0336
1990	1.0124	0.9646	1.0075	0.9994	1.0019	1.0267	1.0134	1.0013
1991	0.9805	1.0027	0.9877	0.9797	1.0108	0.9894	1.0105	0.9902
1992	1.0060	1.0310	0.9878	0.9839	1.0108	0.9878	1.0056	0.9945
1993	1.0189	1.0273	0.9981	1.0014	0.9896	0.9990	1.0037	0.9910
1994	1.0282	1.0068	0.9991	0.9946	0.9996	1.0231	1.0051	0.9941
1995	1.0399	1.0082	0.9940	0.9992	1.0084	1.0241	1.0056	1.0076
1996	1.0531	1.0214	0.9950	1.0007	1.0090	1.0176	1.0086	1.0097
1997	1.0260	1.0261	0.9866	0.9860	1.0228	0.9961	1.0089	1.0084
1998	1.0628	1.0447	0.9917	1.0064	0.9938	1.0152	1.0103	1.0002
1999	1.0336	1.0251	1.0054	0.9903	0.9954	1.0045	1.0128	0.9858
2000	1.0392	1.0012	0.9953	1.0020	1.0109	1.0175	1.0118	1.0129
2001	1.0290	1.0019	0.9967	1.0262	0.9810	1.0111	1.0124	1.0067
2002	1.0345	1.0259	0.9952	0.9959	1.0096	0.9979	1.0098	1.0055
2003	1.0441	1.0181	0.9957	0.9867	1.0216	1.0121	1.0095	1.0080
2004	1.0503	1.0028	0.9988	0.9846	1.0417	1.0100	1.0123	1.0256
Average	1.0376	1.0149	0.9981	0.9975	1.0036	1.0123	1.0111	1.0010

Table 2: **Decomposition of Market Sector Real Income Levels into Translog Productivity, Real Output Price Change and Input Quantity Contributions Factors**

Year	ρ^t/ρ^0	T^t	$A_D{}^t$	$A_X{}^t$	$A_M{}^t$	$B_L{}^t$	$B_K{}^t$	$A_T{}^t$
1960	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1961	1.0058	0.9680	0.9977	0.9874	1.0056	1.0325	1.0159	0.9929
1962	1.0901	1.0207	1.0044	0.9869	1.0084	1.0353	1.0320	0.9952
1963	1.1219	1.0158	1.0023	0.9902	1.0082	1.0533	1.0479	0.9983
1964	1.2756	1.0973	1.0046	1.0037	1.0125	1.0689	1.0653	1.0163
1965	1.2578	1.0536	1.0052	0.9919	1.0164	1.0856	1.0851	1.0082
1966	1.3025	1.0527	1.0020	0.9893	1.0203	1.1095	1.1026	1.0094
1967	1.4197	1.1109	1.0067	0.9848	1.0249	1.1230	1.1200	1.0093
1968	1.5863	1.2169	1.0025	0.9758	1.0279	1.1385	1.1387	1.0030
1969	1.6084	1.1904	1.0012	0.9754	1.0326	1.1525	1.1626	1.0072
1970	1.7156	1.2275	1.0014	0.9771	1.0330	1.1698	1.1820	1.0094
1971	1.7808	1.2359	1.0031	0.9632	1.0359	1.2003	1.1994	0.9978
1972	1.7657	1.1988	1.0093	0.9597	1.0279	1.2173	1.2152	0.9864
1973	1.9457	1.2579	1.0065	0.9836	1.0344	1.2308	1.2273	1.0174
1974	2.0678	1.2746	1.0073	0.9960	1.0381	1.2573	1.2389	1.0339
1975	2.0546	1.2021	1.0333	0.9931	1.0198	1.3027	1.2539	1.0128
1976	2.1532	1.2761	1.0359	0.9796	1.0233	1.2879	1.2617	1.0024
1977	2.1693	1.3011	1.0362	0.9803	1.0155	1.2728	1.2700	0.9954
1978	2.2255	1.3435	1.0325	0.9712	1.0085	1.2823	1.2774	0.9795
1979	2.2949	1.3614	1.0219	0.9759	1.0039	1.3096	1.2858	0.9797
1980	2.3818	1.3789	1.0180	0.9974	0.9899	1.3249	1.2973	0.9873
1981	2.4755	1.3970	1.0204	0.9932	0.9929	1.3470	1.3074	0.9862
1982	2.4767	1.3747	1.0307	0.9802	1.0063	1.3422	1.3204	0.9864
1983	2.5665	1.4510	1.0304	0.9758	1.0090	1.3071	1.3339	0.9846
1984	2.6426	1.4758	1.0196	0.9720	1.0185	1.3191	1.3450	0.9899
1985	2.6996	1.4560	1.0164	0.9753	1.0107	1.3643	1.3563	0.9858
1986	2.7536	1.4690	1.0164	0.9687	0.9933	1.4003	1.3689	0.9622
1987	2.8584	1.5114	1.0085	0.9569	0.9938	1.4261	1.3826	0.9510
1988	3.0060	1.5368	0.9906	0.9557	1.0137	1.4589	1.3970	0.9688
1989	3.1701	1.5285	0.9806	0.9544	1.0492	1.4943	1.4136	1.0013
1990	3.2094	1.4744	0.9879	0.9537	1.0512	1.5343	1.4324	1.0026
1991	3.1468	1.4784	0.9757	0.9343	1.0626	1.5180	1.4475	0.9928
1992	3.1657	1.5241	0.9638	0.9192	1.0740	1.4996	1.4556	0.9873
1993	3.2254	1.5658	0.9621	0.9205	1.0629	1.4980	1.4609	0.9784
1994	3.3164	1.5764	0.9612	0.9155	1.0624	1.5326	1.4684	0.9726
1995	3.4486	1.5893	0.9555	0.9148	1.0712	1.5695	1.4765	0.9800
1996	3.6316	1.6233	0.9507	0.9155	1.0808	1.5971	1.4892	0.9894
1997	3.7259	1.6657	0.9379	0.9026	1.1055	1.5909	1.5025	0.9978
1998	3.9598	1.7402	0.9302	0.9084	1.0986	1.6150	1.5179	0.9979
1999	4.0929	1.7839	0.9351	0.8996	1.0936	1.6222	1.5374	0.9838
2000	4.2532	1.7860	0.9308	0.9014	1.1055	1.6506	1.5555	0.9964
2001	4.3766	1.7894	0.9277	0.9250	1.0845	1.6690	1.5749	1.0031
2002	4.5278	1.8358	0.9232	0.9212	1.0949	1.6654	1.5903	1.0086
2003	4.7272	1.8691	0.9192	0.9090	1.1185	1.6856	1.6054	1.0167
2004	4.9648	1.8743	0.9181	0.8950	1.1651	1.7025	1.6251	1.0428

Figure 1: **Contributions of Productivity, Terms of Trade, Real Output Price Change and Input Quantity Factors to Market Sector Real Income Levels**

