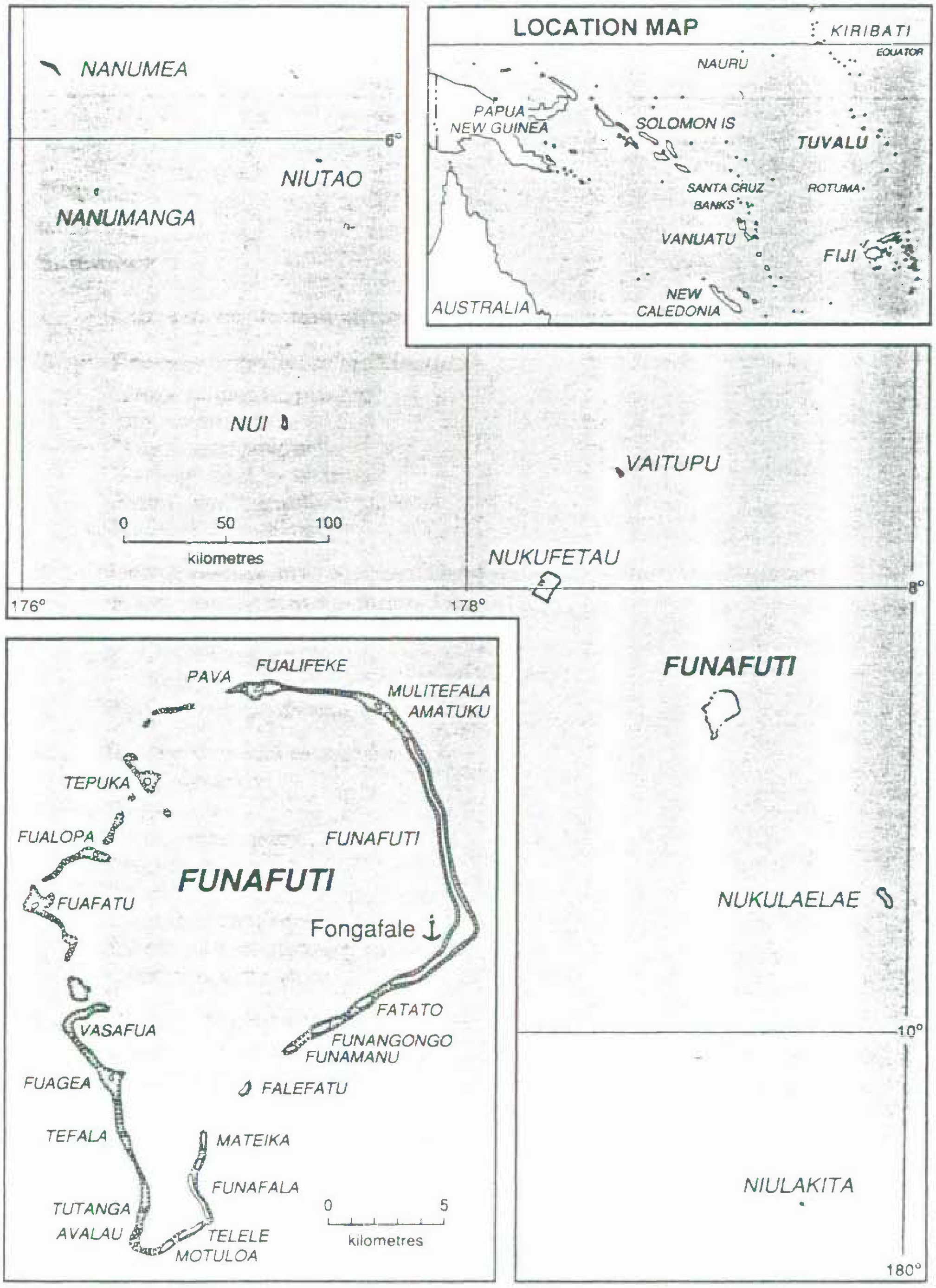
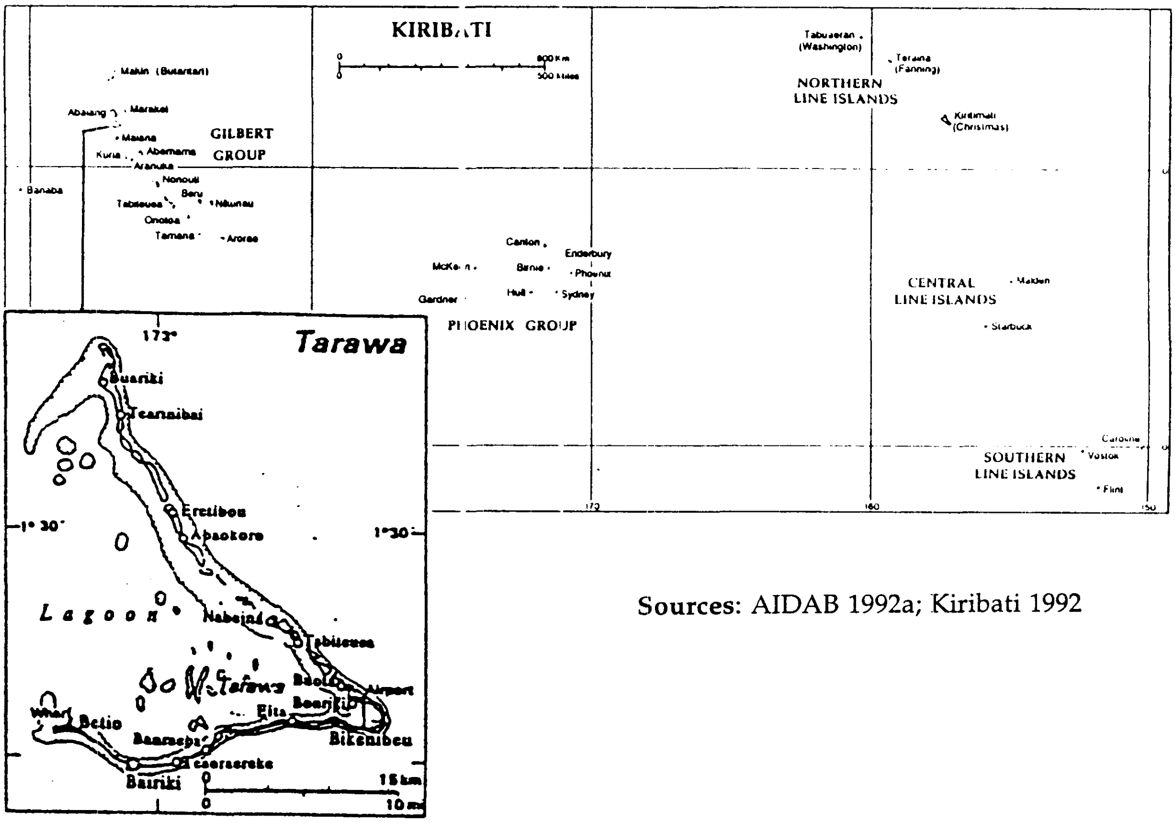
# APPENDIX 2.1

