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A general equilibrium model of Papua New Guinea Part I

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Key to symbols used in tables

n.a.	Not applicable
..	Not available
-	Zero
.	Insignificant

Theodore Levantis has just completed a PhD thesis on the structure of the labour market in Papua New Guinea at the Research School of Pacific and Asian Studies, The Australian National University.

abstract

This paper outlines the most recent version of a computable general equilibrium model of Papua New Guinea operated by the National Centre for Development Studies. The purpose is to give a complete overview of the structure of the model. In general, the model follows the ORANI framework, but with crime being so prevalent in Papua New Guinea, particular attention is paid to its adaption into the model. An important feature of the model is its ability to derive an equivalent variation measure of the change in welfare, disaggregated across various components.

a general equilibrium model of Papua New Guinea

1. The model

Computable general equilibrium (CGE) models can provide extremely valuable tools in assessing policy proposals. Typical uses of CGE models include assessments of prospective changes in tax or tariff structures or of reviews in labour market policy. CGE models are also used to understand the implications of exogenous changes in the economy such as an exchange rate adjustment (exogenous under conditions of a floating exchange rate) or a price shock on an important export commodity. In this paper we develop a CGE model for Papua New Guinea. The general purpose of the paper is to provide a thorough description of the basic structure of the model with the complete model being presented in the appendices. The model is an 'ORANI' type static general equilibrium model which, as described by Dervis (1975:78), postulates '...neo-classical production functions and price responsive demand functions, linked around an input-output matrix in a Walrasian general equilibrium model that endogenously determines quantities and prices' (cited in Dixon et al. 1982:5).[1] The general function of the model is to allow comparisons to be made between the new Walrasian equilibrium of the economy and the initial equilibrium after an exogenous shock is imposed on the initial equilibrium. The exogenous shock may be due to a policy change or the result of an exogenous change outside the control of the policymakers. A feature of this type of model is that the final impact on each endogenous variable can be traced and, importantly, the effect of the shock on social welfare can be estimated. What makes the use of CGE models particularly attractive is that its application is made practical with the well developed GEMPACK software specifically designed for this class of models. To counter these attributes, a significant disadvantage is that these are one period models since only the initial point in time and the end point at which equilibrium is restored are considered. With this restriction there can be no sense in savings and investment as utility can only be realised in the reference period. To overcome these deficiencies one could use a dynamic general equilibrium model which incorporates intertemporal decision-making, however, the benefits are somewhat offset by the increases in complexity. The equations of our model are generally non-linear, however computational problems are avoided by following the Johansen procedure of linearising the system into change variables.[2]

This is not the first time a CGE model has been developed for Papua New Guinea. Vincent et al. (1991) developed a model which was later updated by Woldekiden (1993). The model developed in this paper, is significantly different, nevertheless it shares similarities in its structure (as do all models of the ORANI family) with these earlier works. The major differences between the model presented here and the Vincent model is the inclusion of a comprehensive description of the labour market, the treatment of crime and the informal sector, and the ability to derive an equivalent variation measure for the change in social welfare. A somewhat large and cumbersome database has been created for this model, however, its design and derivation is not discussed in detail.[3] Information on the sources of data for each coefficient of the model are presented in Appendix 3. An important feature of the database is that it is structured so that the data are consistent. For example, the aggregate value of commodities purchased for private consumption or investment purposes must equate with total disposable income. As a further example, the total revenue received from output for each industry must equate to the application of these funds to costs and to payments to the recipients of profits. All data in the model are from 1994 and are scaled in thousands of kina.

In determining the equations and closure for the model a sources and uses of funds approach is followed. By ensuring that for each use of funds there is a corresponding source, the model becomes robust and the closure complete. The next section of the paper provides definitions of industry and commodity categories and the remainder of the paper describes the model structure in detail.

2 Industry and commodity categories

2.1 Industry and commodity categories in general

There are 42 distinct industry categories identified for Papua New Guinea which are aggregated into four industry sectors: the village, plantation, urban and urban murky sectors. It is taken that labour is separated into these sectors of the economy and these subsets of industries are identified to reflect this assumption. This separation of industry sectors is essential to allow us to provide a Harris-Todaro type labour market structure in the model. A list of industries including the industry sector that each industry belongs to is provided in Table 1. The village sector covers traditional village-based smallholders and is subdivided into the main export crop industries and a ‘traditional agriculture’ industry for those not engaged in export crop production. All formal largeholder producers are considered to be part of the plantation sector, and besides the main export crop industries, this sector includes ‘fruit and vegetables’, ‘fishing’, ‘forestry’, and ‘other agriculture’. The latter industry mainly entails beef, eggs and sugar. We could perhaps think of the urban sector as the modern sector since it encompasses all modern sector industries including mining industries. Because of the importance of the Porgera and Ok Tedi mines relative to the overall size of the economy, they are given separate industry categories. Apart from the mining industries the remainder of the modern sector is subdivided into various manufacturing and service industries. All industries from ‘road transport’ to ‘security services’ are service industries (Table 1). The concept of the ‘urban murky’ sector is introduced by Fields (1975) and embraces all legitimate and illegitimate informal income earning activities. The ‘informal retail’ industry is taken as the legitimate side of the murky sector and mainly comprises street-vending type operations, while ‘crime’ is of course the illegitimate ‘industry’. The peculiar step of including crime as a separate ‘industry’ in the model is taken because of its importance in the economy and the labour market. Consistent with national accounting standards, the ‘commerce’ and ‘informal retail’ industries are margin industries so that the value of the service commodities produced by these industries is the retail margin and not the gross value of sales. Purchases for resale are therefore not considered as intermediate inputs and so are considered not to be ‘used’ by the industry.

The 37 commodities produced by these industries are shown in Table 2 with an indication of the commodities subject to import competition and which commodities are exported. The Armington assumption is adopted in the model so that the imported commodities are imperfect substitutes for the domestically produced commodities. In this sense, we can think of the imported and domestically produced varieties as being distinct commodities belonging to the same commodity group. Those domestically produced commodities that are not exported we consider as non-traded goods. All industries are assumed to produce a single commodity except for those of the village sector, the ‘other agriculture’ industry, and the mining industries. This fact can be seen in the output matrix of Appendix 4. Further, all tree crop commodities, ‘fruit, vegetables & betel nut’, ‘non-ruminant livestock’, ‘gold’ and ‘other minerals’ are produced across more than one industry.

2.2. The category of ‘crime’

Special discussion of the industry and commodity group ‘crime’ is required. The ‘crime’ industry we could think of as consisting of ‘self-employed’ criminals engaging in illegitimate activities. For the purposes of our model we will consider larceny as the only activity of this industry so that crimes with motivations other than a transfer of wealth are not covered. We can think of the ‘crime’ industry (perversely) as a service industry where output is represented by the payoffs of the industry’s larcenous activities. It is assumed that the recipients of the larcenous activities (i.e. the victims) are purchasers of the output of the ‘crime’ industry, and the price paid for a crime is the payoff. Categorising the ‘crime’ industry as a ‘service’ industry would seem to be ludicrous because of the unpalatable nature of its activities. When a commodity is purchased by a rational agent, whether it be a consumer or a business purchasing an input, the transaction is performed with the expectation that the benefits accruing from the acquisition of the commodity would not be exceeded by the outlay. This is naturally the case otherwise the transaction would not proceed. Clearly this proposition does not apply in the case of the 'purchase' of crime since the cost of the purchase (the payoff) is not offset by any benefits for the purchaser. The 'transaction' nevertheless proceeds, however, because it is *involuntarily* imposed on the buyer. It is this involuntary nature of the purchase of crime which distinguishes it from other service commodities.

The cost of crimes of larceny we disaggregate in the CGE model between households, businesses and the government. For households, transfers made due to larceny are considered to be involuntary consumption expenditures on the commodity of crime. These directly affect the budget constraint for voluntarily consumed goods which are assumed to be purchased according to conventional utility maximisation theory. This is expanded on further in Section 5.1. The 'purchases' of crime by the government are similarly thought of as involuntary government consumption expenditure and so directly affect the government budget. Whereas we sidestep the problem of modelling behaviour in government expenditure on commodities that are voluntarily purchased by assuming them to be exogenous, the involuntary purchases of crime are endogenous to the model. We explain government expenditure on crime further in Sections 5.2 and 9.2. Expenditure on crime by producers is dealt with as involuntarily imposed intermediate input purchases and this is discussed in Section 6.5. All other intermediate input purchases are made according to profit maximisation principles.

In addition to the property transferred to larcenists, crime typically imposes significant external costs to the community. An example of this is the property damage that may occur in the process of performing a larceny. These external costs require special treatment in the model as they do not represent any flow of funds yet are a cost to society. In a sense, we could think of these losses as a withdrawal of funds from the economy and so we can treat them as funds transferred abroad.[4] In this way, we can interpret the imposition of external costs as equivalent to having funds 'thrown to sea'. For businesses, the losses due to external costs are taken as directly affecting the return to capital, while for the government, the external costs directly impact upon the budget position. The effect of the external costs for households is felt by the direct impact on disposable income.