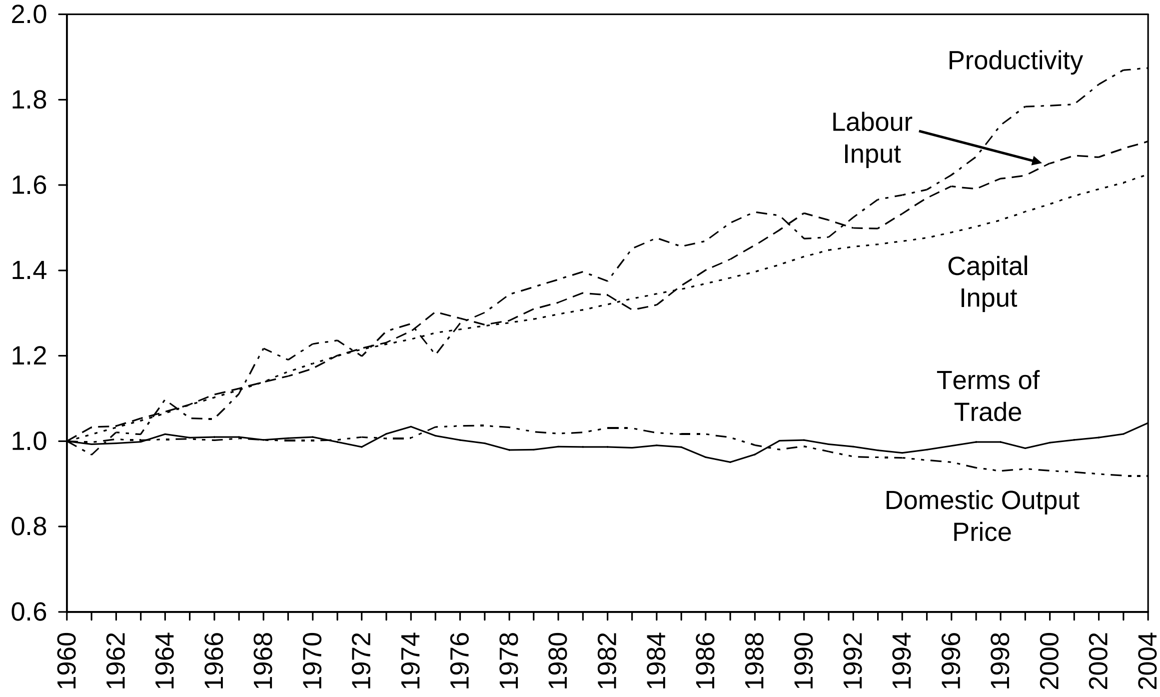
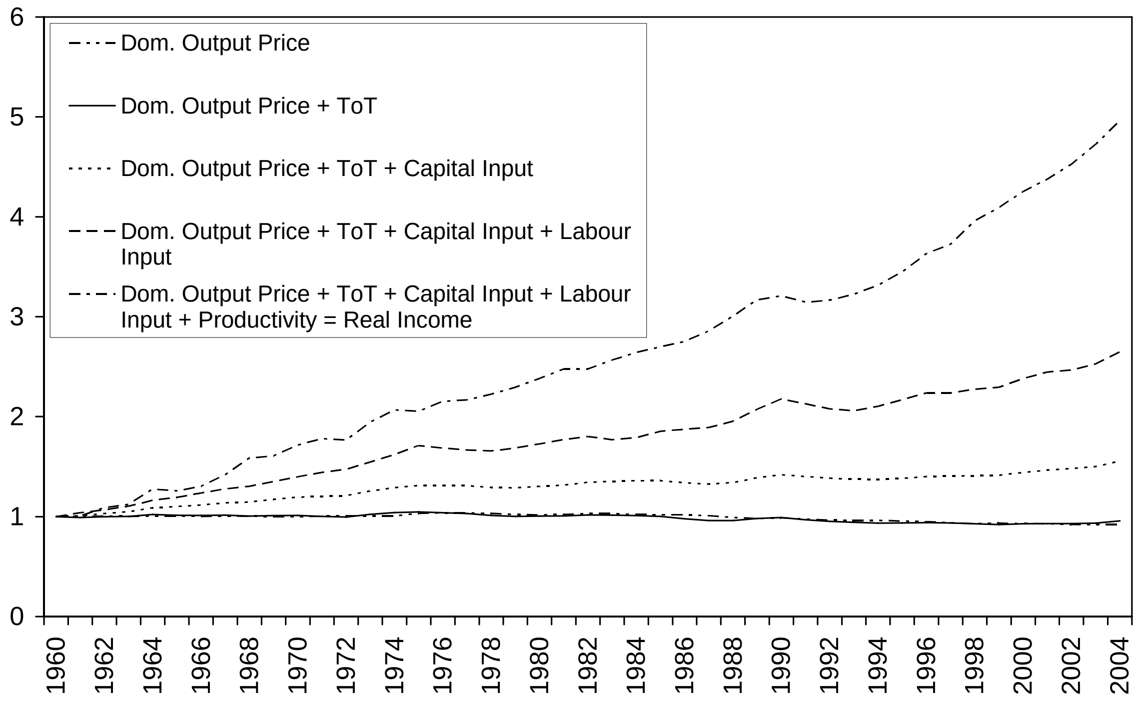


Figure 2: **Cumulative Contributions of Productivity, Terms of Trade, Real Output Price Change and Input Quantity Factors to Market Sector Real Income Levels**



The chain link information on period by period changes in real income that corresponds to

(13) (generalised to include separate contribution factors for changes in real domestic, export and import prices, α_D^t, α_X^t and α_M^t respectively and separate contribution factors for growth in labour and capital input, β_L^t and β_K^t respectively) is given in Table 1. The last column in Table 1, α_T^t, is the contribution factor for *real changes in the terms of trade* and is simply the product of the export and import price factors, α_X^t and α_M^t.

From the average contribution factors listed in the last row of Table 1, it can be seen that real market sector income in Australia grew at an average annual rate of 3.76 per cent per year. Productivity growth accounted for 1.48 per cent of this growth, labour input growth for 1.23 per cent and capital input 1.11 per cent of this growth on average while the real domestic output price effects were negligible on average.

The annual change information in Table 1 can be converted into levels using equations (46) (with obvious extensions to multiple inputs and outputs).[9] Table 2 and Figure 1 give this levels information.

Thus, over the 45 year period, real income ρ^t/ρ^0 (from the gross domestic product point of view) grew almost fivefold (4.9648 times), which is very respectable growth. From Table 2 and Figure 1, it can be seen that productivity growth T^t contributes the most to the overall growth in market sector real income (the growth factor is 1.874), the growth in labour input B_L^t makes the next largest contribution (the growth factor is 1.702) followed closely by the growth in capital service input B_K^t (the growth factor is 1.625) while the change in domestic real output prices A_D^t makes a small negative contribution (0.918) as does the growth in real export prices A_X^t (.895) and the change in import prices A_M^t makes a modest positive contribution (1.165). The terms of trade cumulated contribution factor grows from 0.9838 in 1999 to 1.0428 in 2004, which represents a six percent increase in real income due to favourable changes in real export and import prices. All of the improvement comes from declining import prices.

An alternative way of presenting the information in Table 2 and Figure 1 is to progressively cumulate the individual contributors up to market sector real income. Given the logarithmic form of the indexes, this is done by progressively multiplying the levels indexes together. These cumulative effects are presented in Figure 2. The bottom dashed line in Figure 2 shows how market sector real income would have changed if there had only been the observed change in real domestic output prices and all else had remained unchanged. The solid line

[9] The last column in Table 6 denoted by A_T^t is the cumulative effect of changes in the real prices of exports and imports and is equal to the product of the entries denoted by A_X^t and A_M^t.

near the bottom of Figure 2 shows how market sector real income would have changed if there had only been the observed change in real domestic output prices and the terms of trade and all else had remained unchanged. In this case, because the terms of trade impact is quite small, it is difficult to distinguish these two lines. We next add in the observed growth in the capital stock (but assume labour and productivity remain unchanged) to give us the third line from the bottom, and so on. The cumulated line at the top of Figure 2 now equates to the actual level of market sector real income observed over the period.

By comparing the 'wedges' between the progressive cumulative component lines in Figure 2 we have another way of observing the relative contributions of the components to market sector real income. Thus, in this case, we have the largest wedge or increment to real income from productivity growth, the second largest from labour force growth and the third largest from capital stock growth. The terms of trade makes only a very small contribution to real income growth over the period.

5 THE DEFLATED NDP TRANSLOG APPROACH

There is a potential shortcoming with the analysis presented in the previous sections. The problem is that depreciation payments are part of the user cost of capital for each asset but depreciation does not provide households with any sustainable purchasing power. Hence our real income measure defined by (2) above is overstated.