## Maps of the MIRAB countries

### Tuvalu

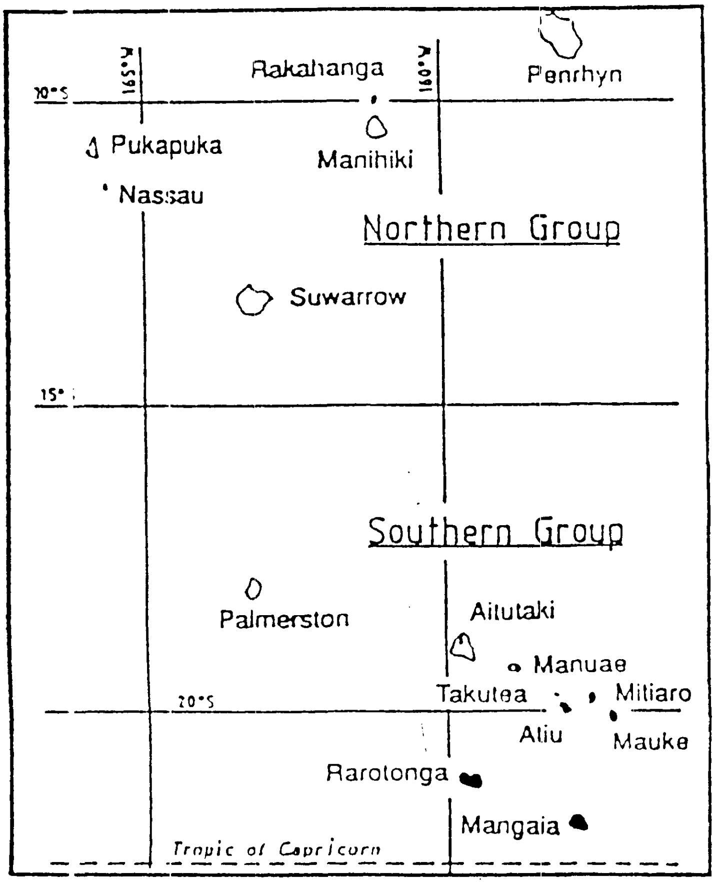



Source: AIDAB 1993

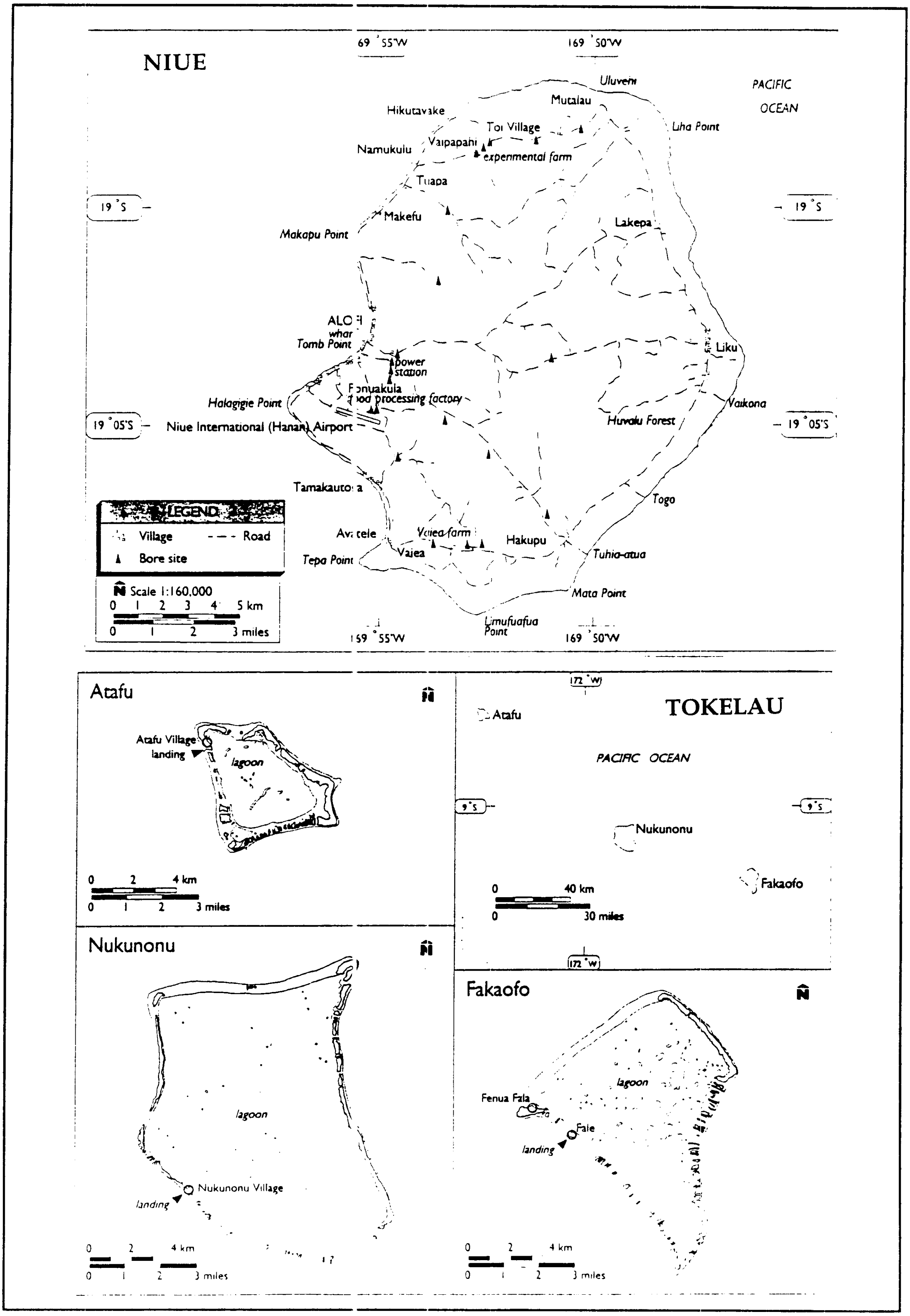



Sources: AIDAB 1992a; Kiribati 1992

COOK ISLANDS




Source: Mataio 1991




**Sources:** Ioane 1994; Lane 1994

# APPENDIX 6.1

## Data used in the regression of public current expenditure on aid (figure 6.3)

| | Kiribati | | | Tuvalu | | | Cook Is. | | | Niue | | | Tokelau | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Year* | Aid | PubC | *Year* | Aid | PubC | *Year* | Aid | PubC | *Year* | Aid | PubC | *Year* | Aid | PubC |
| | | | | | | | | | | | | *1980* | 2171 | 1699 |
| | | | | | | | | | | | | *1981* | 1332 | 1549 |
| *1982* | 13800 | 16016 | *1982* | 6222 | 3097 | *1982* | 9358 | 13427 | *1982* | 4314 | 4486 | *1982* | 1863 | 2032 |
| *1983* | 16742 | 15300 | *1983* | 4388 | 3042 | *1983* | 9331 | 14046 | *1983* | 5730 | 3984 | *1983* | 1842 | 1809 |
| *1984* | 14126 | 14187 | *1984* | 5276 | 3142 | *1984* | 8506 | 12831 | *1984* | 3191 | 3853 | *1984* | 1795 | 1570 |
| *1985* | 14590 | 14420 | *1985* | 3771 | 3272 | *1985* | 9952 | 14465 | *1985* | 3876 | 4033 | *1985* | 1639 | 1793 |
| *1986* | 16544 | 13235 | *1986* | 4186 | 3085 | *1986* | 9227 | 17273 | *1986* | 4465 | 4733 | *1986* | 1239 | 1830 |
| *1987* | 16255 | 12956 | *1987* | 5167 | 2847 | *1987* | 7742 | 20503 | *1987* | 4209 | 5391 | *1987* | 1621 | 2332 |
| *1988* | 12908 | 14282 | *1988* | 5870 | 3201 | *1988* | 8284 | 25657 | *1988* | 3659 | 5048 | | | |
| *1989* | 10608 | 13525 | *1989* | 5274 | 3184 | *1989* | 8125 | 22846 | | | | | | |
| *1990* | 15540 | 13018 | *1990* | 4293 | 3549 | *1990* | 7469 | 23064 | | | | | | |
| *1991* | 12187 | 15611 | | | | *1991* | 7909 | 28350 | | | | | | |

**Note**: All values are in 1982 A$'000.
**Sources**: SPC; SPD; NCDS, *Pacific Economic Bulletin*, various issues; Mataio 1991; AIDAB 1992a, 1993; Bertram 1993, pers. comm.; CIA 1995.

*Aid*: Refers to the real value of total aid flows received by each country. Current values were deflated by the New Zealand Consumer Price Index (Niue, Tokelau, Cook Islands) or by the Australian Retail Price Index (Kiribati and Tuvalu).

*Pub C*: Refers to public consumption expenditure in real terms. Current values in each country were deflated by that country's CPI, except for Tokelau (for which no CPI is available), where the deflator used was the New Zealand CPI.

*Currency conversion*: New Zealand dollar values were converted into Australian dollar values using the average yearly exchange rate (IMF).

# APPENDIX 6.2

## Data used in the regression of the real exchange rate on aid (table 6.9)

| | Kiribati | | | Tuvalu | | | Cook Is. | | | Niue | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Year* | Aid | RER | *Year* | Aid | RER | *Year* | Aid | RER | *Year* | Aid | RER |
| *1982* | 13800 | 100.0 | *1982* | 6222 | 100.0 | *1982* | 9358 | 100.0 | *1982* | 4314 | 100.0 |
| *1983* | 16742 | 96.6 | *1983* | 4388 | 96.5 | *1983* | 9331 | 107.6 | *1983* | 5730 | 102.1 |
| *1984* | 14126 | 96.2 | *1984* | 5276 | 85.9 | *1984* | 8506 | 92.1 | *1984* | 3191 | 100.8 |
| *1985* | 14590 | 94.5 | *1985* | 3771 | 91.3 | *1985* | 9952 | 79.6 | *1985* | 3876 | 105.2 |
| *1986* | 16544 | 93.7 | *1986* | 4186 | 108.4 | *1986* | 9227 | 71.4 | *1986* | 4465 | 115.1 |
| *1987* | 16255 | 87.7 | *1987* | 5167 | 111.6 | *1987* | 7742 | 72.9 | *1987* | 4209 | 117.1 |
| *1988* | 12908 | 90.9 | *1988* | 5870 | 112.1 | *1988* | 8284 | 46.2 | *1988* | 3659 | 121.8 |
| *1989* | 10608 | 88.0 | *1989* | 5274 | 101.3 | *1989* | 8125 | 58.6 | | | |
| *1990* | 15540 | 87.0 | *1990* | 4293 | 103.1 | *1990* | 7469 | 56.8 | | | |

**Note**: Aid values in 1982 A$'000.
**Sources**: SPC; SPD; AIDAB 1992a, 1993; Booth and Muthiah 1992; Kiribati 1992.

*Aid*: As defined in appendix 6.1.

*RER*: Ratio of $P_t$ over $P_{nt}$, expressed as a percentage. $P_t$ and $P_{nt}$ as defined in the text (see explanations pertaining to figure 6.6).

*Currency conversion*: As in appendix 6.1.

# APPENDIX 6.3

## Data used in the regression of the real wage rate on aid (table 6.10)

| | Kiribati | | | Cook Is. | |
|---|---|---|---|---|---|
| *Year* | Aid | RW | *Year* | Aid | RW |
| *1979* | 12869 | 2874.9 | *1979* | 10765 | 1.9 |
| *1980* | 18437 | 2877.0 | *1980* | 11877 | 2.1 |
| *1981* | 18535 | 2724.4 | *1981* | 8461 | 1.9 |
| *1982* | 13800 | 2686.0 | *1982* | 9358 | 2.0 |
| *1983* | 16742 | 2607.3 | *1983* | 9331 | 2.0 |
| *1984* | 14126 | 2579.2 | *1984* | 8506 | 1.8 |
| *1985* | 14590 | 2433.0 | *1985* | 9952 | 1.9 |
| *1986* | 16544 | 2426.1 | *1986* | 9227 | 1.9 |
| *1987* | 16255 | 2393.6 | *1987* | 7742 | 1.8 |
| *1988* | 12908 | 2448.5 | *1988* | 8284 | 1.8 |
| *1989* | 10608 | 2367.6 | *1989* | 8125 | 1.8 |
| *1990* | 15540 | 2371.8 | *1990* | 7469 | 1.7 |
| *1991* | 12187 | 2367.7 | | | |

**Note**: Aid values in 1982 A$'000. RW values in 1982 A$.

**Sources**: SPC; SPD; Mataio 1991; Booth and Muthiah 1992; Sinclair 1993.

*Aid*: As defined in appendix 6.1.