3. The central equations of the model: a sources and applications of funds approach

The economy of Papua New Guinea is ultimately driven by the utility its residents receive from the consumption of commodities and this provides the motivation to source funds to apply to the purchase of commodities. The desire of people to provide their labour or capital as factors of production is based on this motivation to source funds, and production units are set up with the objective of earning profits so as to return funds to the owners. The motivation for the central government to source its funds (ultimately at the expense of income to the people), at least for the purposes of our model, is to provide public goods and the utility received from public goods serves the desire of the people to have a central government. The circular flow of funds in the economy can ultimately be summarised by the Walrasian general equilibrium condition at (3.1) and it is this condition that forms the central equation of our model. This condition is verbally described by (3.1a) with the supply of goods on the left hand side and the demand on the right hand side of the equation. Imports are given on the left hand side since they are the supply of commodities produced externally. Essentially, the general equilibrium model is a disaggregation of (3.1) where all the equations can be related back to it. Each term in (3.1) that represents an application of funds must have a corresponding source and vice versa; furthermore equilibrium conditions that spin off (3.1) will be required to capture these flows. Because the model is a disaggregation of equation (3.1) it will be a descriptive equation that does nothing more than summarise the model and so does not enter into the model itself; that is, no variable will be explained by this equation.

Table 1 **Industry categories of the Papua New Guinea model**

Industry	*Sector*	*Industry*	*Sector*
1. traditional agriculture 2. smallholder coffee 3. smallholder cocoa 4. smallholder palm oil 5. smallholder copra 6. smallholder other tree crops	Village sector industries	16. Porgera mining 17. Ok Tedi mining 18. other mining 19. oil mining 20. quarrying 21. timber processing	Modern sector industries
7. plantation coffee 8. plantation cocoa 9. plantation palm oil 10. plantation copra 11. plantation other tree crops 12. plantation fruit and veg 13. other agriculture 14. fishing 15. forestry	Plantation sector industries	22. food processing 23. beverages and tobacco 24. metals and engineering 25. machinery 26. chemicals and oils 27. petroleum refining 28. other manufacturing 29. road transport 30. water transport 31. air transport 32. education 33. health 34. electricity and garbage 35. building and construction 36. commerce 37. finance and investment 38. govt admin and defence 39. other services 40. security services	
		41. informal retail 42. crime	Murky sector industries

Table 2 **Commodity categories of the Papua New Guinea model**

Commodity	Exported?	Imported substitute?	Commodity	Exported?	Imported substitute?
1. fruit, vegies and betel nut	non-traded	yes	20. machinery	non-traded	yes
2. non-ruminant livestock	non-traded	yes	21. chemicals and oils	exported	yes
3. coffee	exported	no	22. refined petroleum	non-traded	yes
4. cocoa	exported	no	23. other manufacturing	exported	yes
5. palm oil	exported	no	24. road transport	non-traded	yes
6. copra	exported	no	25. water transport	exported	yes
7. other tree crops	exported	no	26. air transport	exported	yes
8. other agriculture	exported	yes	27. education	non-traded	no
9. fishing	exported	yes	28. health	non-traded	no
10. forestry	exported	no	29. electricity and garbage	non-traded	no
11. copper	exported	no	30. building and construction	non-traded	no
12. gold	exported	no	31. commerce	exported	yes
13. other minerals	exported	yes	32. finance and investment	exported	no
14. crude oil	exported	no	33. govt admin and defence	non-traded	no
15. quarrying	non-traded	yes	34. other services	exported	yes
16. timber processing	exported	yes	35. security services	non-traded	no
17. food processing	non-traded	yes	36. informal retail	non-traded	no
18. beverages and tobacco	non-traded	yes	37. crime	non-traded	no
19. metals and engineering	non-traded	yes			

The complications of explaining real investment demand within a one-period model are avoided by assuming it to be exogenously determined. Further, we escape from explaining government behaviour in purchases for consumption and investment by also assuming them to be exogenous (with the exception of government consumption of the 'crime' commodity).

production + imports = intermediate inputs + consumption + investment
+ govt consumption + govt investment + exports (3.1a)

$$PX = PX^1 + PX^2 + PX^3 + PX^4 + PX^5 + PX^6 \tag{3.1}$$

where

$P = \{P_{1,1}, \ldots, P_{37,1}, P_{1,2}, \ldots, P_{37,2}\}$ = *the price vector of commodities 'is' before any consumption tax distortions but after production taxes - hence, for traded goods, it is the world price vector, for imported goods it is c.i.f.*

$X = \{X_{1,1}, \ldots, X_{37,1}, X_{1,2}, \ldots, X_{37,2}\}$ = *the supply vector of commodities 'is'*

$X^1 = \{X^1_{1,1},\ldots,X^1_{37,1},X^1_{1,2},\ldots,X^1_{37,2}\}$ = *intermediate input usage vector of commodities 'is'*

$X^2 = \{X^2_{1,1},\ldots,X^2_{37,1},X^2_{1,2},\ldots,X^2_{37,2}\}$ = *consumer demand vector for commodities 'is'*

$X^3 = \{X^3_{1,1},\ldots,X^3_{37,1},X^3_{1,2},\ldots,X^3_{37,2}\}$ = *private investment demand vector for commodities 'is'*

$X^4 = \{X^4_{1,1},\ldots,X^4_{37,1},X^4_{1,2},\ldots,X^4_{37,2}\}$ = *government consumption vector of commodities 'is'*

$X^5 = \{X^5_{1,1},\ldots,X^5_{37,1},X^5_{1,2},\ldots,X^5_{37,2}\}$ = *government investment demand for commodities 'is'*

$X^6 = \{X^6_{1,1},\ldots,X^6_{37,1}\}$ = *export demand vector for commodities 'i1'*

and, 'i' refers to the commodity group as defined in Table 2 where there are 37 commodities,
's' refers to the variety of the commodity where $s = 1$ *is the domestically produced good and* $s = 2$ *the imported good.*

The circular flow of funds explained by the Walrasian equilibrium condition of equation (3.1) is broken down into four sectors of the economy: the production sector, household sector, government sector, and the foreign trade sector. The details of the disaggregation of the Walrasian condition are discussed below (see Appendix 4 for a summary of the disaggregation in a flow chart). First, consider the term on the left hand side of (3.1) for production of domestically produced goods (that is, for $s=1$). Pure profits are not explicitly defined in the model, so, for the village and murky sector industries, where there is assumed to be no capital employed, profits are given as returns to labour. For all other industries, profits are returned to capital. The funds earned in selling output (at the undistorted prices) will therefore be applied to: the purchase of intermediate inputs (including crime); the payment of taxes to the government in the form of production taxes, import taxes on imported intermediate inputs, company profit taxes and other taxes; payments to factors of production; and payments due to the external effects of crime. In Section 2.2 we mentioned that the victims of crime typically incur significant external costs in addition to the property lost to larcenists. Whereas transfers to criminals are treated as involuntary intermediate input purchases, the funds lost by businesses in financing the external losses due to crime we treat as a separate application of funds. The sources and applications of funds for the production sector of the economy are described by (3.2a) and (3.2), where the left hand side gives the source of funds and the right hand side the applications.

production = intermediate inputs + tax payments + factor payments
+ external costs of crime (3.2a)

$$P_1 X_1 = PX^1 + (T^x P_1 X_1 + T^m P_2 X^1_2 + T^k R^g K + T^o) + (W^g N + RK) + \Lambda^k \qquad (3.2)$$

where the subscripts refer to the variety of the commodity (i.e. '1' refers to domestically produced commodities and '2' imported commodities); and

$T^x = \{T_1^x, \ldots, T_{37}^x\}$ = *the ad valorem production tax vector (negative if a production subsidy)*
$T^m = \{T_1^m, \ldots, T_{37}^m\}$ = *the ad valorem import tariff vector*
T^k = *tax rate on company profits*
T^o = *total other lump sum tax payments to the government made by businesses*
$W^g = \{W_{unskill,1}^g, \ldots, W_{unskill,42}^g, W_{skill,1}^g, \ldots, W_{skill,42}^g\}$ = *the vector of gross wage rates paid by each of the 42 industries (as defined in Table 1) and each skill level*
$N = \{N_{unskill,1}, \ldots, N_{unskill,42}, N_{skill,1}, \ldots, N_{skill,42}\}$ = *the vector of employment in each wage category*
$R^g = \{R_1^g, \ldots, R_{42}^g\}$ = *the vector of gross rental rates of capital in each industry*
$R = \{R_1, \ldots, R_{42}\}$ = *the vector of net rental rates of capital in each industry*
$K = \{K_1, \ldots, K_{42}\}$ = *the vector of private capital stock in each industry*
Λ^k = *total external costs of crime imposed on businesses*

All variables in (3.2) are endogenous except for the tax rate vectors and capital stock. Appendix 1, at the end of the chapter, presents the CGE model in linearised change and percentage change form (where percentage change variables are represented by lower case). The variables of the model are detailed in Appendix 2 and the parameters and coefficients in Appendix 3. Equation (3.2) can be disaggregated to an industry level, so, for a representative industry we differentiate (3.2) and put it into percentage change form. This is given at equation (1.1) of Appendix 1.