To see why Gross Domestic Product overstates income, consider the model of production that is described by the following quotations:

"We must look at the production process during a period of time, with a beginning and an end. It starts, at the commencement of the Period, with an Initial Capital Stock; to this there is applied a Flow Input of labour, and from it there emerges a Flow Output called Consumption; then there is a Closing Stock of Capital left over at the end. If Inputs are the things that are put in, the Outputs are the things that are got out, and the production of the Period is considered in isolation, then the Initial Capital Stock is an Input. A Stock Input to the Flow Input of labour; and further (what is less well recognized in the tradition, but is equally clear when we are strict with translation), the Closing Capital Stock is an Output, a Stock Output to match the Flow Output of Consumption Goods. Both input and output have stock and flow components; capital appears both as input and as output" John R. Hicks (1961; 23).

"The business firm can be viewed as a receptacle into which factors of production, or inputs, flow and out of which outputs flow...The total of the inputs with which the firm can work within the time period specified includes those inherited from the previous period and those acquired during the current period. The total of the outputs of the business firm in the same period includes the amounts of outputs currently sold and the amounts of inputs which are bequeathed to the firm in its succeeding period of activity." Edgar O. Edwards and Philip W. Bell (1961; 71-72).

Hicks and Edwards and Bell obviously had the same model of production in mind: in each accounting period, the business unit combines the capital stocks and goods in process that it has inherited from the previous period with "flow" inputs purchased in the current period (such as labour, materials, services and additional durable inputs) to produce current period "flow" outputs as well as end of the period depreciated capital stock components which are regarded as outputs from the perspective of the current period (but will be regarded as inputs from the perspective of the next period).[10]

All of the "flow" inputs that are purchased during the period and all of the "flow" outputs that are sold during the period are the inputs and outputs that appear in the usual definition of cash flow. These are the flow inputs and outputs that are very familiar to national income accountants. But this is not the end of the story: the firm inherits an endowment of assets at the beginning of the production period and at the end of the period, the firm will have the net profit or loss that has occurred due to its sales of outputs and its purchases of inputs during the period. As well, *it will have a stock of assets that it can use when it starts production in the following period*. Just focusing on the flow transactions that occur within the production period will not give a complete picture of the firm's productive activities. Hence, to get a complete picture of the firm's production activities over the course of a period, it is necessary to add the value of the closing stock of assets less the beginning of the period stock of assets to the cash flow that accrued to the firm from its sales and purchases of market goods and services during the accounting period.

We illustrate the above theory by considering a very simple two output, two input model of the market sector. One of the outputs is output in period t, Y^t and the other output is an investment good, I^t. One of the inputs is the flow of noncapital primary input X^t and the other input is K^t, capital services. Suppose that the average prices during period t of a unit of Y^t, X^t and I^t are P_Y^t, P_X^t and P_I^t , respectively. Suppose further that the interest rate prevailing at the beginning of period t is r^t. The value of the beginning of period t capital stock is assumed to be P_I^t, the investment price for period t. In order to induce households to let the

[10] For more on this model of production and additional references to the literature, see the Appendices in Diewert (1977) (1980). The usual user cost of capital can be derived from this framework if depreciation is independent of use.

business sector use the initial stock of capital, firms have to pay households interest equal to $r^t P_I^t K^t$. Then neglecting balance sheet items, the market sector's period t *cash flow* is:[11]

$$(30)\ CF^t \equiv P_Y^t Y^t + P_I^t I^t - P_X^t X^t - r^t P_I^t K^t.$$

K^t is interpreted as the firm's beginning of period t stock of capital it has at its disposal and its end of period stock of capital is defined to be K^{t+1}. These capital stocks are valued at the balance sheet prices prevailing at the beginning and end of period t, P_I^t and P_I^{t+1}, respectively.

The market sector period t *pure profit* is defined as its cash flow plus the value of its end of period t capital stock less the value of its beginning of period t capital stock:

$$(31)\ \prod^t \equiv CF^t + P_I^{t+1} K^{t+1} - P_I^t K^t.$$

Now, the end of period depreciated stock of capital is related to the beginning of the period stock by the following equation:

$$(32)\ K^{t+1} = (1 - \delta)K^t$$

where $0 < \delta < 1$ denotes the depreciation rate.

Now substitute (30) and (32) into the definition of pure profits (31) and we obtain the following expression:

$$(33)\ \prod^t \equiv P_Y^t Y^t + P_I^t I^t - P_X^t X^t - r^t P_I^t K^t + P_I^{t+1}(1 - \delta)K^t - P_I^t K^t$$
$$= P_Y^t Y^t + P_I^t I^t - P_X^t X^t - \{r^t P_I^t + \delta P_I^{t+1} - (P_I^{t+1} - P_I^t)\}K^t.$$

The expression that precedes the capital stock K^t, $\{r^t P_I^t + \delta P_I^{t+1} - (P_I^{t+1} - P_I^t)\}$, can be recognised as the *user cost of capital*; it is the gross rental price that must be paid to a capitalist in order to induce him or her to loan the services of a unit of the capital stock to the production sector.

Some simplifications for (33) occur if we make two additional assumptions:

- Assume that producers and households expect price level stability so that the end of the

[11] For equity financed firms, we need to include an imputed return for equity capital.

period price for a new unit of capital P_I^{t+1} is expected to be equal to the beginning of the period price for a new unit of capital P_I^t; in this case, we can interpret r^t as the period t real interest rate;

- Assume that pure profits are zero so that Π^t equals zero.

Substituting these two assumptions into equation (33) leads to the following expression:

(34) $\Pi^t = P_Y^t Y^t + P_I^t I^t - P_X^t X^t - \{r^t P_I^t + \delta P_I^t\}K^t = 0.$

Equation (34) can be rearranged to yield the following value of output equals value of input equation:

(35) $P_Y^t Y^t + P_I^t I^t = P_X^t X^t + \{r^t P_I^t + \delta P_I^t\}K^t.$

Equation (35) is essentially the closed economy counterpart to the (gross) value of outputs equals (gross) value of primary inputs equation $P^t \cdot y^t = W^t \cdot x^t$, that we have been using thus far in this study. However, *the (gross) payments to primary inputs that is defined by the right hand side of (35) is not income*, in the sense of Hicks.[12] The owner of a unit of capital cannot spend the entire period t gross rental income $\{r^t P_I^t + \delta P_I^t\}$ on consumption during period t because the depreciation portion of the rental, δP_I^t, is required in order to keep his or her capital intact. Thus, the owner of a new unit of capital at the beginning of period t loans the unit to the market sector and gets the gross return $\{r^t P_I^t + \delta P_I^t\}$ at the end of the period plus the depreciated unit of the initial capital stock, which is worth only $(1 - \delta)P_I^t$. Thus δP_I^t of this gross return must be set aside in order to restore the lender of the capital services to his or her original wealth position at the beginning of period t. This means that *period t Hicksian market sector income* is not the value of payments to primary inputs, $P_X^t X^t + \{r^t P_I^t + \delta P_I^t\}K^t$; instead it is the value of payments to labour $P_X^t X^t$ plus the reward for waiting, $r^t P_I^t K^t$. Using this definition of market sector (net) Hicksian income, we can rearrange equation (35) as follows:

(36) Hicksian market sector income $\equiv P_X^t X^t + r^t P_I^t K^t$

$= P_Y^t Y^t + P_I^t I^t - \delta P_I^t K^t$

= Value of consumption + value of gross investment – value of depreciation.

Thus, in this Hicksian net income framework, our new output concept is equal to our old

[12] We will use Hicks' third concept of income here: "Income No. 3 must be defined as the maximum amount of money which the individual can spend this week, and still be able to expect to spend this week, and still be able to expect to spend the same amount *in real terms* in each ensuing week." J.R. Hicks (1946; 174).

output concept less the value of depreciation. We take the price of depreciation to be the corresponding investment price P_I^t and the quantity of depreciation is taken to be the depreciation rate times the beginning of the period stock, δK^t.