*RW*: Refers to the real wage rate, as defined in the text (see explanations pertaining to table 6.10). Current values were deflated by the CPI for each country.

*Currency conversion*: As in appendix 6.1.

# APPENDIX 7.1

**Increase in output as a result of an improvement in terms of trade (one-sector model)**

For simplicity, the following additional assumptions are introduced:

- all output consists of exportables;
- all absorption (including the consumption of workers) consists of importables;
- real output is measured in terms of importables (numéraire good); and
- the price level (P) refers to the price of importables.

Let an improvement in terms of trade occur, caused by a rise in export prices. This means that each physical unit of export output is equivalent to a greater number of units of importables. This has two implications: (i) the existing level of output, as measured in terms of the numéraire, increases; and (ii) the productivity of labour, also measured in terms of the numéraire, increases (the AS curve shifts to the right). A more productive labour force leads to more workers being employed at the pre-determined real wage rate $\overline{W} / \overline{P}$ (in figure 7.1, the $L_{D1}$ curve shifts out). This increase in domestic employment leads to a further increase in output. Hence, the shift to the right of the aggregate supply curve has been caused by both a valuation effect and a productivity-induced increase in the physical number of units produced.

# APPENDIX 7.2

## Existence of an inverse relationship between the IOCR and k (one-sector model)

From equation 7.16:

$$IOCR = (MP_K + \frac{MP_L}{k}) \quad (1)$$

From equations 7.8 and 7.9:

$$MP_K = \frac{d}{dk}[F(k)] \quad (2)$$

$$MP_L = F(k) - k\frac{d}{dk}[F(k)] \quad (3)$$

Using equations 2 and 3 to substitute for $MP_K$ and $MP_L$ in equation 1:

$$IOCR = \frac{d}{dk}[F(k)] + \frac{1}{k}\{F(k) - k\frac{d}{dk}[F(k)]\} \quad (4)$$

$$= \frac{d}{dk}[F(k)] + \frac{F(k)}{k} - \frac{d}{dk}[F(k)] \quad (5)$$

$$= \frac{F(k)}{k} \quad (6)$$

Totally differentiating equation 6 yields:

$$dIOCR = \frac{\delta IOCR}{\delta F(k)} dF(k) + \frac{\delta IOCR}{\delta k} dk \quad (7)$$

$$= \frac{1}{k}\frac{d}{dk}F(k)\, dk + (-\frac{F(k)}{k^2})\, dk \quad (8)$$

Dividing through by dk and factorising $\frac{1}{k^2}$ yields:

$$\frac{dIOCR}{dk} = \frac{1}{k^2}\{k\frac{d}{dk}[F(k)] - F(k)\} \quad (9)$$

From equation 3, this is equivalent to:

$$\frac{dIOCR}{dk} = \frac{1}{k^2}(- MP_L) \quad (10)$$

Given that, in a well-behaved production function, the marginal product of both factors is always positive, it follows that $MP_L$ is positive and that, therefore:

$$\frac{dIOCR}{dk} < 0$$ **QED**

# APPENDIX 8.1

### Real wage elasticity of the demand for labour in a Cobb-Douglas production function

Given the production functions postulated, the sectoral marginal products of labour are equal to:

$$MPL_t = \frac{\partial X_t}{\partial L_t} = \beta\left(\frac{K_t}{L_t}\right)^{\alpha} \tag{1}$$

$$MPL_{nt} = \frac{\partial X_{nt}}{\partial L_{nt}} = \delta\left(\frac{K_{nt}}{L_{nt}}\right)^{\gamma} \tag{2}$$

Then, by log differentiation of equations 1 and 2, it must be the case that (see e.g. Chiang 1984, pp. 304-5):

$$\frac{dMPL_t}{MPL_t} = -\alpha\frac{dL_t}{L_t} \tag{3}$$

$$\frac{dMPL_{nt}}{MPL_{nt}} = -\gamma\frac{dL_{nt}}{L_{nt}} \tag{4}$$

Re-arranging:

$$\frac{dL_t}{L_t} = -\frac{1}{\alpha}\frac{dMPL_t}{MPL_t}$$

$$\frac{dL_{nt}}{L_{nt}} = -\frac{1}{\gamma}\frac{dMPL_{nt}}{MPL_{nt}}$$

**QED**

# APPENDIX 8.2

**Elasticity of sectoral own-product real wages with respect to the price of non-tradables (unrestricted model)**

From equation 8.10:

$$d\left(\frac{W_0}{P_{nt}}\right) = -\frac{\bar{w}\,\theta P_t}{P_{nt}^2}\,dP_{nt}$$

$$=> \quad d\left(\frac{W_0}{P_{nt}}\right) = -\frac{\bar{w}\,\theta P_t}{P_{nt}^2}\,\frac{P_{nt}}{(W_0/P_{nt})}\,\frac{dP_{nt}}{P_{nt}}\,\frac{W_0}{P_{nt}}$$

$$=> \quad \frac{d(W_0/P_{nt})}{(W_0/P_{nt})} = -\frac{\bar{w}\,\theta P_t}{P_{nt}^2}\,\frac{P_{nt}^2}{W_0}\,\frac{dP_{nt}}{P_{nt}}$$

$$= -\frac{\bar{w}\,\theta P_t}{W_0}\,\frac{dP_{nt}}{P_{nt}} \qquad (1)$$

From equation 8.8:

$$\frac{\bar{w}}{W_0} = \frac{1}{[\theta P_t + (1-\theta)P_{nt}]}$$

Substituting for $\frac{\bar{w}}{W_0}$ in equation 1:

$$\frac{d(W_0/P_{nt})}{(W_0/P_{nt})} = -\frac{\theta\,Pt}{[\theta P_t + (1-\theta)P_{nt}]}\,\frac{dP_{nt}}{P_{nt}} \qquad \textbf{QED}$$

---

From equation 8.13:

$$d\left(\frac{W_0}{P_t}\right) = \frac{\bar{w}\,(1-\theta)}{P_t}\,dP_{nt}$$

$$=> \quad d\left(\frac{W_0}{P_t}\right) = \frac{\bar{w}\,(1-\theta)}{P_t}\,\frac{P_{nt}}{(W_0/P_t)}\,\frac{dP_{nt}}{P_{nt}}\,\frac{W_0}{P_t}$$

$$=> \quad \frac{d(W_0/P_t)}{(W_0/P_t)} = \frac{\bar{w}\,(1-\theta)}{P_t}\,\frac{P_{nt}P_t}{W_0}\,\frac{dP_{nt}}{P_{nt}}$$

$$= \frac{\overline{w}\,(1-\theta)\,P_{nt}}{W_0}\;\frac{dP_{nt}}{P_{nt}} \qquad (2)$$

Substituting for $\frac{\overline{w}}{W_0}$ in equation 2:

$$\frac{d(W_0/P_t)}{(W_0/P_t)} = \frac{(1-\theta)\,P_{nt}}{[\theta P_t + (1-\theta)P_{nt}]}\;\frac{dP_{nt}}{P_{nt}}$$

**QED**

# APPENDIX 8.3

**Solution of the CGE short run unrestricted model**

Three preliminary results are required (Results A, B, and C).

**1.** First, it is necessary to derive an expression for the proportional change in real GDP. Using tradables as numéraire good (i.e. letting $P_t = 1$), it is possible to express real GDP in the economy as:

$$Y = X_t + \frac{P_{nt}}{P_t} X_{nt}$$

Totally differentiating Y (with $P_t$ constant):

$$dY = dX_t + \frac{P_{nt}}{P_t} dX_{nt} + \frac{X_{nt}}{P_t} dP_{nt} = \frac{X_t}{Y}\frac{dX_t}{X_t} Y + \frac{P_{nt}}{P_t}\frac{X_{nt}}{Y}\frac{dX_{nt}}{X_{nt}} Y + \frac{X_{nt}}{P_t}\frac{P_{nt}}{Y}\frac{dP_{nt}}{P_{nt}} Y$$

Letting $\frac{X_t}{Y} = \lambda$ and $\frac{P_{nt}X_{nt}}{P_t Y} = (1\text{-}\lambda)$, and dividing through by Y:

$$\hat{Y} = \lambda\widehat{X_t} + (1\text{-}\lambda)\widehat{X_{nt}} + (1\text{-}\lambda)\widehat{P_{nt}}$$ **Result A**

**2.** Secondly, it is necessary to derive an expression for the proportional change in $\frac{P_{nt}}{P_t}$.

Totally differentiating $\frac{P_{nt}}{P_t}$ yields:

$$d[\frac{P_{nt}}{P_t}] = \frac{\partial[P_{nt}/P_t]}{\partial P_{nt}} dP_{nt} + \frac{\partial[P_{nt}/P_t]}{\partial P_t} dP_t$$

Given that $dP_t = 0$ by definition this is equivalent to:

$$d[\frac{P_{nt}}{P_t}] = \frac{1}{P_t} dP_{nt} = \frac{1}{P_t}\frac{P_{nt}}{[P_{nt}/P_t]}\frac{dP_{nt}}{P_{nt}} [P_{nt}/P_t]$$

Simplifying and dividing through by $[\frac{P_{nt}}{P_t}]$:

$$\widehat{\left[\frac{P_{nt}}{P_t}\right]} = \widehat{P_{nt}}$$ **Result B**

**3.** Assuming that, prior to the injection of aid, the absorption of non-tradables is a function of real GDP in terms of good T (Y), and the relative price of non-tradables ($\frac{P_{nt}}{P_t}$), it is possible to write that:

$$C_{nt} = f(Y, \frac{P_{nt}}{P_t}) \qquad f_y > 0 \qquad f_{(P_{nt}/P_t)} < 0$$

Totally differentiating this function yields:

$$dC_{nt} = \frac{\partial C_{nt}}{\partial Y} dY + \frac{\partial C_{nt}}{\partial [P_{nt}/P_t]} d[P_{nt}/P_t]$$

Or, in terms of elasticities:

$$\widehat{C_{nt}} = \eta \hat{Y} + \varepsilon_{nt} \widehat{\left[\frac{P_{nt}}{P_t}\right]}$$

where $\eta$ = real income elasticity of the absorption of non-tradables
$\varepsilon_{nt}$ = elasticity of the absorption of non-tradables with respect to the relative price of non-tradables.