Consumers and private investors source their funds from government transfers and from the rents received by supplying their factors to producers. These funds are applied to the purchase of consumption and investment goods (including involuntary consumption purchases of crime), to the external losses incurred by victims of crime (discussed in Section 2.2), and to the payment of income taxes, consumption taxes and import tariffs. The cost of crime due to the transfer of wealth to criminals is treated as an involuntary consumption of the crime commodity and so is embraced in the consumption term. Papua New Guinea typically operates a current account surplus offset by net outflows of capital, predominantly comprising of repayments on loans. In addition, the current account incorporates a large net outflow of dividend payments. These repatriated returns and repayments to capital are accounted for in our model by deducting them from the households' source of funds. The value of this we take as exogenous to the model. Papua New Guinea also operates a budget deficit which we similarly account for in the model by allowing it to be financed by the private sector. The return to capital that flows to the household sector is reduced by the amount of the deficit. In the same way as for the current account surplus, the budget deficit is treated as exogenous to the model so that simulations are interpreted as the effects given a constant current account and budgetary position. The applications of funds are given on the right hand side of (3.3a) and (3.3), while the sources of funds for the household sector are on the left hand side. For a clearer picture of where the funds sourced come from and where the applications go to refer to Appendix 4. Equations (1.2)-(1.3) of Appendix 1 provide the percentage change form of (3.3), with the modification of splitting (3.3) into two equations; one explaining the sources of disposable income and the other the applications of disposable income.

net factor payments + govt transfers = consumption + investment
+ tax payments + external costs of crime (3.3a)

$$(W^g N + RK - B - Q) + G^o$$
$$= PX^2 + PX^3 + [T^w W^g N + T^c \hat{P} X^2 + T^m P(X_2^2 + X_2^3)] + \Lambda^c \qquad (3.3)$$

where

$\hat{P} = \{\hat{P}_{1,1}, \ldots, \hat{P}_{37,1}, \hat{P}_{1,2}, \ldots, \hat{P}_{37,2}\}$ = *price vector after the imposition of import tariffs (the domestic good elements will, of course, be the same as for the undistorted price vector)*

$T^c = \{T_1^c, \ldots, T_{37}^c\}$ = *ad valorem tax rate on consumption goods*

T^w = *income tax rate*

G^o = *transfers from the government*

B = *exogenous value of transfers to the government to finance the budget deficit*

Q = *exogenous value of transfers of returns and repayments to capital to the foreign owners*

Λ^c = *total external costs of crime incurred by households*

The government sources its funds for investment, consumption (which includes direct involuntary payments to crime), transfers, and external losses due to crime from the various types of tax collections as well as from the receipt of foreign aid and from government borrowings. The treatment of the external costs of crime as a direct application of funds is consistent with the approach used for producers and consumers. We assume that the government maintains a constant budgetary position. The bottom line of this assumption is that comparative static exercises are performed given that the government compensates the private sector for any change in the budget. This is achieved by keeping government transfers endogenous to the model so that households are directly compensated for changes in the government position. The circular flow of funds for the government is described by (3.4a) and (3.4) with all tax rates being exogenous to the model as is real government consumption (except for 'crime') and investment expenditure. Equation (1.4) of Appendix 1 summarises (3.4) in change form.

tax revenue + foreign grants + budget deficit = govt consumption
+ govt investment + govt transfers + external costs of crime (3.4a)

$$T^{w}W^{g}N + T^{k}R^{g}K + T^{c}\hat{P}X^{2} + T^{m}P(X_{2}^{1} + X_{2}^{2} + X_{2}^{3}) + T^{x}P_{1}X_{1} + T^{o} + F + B = PX^{4} + PX^{5} + G^{o} + \Lambda^{g} \qquad (3.4)$$

where

F = foreign aid

Λ^{g} = *total external costs of crime incurred by the government*

Consider now the left hand side term of (3.1) for imports ($s=2$). The purchase of imports and the net outflow of capital represent the sources for international traders to purchase the Kina for which is applied to purchasing exports of Papua New Guinea and of obtaining foreign aid. Since the source and use of funds equate for the production sector, household sector and government sector, then for the Walrasian equilibrium condition to be satisfied, so that all funds are accounted for, we must also have equilibrium in the foreign trade sector and hence a balance of payments equal to zero. The source and application of funds for the foreign trade sector is given below at (3.5a) and (3.5). The external losses due to crime incurred by the production, household and government sectors of the economy are expenditures for which there are no recipients. This is in contrast to the direct costs of crime which are merely transfers to the criminals. The only way within the Walrasian equilibrium framework in which we can deal with this withdrawal of funds from the economy is to treat these costs as transfers abroad. In a sense, we could interpret these losses as exports for which payment is not received. At Section 10.2 we describe the clearing commodity markets conditions. These can, in a sense, be thought of as a disaggregation of equation (3.1) in that by multiplying both sides of these equations by the undistorted prices and adding these equations together we get (3.1). As a consequence, equation (3.5) is implicitly defined in the model and so does not need to be explicitly specified. This is so because if we substitute (3.2)-(3.4) into (3.1) we will get (3.5).

imports + net capital outflows + external costs of crime
= exports + foreign grants (3.5a)

$$P_{2}X_{2} + Q + (\Lambda^{k} + \Lambda^{c} + \Lambda^{g}) = P_{1}X_{1}^{6} + F \qquad (3.5)$$

The central equations described here form the basis of the model, but by no means do they indicate the complete closure of the model. Other equations need to be introduced to ensure equilibriums with respect to resource allocations. In particular, there are equations that impose labour market equilibrium, capital market equilibrium, and goods market equilibrium, and underlying these are equations explaining the respective demands and supplies. In the remaining sections of this paper these other conditions are presented.

4. The determination of commodity supplies

4.1. The optimal product mix

Some industries in the agricultural and mining sectors produce more than one commodity from the same inputs. What is therefore required is to derive identities that explain the supply of each commodity produced by multiproduct industries. One could take the easy route and assume that such industries produce their outputs in fixed ratios, however, it is far more realistic to allow a framework where the production mixes can be altered in response to changes in the relative prices of its products. As is conventional, this is done by assuming constant elasticity of substitution (CES) production possibilities functions for each of these industries. Suppose for a representative industry we have the following CES production function;

$$Z = (b_1 X_1^{r} + b_2 X_2^{r})^{1/r} \tag{4.1}$$

where

Z = total output

X_i = production of commodity i

b_1, b_2, and r are parameters

Assuming that all firms are profit maximisers then the output combinations supplied will be chosen so as to maximise revenue subject to the production function of (4.1) where revenue is given by

$$R = P_1^{p} X_1 + P_2^{p} X_2 \tag{4.2}$$

where P_i^{p} is the producer supply price of 'i', and so the price after production taxes are imposed.

Using the Lagrangian method we can derive from (4.1) and (4.2) the supply mix of commodities X_1 and X_2 such that revenue is maximised. In linearised percentage change form this becomes[5]

$$x_1 = z + s^{T}.(p_1^{p} - R_1 p_1^{p} - R_2 p_2^{p}) \tag{4.3}$$

$$x_2 = z + \sigma^T.(p_2^\pi - R_1 p_1^\pi - R_2 p_2^\pi) \qquad (4.4)$$

where

R_1, R_2 *are revenue shares out of total revenue from commodities* X_1 *and* X_2

σ^T = *the elasticity of transformation between* X_1 *and* X_2 *and* $\sigma^T = \frac{1}{\rho - 1}$. *The greater is* σ^T*, the more responsive the change in the product ratios due to changes in price ratios*

and where upper case letters indicate levels and lower case represents percentage change.[6]

Equation (2.1) of Appendix 1 provides a general form to the supply functions of multiproduct industries in percentage change form, and (2.2) determines the percentage change in aggregate supply of each commodity. This is easily derived as the weighted sum of the percentage changes of supply in each industry. At equation (2.3), the percentage change in the producer price is derived from the undistorted price, and the relationship between the undistorted price and the foreign currency price is at (2.4).

4.2. The total supply of output

Whereas we have derived the optimal supply mix as a function of the respective output prices and total output, it remains to explain what determines total output. For village and murky sector industries, it is assumed that the only primary factor used is labour. Further, the surpluses in these industries are shared and incorporated into the price of labour. This approach is taken because labour in these industries is taken to be self-employed so a person that supplies their labour resources will receive the value of their marginal product plus a share of the industry surplus. The share of industry surplus, however, will only be received if labour is supplied. The implication is that the implicit demand for labour by these industries (hence the supply of output)[7] is not determined optimally but at a point where the value of the *average* product of labour equates to the supply price of labour. In the CGE model, the relationship between implicit labour demand and the price paid to labour for village and murky industries is already effectively given by equation (3.2). Here, as output and so labour demand increases, the price of labour for the industry (the value of the average product of labour) monotonically declines due to the assumption of decreasing returns to scale. The level of labour usage, and hence output, is then determined in the labour market. To qualify this, the informal industry is assumed to be subject to constant returns to scale. We nevertheless have a negative relationship between the implicit demand and price of labour because as labour increases, output will increase proportionally, but the push on supply will put downward pressure on the price of the informal commodity and hence on the value of the average product of labour.

The plantation and urban industries are assumed to have conventional profit maximising agents. In Section 6.2 we derive the level of demand for labour and capital to be such that profit is maximised. The demands for these primary factors adjust to allow output to increase until the revenue received by a marginal unit of output equates to its marginal cost.