Hence, the overstatement of income problem that is implicit in the approaches used in previous sections can readily be remedied: all we need to do is to take the user cost formula for an asset and decompose it into two parts:

- One part that represents depreciation and foreseen obsolescence, $\delta P_I^t K^t$, and
- The remaining part that is the reward for postponing consumption, $r^t P_I^t K^t$.

In the Diewert Lawrence database used in the previous section, the user costs had the following form:

(37) $u^t = (r^t + \delta^t + \tau^t)P_I^t$

where r^t was the balancing period t real rate of interest, δ^t was a geometric depreciation rate for period t,[13] τ^t was an average capital taxation rate on the asset and P_I^t was the period t investment price for the asset. Thus, in this section we split up each user cost times the beginning of the period stock K^t into the depreciation component $\delta^t P_I^t K^t$ and the remaining term $(r^t + \tau^t)P_I^t K^t$ and we regard the second term as a genuine income component but the first term is treated as an intermediate input cost for the market sector and is an offset to gross investment made by the market sector during the period under consideration. *Thus, in this section, we use a net product approach instead of a gross product approach.* In this section, our investment aggregate I is a *net investment aggregate* (gross investment components are indexed with a positive sign in the aggregate and depreciation components are indexed with a negative sign in the aggregate). Our capital services aggregate is now a “reward for waiting” capital services aggregate rather than the gross return aggregate that was used in the previous section.[14] Our old gross investment price index P_I is now broken into the new price for “waiting” capital services P_{KW}, the price of the depreciation aggregate P_{DEP} and the price of the new net investment aggregate P_{NI}.

[13] We used the geometric depreciation rates that were close to the rates used by the Australian Bureau of Statistics, which were constant except for computers, where an increasing geometric rate was assumed.

[14] This approach seems to be broadly consistent with an approach advocated by Rymes (1968) (1983), who stressed the role of waiting services: “Second, one can consider the ‘waiting’ or ‘abstinence’ associated with the net returns to capital as the nonlabour primary input.”

Table 3: **Decomposition of Market Sector Real Income Growth into Productivity, Real Output Price Change and Input Quantity Contribution Factors using the Translog Net Product Approach**

Year	γ^t	τ^t	$\alpha_D{}^t$	$\alpha_X{}^t$	$\alpha_M{}^t$	$\beta_L{}^t$	$\beta_K{}^t$	$\alpha_T{}^t$
1961	0.9995	0.9642	0.9990	0.9859	1.0063	1.0364	1.0091	0.9921
1962	1.0834	1.0614	1.0055	0.9995	1.0031	1.0031	1.0095	1.0026
1963	1.0256	0.9947	0.9979	1.0037	0.9998	1.0196	1.0099	1.0036
1964	1.1462	1.0905	1.0027	1.0154	1.0047	1.0166	1.0108	1.0202
1965	0.9759	0.9555	1.0004	0.9868	1.0044	1.0176	1.0123	0.9911
1966	1.0305	0.9990	0.9971	0.9970	1.0044	1.0249	1.0080	1.0014
1967	1.0912	1.0630	1.0048	0.9948	1.0052	1.0139	1.0077	0.9999
1968	1.1260	1.1085	0.9972	0.9897	1.0033	1.0156	1.0102	0.9930
1969	1.0056	0.9754	0.9969	0.9996	1.0051	1.0139	1.0152	1.0047
1970	1.0671	1.0355	1.0006	1.0020	1.0005	1.0171	1.0101	1.0025
1971	1.0361	1.0078	1.0029	0.9838	1.0032	1.0297	1.0087	0.9870
1972	0.9821	0.9659	1.0073	0.9959	0.9911	1.0162	1.0064	0.9870
1973	1.1096	1.0566	0.9977	1.0285	1.0072	1.0126	1.0033	1.0360
1974	1.0673	1.0151	1.0032	1.0143	1.0041	1.0246	1.0044	1.0185
1975	0.9817	0.9390	1.0244	0.9967	0.9799	1.0413	1.0035	0.9767
1976	1.0473	1.0710	1.0013	0.9844	1.0039	0.9870	1.0013	0.9882
1977	1.0037	1.0226	1.0012	1.0008	0.9912	0.9864	1.0017	0.9921
1978	1.0239	1.0377	0.9952	0.9893	0.9921	1.0086	1.0015	0.9815
1979	1.0301	1.0153	0.9877	1.0056	0.9947	1.0247	1.0022	1.0003
1980	1.0355	1.0149	0.9943	1.0255	0.9839	1.0136	1.0034	1.0089
1981	1.0436	1.0152	1.0065	0.9951	1.0036	1.0193	1.0033	0.9987
1982	0.9922	0.9818	1.0112	0.9848	1.0156	0.9958	1.0034	1.0002
1983	1.0315	1.0650	0.9988	0.9948	1.0031	0.9695	1.0022	0.9979
1984	1.0308	1.0200	0.9906	0.9954	1.0110	1.0107	1.0030	1.0063
1985	1.0208	0.9844	0.9985	1.0040	0.9911	1.0402	1.0033	0.9951
1986	1.0111	1.0105	0.9957	0.9920	0.9798	1.0310	1.0028	0.9719
1987	1.0328	1.0343	0.9877	0.9857	1.0006	1.0219	1.0030	0.9863
1988	1.0578	1.0199	0.9837	0.9984	1.0238	1.0272	1.0041	1.0221
1989	1.0619	0.9937	0.9938	0.9984	1.0413	1.0286	1.0057	1.0396
1990	1.0060	0.9586	1.0097	0.9993	1.0022	1.0315	1.0062	1.0015
1991	0.9753	1.0031	0.9924	0.9760	1.0128	0.9875	1.0036	0.9885
1992	1.0092	1.0367	0.9923	0.9809	1.0128	0.9856	1.0019	0.9935
1993	1.0189	1.0324	0.9973	1.0016	0.9877	0.9988	1.0016	0.9893
1994	1.0264	1.0080	0.9963	0.9936	0.9995	1.0274	1.0018	0.9931
1995	1.0444	1.0097	0.9949	0.9991	1.0099	1.0285	1.0020	1.0090
1996	1.0578	1.0252	0.9966	1.0008	1.0105	1.0207	1.0030	1.0114
1997	1.0306	1.0306	0.9915	0.9836	1.0267	0.9954	1.0033	1.0099
1998	1.0665	1.0523	0.9922	1.0075	0.9927	1.0177	1.0035	1.0002
1999	1.0280	1.0294	1.0051	0.9887	0.9947	1.0052	1.0051	0.9835
2000	1.0410	1.0014	0.9992	1.0023	1.0127	1.0205	1.0044	1.0151
2001	1.0295	1.0022	1.0026	1.0307	0.9778	1.0130	1.0036	1.0078
2002	1.0364	1.0303	0.9990	0.9952	1.0112	0.9975	1.0031	1.0064
2003	1.0493	1.0211	1.0006	0.9846	1.0251	1.0141	1.0033	1.0093
2004	1.0568	1.0032	1.0058	0.9822	1.0483	1.0116	1.0055	1.0297
Average	1.0370	1.0173	0.9991	0.9971	1.0041	1.0142	1.0050	1.0012

Table 4: **Decomposition of Market Sector Real Income Levels into Productivity, Real Output Price Change and Input Quantity Contribution Factors using the Translog Net Product Approach**