Or, replacing $\widehat{\left[\frac{P_{nt}}{P_t}\right]}$ with Result B:

$$\widehat{C_{nt}} = \eta \hat{Y} + \varepsilon_{nt} \widehat{P_{nt}}$$

Now, let an inflow of aid, equal to $\frac{F}{P_t}$ in terms of the numéraire, be received. Assuming that this aid consists of an untied grant, and, further, that a fraction $\sigma$ of that grant is spent on NT goods, the total change in $C_{nt}$ becomes:

$$dC_{nt} = \frac{\partial C_{nt}}{\partial Y} dY + \frac{\partial C_{nt}}{\partial [P_{nt}/P_t]} d[P_{nt}/P_t] + \frac{\sigma F}{P_t}$$

$$= \frac{\partial C_{nt}}{\partial Y} \frac{Y}{C_{nt}} \frac{dY}{Y} C_{nt} + \frac{\partial C_{nt}}{\partial [P_{nt}/P_t]} \frac{[P_{nt}/P_t]}{C_{nt}} \frac{d[P_{nt}/P_t]}{[P_{nt}/P_t]} C_{nt} + \frac{\sigma F}{P_t C_{nt}} C_{nt}$$

Dividing through by $C_{nt}$:

$$\widehat{C_{nt}} = \eta \hat{Y} + \varepsilon_{nt} \widehat{\left[\frac{P_{nt}}{P_t}\right]} + \frac{\sigma F}{P_t C_{nt}}$$

Replacing $\widehat{\left[\frac{P_{nt}}{P_t}\right]}$ with Result B:

$$\widehat{C_{nt}} = \eta\widehat{Y} + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\, C_{nt}}$$ **Result C**

---

**Specification and solution of the GE model**

It is now possible to specify the complete GE model describing the short run unrestricted model as a system of 4 equations and one equilibrium condition.

Supply equations (from equations 8.17 and 8.18):

$$\widehat{X_{nt}} = \frac{\delta\theta P_t}{\gamma CPI}\widehat{P_{nt}} \tag{1}$$

$$\widehat{X_t} = -\frac{\beta(1\text{-}\theta)P_{nt}}{\alpha CPI}\widehat{P_{nt}} \tag{2}$$

Absorption equation (from Result C):

$$\widehat{C_{nt}} = \eta\widehat{Y} + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\, C_{nt}} \tag{3}$$

Income equation (from Result A):

$$\widehat{Y} = \lambda\widehat{X_t} + (1\text{-}\lambda)\widehat{X_{nt}} + (1\text{-}\lambda)\widehat{P_{nt}} \tag{4}$$

Equilibrium condition:

$$\widehat{X_{nt}} = \widehat{C_{nt}} \tag{5}$$

Endogenous variables appearing in this system are $\widehat{X_t}$, $\widehat{X_{nt}}$, $\widehat{P_{nt}}$, $\widehat{C_{nt}}$, $\widehat{Y}$. Predetermined variables are the initial values of $P_t$, $P_{nt}$, $\lambda$, and $C_{nt}$. The only exogenous variable is F. This system can be solved for $\widehat{P_{nt}}^*$, using the elimination of variables method.

Substituting for $\hat{Y}$ in equation (3):

$$\widehat{C_{nt}} = \eta\left[\lambda\widehat{X_t} + (1-\lambda)\widehat{X_{nt}} + (1-\lambda)\widehat{P_{nt}}\right] + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\, C_{nt}} \tag{6}$$

Expanding:

$$\widehat{C_{nt}} = \eta\lambda\widehat{X_t} + \eta(1-\lambda)\widehat{X_{nt}} + \eta(1-\lambda)\widehat{P_{nt}} + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\, C_{nt}} \tag{7}$$

Substituting for $\widehat{X_t}$ and $\widehat{X_{nt}}$ in equation 7:

$$\widehat{C_{nt}} = \eta\lambda\left[-\frac{\beta(1-\theta)P_{nt}}{\alpha CPI}\widehat{P_{nt}}\right] + \eta(1-\lambda)\left[\frac{\delta\theta P_t}{\gamma CPI}\widehat{P_{nt}}\right] + \eta(1-\lambda)\widehat{P_{nt}} + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\, C_{nt}} \tag{8}$$

Factorising and re-arranging:

$$\widehat{C_{nt}} = \widehat{P_{nt}}\left\{-\frac{\eta\lambda\beta(1-\theta)P_{nt}}{\alpha CPI} + \frac{\eta(1-\lambda)\delta\theta P_t}{\gamma CPI} + \eta(1-\lambda) + \varepsilon_{nt}\right\} + \frac{\sigma F}{P_t\, C_{nt}} \tag{9}$$

Using equations 1 and 9 to substitute for $\widehat{X_{nt}}$ and $\widehat{C_{nt}}$ in equation 1:

$$\frac{\delta\theta P_t}{\gamma CPI}\widehat{P_{nt}} = \widehat{P_{nt}}\left\{-\frac{\eta\lambda\beta(1-\theta)P_{nt}}{\alpha CPI} + \frac{\eta(1-\lambda)\delta\theta P_t}{\gamma CPI} + \eta(1-\lambda) + \varepsilon_{nt}\right\} + \frac{\sigma F}{P_t\, C_{nt}} \tag{10}$$

Re-arranging:

$$\widehat{P_{nt}}\left\{\frac{\delta\theta P_t}{\gamma CPI} + \frac{\eta\lambda\beta(1-\theta)P_{nt}}{\alpha CPI} - \frac{\eta(1-\lambda)\delta\theta P_t}{\gamma CPI} - \eta(1-\lambda) - \varepsilon_{nt}\right\} = \frac{\sigma F}{P_t\, C_{nt}} \tag{11}$$

Factorising $\frac{\delta\theta P_t}{\gamma CPI}$, and re-arranging:

$$\widehat{P_{nt}}^{*} = \frac{\sigma F}{P_t C_{nt} \left\{ \frac{\delta \theta P_t}{\gamma \, CPI} \left[ 1 - \eta(1-\lambda) \right] + \frac{\eta \lambda \beta}{o} \frac{(1-\theta) P_{nt}}{CPI} - \eta(1-\lambda) - \varepsilon_{nt} \right\}}$$ **QED**

# APPENDIX 8.4

## Output change equations in the long run unrestricted model

From equation 8.4:

$$\widehat{X_t} = \alpha \widehat{K_t} + \beta \widehat{L_t}$$

$$<=> \quad \widehat{X_t} = \alpha \widehat{K_t} + \beta [\widehat{K_t} - \frac{(1-\theta) P_{nt}}{\alpha CPI} \widehat{P_{nt}}] \qquad \text{(from equation 8.23)}$$

$$<=> \quad \widehat{X_t} = (\alpha + \beta) \widehat{K_t} - \beta \frac{(1-\theta) P_{nt}}{\alpha CPI} \widehat{P_{nt}}$$

$$<=> \quad \widehat{X_t} = \widehat{K_t} - \frac{\beta (1-\theta) P_{nt}}{\alpha CPI} \widehat{P_{nt}} \qquad \textbf{QED}$$

Similarly:

$$\widehat{X_{nt}} = \gamma \widehat{K_{nt}} + \delta \widehat{L_{nt}}$$

$$<=> \quad \widehat{X_{nt}} = \gamma \widehat{K_{nt}} + \delta [\widehat{K_{nt}} + \frac{\theta Pt}{\gamma CPI} \widehat{P_{nt}}] \qquad \text{(from equation 8.24)}$$

$$<=> \quad \widehat{X_{nt}} = (\gamma + \delta) \widehat{K_{nt}} + \delta \frac{\theta Pt}{\gamma CPI} \widehat{P_{nt}}$$

$$<=> \quad \widehat{X_{nt}} = \widehat{K_{nt}} + \frac{\delta \theta Pt}{\gamma CPI} \widehat{P_{nt}} \qquad \textbf{QED}$$

# APPENDIX 8.5

## Solution of the GE long run unrestricted model

The complete GE model describing the long run unrestricted model consists of a system of 4 equations and one equilibrium condition.