5. Final demands

5.1. Consumer demand

All consumers are assumed to possess the same utility function. Commodities from different groups are substitutable and the Armington assumption is used so that those commodities within a commodity group (the domestic and imported varieties) are imperfect substitutes for which we will assume a constant elasticity of substitution. We have a separable and additive utility function which, for a representative individual, can be described by;

$$U = U[U_1(X_1^*), U_2(X_2^*), \ldots\ldots, U_{36}(X_{36}^*)] \qquad (5.1)$$

where X_i^* is a composite commodity described by the CES function at (5.2), and the asterisks denote individual consumption rather than aggregate consumption. This utility function refers to the utility received from the consumption of voluntarily purchased goods, of which there are 36, and so excludes crime (refer Table 2).

$$X_i^* = (\beta_{i1} X_{i1}^{*\,\rho} + \beta_{i2} X_{i2}^{*\,\rho})^{1/\rho} \qquad (5.2)$$

where

X_{i1}^* *= consumption of domestically produced variety of commodity i*

X_{i2}^* *= consumption of imported variety of commodity i*

and, $\frac{1}{1-\rho}$ *= elasticity of substitution between the domestic and imported varieties*

Utility is assumed to be maximised subject to the individual's expenditure constraint. Since consumption of crime is involuntarily imposed this is deducted from the aggregate level of consumption expenditure in order to obtain an expenditure constraint for voluntary consumption. This is the reasonable approach to take because we are examining the optimal consumption decisions after income (or wealth) is affected by crime which is exogenously determined from the point of view of the consumer. The external costs of crime already impact directly upon disposable income as discussed in Section 3. The expenditure constraint is therefore given as;

$$\tilde{C}^{*} = C^{*} - P_{37} . X^{*}_{37} = \sum_{i=1}^{36} P_i X^{*}_i \qquad (5.3)$$

where

P_i *= composite commodity price after including tax distortions faced by consumers*

$\tilde{C}^{*}$ *= the expenditure constraint after transfers for criminal activities*

C^{*} *= aggregate expenditure including involuntary outlays for crime*

$P_{37} . X^{*}_{37}$ *= the value of expenditure on criminal activities (where crime is commodity number 37)*

The percentage change form of the composite commodity price is given by (3.1) in Appendix 1, and the determination of commodity prices is at (3.2)-(3.4). If a person chooses the consumption bundle that maximises utility given by (5.1), subject to the expenditure constraint (5.3), we get the Marshallian demand functions for all aggregate commodities, apart from crime, of (5.4).

$$X^{*}_i = X^{*}_i (\tilde{P}, \tilde{C}^{*}) \qquad (5.4)$$

where $\tilde{P}$ *is the vector of composite commodity prices across voluntarily consumed goods.*

Differentiating (5.4) and putting into percentage change form we get;

$$x^{*}_i = \mathrm{e}_i . \tilde{c}^{*} + \sum_{k=1}^{36} \mathrm{h}_{ik} . p_k \qquad (5.5)$$

where

e_i *= the elasticity of demand for the composite good i with respect to expenditure*

h_{ik} *= the cross price elasticities.*

and lower case denotes percentage change variables.

Aggregate demand for commodity '*i*' is given by the sum of demand across all individuals. Because, as an approximation, we assume all people possess the same utility functions, aggregate demand for each commodity is simply derived as;

$$x_i = e_i.\tilde{c} + \sum_{k=1}^{36} h_{ik}.p_k \tag{5.6}$$

where x_i *and* $\tilde{c}$ *are aggregate change variables.*

In Appendix 1 this equation explaining consumer demand is given at (3.5). In all, there are 1296 price elasticities in the model and 36 expenditure elasticities so it would be a fruitless exercise to try and obtain reasonable estimates for all these elasticities. Because we have assumed an additive utility function, however, all of the price elasticities can be derived from the expenditure elasticities.[8] In our database we obtain estimates for all expenditure elasticities from various sources[9] and then derive the cross price elasticities from the condition due to Powell (1974) at (5.7) and the own price elasticities using the homogeneity condition at (5.8).

$$h_{ik} = -e_i.S_k(1 - \frac{e_k}{w}) \tag{5.7}$$

$$h_{ii} = -e_i - \sum_{k \neq i} h_{ik} \tag{5.8}$$

where

S_k = *the share of expenditure on commodity k out of total expenditure*

w = *the 'Frisch' parameter which is the elasticity of the marginal utility of expenditure with respect to expenditure and is set at w = 2*[10].

For commodities within commodity groups, we can derive the demand functions in percentage change form using a methodology similar to that for deriving the factor demand functions for production in Section 6 below. We get, for all commodities apart from crime;

$$x_{is} = x_i - s_i.(p_{is} - \sum_{s=1}^{2} S_{is}p_{is}) \tag{5.9}$$

where

s_i = *the elasticity of substitution between the domestic and imported varieties of commodity i*

S_{is} = *The share of expenditure on commodity 'is' out of total expenditure on the commodity group 'i'*

In Appendix 1, (5.9) is reproduced as (3.6).

5.2. Involuntary government demand for crime

All voluntary real expenditure by the government on consumption and investment goods is considered to be exogenous to the model. The government's involuntary consumption expenditure on 'crime', however, is endogenous to the model. The expenditure on crime incurred by the government is assumed to be a fixed ratio of the total expenditure on crime by private businesses, households and the government. In other words, if the 'supply' of crime were to increase, then the expenditure by the government on crime would also increase proportionally. This relationship is captured by (3.7) of Appendix 1. Expenditure on the external effects of crime are assumed to affect the government's budget directly and is dealt with in Section 9.2.

6. Demand for factors of production

6.1. The production function

The inputs into production include intermediate inputs and primary factors and it is assumed that substitution between these two factor groups is not possible. Furthermore substitution between commodity groups is not possible for intermediate inputs. It is therefore assumed that we have a Leontief production function which, for a representative industry, is expressed as;

$$Z = \min[f_V(K,N), f_1(X_{1,1}, X_{1,2}), \ldots, f_{36}(X_{36,1}, X_{36,2})] \qquad (6.1)$$

where

Z = total output

K = capital input

N = labour input

X_{is} *= intermediate inputs where the subscripts 'i' and 's' respectively refer to the commodity and variety where s = 1 is the domestic and s = 2 the imported variety.*

Each commodity group contains a domestic and imported variety which are substitutable. Of course, different industries will use different intermediate inputs and it will not necessarily be the case (and is not usually the case) that all commodity groups will be utilised as intermediate inputs. Where this is the case, the commodity groups that are not utilised will simply drop out of equation (6.1). The commodity group 'crime' (commodity no. 37) does not enter into the production function since it is not an input that can contribute to production. Cost minimisation ensures that each production function (f_V *and* $f_1, \ldots, f_{36}$) equates to *Z*, and each production function is assumed to be of the constant elasticity of substitution form.

The foreign currency export price is assumed to be exogenous in the model implying a perfectly elastic demand for exports. This being the case, we think of the quantity of exports supplied to world markets as being the implicit demand for exports. The perfect elasticity assumption is wrought with danger unless appropriate assumptions are made to allow an upward sloping supply curve for the commodity. For example, suppose there is an industry producing exports that returns normal profits and we have an exogenous increase in the world price. Further, suppose that the industry has constant returns to scale and factors are mobile between industries so that there is no barrier to capital relocating into this industry. We therefore have a perfectly elastic supply curve and pure profits will be returned in this industry regardless of how many firms divert production to this commodity. We will therefore see a wholesale movement of factors to this industry until, say, an exchange rate adjustment stops the exodus. To deal with this unrealistic scenario it is assumed that capital is immobile between industries. Output can only be increased by increasing intermediate inputs and labour. With capital input restricted we will eventually have decreasing returns to scale and hence the upward sloping supply curve. The village and murky sector industries, however, are assumed not to use capital. For village industries we explicitly assume decreasing returns to scale with respect to labour so that increasing labour by a certain percentage will provide a less than proportional increase in output. This property is also assumed for the crime industry where output of the crime industry is defined as the value of transfers to criminals. For the informal industry, however, constant returns are assumed. This assumption is acceptable since the output of the informal industry is non-traded which means the price of output will respond to supply.

6.2. The demand for primary factors

In this section we determine the optimal mix of primary factor inputs for a given level of primary factor requirement, which in turn will be for a given level of output. The primary factor component of the production function of (6.1) is assumed to be of a constant elasticity of substitution form so that for a representative industry we have;

$$Z = f_v = (\delta_n N^{\rho} + \delta_k K^{\rho})^{\theta / \rho} \tag{6.2}$$

where

θ *= the returns to scale and for village industries and the crime industry we have decreasing returns so that* $\theta \in (0,1)$. *Plantation and urban sector industries as well as the informal industry have constant returns and so* $\theta = 1$.