Year	ρ^t/ρ^0	T^t	$A_D{}^t$	$A_X{}^t$	$A_M{}^t$	$B_L{}^t$	$B_K{}^t$	$A_T{}^t$
1960	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1961	0.9995	0.9642	0.9990	0.9859	1.0063	1.0364	1.0091	0.9921
1962	1.0828	1.0234	1.0044	0.9854	1.0094	1.0396	1.0187	0.9946
1963	1.1106	1.0180	1.0023	0.9891	1.0092	1.0600	1.0287	0.9982
1964	1.2729	1.1100	1.0050	1.0042	1.0140	1.0776	1.0398	1.0183
1965	1.2422	1.0606	1.0054	0.9910	1.0184	1.0966	1.0526	1.0092
1966	1.2801	1.0596	1.0025	0.9880	1.0229	1.1239	1.0610	1.0106
1967	1.3969	1.1263	1.0074	0.9829	1.0281	1.1395	1.0692	1.0105
1968	1.5729	1.2485	1.0045	0.9727	1.0315	1.1573	1.0801	1.0034
1969	1.5817	1.2178	1.0014	0.9723	1.0368	1.1734	1.0965	1.0081
1970	1.6878	1.2610	1.0020	0.9743	1.0373	1.1934	1.1076	1.0106
1971	1.7488	1.2708	1.0049	0.9585	1.0406	1.2288	1.1172	0.9975
1972	1.7174	1.2275	1.0123	0.9545	1.0314	1.2487	1.1243	0.9845
1973	1.9056	1.2969	1.0100	0.9818	1.0388	1.2645	1.1281	1.0199
1974	2.0338	1.3166	1.0132	0.9958	1.0431	1.2956	1.1330	1.0387
1975	1.9966	1.2363	1.0380	0.9925	1.0222	1.3490	1.1369	1.0145
1976	2.0911	1.3240	1.0393	0.9770	1.0261	1.3315	1.1384	1.0025
1977	2.0988	1.3539	1.0405	0.9778	1.0171	1.3135	1.1404	0.9946
1978	2.1490	1.4050	1.0356	0.9674	1.0091	1.3248	1.1421	0.9762
1979	2.2136	1.4265	1.0228	0.9729	1.0037	1.3575	1.1446	0.9765
1980	2.2922	1.4478	1.0170	0.9976	0.9875	1.3759	1.1485	0.9852
1981	2.3922	1.4698	1.0236	0.9928	0.9911	1.4025	1.1522	0.9839
1982	2.3735	1.4430	1.0351	0.9777	1.0066	1.3967	1.1561	0.9841
1983	2.4481	1.5368	1.0339	0.9727	1.0097	1.3541	1.1586	0.9821
1984	2.5236	1.5676	1.0242	0.9682	1.0208	1.3687	1.1621	0.9883
1985	2.5762	1.5431	1.0226	0.9721	1.0117	1.4237	1.1660	0.9834
1986	2.6048	1.5593	1.0183	0.9643	0.9913	1.4679	1.1693	0.9559
1987	2.6901	1.6127	1.0058	0.9505	0.9919	1.5000	1.1728	0.9428
1988	2.8455	1.6447	0.9894	0.9490	1.0154	1.5408	1.1777	0.9636
1989	3.0216	1.6343	0.9832	0.9475	1.0573	1.5849	1.1844	1.0018
1990	3.0397	1.5667	0.9927	0.9468	1.0597	1.6347	1.1917	1.0032
1991	2.9645	1.5716	0.9852	0.9240	1.0732	1.6143	1.1960	0.9917
1992	2.9919	1.6293	0.9776	0.9064	1.0869	1.5911	1.1983	0.9852
1993	3.0485	1.6820	0.9749	0.9079	1.0736	1.5892	1.2002	0.9747
1994	3.1289	1.6955	0.9713	0.9021	1.0730	1.6327	1.2024	0.9679
1995	3.2679	1.7119	0.9663	0.9013	1.0836	1.6792	1.2047	0.9766
1996	3.4568	1.7550	0.9630	0.9020	1.0950	1.7139	1.2083	0.9876
1997	3.5624	1.8087	0.9548	0.8872	1.1242	1.7060	1.2123	0.9974
1998	3.7992	1.9034	0.9473	0.8938	1.1161	1.7363	1.2166	0.9976
1999	3.9056	1.9593	0.9521	0.8838	1.1101	1.7453	1.2227	0.9811
2000	4.0657	1.9620	0.9513	0.8858	1.1243	1.7811	1.2281	0.9959
2001	4.1857	1.9664	0.9538	0.9129	1.0994	1.8042	1.2325	1.0036
2002	4.3382	2.0259	0.9528	0.9086	1.1117	1.7997	1.2363	1.0101
2003	4.5521	2.0687	0.9534	0.8946	1.1396	1.8251	1.2404	1.0195
2004	4.8106	2.0753	0.9590	0.8787	1.1947	1.8463	1.2472	1.0498

Figure 3: **Contributions of Productivity, Terms of Trade, Real Output Price Change and Input Quantity Factors to Market Sector Real Income Levels Using the Net Product Approach**

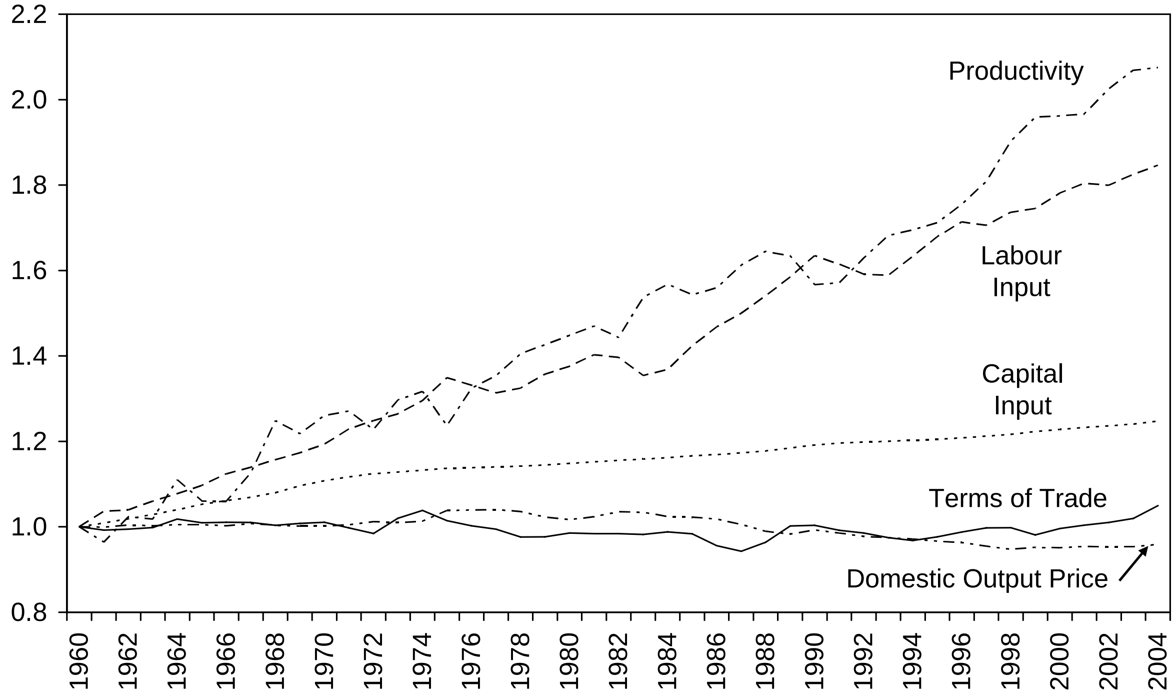
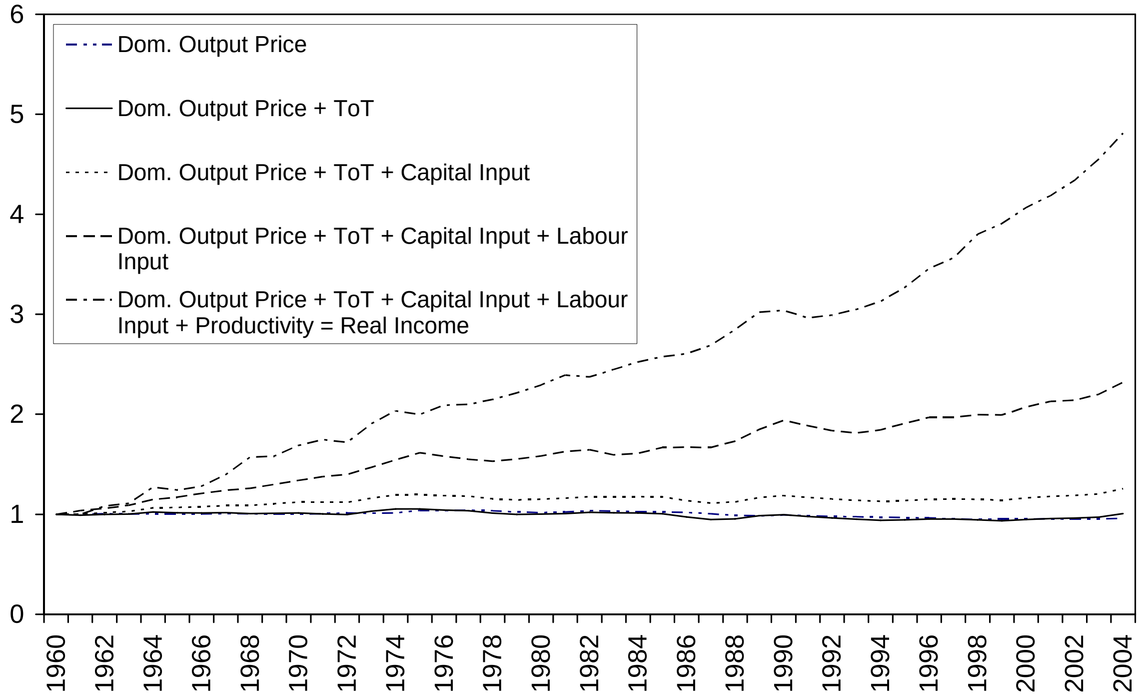