Supply equations (from equations 8.23 and 8.24):

$$\widehat{X_t} = \widehat{K_t} - \frac{\beta\,(1-\theta)\,P_{nt}}{\alpha\,CPI}\,\widehat{P_{nt}} \tag{1}$$

$$\widehat{X_{nt}} = \widehat{K_{nt}} + \frac{\delta\,\theta\,Pt}{\gamma CPI}\,\widehat{P_{nt}} \tag{2}$$

By analogy with Result C in appendix 8.3, the absorption equation in the long run (when F = 0) can be written as:

$$\widehat{C_{nt}} = \varepsilon_{nt}\widehat{P_{nt}} + \eta\widehat{Y} \tag{3}$$

Income equation (from Result A in appendix 8.3):

$$\widehat{Y} = \lambda\widehat{X_t} + (1-\lambda)\widehat{X_{nt}} + (1-\lambda)\widehat{P_{nt}} \tag{4}$$

Equilibrium condition:

$$\widehat{X_{nt}} = \widehat{C_{nt}} \tag{5}$$

Endogenous variables appearing in this system are $\widehat{X_t}$, $\widehat{X_{nt}}$, $\widehat{P_{nt}}$, $\widehat{C_{nt}}$, $\widehat{Y}$. Predetermined variables are the initial values of $P_t$, $P_{nt}$, $\lambda$, and $C_{nt}$. Exogenous variables are $\widehat{K_t}$ and $\widehat{K_{nt}}$. This system can be solved for $\widehat{P_{nt}}^*$, using the elimination of variables method.

Substituting for $\widehat{Y}$ in equation 3:

$$\widehat{C_{nt}} = \varepsilon_{nt}\widehat{P_{nt}} + \eta\left[\lambda\widehat{X_t} + (1-\lambda)\widehat{X_{nt}} + (1-\lambda)\widehat{P_{nt}}\right] \tag{6}$$

$$= \varepsilon_{nt}\widehat{P_{nt}} + \eta\lambda\widehat{X_t} + \eta(1-\lambda)\widehat{X_{nt}} + \eta(1-\lambda)\widehat{P_{nt}} \tag{7}$$

Substituting for $\widehat{X_t}$ and $\widehat{X_{nt}}$ in equation 7:

$$\widehat{C_{nt}} = \varepsilon_{nt}\widehat{P_{nt}} + \eta\lambda\left[\widehat{K_t} - \frac{\beta(1-\theta)P_{nt}}{\alpha CPI}\widehat{P_{nt}}\right] + \eta(1-\lambda)\left[\widehat{K_{nt}} + \frac{\delta\theta P_t}{\gamma CPI}\widehat{P_{nt}}\right] + \eta(1-\lambda)\widehat{P_{nt}} \tag{8}$$

Expanding and factorising:

$$\widehat{C_{nt}} = \widehat{P_{nt}}\left[\varepsilon_{nt} - \frac{\eta\lambda\beta(1-\theta)P_{nt}}{\alpha CPI} + \frac{\eta(1-\lambda)\delta\theta P_t}{\gamma CPI} + \eta(1-\lambda)\right] + \eta\lambda\widehat{K_t} + \eta(1-\lambda)\widehat{K_{nt}} \quad (9)$$

Using equations 2 and 9 to substitute for $\widehat{X_{nt}}$ and $\widehat{C_{nt}}$ in equation 5:

$$\widehat{K_{nt}} + \frac{\delta\,\theta\,Pt}{\gamma CPI}\widehat{P_{nt}} = \widehat{P_{nt}}\left[\varepsilon_{nt} - \frac{\eta\lambda\beta(1-\theta)P_{nt}}{\alpha CPI} + \frac{\eta(1-\lambda)\delta\theta P_t}{\gamma CPI} + \eta(1-\lambda)\right] + \eta\lambda\widehat{K_t} + \eta(1-\lambda)\widehat{K_{nt}} \quad (10)$$

Re-arranging:

$$\widehat{P_{nt}}\left\{\frac{\delta\theta P_t}{\gamma CPI} + \frac{\eta\lambda\beta(1-\theta)P_{nt}}{\alpha CPI} - \frac{\eta(1-\lambda)\delta\theta P_t}{\gamma CPI} - \eta(1-\lambda) - \varepsilon_{nt}\right\} = \eta\lambda\widehat{K_t} + \eta(1-\lambda)\widehat{K_{nt}} - \widehat{K_{nt}} \quad (11)$$

Factorising on both sides:

$$\widehat{P_{nt}}\left\{\frac{\delta\theta P_t}{\gamma CPI}[1-\eta(1-\lambda)] + \frac{\eta\lambda\beta(1-\theta)P_{nt}}{\alpha CPI} \cdot \eta(1-\lambda) - \varepsilon_{nt}\right\} = \eta\lambda\widehat{K_t} + \widehat{K_{nt}}[\eta(1-\lambda)-1] \quad (12)$$

Re-arranging:

$$\widehat{P_{nt}}^{*} = \frac{\eta\lambda\widehat{K_t} - \left[1+\eta\lambda-\eta\right]\widehat{K_{nt}}}{\left\{\frac{\delta\theta P_t}{\gamma CPI}\left[1-\eta(1-\lambda)\right] + \frac{\eta\lambda\beta(1-\theta)P_{nt}}{\alpha CPI} - \eta(1-\lambda) - \varepsilon_{nt}\right\}} \quad \textbf{QED}$$

# APPENDIX 8.6

### Proportional change in sector T's nominal wage when $P_{nt}$ changes (short run restricted model)

Three preliminary results must be derived (A, B and C):

*Result A*

Given: $W_t = \frac{L_{nt}}{L_u} W_{nt}$

Totally differentiating $W_t$:

$$\Rightarrow \quad dW_t = \frac{W_{nt}}{L_u} dL_{nt} - \frac{L_{nt} W_{nt}}{L_u^2} dL_u + \frac{L_{nt}}{L_u} dW_{nt}$$

$$= \frac{W_{nt}}{L_u} \frac{L_{nt}}{W_t} \frac{dL_{nt}}{L_{nt}} W_t - \frac{L_{nt} W_{nt}}{L_u^2} \frac{L_u}{W_t} \frac{dL_u}{L_u} W_t + \frac{L_{nt}}{L_u} \frac{W_{nt}}{W_t} \frac{dW_{nt}}{W_{nt}} W_t$$

Replacing $\frac{L_{nt} W_{nt}}{L_u}$ with $W_t$ on the RHS:

$$dW_t = \frac{W_t}{W_t} \frac{dL_{nt}}{L_{nt}} W_t - \frac{W_t}{W_t} \frac{dL_u}{L_u} W_t + \frac{W_t}{W_t} \frac{dW_{nt}}{W_{nt}} W_t$$

Simplifying and dividing through by $W_t$:

$$\widehat{W_t} = \widehat{L_{nt}} - \widehat{L_u} + \widehat{W_{nt}} \qquad \textbf{Result A}$$

*Result B*

Given: $L_u = \bar{L} - L_t$

Totally differentiating (with $\bar{L}$ constant):

$$dL_u = - dL_t$$

$$= - \frac{L_t}{L_u} \frac{dL_t}{L_t} L_u$$

Dividing through by $L_u$:

$$\widehat{L_u} = - \frac{L_t}{(\bar{L} - L_t)} \widehat{L_t} \qquad \textbf{Result B}$$

*Result C*

From equation 8.8:

$$dW_{nt} = \overline{w}\,(1\text{-}\theta)\,dP_{nt}$$

$$= \overline{w}\,(1\text{-}\theta)\,\frac{P_{nt}}{W_{nt}}\,\frac{dP_{nt}}{P_{nt}}\,W_{nt}$$

$$\Leftrightarrow \quad \frac{dW_{nt}}{W_{nt}} = \frac{\overline{w}\,(1\text{-}\theta)\,P_{nt}}{W_{nt}}\,\frac{dP_{nt}}{P_{nt}}$$

Given that $\frac{\overline{w}}{W_{nt}} = \frac{1}{\theta P_t + (1\text{-}\theta)\,P_n}$ (by analogy with $\frac{\overline{w}}{W_0}$ in appendix 8.2), this is equivalent to:

$$\widehat{W_{nt}} = \frac{(1\text{-}\theta)\,P_{nt}}{CPI}\,\widehat{P_{nt}} \qquad \textbf{Result C}$$

---

**Derivation of $\widehat{W_t}$**

From Result A:

$$\widehat{W_t} = \widehat{L_{nt}} - \widehat{L_u} + \widehat{W_{nt}}$$

Replacing the terms on the RHS with results already obtained yields:

$$\widehat{W_t} = \frac{\theta\,Pt}{\gamma CPI}\,\widehat{P_{nt}} + \frac{L_t}{(\overline{L} - L_t)}\,\widehat{L_t} + \frac{(1\text{-}\theta)\,P_{nt}}{CPI}\,\widehat{P_{nt}} \qquad (1)$$

Term one on the RHS replaces $\widehat{L_{nt}}$ (from equation 8.31); term two replaces - $\widehat{L_u}$ (from Result B above); term three replaces $\widehat{W_{nt}}$ (from Result C). As can be verified from figure 8.7, the short run change in $L_t$ is due to the change in $W_t$. It is therefore possible to write (by analogy with equation 8.6) that:

$$\widehat{L_t} = -\,\frac{\widehat{W_t}}{\alpha}$$

Replacing $\widehat{L_t}$ in equation 1 above yields:

$$<=> \quad \widehat{W_t} = \frac{\theta\, Pt}{\gamma CPI}\widehat{P_{nt}} + \frac{L_t}{(\bar{L} - L_t)}(-\frac{\widehat{W_t}}{\alpha}) + \frac{(1\text{-}\theta)\, P_{nt}}{CPI}\widehat{P_{nt}}$$

$$= \widehat{P_{nt}}\left[\frac{\theta\, Pt}{\gamma CPI} + \frac{(1\text{-}\theta)\, P_{nt}}{CPI}\right] + \frac{L_t}{(\alpha\bar{L} - L_t)}(-\frac{\widehat{W_t}}{\alpha})$$

$$= \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right] - \frac{L_t\widehat{W_t}}{\alpha(\bar{L} - L_t)}$$

Re-arranging:

$$<=> \quad \widehat{W_t} + \frac{L_t\widehat{W_t}}{\alpha(\bar{L} - L_t)} = \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right]$$

$$<=> \quad \widehat{W_t}\left[1 + \frac{L_t}{\alpha(\bar{L} - L_t)}\right] = \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right]$$

$$<=> \quad \widehat{W_t}\left[\frac{\alpha(\bar{L} - L_t) + L_t}{\alpha(\bar{L} - L_t)}\right] = \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right]$$

$$<=> \quad \widehat{W_t}\left[\frac{\alpha\bar{L} + (1\text{-}\alpha)L_t}{\alpha\bar{L} - \alpha L_t}\right] = \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right]$$

Re-arranging:

$$\widehat{W_t} = \left[\frac{\alpha\bar{L} - \alpha L_t}{\alpha\bar{L} + \beta L_t}\right]\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right]\widehat{P_{nt}}$$

**QED**

# APPENDIX 8.7

## Solution of the GE short run restricted model

The complete GE model describing the short run restricted model consists of a system of 4 equations and one equilibrium condition.