$\frac{1}{1-\rho}$ *= the elasticity of substitution between labour and capital.*

Murky and village sector industries are assumed not to use capital so for such industries the primary factor requirement simplifies to;

$$Z = \delta_n N^{\theta} \tag{6.3}$$

For plantation and urban sector industries, optimising behaviour is assumed and so the inputs of capital and labour will be chosen such that profits are maximised. Given this optimising behaviour, and given that from the Leontief production function of (6.1) each intermediate input commodity group is used at a fixed proportion of output (due to the assumption of constant returns to scale), it is possible to derive the demand functions for capital and labour inputs in percentage change form as follows[11]

$$n = \frac{1}{S^p}.z - \sigma^p.(p_n - \hat{C}_n p_n - \hat{C}_k p_k) \tag{6.4}$$

$$k = \frac{1}{S^p}.z - \sigma^p.(p_k - \hat{C}_n p_n - \hat{C}_k p_k) \tag{6.5}$$

where

n = percentage change in labour demand

k = percentage change in capital demand

σ^p is the elasticity of substitution between capital and labour

p_n = price of labour input

p_k = price of capital input

$\hat{C}_n$ and $\hat{C}_k$ are cost shares out of total primary factor costs attributable to labour and capital

S^p is the share out of total primary factor costs plus exogenous fixed costs attributable to primary factors

In Section 6.1 we assumed that capital is immobile and hence in fixed supply to each industry. This being the case it will be the price of capital in equation (6.5) that adjusts to enable the demand for capital to equate to the fixed supply. Equation (4.1) of Appendix 1 provides the labour demand function of (6.4) for all industries in general form with more generalised notation and this equation also encompasses the labour demand function for village and murky sector industries (equation (6.3)). Capital demand is at (4.2).

6.3. The demand for intermediate inputs

In the case of intermediate inputs to production we have constant returns to scale production functions for each commodity group, and for a representative commodity group '*i*' the production function will be

$$Z = f_i = (\delta_{i1} X_{i1}^{\rho} + \delta_{i2} X_{i2}^{\rho})^{1/\rho} \tag{6.6}$$

where X_{i1} is the domestically sourced variety of commodity i and X_{i2} is the imported variety.

All industries are assumed to employ the combinations of intermediate inputs such that costs are minimised. Using the same techniques as for primary factors, we can derive the demand functions for the intermediate inputs from commodity group '*i*' in percentage change form for each industry group as

$$x_{i1} = z - \sigma^{i}.(\hat{p}_{i1} - C_{i1}\hat{p}_{i1} - C_{i2}\hat{p}_{i2}) \tag{6.7}$$

$$x_{i2} = z - \sigma^{i}.(\hat{p}_{i2} - C_{i1}\hat{p}_{i1} - C_{i2}\hat{p}_{i2}) \tag{6.8}$$

where

σ^{i} = *the substitution elasticity between the imported and domestic good*

$\hat{p}_{is}$ = *the price of intermediate input commodity 'is' at producers purchase prices where s = 1 refers to the domestic and s = 2 the imported variety*

C_{is} = *the share of expenditure on commodity 'i' attributable to variety 's'.*

The intermediate input demand equations are reproduced in more general form at (4.3) of Appendix 1. These equations cover all commodities except 'crime' which is an involuntary imposed purchase and so dealt with differently. This is discussed further at Section 6.5.

6.4. The demand for labour by skill category

There are two broad categories of labour identified in our model, skilled and unskilled. The aggregate level of labour as an input is assumed to be described by the following CES function

$$N = (\delta_1 N_1^{\rho} + \delta_2 N_2^{\rho})^{1/\rho} \tag{6.9}$$

where

N_1 = *unskilled labour*

N_2 = *skilled labour*

$\frac{1}{1-\rho}$ = *the elasticity of substitution between unskilled and skilled labour*

The assumption that firms are profit maximisers implies that the combinations of unskilled and skilled labour will be chosen so as to minimise costs subject to the requirement of a particular level of labour (i.e. *N*). Using the Lagrangian method of deriving the optimising conditions, we can derive the labour demand by occupation functions for each industry in percentage change form as[12]

$$n_1 = n - \sigma^n.(p_{n1} - C_{n1}p_{n1} - C_{n2}p_{n2}) \quad (6.10)$$

$$n_2 = n - \sigma^n.(p_{n2} - C_{n1}p_{n1} - C_{n2}p_{n2}) \quad (6.11)$$

where

σ^n = *the elasticity of substitution between unskilled and skilled labour*

C_{nq} = *the share of labour demand attributable to skill category q where q = 1 refers to unskilled labour and q = 2 is skilled labour*

p_{n1} = *the wage rate attributable to unskilled labour*

p_{n2} = *the wage rate for skilled labour*

The general form with generalised notation is given by (4.4) and (4.5) in Appendix 1. The village and murky sector industries are assumed not to utilise skilled labour. In these cases equation (6.10) will collapse to $n_1 = n$, and while we may derive a non-zero percentage change for skilled labour from (6.11), this will be irrelevant since the initial employment of skilled labour is zero. For those industries that employ both skilled and unskilled labour we should expect the substitution elasticities to be low. It is not reasonable to expect a great deal of flexibility in the employment structure of a firm. For example, tasks that require skill are not likely to be able to be performed by unskilled personnel. Conversely, occupations that require physical input and little skill will benefit little if filled by people with skills. In the model by Vincent et al. (1991) these elasticities are set at 2.0. This is perhaps a little unrealistic and in the absence of more enlightening data we set these elasticities at a less substitutable 0.5 which is consistent with the default labour to capital elasticity.

6.5. Involuntary intermediate input demand for crime

Losses for businesses due to crime are unwittingly incurred costs which will need to be captured in our model. To do this, we take the approach that the amounts transferred to the larcenists are involuntarily imposed intermediate input purchases of ‘crime’. This is perhaps a little difficult to fathom because such purchases contribute nothing to output. In the case of individuals, we treated losses due to crime in a similar manner by classifying such losses as consumption despite the fact that there was no contribution to utility. We justify these approaches courtesy of the fact that the ‘purchases’ of crime are involuntarily imposed. For individuals, outlays on crime reduces the expenditure constraint available for other consumption goods. In the case of businesses, the involuntary purchases of crime are indeed a purchase of a commodity within the scope of the model, however, as such purchases do not relate to production they will only impact directly upon the surplus to production. It is assumed that losses for businesses due to transfers to criminals is at a fixed proportion to total losses from crime in the community and this is captured by equation (4.6) of Appendix 1.

7. Labour resource allocation conditions

7.1. Aggregate demand for labour by sector and category

At Table 1 we identified four sectors of the labour market; the village, plantation, urban formal, and urban murky sectors. In addition we have assumed two skill categories of labour, skilled and unskilled, with only unskilled labour being employed in the village and murky industries. We will assume perfect mobility of labour between industries so that labour market conditions can be analysed by splitting the labour market into these sectors rather than at the industry level. Perhaps we could be accused of being unrealistic in these assumptions, particularly in the case of skilled labour. First, the skilled labour market is typically characterised by a vast array of types of skilled labour. Further, the mobility of skilled labour varies across occupations since some positions would require industry specific skills while others may be more general across industries. These realities ensure that we experience a vast array of returns to skilled labour. The model contradicts these real world scenarios in that homogeneity is assumed for the characteristics of skilled employees along with perfect mobility between industries. Of course, one must accept a trade off between realism and complexity in the model, and adding complexity to the model should be avoided unless it adds to the quality of the results. One would expect that skilled labour should, on average, be reasonably mobile between industries so that assuming complete mobility would not be too distorting. Although this assumption will exaggerate the effects on employment and output by industry of any shocks, it should not affect direction. In any case, our assumption of a homogeneous wage across all skilled workers should not provide any important implications if we interpret the results in percentage change form. It would perhaps not be unreasonable to expect that a shock affecting returns to skilled labour will affect all levels of skilled occupations by approximately the same percentage. Equations (5.1)-(5.4) of Appendix 1 present the aggregate demand for labour by sector and skill level in percentage change form. In the case of the village and murky sectors all labour is assumed to be self-employed, hence we are examining the implicit labour demands.

7.2. Payments to labour by category of labour

Equations (5.5)-(5.9) of Appendix 1 describe the net payments to labour by sector and skill level in change form. Our assumptions of perfect mobility of labour between industries and homogeneous characteristics of workers within the skilled and unskilled categories ensures that these payments equate across all industries within a sector. Within the murky sector, the payment to labour in the crime industry would typically be higher than for informal industry because of the risks involved in crime. We nevertheless take it that the expected returns equate after one makes allowances for such risks. Income tax is assumed not to be applied to village or murky sector workers, however, urban formal sector and plantation workers do incur income tax[13]. This implies that for all plantation and urban formal sector industries net wage payments will be;

$$W_q^2 = (1 - T_q^2) P_{qj} \tag{7.1}$$

$$W_q^3 = (1 - T_q^3) P_{qj} \tag{7.2}$$

where

W_q^h *= the net wage rates for those in occupation of skill level q and sector h*

P_{qj} *= The gross price of labour paid to occupation q by industry j*

T_q^h *= the ad valorem income tax rates paid by those in occupation q and sector h*

and, q = 1 is unskilled labour, q = 2 is skilled labour, h = 2 is the plantation sector and h = 3 is the urban formal sector.

Equation (7.1) is presented in change form with more general notation at (5.6) of Appendix 1, and (7.2) is disaggregated into (5.7)-(5.8) and (5.22).