Figure 4: **Cumulative Contributions of Productivity, Terms of Trade, Real Output Price Change and Input Quantity Factors to Market Sector Real Income Levels Using the Net Product Approach**



The price of waiting capital services increases much more rapidly than the other investment prices. This is due to the fact that land services are included in the capital services aggregate but there is very little investment in land. Hence, the situation is explained by the fact that land prices in Australia have been increasing much more rapidly than the prices of investment goods in recent years.

Gross investment in Australia grew 7.3 fold over the sample period whereas net investment grew only 6.6 fold. Note also that gross investment is well above depreciation or replacement investment for every year. All of the analysis presented in section 2 above applies to the new situation. The counterpart to Table 1 in the previous section using the new framework is Table 3 below.

In the previous GDP model, the average rate of increase in real income was 3.76 per cent per year, which has now marginally decreased to 3.70 per cent. However, there are some big shifts in the explanatory factors: productivity growth now accounts for an average contribution of 1.73 per cent per year compared to the old 1.48 per cent; the contribution of labour input growth has increased from 1.23 per cent per year to 1.42 per cent and the contribution of capital services input growth has dramatically decreased from 1.11 per cent per year to 0.50 per cent per year. The contributions of real output price changes (including changes in real export and import prices) are little changed and are generally small.

The above period to period results can also be presented in levels form and Table 4 and Figure 3 are the counterparts of Table 2 and Figure 1 in the GDP framework while Figure 4 presents the cumulative analysis corresponding to Figure 2 in the earlier section.

From Table 4 the overall growth in real net income in Australia over the 45 year period was a 4.810 fold increase. From Table 4 and Figure 3 the main explanatory factors were productivity growth (2.075 fold increase in real net income), increases in labour input (1.846 fold increase) and increases in (waiting) capital services (1.247 fold increase). There were small effects due to the relative fall in the price of domestic C + G + I relative to the price of C (0.959 fold increase), the relative fall in the price of exports (0.879 fold increase) and the relative fall in the price of imports (1.195 fold increase). The combined effects of changes in the prices of exports and imports relative to the price of consumption was a 1.050 fold increase in real net income over the sample period; ie improvements in the terms of trade contributed to an overall increase in real net income of 5 per cent over the sample period.

The change in relative contributions is graphically evident in Figure 4 where we now have a larger wedge between the two top lines in the figure representing the increased relative contribution of productivity change and a somewhat larger wedge between the second and third lines form the top representing the slightly larger contribution of labour force growth. The much smaller wedge between the third and fourth lines from the top shows the reduced contribution of capital in the net product framework.

To reiterate, the reduced contribution from capital arises because we had previously overstated the level of real income in the gross product framework as we counted all investment as part of real output. In the net product framework we recognise that part of investment (equal to depreciation of the capital stock) goes to maintain the size of the capital stock and only net investment should be counted as part of real income. This leads to a lower level of real income in the net product framework compared to the gross product framework although it should be noted that both measures of real income grow at roughly similar rates. As only net investment is now counted as a part of real income, capital growth makes a smaller contribution to real income growth in the net product framework.

While changes in the terms of trade have made only a small contribution to real income growth over the last four and half decades, it is instructive to examine the last decade separately. This has been a period when cheaper imports have become available, partly due to the increasing use of computerised equipment whose prices have fallen with advances in technology and partly due to the availability of cheaper manufactured goods from China, in particular. On the export side, Australia has also benefited from relatively firm commodity prices over this period. It has also encompassed what many believe to be a sizable acceleration in Australia’s rate of productivity growth.

In Figures 5 and 6 we represent the individual and cumulative contributions, respectively, to real net income for the period 1994–95 to 2003–04. Over this 10 year period Australia’s real net income increased by 47 per cent. From Figure 5 we see that the higher rate of productivity growth contributed almost half of this increase, accounting for an increase in real net income of 21 per cent. Labour force growth was the next largest contributor accounting for an increase in real net income of 10 per cent. This is now followed closely by the terms of trade which accounted for an increase in real net income of 7.5 per cent. Capital growth, on the other hand, now only contributes an increase in real net income of 3.5 per cent while real consumption price changes have a negligible impact. This result highlights the potentially important impact of terms of trade changes on real net income over selected periods and how Australia has benefited from favourable movements in world prices over the last decade.