Supply equations (from equations 8.32 and 8.35):

$$\widehat{X_{nt}} = \frac{\delta\ \theta\ P_t}{\gamma\, CPI}\widehat{P_{nt}} \tag{1}$$

$$\widehat{X_t} = -\left[\frac{\beta\overline{L} - \beta L_t}{\alpha\overline{L} + \beta L_t}\right]\left[\frac{\theta P_t + \gamma(1-\theta)P_{nt}}{\gamma\, CPI}\right]\widehat{P_{nt}} \tag{2}$$

Absorption equation (from Result C in appendix 8.3):

$$\widehat{C_{nt}} = \eta\widehat{Y} + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\, C_{nt}} \tag{3}$$

Income equation (from Result A in appendix 8.3):

$$\widehat{Y} = \lambda\widehat{X_t} + (1-\lambda)\widehat{X_{nt}} + (1-\lambda)\widehat{P_{nt}} \tag{4}$$

Equilibrium condition:

$$\widehat{X_{nt}} = \widehat{C_{nt}} \tag{5}$$

Endogenous variables appearing in this system are $\widehat{X_t}$, $\widehat{X_{nt}}$, $\widehat{P_{nt}}$, $\widehat{C_{nt}}$, $\widehat{Y}$. Predetermined variables are the values of $\overline{L}$, $L_t$, $P_t$, and $P_{nt}$. The only exogenous variable is F. The system can be solved for $\widehat{P_{nt}}^*$, using the substitution of variables method.

$$\text{Let}\left[\frac{\beta\overline{L} - \beta L_t}{\alpha\overline{L} + \beta L_t}\right] = R$$

Substituting for $\widehat{Y}$ in equation 3:

$$\widehat{C_{nt}} = \eta\left[\lambda\widehat{X_t} + (1-\lambda)\widehat{X_{nt}} + (1-\lambda)\widehat{P_{nt}}\right] + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\, C_{nt}} \tag{6}$$

Expanding:

$$\widehat{C_{nt}} = \eta\lambda\widehat{X_t} + \eta(1\text{-}\lambda)\widehat{X_{nt}} + \eta(1\text{-}\lambda)\widehat{P_{nt}} + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\,C_{nt}} \tag{7}$$

Substituting for $\widehat{X_t}$ and $\widehat{X_{nt}}$ in equation 7:

$$\widehat{C_{nt}} = \eta\lambda\left\{-\,R\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma\,CPI}\right]\widehat{P_{nt}}\right\} + \eta(1\text{-}\lambda)\left[\frac{\delta\theta P_t}{\gamma CPI}\widehat{P_{nt}}\right] + \eta(1\text{-}\lambda)\widehat{P_{nt}} + \varepsilon_{nt}\widehat{P_{nt}} + \frac{\sigma F}{P_t\,C_{nt}} \tag{8}$$

Factorising and re-arranging:

$$\widehat{C_{nt}} = \widehat{P_{nt}}\left\{-\eta\lambda R\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma\,CPI}\right] + \frac{\eta(1\text{-}\lambda)\delta\theta P_t}{\gamma CPI} + \eta(1\text{-}\lambda) + \varepsilon_{nt}\right\} + \frac{\sigma F}{P_t\,C_{nt}} \tag{9}$$

Using equations 1 and 9 to substitute for $\widehat{X_{nt}}$ and $\widehat{C_{nt}}$ in equation 5:

$$\frac{\delta\theta P_t}{\gamma CPI}\widehat{P_{nt}} = \widehat{P_{nt}}\left\{-\eta\lambda R\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma\,CPI}\right] + \frac{\eta(1\text{-}\lambda)\delta\theta P_t}{\gamma CPI} + \eta(1\text{-}\lambda) + \varepsilon_{nt}\right\} + \frac{\sigma F}{P_t\,C_{nt}} \tag{10}$$

Re-arranging:

$$\widehat{P_{nt}}\left\{\frac{\delta\theta P_t}{\gamma CPI} + \eta\lambda R\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma\,CPI}\right] - \frac{\eta(1\text{-}\lambda)\delta\theta P_t}{\gamma CPI} - \eta(1\text{-}\lambda) - \varepsilon_{nt}\right\} = \frac{\sigma F}{P_t\,C_{nt}} \tag{11}$$

Factorising $\frac{\delta\theta P_t}{\gamma CPI}$, and re-arranging:

$$\widehat{P_{nt}}^{*} = \frac{\sigma F}{P_tC_{nt}\left\{\frac{\delta\theta P_t}{\gamma CPI}\left[1\text{-}\eta(1\text{-}\lambda)\right] + \eta\lambda\,R\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right] - \eta(1\text{-}\lambda) - \varepsilon_{nt}\right\}} \qquad \textbf{QED}$$

# APPENDIX 8.8

### Proportional change in sector T's nominal wage when $P_{nt}$ changes (long run restricted model)

Recalling the three results derived in appendix 8.6:

*Result A*

$$\widehat{W_t} = \widehat{L_{nt}} - \widehat{L_u} + \widehat{W_{nt}}$$

*Result B*

$$\widehat{L_u} = - \frac{L_t}{(\bar{L} - L_t)} \widehat{L_t}$$

*Result C*

$$\widehat{W_{nt}} = \frac{(1-\theta)\, P_{nt}}{CPI} \widehat{P_{nt}}$$

---

**Derivation of $\widehat{W_t}$**

From Result A:

$$\widehat{W_t} = \widehat{L_{nt}} - \widehat{L_u} + \widehat{W_{nt}}$$

Replacing the terms on the RHS with results already obtained yields:

$$\widehat{W_t} = \widehat{K_{nt}} + \frac{\theta\, Pt}{\gamma CPI} \widehat{P_{nt}} + \frac{L_t}{(\bar{L} - L_t)} \widehat{L_t} + \frac{(1-\theta)\, P_{nt}}{CPI} \widehat{P_{nt}} \qquad (1)$$

Terms one and two on the RHS replace $\widehat{L_{nt}}$ (from equation 8.37); term three replaces - $\widehat{L_u}$ (from Result B above); term four replaces $\widehat{W_{nt}}$ (from Result C). As can be verified from figure 8.8, the total proportional change in $L_t$ must be equal to the sum of the capital effect ($\widehat{K_t}$) and the wage effect ($-\frac{\widehat{W_t}}{\alpha}$). Thus, replacing $\widehat{L_t}$ in equation 1 yields:

$$\Leftrightarrow \quad \widehat{W_t} = \widehat{K_{nt}} + \frac{\theta\, Pt}{\gamma CPI} \widehat{P_{nt}} + \frac{L_t}{(\bar{L} - L_t)} (\widehat{K_t} - \frac{\widehat{W_t}}{\alpha}) + \frac{(1-\theta)\, P_{nt}}{CPI} \widehat{P_{nt}}$$

$$= \widehat{K_{nt}} + \frac{\theta\, Pt}{\gamma\, CPI}\widehat{P_{nt}} + \frac{L_t\,\widehat{K_t}}{(\bar{L} \cdot L_t)} - \frac{L_t\,\widehat{W_t}}{\alpha(\bar{L} - L_t)} + \frac{(1\text{-}\theta)\, P_{nt}}{CPI}\widehat{P_{nt}}$$

Re-arranging and factorising:

$$<=> \quad \widehat{W_t}\,(1 + \frac{L_t}{\alpha(\bar{L} - L_t)}) = \widehat{K_{nt}} + \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right] + \frac{L_t\,\widehat{K_t}}{(\bar{L} - L_t)}$$

$$<=> \quad \widehat{W_t}\left[\frac{\alpha\bar{L} + \beta L_t}{\alpha\bar{L} - \alpha L_t}\right] = \widehat{K_{nt}} + \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right] + \frac{L_t\,\widehat{K_t}}{(\bar{L} - L_t)}$$

$$<=> \quad \widehat{W_t} = \left[\frac{\alpha\bar{L} - \alpha L_t}{\alpha\bar{L} + \beta L_t}\right]\left\{\widehat{K_{nt}} + \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1\text{-}\theta)P_{nt}}{\gamma CPI}\right] + \frac{L_t\,\widehat{K_t}}{(\bar{L} - L_t)}\right\} \qquad \text{QED}$$

# APPENDIX 8.9

## Solution of the GE long run restricted model

The complete GE model describing the long run restricted model consists of a system of 5 equations and one equilibrium condition.