We bring to the CGE model the Harris-Todaro framework developed in Levantis (1997) for explaining a stable disequilibrium scenario in the unskilled labour market of Papua New Guinea. To give a brief overview of this model, we have 3 sectors of the labour market, the rural, urban formal and murky sectors. The rural sector can be further disaggregated into the village and plantation sectors. The urban formal sector wage is subject to a distortion where the rate is pushed above the market clearing level. This induces people to relocate from rural to urban areas in pursuit of the higher paying opportunities and so causing a situation of surplus labour in urban centres of which becomes absorbed into the murky sector. Due to this surplus labour there will only be a probability associated with formal employment, and since formal employment is fixed (due to a rigid wage), the expected wage of an urban resident will be a function of murky sector employment (the greater the level of murky sector employment the lower the chance of obtaining formal employment). With allowances for risk averse behaviour in the model, a steady state is achieved in the unskilled labour market when the certainty equivalent of the expected urban wage equates to the rural wage. The certainty equivalent of the expected urban wage can be derived as follows and is reproduced from Levantis (1997)

$$W^e = \left\{ \frac{N_1^3}{N_1^4 + N_1^3} \cdot (W_1^3)^{\delta} + \frac{N_1^4}{N_1^4 + N_1^3} \cdot (W_1^4)^{\delta} \right\}^{\frac{1}{\delta}} \tag{7.3}$$

where

W^e *= the certainty equivalent of the expected urban wage for unskilled labour*

N_q^h *= the demand for labour of skill type q to sector h*

W_q^h *= the net wage rates for those in occupation q and sector h*

d = *risk aversion parameter where risk aversion is implied if* $d \in (0,1)$ *whereas* d = *1 implies risk neutral behaviour*

and, q = 1 implies unskilled labour, h = 3 is the urban formal sector and h = 4 is the murky sector.

Differentiating and arranging (7.3) into change form we get (5.10) of Appendix 1.

7.3. Clearing labour market conditions

The labour market clears when there is no excess demand for labour. The Harris-Todaro scenario in urban areas means that the excess supply of unskilled labour to the formal labour markets is presumed to be absorbed into the murky sector, hence we have unskilled labour market equilibrium when the shortfall in demand for labour in the formal sector is cancelled by the implicit excess demand in the murky sector. Note that it is assumed that there is no open unemployment. As was found from the results of surveying in Levantis (1997), open unemployment (where we define those earning an income from crime and other informal activities as employed) represents less than 5 per cent of the urban labour force and so is not particularly important in Papua New Guinea. Equilibrium in the labour market is established when the demand for each category of labour (i.e. skilled or unskilled) in each sector of the economy equates to the supply of labour to that sector. The excess supply of unskilled labour to the urban formal sector we consider to be the supply of labour to the murky sector. Equations (5.11)–(5.14) of Appendix 1 capture the equilibrium conditions for each labour market sector and skill category.

The total size of the skilled and unskilled labour markets and hence the aggregate supply of the respective types of labour are assumed to be fixed. Since labour is assumed to be completely mobile between sectors, however, the relative sizes of the labour force in each sector may be fluid. In order for there to be equilibrium in the movement of labour between sectors, the net returns to labour must equate in each sector. This presents an important complication since the real value of nominal wages is lower in urban centres relative to rural areas.[14] This is due to cost of living and other qualitative differences. Within the scope of our model it is not consistent to apply a relative price index to compensate for the lower cost of living in rural areas. We have assumed that all domestic consumers face the same prices and to assume different prices apply to different sets of consumers would significantly complicate the model. If we were to apply some index to compensate for the different value of nominal wages in rural and urban areas while assuming the same prices apply to all consumers then we will have problems with our equivalent variation measure of welfare changes which are discussed in Section 11. For example, the welfare impact of a movement in labour resources from the murky sector to the village sector would understate the value of the labour resources gained in the village sector relative to that lost in the murky sector. One way to deal with the different value of nominal wages without affecting the consistency of the model is to assume that there are additional costs to leisure for a person employed in urban centres caused by, say, transport around the urban centres. We could suppose that the time one supplies for labour exceeds that actually used by firms as a result of this time lost. Suppose that all rural and urban residents supply a fixed amount of labour of H^* hours each. In rural areas this translates to H^* hours in production, however, in urban centres the effective units of labour used in production is only H hours where

$$H^* = (1+\Psi).H \tag{7.4}$$

where Ψ *= the proportion of productive hours lost in transport, and* $\Psi > 0$*, so that* $\Psi.H$ *is the hours wasted in supplying labour.*

The aggregate supply of unskilled labour is fixed so we have;

$$\overline{N} = N_1 + N_2 + N_3^* + N_4^* \tag{7.5}$$

where

N_1 *= supply of labour to villages*
N_2 *= supply of labour to plantations*
N_3^* *= supply of labour to the formal urban sector including time wasted in labour supply*
N_4^* *= supply of labour to the murky sector including time wasted in labour supply*

Now assume that the lost time across all urban residents is the same, then we can express (7.4) in aggregate terms as

$$N_h^* = (1+\Psi).N_h \tag{7.6}$$

where N_h *= the effective units of labour supplied to urban centres and h = 3 refers to formal sector employment and h = 4 is murky sector employment.*

The aggregate labour supply condition of (7.5) expressed in effective supply units will therefore be

$$\overline{N} = N_1 + N_2 + (1+\Psi).(N_3 + N_4) \tag{7.7}$$

This aggregate unskilled labour supply condition in change form is given by (5.15) of Appendix 1. The equivalent condition for skilled labour is at (5.16). For an urban resident, the equivalent expected urban wage for unskilled labour at (7.3) refers to payment for effective units of labour.[15] The actual rate received by the supplier, including time lost, will be;

$$W^{e*} = \frac{1}{(1+\Psi)}.W^{e} \tag{7.8}$$

We have indifference between the sector to locate in for unskilled workers when the rural wage equates to the above. This equilibrium condition in change form is at (5.18) of Appendix 1 while the condition for equilibrium between the two rural sectors is at (5.17). The equilibrium condition for skilled labour is at (5.19).

7.4. Determination of the urban unskilled wage

Because we assume a distorting floor under the formal urban unskilled nominal wage, it will be independent of labour demand and will only be determined by the inflation rate (if there is some sort of wage indexation) and by other exogenous factors. This is captured below and at equation (5.20) of Appendix 1.

$$dW = \mathrm{m}\frac{d\mathrm{e}^{c}}{\mathrm{e}^{c}}.W + dF \tag{7.9}$$

where

dW = the change in the nominal urban unskilled wage rate

m = the wage indexation parameter and $\mathrm{m} \in [0,1]$. If $\mathrm{m} = 0$, then there is no indexation, and if $\mathrm{m} = 1$ we have full wage indexation

e^{c} = the consumer price index

dF = exogenous shocks to the gross wage rate, or, if $\mathrm{m} = 1$, the change in the real wage.

The evidence from Levantis (1997) suggests that the nominal rate is currently independent of movements in the consumer price index which implies that the parameter m in (7.9) should be zero. We nevertheless include this term to allow us the option of examining the impact of policies in a retrospective scenario when there was indexation of wage rates. In any case, if a simulation requires a shock to the real unskilled formal wage then we need to set the parameter m to 1 which allows *dF* to approximate the change in the real wage.

Included in the CGE model is equation (7.11) below, reproduced at (5.23) of Appendix 1, which measures the change in the distortion between the murky and formal wage rates. Its main purpose is to allow an assessment of the implications of moving from a distorted labour market to an undistorted market. Equation (7.11) is derived from (7.10) which measures the difference between the real wage rates in the formal and murky sectors.

$$A = \frac{W_1^3}{\mathrm{e}^{c}} - \frac{W_1^4}{\mathrm{e}^{c}} \tag{7.10}$$

where

A = distortion between the formal and murky sector real wage rates

W_q^h *= the net nominal wage rates for those in occupation q and sector h, and q =* 1 *implies unskilled labour, h =* 3 *is the urban formal sector and h =* 4 *the murky sector.*

Totally differentiating and expressing in change form we get

$$dA = \frac{dW_1^3}{e^c} - \frac{dW_1^4}{e^c} - A.\frac{de^c}{e^c} \tag{7.11}$$

If the distortion '*dA*' is set exogenous, then by imposing a shock on *dA* equivalent to the real wage divergence we will eliminate the difference between the two urban wage rates and allow the urban unskilled rate to be determined according to labour demand and supply conditions. This simulation will therefore estimate the effects of moving to an undistorted labour market from the initial distorted scenario. In doing this, we must also make the '*dF*' term at (7.9) endogenous and the indexation parameter, m, zero so as to allow the wage rate to move freely. This term will then simply measure the movements in the urban unskilled nominal wage rate. Under normal circumstances '*dA*' is endogenous to the model, in which case it represents a measurement of how the real wage differential is affected in a simulation, and '*dF*' is exogenous.