Figure 5: **Contributors to Real Net Income Levels, 1995–2004**

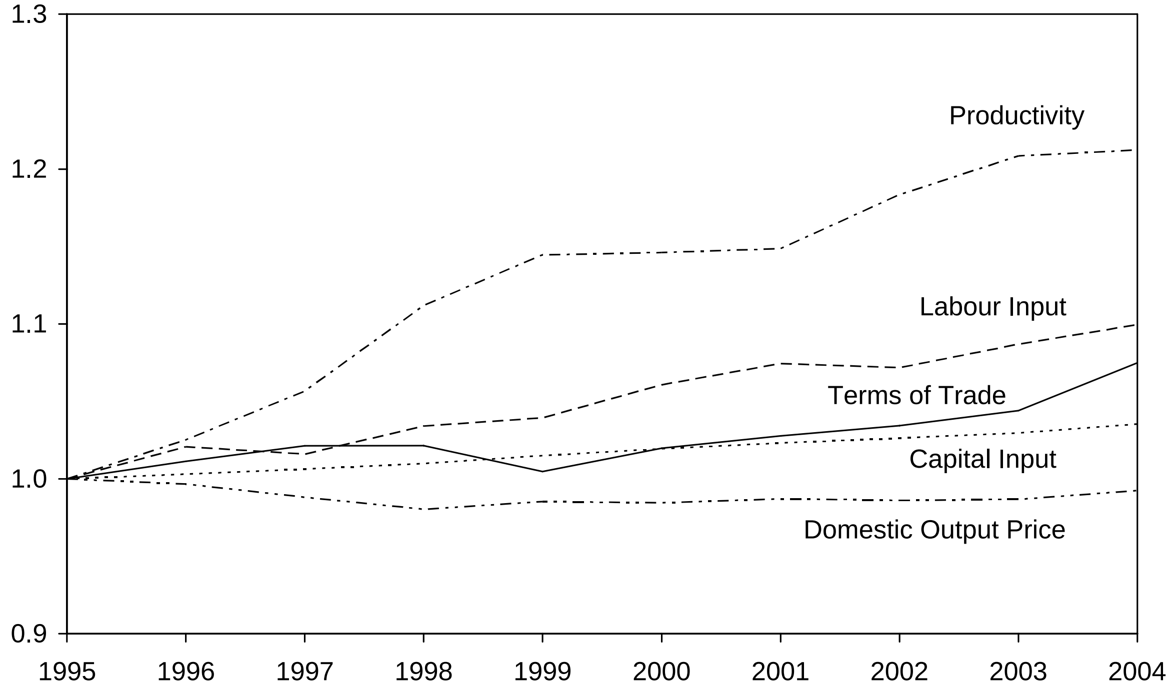
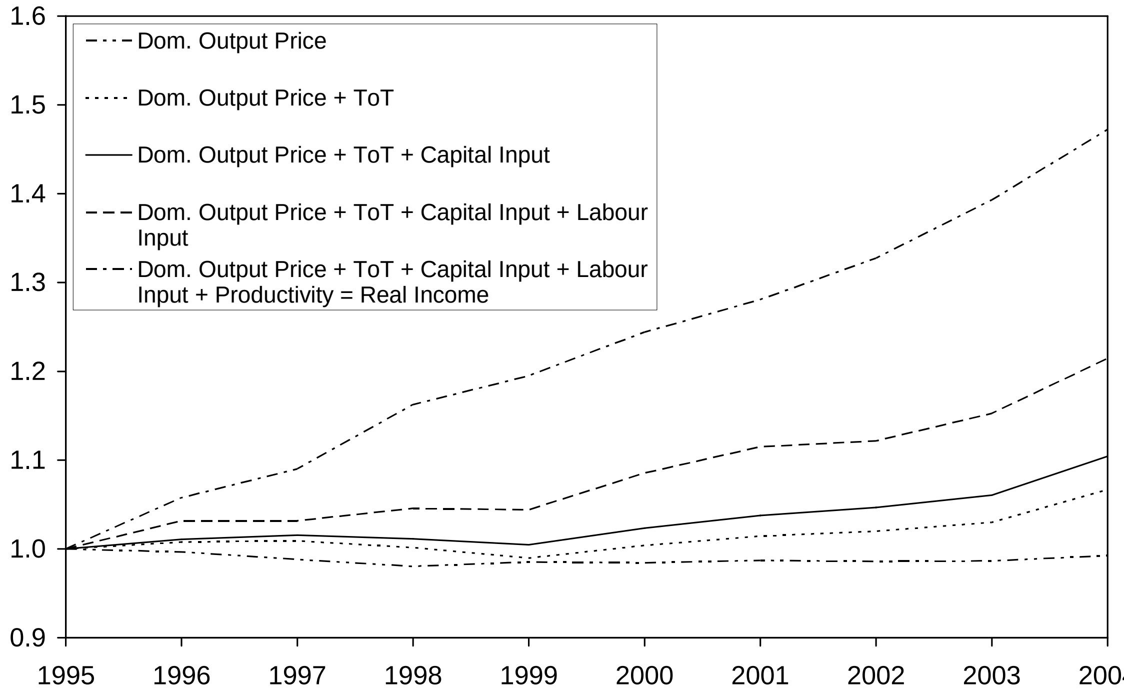


Figure 6: **Cumulative Contributions to Real Net Income Levels, 1995–2004**

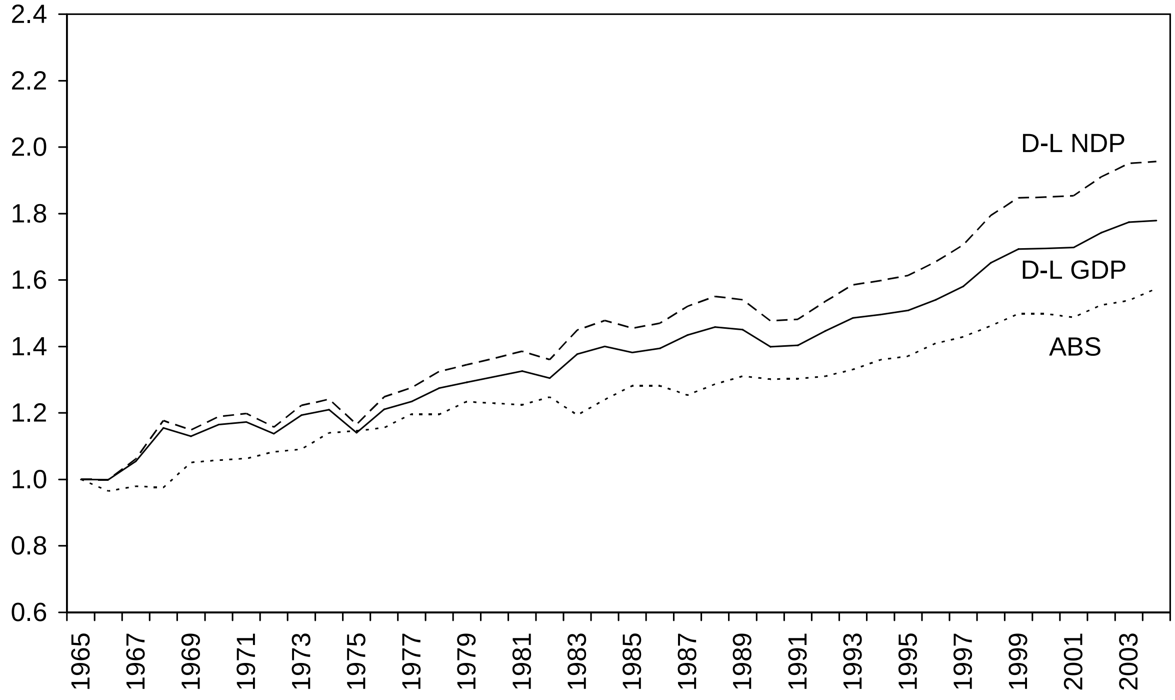


Finally, the impact of using the net product framework on productivity measures is noteworthy. In Figure 7 we present total factor productivity indexes for the Diewert–

Lawrence database using the gross and net output frameworks. We also present the ABS Multifactor Productivity index for comparison. As the ABS index runs over a shorter period, the time period used is 1965–66 to 2003–04.

Two interesting results are evident. Firstly, the gross output based Diewert–Lawrence TFP index increases more than does the ABS MFP index. The Diewert–Lawrence database covers a much higher proportion of the economy's output accounting for around 95 per cent of industry gross product whereas the ABS database only covers around two thirds of industry gross product. The Diewert–Lawrence database also builds up its output measure from final consumption components rather than sectoral gross value added and contains a number of methodological differences compared to the ABS database including the use of producer rather than consumer prices. The relatively rapid growth of the service sector components excluded from the ABS database may account for this difference but more work needs to be done to determine the exact sources of this difference.

Figure 7: **Alternative Productivity Measures, 1966–2004**



The second interesting result in Figure 7 is that the net product based TFP index increases by more than does the gross product based TFP index. This is because the denominator in the net product based measure is smaller than that in the gross product based measure as it excludes the depreciation component. The use of the smaller measure of capital input leads to a higher growth of TFP.

10 CONCLUSIONS

The main conclusion emerging from this study is that, taken over long time periods of several decades, changes in the terms of trade have relatively little impact on Australian welfare. Welfare benefits from improvements in the terms of trade in one period tend to be offset by losses from subsequent deteriorations in the terms of trade. Over the last four and a half decades changes in the terms of trade have increased real income by less than 5 per cent in aggregate. Over the same period real income has increased by almost four fold. Productivity improvements were the largest single source of improvements in real income followed by labour force increases and capital stock increases. This finding is consistent with Industry Commission (1995) which found little overall impact from terms of trade changes in the two and a half decades up to 1993–94.