Supply equations (from equations 8.38 and 8.41):

$$\widehat{X_{nt}} = \widehat{K_{nt}} + \frac{\delta\ \theta\ Pt}{\gamma CPI}\widehat{P_{nt}} \tag{1}$$

$$\widehat{X_t} = \widehat{K_t} - \frac{\beta \widehat{W_t}}{\alpha} \tag{2}$$

Tradable sector wage equation (from equation 8.39):

$$\widehat{W_t} = \left[\frac{\alpha\bar{L} - \alpha L_t}{\alpha\bar{L} + \beta L_t}\right]\left\{\widehat{K_{nt}} + \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1-\theta)P_{nt}}{\gamma CPI}\right] + \frac{L_t \widehat{K_t}}{(\bar{L} - L_t)}\right\} \tag{3}$$

Absorption equation (from Result C in appendix 8.3):

$$\widehat{C_{nt}} = \varepsilon_{nt}\widehat{P_{nt}} + \eta\hat{Y} \tag{4}$$

Income equation (from Result A in appendix 8.3):

$$\hat{Y} = \lambda\widehat{X_t} + (1-\lambda)\widehat{X_{nt}} + (1-\lambda)\widehat{P_{nt}} \tag{5}$$

Equilibrium condition:

$$\widehat{X_{nt}} = \widehat{C_{nt}} \tag{6}$$

In this system, endogenous variables are $\widehat{X_t}$, $\widehat{X_{nt}}$, $\widehat{P_{nt}}$, $\widehat{C_{nt}}$, $\hat{Y}$. The pre-determined variables are $\bar{L}$, $L_t$, $P_t$, and $P_{nt}$. The exogenous variables are $\widehat{K_t}$, and $\widehat{K_{nt}}$. The system can be solved for $\widehat{P_{nt}}^*$, using the substitution of variables method.

Substituting for $\widehat{W_t}$ in equation 2:

$$\widehat{X_t} = \widehat{K_t} - \frac{\beta}{\alpha}\left[\frac{\alpha\bar{L} - \alpha L_t}{\alpha\bar{L} + \beta L_t}\right]\left\{\widehat{K_{nt}} + \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1-\theta)P_{nt}}{\gamma CPI}\right] + \frac{L_t \widehat{K_t}}{(\bar{L} - L_t)}\right\} \tag{7}$$

$$= \widehat{K_t} - \left[\frac{\beta\bar{L} - \beta L_t}{\alpha\bar{L} + \beta L_t}\right]\left\{\widehat{K_{nt}} + \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1-\theta)P_{nt}}{\gamma CPI}\right] + \frac{L_t\widehat{K_t}}{(\bar{L} - L_t)}\right\} \tag{8}$$

$$\text{Let}\left[\frac{\beta\bar{L} - \beta L_t}{\alpha\bar{L} + \beta L_t}\right] = R$$

$$\widehat{X_t} = \widehat{K_t} - R\left\{\widehat{K_{nt}} + \widehat{P_{nt}}\left[\frac{\theta P_t + \gamma(1-\theta)P_{nt}}{\gamma CPI}\right] + \frac{L_t\widehat{K_t}}{(\bar{L} - L_t)}\right\} \tag{9}$$

Substituting for $\hat{Y}$ in equation 4:

$$\widehat{C_{nt}} = \eta\left[\lambda\widehat{X_t} + (1-\lambda)\widehat{X_{nt}} + (1-\lambda)\widehat{P_{nt}}\right] + \varepsilon_{nt}\widehat{P_{nt}} \tag{10}$$

Expanding and substituting for $\widehat{X_t}$ and $\widehat{X_{nt}}$:

$$\widehat{C_{nt}} = \eta\lambda\left\langle\widehat{K_t} - R\left\{\widehat{K_{nt}} + \widehat{P_{nt}}\left[\frac{\theta P_t+\gamma(1-\theta)P_{nt}}{\gamma CPI}\right] + \frac{L_t\widehat{K_t}}{(\bar{L} - L_t)}\right\}\right\rangle$$
$$+ \eta(1-\lambda)\left[\widehat{K_{nt}} + \frac{\delta\theta P_t}{\gamma CPI}\widehat{P_{nt}}\right] + \eta(1-\lambda)\widehat{P_{nt}} + \varepsilon_{nt}\widehat{P_{nt}} \tag{11}$$

$$\text{Let}\left[\frac{\theta P_t+\gamma(1-\theta)P_{nt}}{\gamma CPI}\right] = a_1;\ \text{let}\ \frac{L_t}{(\bar{L} - L_t)} = a_2;\ \text{let}\ \frac{\delta\theta P_t}{\gamma CPI} = a_3.$$

Expanding $\widehat{C_{nt}}$:

$$\widehat{C_{nt}} = \eta\lambda\left\{\widehat{K_t} - R\widehat{K_{nt}} - Ra_1\widehat{P_{nt}} - Ra_2\widehat{K_t}\right\} + \eta(1-\lambda)\widehat{K_{nt}}$$
$$+ \eta(1-\lambda)a_3\widehat{P_{nt}} + \eta(1-\lambda)\widehat{P_{nt}} + \varepsilon_{nt}\widehat{P_{nt}} \tag{12}$$

$$= \eta\lambda\widehat{K_t} - \eta\lambda R\widehat{K_{nt}} - \eta\lambda Ra_1\widehat{P_{nt}} - \eta\lambda Ra_2\widehat{K_t} + \eta(1-\lambda)\widehat{K_{nt}}$$
$$+ \eta(1-\lambda)a_3\widehat{P_{nt}} + \eta(1-\lambda)\widehat{P_{nt}} + \varepsilon_{nt}\widehat{P_{nt}} \tag{13}$$

$$= \widehat{K_t}\left[\eta\lambda-\eta\lambda Ra_2\right] + \widehat{K_{nt}}\left[\eta(1-\lambda)-\eta\lambda R\right] + \widehat{P_{nt}}\left[-\eta\lambda Ra_1+\eta(1-\lambda)a_3+\eta(1-\lambda)+\varepsilon_{nt}\right] \tag{14}$$

Using equations 1 and 14 to substitute for $\widehat{X_{nt}}$ and $\widehat{C_{nt}}$ in equation 6:

$$\widehat{K_{nt}}+\frac{\delta\theta P_t}{\gamma CPI}\widehat{P_{nt}}=\widehat{K_t}\left[\eta\lambda-\eta\lambda Ra_2\right]+\widehat{K_{nt}}\left[\eta( -\lambda)-\eta\lambda R\right]+\widehat{P_{nt}}\left[-\eta\lambda Ra_1+\eta(1-\lambda)a_3+\eta(1-\lambda)+\varepsilon_{nt}\right] \quad (15)$$

Re-arranging and factorising:

$$\widehat{P_{nt}}\left[a_3+\eta\lambda Ra_1-\eta(1-\lambda)a_3-\eta(1-\lambda)-\varepsilon_{nt}\right]=\widehat{K_t}\left[\eta\lambda-\eta\lambda Ra_2\right]+\widehat{K_{nt}}\left[\eta(1-\lambda)-\eta\lambda R\right]-\widehat{K_{nt}} \quad (16)$$

The RHS of equation 16 is equivalent to:

$$\widehat{K_t}\left[\eta\lambda-\eta\lambda Ra_2\right]+\widehat{K_{nt}}\left[\eta(1-\lambda)-\eta\lambda R\right]-\widehat{K_{nt}}$$

$$=\widehat{K_t}\left[\eta\lambda(1-Ra_2)\right]+\widehat{K_{nt}}\left[\eta(1-\lambda)-\eta\lambda R-1\right]$$

$$=\widehat{K_t}\left\langle \eta\lambda\left\{1-\left[\frac{\beta\bar{L}-\beta L_t}{\alpha\bar{L}+\beta L_t}\right]\left[\frac{L_t}{(\bar{L}-L_t)}\right]\right\}\right\rangle+\widehat{K_{nt}}\left[\eta-\eta\lambda-\eta\lambda R-1\right]$$

$$=\eta\lambda\left[1-\left(\frac{\beta L_t}{\alpha\bar{L}+\beta L_t}\right)\right]\widehat{K_t}-\left[1+\eta\lambda(1+R)-\eta\right]\widehat{K_{nt}}$$

The LHS of equation 16 is equivalent to:

$$\widehat{P_{nt}}\left[a_3+\eta\lambda Ra_1-\eta(1-\lambda)a_3-\eta(1-\lambda)-\varepsilon_{nt}\right]$$

$$=\widehat{P_{nt}}\left\{\frac{\delta\theta P_t}{\gamma CPI}\left[1-\eta(1-\lambda)\right]+\eta\lambda R\left[\frac{\theta P_t+\gamma(1-\theta)P_{nt}}{\gamma CPI}\right]-\eta(1-\lambda)-\varepsilon_{nt}\right\}$$

Substituting for the LHS and the RHS of equation 16:

$$\widehat{P_{nt}}\left\{\frac{\delta\theta P_t}{\gamma CPI}\left[1-\eta(1-\lambda)\right]+\eta\lambda R\left[\frac{\theta P_t+\gamma(1-\theta)P_{nt}}{\gamma CPI}\right]-\eta(1-\lambda)-\varepsilon_{nt}\right\}$$

$$=\eta\lambda\left[1-\left(\frac{\beta L_t}{\alpha\bar{L}+\beta L_t}\right)\right]\widehat{K_t}-\left[1+\eta\lambda(1+R)-\eta\right]\widehat{K_{nt}} \quad (17)$$

Re-arranging:

$$\widehat{P_{nt}}^{*} = \frac{\eta\lambda\left[1 - \left(\frac{\beta L_t}{\alpha\bar{L}+\beta L_t}\right)\right]\widehat{K_t} - \left[1+\eta\lambda(1+R)-\eta\right]\widehat{K_{nt}}}{\left\{\frac{\delta\theta P_t}{\gamma CPI}\left[1-\eta(1-\lambda)\right] + \eta\lambda\, R\left[\frac{\theta P_t + \gamma(1-\theta)P_{nt}}{\gamma CPI}\right] - \eta(1-\lambda) - \varepsilon_{nt}\right\}} \qquad \textbf{QED}$$

# APPENDIX 9.1

**I. Data and results of OLS regression analysis used to estimate the absorption of non-tradables function in the Cook Islands.**

I.1 *Data*

All data are from the Cook Islands' national accounts and price statistics contained in the South Pacific Economic and Social Database (NCDS). $X_{nt}$ measures the production of non-tradables, except 'Construction', deflated by a weighted index of tradable commodities (food, alcohol and tobacco, clothing and textiles) in the CPI (1982 = 100). $P_{nt}/P_t$ is a ratio of a similarly derived index of non-tradables prices (housing, household and operation, transport) to the index of tradables prices, as previously defined. Y is a measure of real GDP, obtained by deflating the nominal value of non-subsistence GDP by the index of the price of tradables.