8. Capital market

As was discussed in Section 2.2, the external losses due to crime for businesses are not represented by any flow of funds, yet are a cost to the owners of capital. We therefore incorporate these external costs in the return to capital equation at (6.1) of Appendix 1. This equation is derived from the concept that the gross return to the owners of capital is the price paid by the users less the rate of losses per unit of capital due to the external effects of crime. The determination of the rate of losses due to the external effects of crime is given at equation (6.2) of Appendix 1 (assumed to be proportional to total external losses), while the net after tax return to capital is explained by (6.3). It is assumed that investment does not affect capital in the current period so that the aggregate capital stock is taken to be fixed. Given this restriction, there are two approaches that could be taken with respect to the mobility of capital—either assume capital is totally industry-specific, or completely mobile. If we were to treat capital as being completely mobile, then we would be capturing the long-term responses of capital resource allocation with respect to movements in the relative rates of return for each industry. The assumption that investment does not impact upon the capital stock level in the current period becomes unreasonable if we were to consider the period of the model to be a long-run period, hence, it would be contradictory to take this assumption along with the assumption of perfect capital mobility. Furthermore, as discussed in Section 6.1, the assumption of perfect capital mobility is dangerous in the sense that it may allow a result of wholesale reallocations of capital resources towards a single industry in the event of a positive movement in the international price level for that industry. For these reasons we take the alternative 'short run' approach and assume that capital is totally industry specific. Capital stock by industry then becomes an exogenous variable and the rental rates in each industry will be determined by (4.2) and (6.1) of Appendix 1. Equation (6.4) provides the market clearing condition for capital stock for each industry.

9. Government revenue and expenditure

At equation (3.4) in Section 3 and at (1.4) of Appendix 1 we present the condition that the sources and uses of funds for the government must equate. We require, however, to disaggregate the government revenue and expenditure terms of (1.4) into its determinants. Government revenue is comprised of revenue from personal taxes, company taxes, mining royalties, import tariffs, production taxes, consumption taxes, other tax revenue (assumed to be imposed on companies), and foreign grants. In the case of mining industries, the government receives revenue from taxing profits (the return to capital) and from dividends by holding equity in mining industries. To simplify this, we aggregate these revenues into an implicit company tax on the return to capital. The determination of each type of revenue in percentage change form is given at (7.1)-(7.6) of Appendix 1, and the aggregate government revenue equation, excluding foreign grants, is at (7.7). In the case of revenue from import duties, only the private sector is subject to tariffs so equation (7.3) is based only on the impact to private demand for imports. Equation (8.12) of Appendix 1 determines private demand.

As discussed in Section 2.2, the victims of crime inevitably incur additional external costs on top of the amounts transferred to criminals. The external cost imposed on the government is taken to be proportional to the level of criminal activity imposed on the government and is appropriately explained by equation (7.10) of Appendix 1. The balance of the government's available funds are assumed to be spent on purchasing commodities (including the 'crime' commodity), and providing transfers, the recipient of which is ultimately the household sector. Consumption expenditure is captured by (7.8) of Appendix 1, and investment expenditure by (7.9). Apart from the government's involuntary consumption of crime, which is discussed in Section 5.2, real government demand for all investment and consumption goods is considered to be exogenous to the model. Total government expenditure is at (7.11) and includes 'other government expenditure' which is assumed to be transfers to the household sector. This term is endogenous to the model so as to allow (1.4) of Appendix 1 to be satisfied, that is, to allow total government expenditure to adjust in order for the government budget to remain static. By doing this, we allow for the community to be compensated, via government transfers, for any increases in the budget surplus that arises due to an exogenous shock. The welfare implications of such a shock will therefore be interpreted after such compensation. We thereby overcome the problem of measuring the welfare implications of a change in the government position and allow welfare to be derived from the utility people receive from consumption. This will allow for a well defined derivation of the equivalent variation measure of a welfare change.

10. Other equations

10.1. International trade

The determination of the value of exports and imports is given by equations (8.1)-(8.2) of Appendix 1. These equations are included in the model purely to provide information as to the value of exports and imports. They do not contribute to the model in any other respect. Exports must be interpreted as gross of external costs. If external costs are to be interpreted as exports for which payment is not received, then to calculate effective exports, external costs must be deducted from gross exports.

10.2. Clearing commodity markets

We saw at equation (3.1) that the aggregate value of the supply of commodities will equate to the aggregate value of demands. Equations (8.3)-(8.5) of Appendix 1 close the relationship between supply and demand of each commodity by ensuring the market for each commodity clears. Equation (8.3) gives the market clearing conditions for the domestically produced goods that are traded on the international market, while (8.4) gives the market clearing conditions for non-traded goods. The left hand sides of these equations give commodity supplies while the right hand sides give aggregate demand for the domestically produced goods. The clearing markets for imported goods are given at (8.5) and, similarly, the aggregate demand for imported goods is on the right hand side and the supply of imports on the left hand side. The demand for all commodities for private and public investment is considered exogenous as is government consumption (except for crime), while the determination of consumption demand is derived in Section 5.1, intermediate input demand at 6.3, and the determination of commodity supply is at Section 4.

10.3. GDP

Gross domestic product is given by (8.6) of Appendix 1 and is a sum of real consumption (i.e. voluntary consumption), private investment, government consumption and investment, and the trade surplus. This equation enters into the model purely for information as to the impact of the exogenous shock on nominal GDP. As discussed in Section 10.1, exports are taken as gross of external costs. In this case, GDP is interpreted here as gross output, including production which gets wasted by the external effects of crime.

10.4. Determination of private investment expenditure

Private investment expenditure is described as an application for household disposable income at equation (1.3) of Appendix 1 and it is defined in percentage change form at (8.7). The actual commodity demands are treated as exogenous to the model, so investment expenditure will only vary due to price changes. Aggregate real investment expenditure is therefore constant.

10.5. The determination of the voluntary expenditure constraint

The voluntary consumption expenditure constraint of Section 5.1 is easily determined by deducting involuntary consumption from total consumption expenditure. Equation (8.8) of Appendix 1 gives this relationship in percentage change form while (8.9) determines involuntary consumption. Of course, the value of voluntary consumption can also be derived by summing across the value of consumption of each commodity and this is given in percentage change form at (8.10). This is included only as a ‘check’ equation to expose any possible deficiencies in the model specification. This acts as a valuable check equation because whereas (8.8) is derived from aggregate consumption which is derived from disposable income which in turn is derived from factor incomes, (8.10) comes from changes in prices and demand for commodities.

10.6. Aggregate external cost of crime

Equation (8.11) of Appendix 1 derives the aggregate external cost of crime imposed on victims. This is simply an aggregation of the external cost to firms, households and the government. The importance of deriving this equation stems from its relevance in the welfare equations.

10.7. Determination of the price of crime

The price of crime could otherwise be thought of as the average payoff of a crime. Equation (8.13) of Appendix 1 links the price of crime with the consumer price index. The reasoning behind this is twofold. First, an increase in the CPI will imply an increase in the nominal value of goods stolen. Second, the increased money supply will mean greater cash holdings and hence greater cash payoffs.

11. Social welfare

A social welfare variable is introduced into the model to provide a measure of the change in welfare caused by any exogenous shocks we impose on the system. In an intertemporal model, income may be allocated to investment in the current period in order to obtain flows of utility in future periods. Unfortunately, CGE models are not intertemporal, and in order to avoid the complications of measuring the external gains and losses associated with various forms of investment we will assume that investment purchases do not impact upon social welfare. This does not pose a problem because real investment expenditure is held constant as explained at Section 10.4. Further, by allowing for people to be compensated for any change in the government budgetary position we avoid any difficulties associated with determining its welfare implications. For example, suppose a shock resulted in government revenue increasing (e.g. a tax rise) so that we have a budget surplus at the expense of disposable income and hence consumption. If we are to measure welfare based on the consumption of the people then this we would interpret as impacting negatively on social welfare. In our single period model it would not make sense to interpret a budget surplus itself as affecting welfare because this amounts to government savings which are for applications in future periods. The implications of savings for future expenditure is outside the scope of the model. By enabling the change in the budgetary position to be balanced by transfers to the household sector the funds saved (or borrowed) by the government will be dealt with in the current period. The change in welfare bought about by a simulation is therefore interpreted as that given a constant budgetary position.

Expenditure by the government we should interpret as being for the purchases of public goods. In this case such purchases contribute to social welfare. We overcome any problems associated with measuring these contributions by assuming that real expenditure by the government, except for involuntary purchases of crime, is exogenous to the model. Hence, our calculations of the change in welfare will not be complicated by any changes in these real government expenditures. As for losses incurred by the government due to crime, this will not directly implicate the community, since it does not represent the provision of a public good, but will only act to reduce the budget surplus. The community is therefore indirectly affected through the corresponding impact this will have on the government transfers made to the community. The change in utility attributable to each individual that results from an exogenous shock to the economy we assume is received only from the change in consumption of commodities. To derive this relationship, begin by letting the indirect utility for a representative individual be;

$$U^{*} = U^{*}(P^{2}, \tilde{C}^{*}) \qquad (11.1)$$

where

U = indirect utility

$P^2 = \{P^2_{1,1}, \ldots, P^2_{37,1}, P^2_{1,2}, \ldots, P^2_{37,2}\}$ = *the consumer price vector of commodities 'is' which includes any consumption tax distortions, and 'i' is the commodity type and 's' the variety*