There is evidence, however, that terms of trade changes can have a more important, albeit usually transitory, impact over shorter periods of time. In particular, improvements in the terms of trade over the decade up to 2003–04 led to an increase in real income of 7.5 per cent. The total increase in real income over the same period was 47 per cent with higher productivity growth accounting for almost half this increase. The Diewert and Lawrence database has not yet been updated to include the 2004–05 financial year but preliminary evidence from ABS (2005) indicates that the (standard) terms of trade has made another substantial improvement in the latest year. After an improvement of 7.5 per cent in 2003–04 due to a substantial fall in import prices combined with a modest fall in export prices, the terms of trade increased by 10 per cent in 2004–05 as import prices remained largely unchanged but export prices rebounded with the growing demand for commodities. This could be expected to make a further significant contribution to real income growth.

The other major conclusion to emerge from this study is that it makes a big difference whether we use the market sector gross domestic product or net domestic product framework. The latter framework is the more relevant one for looking at the sources of real income growth generated by the market sector. Traditional gross domestic product measures tend to overstate the level of real income as they treat investment to cover depreciation as part of real output when only net investment increases sustainable final consumption possibilities. When we move to a net domestic product framework from a gross domestic market sector framework, we find that the role of capital deepening as an explanatory factor for improving living standards is reduced and the role of technical progress (or TFP growth) and labour growth is increased.

REFERENCES

Australian Bureau of Statistics (ABS) (2005), *Australian System of National Accounts*, Catalogue No 5204, Canberra.

Christensen, L.R., D.W. Jorgenson and L.J. Lau (1971), "Conjugate Duality and the Transcendental Logarithmic Production Function", *Econometrica* 39, 255-256.

Diewert, W.E. (1973), "Functional Forms for Profit and Transformation Functions", *Journal of Economic Theory* 6, 284-316.

Diewert, W.E., (1974), "Applications of Duality Theory," pp. 106-171 in M.D. Intriligator and D.A. Kendrick (ed.), *Frontiers of Quantitative Economics*, Vol. II, Amsterdam: North-Holland.

Diewert, W.E. (1977), "Walras' Theory of Capital Formation and the Existence of a Temporary Equilibrium", pp. 73-126 in *Equilibrium and Disequilibrium in Economic Theory*, E. Schwödiauer (ed.), Reidel Publishing Company.

Diewert, W.E. (1980), "Aggregation Problems in the Measurement of Capital", pp. 433-528 in *The Measurement of Capital*, D. Usher (ed.), Chicago: The University of Chicago Press.

Diewert, W.E. (1983), "The Theory of the Output Price Index and the Measurement of Real Output Change", pp. 1049-1113 in *Price Level Measurement*, W.E. Diewert and C. Montmarquette (eds.), Ottawa: Statistics Canada.

Diewert, W.E. (2005), "On Measuring Inventory Change in Current and Constant Dollars", Discussion Paper 05-12, Department of Economics, The University of British Columbia, Vancouver, Canada, V6T 1Z1. Available at http://www.econ.ubc.ca/diewert/disc.htm

Diewert, W.E. and D. Lawrence (2005), *Australia's Productivity Growth and the Role of Information and communications Technology: 1960–2004*, Report prepared by Meyrick and Associates for the Department of Communications, Information Technology and the Arts, Canberra.

Diewert, W.E. and D. Lawrence (2006), *Productivity, the Terms of Trade and Australian Welfare: 1960–2004*, Report prepared by Meyrick and Associates for the Productivity Commission, Canberra.

Diewert, W.E. and C.J. Morrison (1986), "Adjusting Output and Productivity Indexes for Changes in the Terms of Trade", *The Economic Journal* 96, 659-679.

Diewert, W. E. and A. M. Smith (1994), "Productivity Measurement for a Distribution Firm", *The Journal of Productivity Analysis* 5, 335–347.

Edwards, E.O. and P.W. Bell (1961), *The Theory and Measurement of Business Income,* Berkeley: University of California Press.

Hicks, J.R. (1946), *Value and Capital*, Second Edition, Oxford: The Clarendon Press.

Hicks, J.R. (1961), "The Measurement of Capital in Relation to the Measurement of Other Economic Aggregates", pp. 18-31 in *The Theory of Capital*, F.A. Lutz and D.C. Hague (eds.), London: Macmillan.

Industry Commission (1995), *The Performance of Australian Industry, 1994–95*, AGPS, Canberra.

Jorgenson, D.W. (1989), "Capital as a Factor of Production", pp. 1–35 in *Technology and Capital Formation*, D.W. Jorgenson and R. Landau (eds.), Cambridge MA: The MIT Press.

Jorgenson, D.W. (1996a), "Empirical Studies of Depreciation", *Economic Inquiry* 34, 24-42.

Jorgenson, D.W. (1996b), *Investment: Volume 2; Tax Policy and the Cost of Capital*, Cambridge, Massachusetts: The MIT Press.

Jorgenson, D.W. and Z. Griliches (1967), The Explanation of Productivity Change", *The Review of Economic Studies* 34, 249–283.

Jorgenson, D.W. and Z. Griliches (1972), "Issues in Growth Accounting: A Reply to Edward F. Denison", *Survey of Current Business* 52:4, Part II (May), 65–94.

Kohli, U. (1978), "A Gross National Product Function and the Derived Demand for Imports and Supply of Exports", *Canadian Journal of Economics* 11, 167-182.

Kohli, U. (1990), "Growth Accounting in the Open Economy: Parametric and Nonparametric Estimates", *Journal of Economic and Social Measurement* 16, 125-136.

Kohli, U. (1991), *Technology, Duality and Foreign Trade: The GNP Function Approach to Modeling Imports and Exports*, Ann Arbor: University of Michigan Press.

Kohli, U. (2003), "Growth Accounting in the Open Economy: International Comparisons", *International Review of Economics and Finance* 12, 417-435.

Kohli, U. (2004a), "An Implicit Törnqvist Index of Real GDP", *Journal of Productivity Analysis* 21, 337-353.

Kohli, U. (2004b), "Real GDP, Real Domestic Income and Terms of Trade Changes", *Journal of International Economics* 62, 83-106.

Morrison, C.J. and W.E. Diewert (1990), "Productivity Growth and Changes in the Terms of

Trade in Japan and the United States", pp. 201-227 in *Productivity Growth in Japan and the United States*, Chicago: University of Chicago Press.

Oulton, N. (2002), *Productivity versus Welfare: or, GDP versus Weitzman's NDP*, Working Paper, Bank of England, London.

Rymes, T.K. (1968), "Professor Read and the Measurement of Total Factor Productivity", *The Canadian Journal of Economics* 1, 359-367.

Rymes, T.K. (1983), "More on the Measurement of Total Factor Productivity", *The Review of Income and Wealth* 29 (September), 297-316.

Törnqvist, L. (1936), "The Bank of Finland's Consumption Price Index", *Bank of Finland Monthly Bulletin* 10: 1-8.

Törnqvist, L. and E. Törnqvist (1937), "Vilket är förhällandet mellan finska markens och svenska kronans köpkraft?", *Ekonomiska Samfundets Tidskrift* 39, 1-39 reprinted as pp. 121-160 in *Collected Scientific Papers of Leo Törnqvist*, Helsinki: The Research Institute of the Finnish Economy, 1981.

Weitzman, M.L. (1976), "On the welfare significance of national product in a dynamic economy", *Quarterly Journal of Economics* XC, 156–62.

Weitzman, M.L. (1997), "Sustainability and technical progress", *Scandinavian Journal of Economics* 99, 1–14.

Woodland, A.D. (1982), *International Trade and Resource Allocation*, Amsterdam: North-Holland.