**Cook Islands data**

| Year | $X_{nt}$ | Y | $P_{nt}/P_t$ |
|---|---|---|---|
| 1982 | 23187 | 25866 | 1.000 |
| 1983 | 23332 | 24109 | 0.926 |
| 1984 | 27004 | 32052 | 1.058 |
| 1985 | 30347 | 40747 | 1.207 |
| 1986 | 32767 | 48042 | 1.314 |
| 1987 | 33337 | 47166 | 1.265 |
| 1988 | 35820 | 76445 | 1.924 |
| 1989 | 39785 | 69806 | 1.618 |
| 1990 | 41476 | 73095 | 1.656 |

**Note**: All values in 1982 NZ$'000.
**Source**: Constructed from SPD data.

I.2 *Regression results*

Dependent variable: ln $X_{nt}$
Independent variables:

| Variable Name | Coefficient | Std. Err. Estimate | t Statistic | Prob > t |
|---|---|---|---|---|
| Constant | -0.7611 | 0.6646 | -1.1453 | 0.290 |
| ln Y | 1.0633 | 0.0648 | 16.4196 | 0.000 |
| ln (Pnt/Pt) | -1.0667 | 0.1144 | -9.3269 | 0.000 |

Diagnostic tests:

| Source | Sum of Squares | Deg. of Freedom | Mean Squares | F-Ratio | Prob>F |
|---|---|---|---|---|---|
| Model | 0.3588 | 2 | 0.1794 | 799.7621 | 0.000 |
| Error | 0.0013 | 6 | 0.0002 | | |
| Total | 0.3601 | 8 | | | |

| | |
|---|---|
| Coefficient of Determination (R^2) | 0.9963 |
| Adjusted Coefficient (R^2) | 0.9950 |
| Coefficient of Correlation (R) | 0.9981 |
| Standard Error of Estimate | 0.0150 |
| Durbin-Watson Statistic | 0.7162 |

**II. Data and results of OLS regression analysis used to estimate the absorption of non-tradables function in Kiribati.**

II.1 *Data*

All data are from Kiribati's national accounts and price statistics contained in the South Pacific Economic and Social Database. $X_{nt}$ measures the production of non-tradables, except 'Construction', deflated by a weighted index of tradable commodities (food, alcohol and tobacco, clothing) in the CPI (1980 = 100). $P_{nt}/P_t$ is a ratio of a similarly derived index of non-tradables prices (housing and transport, household, miscellaneous) to the index of tradables prices, as previously defined. Y is a measure of real GDP, obtained by deflating the nominal value of non-subsistence GDP by the index of the price of tradables.

**Kiribati data**

| Year | $X_{nt}$ | Y | $P_{nt}/P_t$ |
|---|---|---|---|
| 1980 | 16791 | 20277 | 1.000 |
| 1981 | 16191 | 20550 | 1.074 |
| 1982 | 18985 | 23167 | 1.107 |
| 1983 | 17774 | 23061 | 1.135 |
| 1984 | 16623 | 23813 | 1.156 |
| 1985 | 17903 | 21932 | 1.171 |
| 1986 | 18429 | 23313 | 1.201 |
| 1987 | 18675 | 22209 | 1.248 |
| 1988 | 19370 | 27267 | 1.234 |

**Note**: All values in 1980 A$'000.
**Source**: Constructed from SPD data.

## II.2 *Regression results*

Dependent variable: ln $X_{nt}$
Independent variables:

| Variable Name | Coefficient | Std. Err. Estimate | t Statistic | Prob > t |
|---|---|---|---|---|
| Constant | 6.9041 | 2.7756 | 2.4874 | 0.042 |
| lnY | 0.2828 | 0.2798 | 1.0105 | 0.346 |
| Ln(Pnt/Pt) | 0.3498 | 0.3486 | 1.0035 | 0.349 |

Diagnostic tests:

| Source | Sum of Squares | Deg. of Freedom | Mean Squares | F-Ratio | Prob>F |
|---|---|---|---|---|---|
| Model | 0.0164 | 2 | 0.0082 | 3.1874 | 0.114 |
| Error | 0.0155 | 6 | 0.0026 | | |
| Total | 0.0319 | 8 | | | |

| | |
|---|---|
| Coefficient of Determination (R^2) | 0.5151 |
| Adjusted Coefficient (R^2) | 0.3535 |
| Coefficient of Correlation (R) | 0.7177 |
| Standard Error of Estimate | 0.0508 |
| Durbin-Watson Statistic | 2.5748 |

# APPENDIX 9.2

## Estimation of labour's share of sectoral income in the Cook Islands

| Item | | | Year 1989 | Year 1990 | Source |
|---|---|---|---|---|---|
| Average weekly earnings (NZ$) | | | | | |
| (A) | Sector | T | 149.7 | 153.7 | SPD |
| | | NT | 198.8 | 205.3 | SPD |
| Average yearly earnings (NZ$) | | | | | |
| (B = A x 52) | Sector | T | 7,784 | 7,992 | |
| | | NT | 10,338 | 10,676 | |
| Sectoral employment | | | | | |
| (C) | Sector | T | 589 | 651 | SPD |
| | | NT | 3,908 | 4,084 | SPD |
| Yearly wage bill (NZ$M) | | | | | |
| (D = B x C) | Sector | T | 4.584 | 5.202 | |
| | | NT | 40.40 | 43.60 | |
| Sectoral output value (NZ$M) | | | | | |
| (E) | Sector | T | 6.629 | 6.598 | SPD |
| | | NT | 77.877 | 83.079 | SPD |
| Sectoral labour shares | | | | | |
| (F = D/E) | Sector | T | *0.69* | *0.78* | |
| | | NT | *0.52* | *0.52* | |

# APPENDIX 9.3

## Equality between $W_t$ and the average labour income per member of the labour force ($B/\bar{L}$) in the restricted model

Let $B = L_t W_t + L_{nt} W_{nt}$ (1)

Given: $W_t = \frac{L_{nt}}{L_u} W_{nt}$

=> $W_{nt} = \frac{L_u}{L_{nt}} W_t$

Replacing $W_{nt}$ in equation 1:

$$B = L_t W_t + L_{nt} \frac{L_u}{L_{nt}} W_t$$

<=> $B = L_t Wt + L_u W_t$

<=> $B = W_t (L_t + L_u)$

Since $L_t + L_u = \bar{L}$, this is equivalent to:

$$B = \bar{L}\ W_t$$

<=> $W_t = \frac{B}{\bar{L}}$ **QED**

# APPENDIX 9.4

## Estimation of labour s share of sectoral income in Kiribati

| Item (All values in A$ '000) | Year 1987 | Year 1988 | Source |
|---|---|---|---|
| Compensation of employees (B) | 17,500 | 18,000 | SPD |
| Total formal sector labour force ($\bar{L}$) | 10,968 [a] | 11,200 [a] | SPD |
| Yearly earnings per worker ($W_t = B/\bar{L}$) | 1.595 | 1.607 | |
| Employment in the T sector ($L_t$) | 2,948 [a] | 3,010 [a] | AIDAB 1992a |
| Wage bill in the T sector ($B_t = L_t \times W_t$) | 4,702 | 4,837 | |
| Value of T sector output ($V_t = X_t \times P_t$) | 5,617 | 11,678 | SPD |
| Labour's income share in the T sector ($B_t/V_t$) | *0.84* | *0.41* | |
| Employment in the NT sector ($L_{nt}$) | 7,345 [a] | 7,501 [a] | AIDAB 1992a |
| Wage bill in the NT sector ($B_{nt} = B - B_t$) | 12,798 | 13,163 | |
| Value of NT sector output ($V_{nt}$) | 24,030 | 26,496 | SPD |
| Labour's income share in the NT sector ($B_{nt}/V_{nt}$) | *0.53* | *0.50* | |

[a] Based on 1990 figures deflated by the rate of overall population growth.

# APPENDIX 9.5

**Increase in $\frac{W_t}{CPI}$ in the short run restricted model**

From appendix 8.6 (Result A):

$$\widehat{W_t} = \widehat{L_{nt}} - \widehat{L_u} + \widehat{W_{nt}}$$

Given that, by definition, $\widehat{W_{nt}} = \widehat{CPI}$, this can be re-written as:

$$\widehat{W_t} = \widehat{L_{nt}} - \widehat{L_u} + \widehat{CPI}$$

Re-arranging:

$$\widehat{W_t} - \widehat{CPI} = \widehat{L_{nt}} - \widehat{L_u}$$

This expression measures the proportional change in $\frac{W_t}{CPI}$.
Replacing the terms on the right hand side with their values from table 9.12:

$$\widehat{W_t} - \widehat{CPI} = 15.54 - 9.09 = 6.45$$ **QED**

**Increase in $\frac{W_t}{CPI}$ in the long run restricted model**

By analogy with the procedure used above, and using the long run values appearing in table 9.14:

$$\widehat{W_t} - \widehat{CPI} = 5.81 - 0.59 = 5.22$$ **QED**

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