$\tilde{C}$ = *the voluntary consumption expenditure available after the imposition of direct expenditure on crime and external losses due to crime*

and the asterisks indicate that we are referring to a representative individual

This equation follows from (5.1), where we assume a separable utility function that depends on consumption, and the demand functions of (5.4). Differentiate and divide through by λ, the marginal utility of consumption expenditure;

$$\frac{dU^{*}}{\lambda} = \sum_{i \in \tilde{x}} \sum_{s} \frac{1}{\lambda} . \frac{\partial \tilde{U}^{*}}{\partial P^{2}_{is}} . dP^{2}_{is} + d\tilde{C}^{*} \qquad (11.2)$$

where

$\tilde{x}$ *= the set of commodity groups for which there is voluntary consumption (i e excluding crime)*

s = the set of variety of commodities where s = 1 is the domestic and s = 2 the imported variety

λ *= the marginal utility of consumption expenditure*

Substitute Roy's Identity[16] and let $dV^{*} = \frac{dU^{*}}{\lambda}$

$$dV^{*} = -\sum_{i \in \tilde{x}} \sum_{s} X_{is}^{2*} . dP_{is}^{2} + d\tilde{C}^{*} \tag{11.3}$$

where

dV = measurement of the change in utility in monetary terms

X_{is}^{2} *= consumption of commodity 'is' where 'i' is the commodity type and 's' the variety*

The change in utility can be interpreted from (11.3) as the change in real consumption expenditure[17]. The second term on the right hand side gives the change in the total value of consumption expenditure, while the first term deducts from this the amount that is due to changes in prices. Assume a utilitarian social welfare function so that social welfare can be given as[18]

$$V = \sum_{h} V_{h}^{*} \tag{11.4}$$

where *h* is the set of individuals in the community, then $dV = \sum_{h} dV_{h}$, and so we can derive from this and (11.3) a measure of the aggregate change in social welfare as

$$dV = -\sum_{i \in \tilde{x}} \sum_{s} X_{is}^{2} . dP_{is}^{2} + d\tilde{C} \tag{11.5}$$

where deletion of the asterisks indicates aggregate variables.

This equation is presented at (9.1) of Appendix 1 and because the database of the model is scaled in thousands of 1994 Kina, the change in welfare measure will be similarly scaled. Levantis (1997) derives an alternative, more disaggregated measure for the change in welfare. This is given by (11.6) below and is included in the model at equation (9.2) of Appendix 1.

$$dV = \sum_{i \in \tilde{x}} P_{i1}.dX_{i1} - \sum_{i \in \tilde{x}} \sum_{s} \sum_{j} P_{is}.dX^{1}_{isj} + \sum_{i \in T} X^{6}_{i1}.dP_{i1} - \sum_{i} X_{i2}.dP_{i2}$$
$$+ \sum_{i \in \tilde{x}} T^{c}_{i1}.P_{i1}.dX^{2}_{i1} + \sum_{i \in \tilde{x}} (T^{m}_{i} + T^{c}_{i2} + T^{m}_{i}.T^{c}_{i2}).P_{i2}.dX^{2}_{i2} - d\Lambda - dQ + dF \qquad (11.6)$$

This alternative equation allows us to determine some of the components of the change in welfare, as is evident when (11.6) is expressed verbally.

change in welfare = gains in value added + gains in the terms of trade
+ gains due to the marginal social value of increased consumption in distorted markets exceeding the marginal social cost
- external losses due to crime
- losses due to the increased repatriation of capital (which is exogenous and so zero)
+ increase in foreign grants

We go on to disaggregate the welfare equation further by breaking down the value-added term into its components. This is also derived in Levantis (1997) and is given at (11.7). With this level of disaggregation we are able to assess the contribution to the change in welfare of movements in each sector of the labour market. This is done by making one sector the numeraire in a sense (the plantation sector) so that we interpret the implications of reallocations of labour resources as moving in and out of the numeraire sector. At Appendix 1, this equation is given by (9.3), while equations (9.4) to (9.13) determine the value of each of the components. In Table 3 each component of (11.7) is listed along with an interpretation of their contribution to welfare. To report the results for the three alternative measures of the change in welfare is extremely important as they represent three ways of measuring the same thing and so should always equate. Any errors in the derivation of the disaggregated forms will be exposed by discrepancies between the measures. Perhaps more importantly, it has a strong power in exposing faults in the model specification. The alternative forms will not equate, for example, if incorrect coefficients are derived or if there is an error in the calculation of coefficients in the database.

Table 3 **Components of the disaggregated welfare equation**

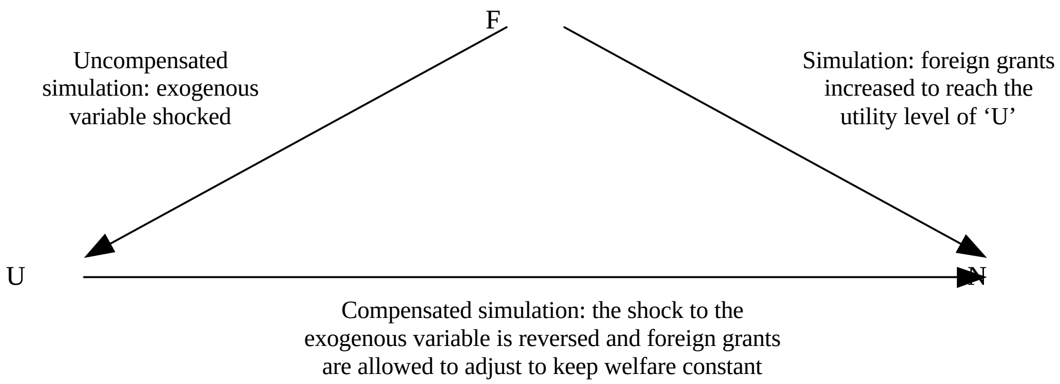
Component	*Equation in Appen*	*Interpretation*
$dV^{vil} = \sum_{j \in \mathrm{a}} [\mathrm{q}_j . W^g_{1j} - W^r_1]. dN_{1j}$	9.4	*The impact on welfare of the change of labour in the village sector due to the distortion between the value of the marginal product of labour in village sector industries and the undistorted rural wage. A distortion will result because labour is employed until the value of the average product of labour equates to the rural wage.*
$dV^{plt} = \sum_{j \in \mathrm{b}} [W^g_{1j} - W^r_1]. dN_{1j}$		*The impact on welfare of the change of labour in the plantation sector due to the distortion between the value of the marginal product of labour in plantation sector industries and the undistorted rural wage. This will be zero since labour is employed optimally in this sector.*
$dV^{urb} = \sum_{j \in \mathrm{g}} [W^g_{1j} - W^e_1]. dN_{1j}$	9.5	*The impact on welfare of the change of labour in the urban formal sector due to the distortion between the value of the marginal product of labour in urban sector industries and the expected urban wage. This will be positive since this sector is subject to a distorting wage.*
$dV^{inf} = [W^g_{41} - W^e_1]. dN_{41}$	9.6	*The impact on welfare of the change of labour employed in the informal industry due to the distortion between the value of the marginal product of labour and the expected urban wage. The distortion occurs due to the Harris-Todaro effect which suppresses the informal wage below the expected wage.*
$dV^{crm} = -(W^e_1 + \mathrm{q}_{42} . \mathrm{z} . W^g_{42}). dN_{42}$	9.7	*The impact on welfare of the change of labour employed in the crime industry due to the distortion between the value of the marginal product of labour and the expected urban wage. Because theft is redistributive, the only output implications are the negative externalities. Hence the value of the marginal product is negative and is the size of the external effect.*
$dV^{it} = \sum_{j \in \mathrm{b,g}} T_{2j} . W^g_{2j} . dN_{2j}$	9.8	*The gains in welfare due to the income tax distortion causing the social value of labour to exceed the social cost.*
$dV^{tot} = \sum_{i \in T} X^6_{i1} .dP_{i1} - \sum_i X_{i2} .dP_{i2}$	9.9	*The impact on welfare of the change in the terms of trade. This will normally be zero due to the small country assumption.*
$dV^{pro} = \sum_i T^x_i . P_{i1} .dX_{i1}$	9.10	*The excess of the social return to the change in output over the direct return to producers (i.e. the change in output by the distortion in producer prices).*
$dV^{int} = \sum_i \sum_j T^m_i . P_{i2} .dX^1_{i2j}$	9.11	*The gains in welfare due to the cost of the change in intermediate input usage for the producer exceeding the social cost.*
$dV^{con} = \sum_{i \in \tilde{x}} T^c_{i1} . P_{i1} .dX^2_{i1} + \sum_{i \in \tilde{x}} (T^m_i + T^c_{i2} + T^m_i . T^c_{i2}). P_{i2} .dX^2_{i2}$	9.12	*The gains in welfare dus to the marginal benefit of consumption exceeding the social cost (the change in consumption by the distortion in consumer prices).*
$dV^{cap} = -dQ$	9.13	*The impact of a change in capital exports which is equivalent to the impact of a change in the current account surplus. This is normally exogenous so will be zero.*
$dV^{for} = dF$	9.14	*The impact of a change in foreign grants. This term will either be set exogenous and so zero, or made endogenous to measure the equivalent variation or the compensating variation.*

$$
\begin{aligned}
dV = & \sum_{j \in \alpha} [\theta_j . W_{1j}^g - W_1^r].dN_{1j} + \sum_{j \in \beta} [W_{1j}^g - W_1^r].dN_{1j} + \sum_{j \in \gamma} [W_{1j}^g - W_1^e].dN_{1j} \\
& + [\theta_{41} . W_{41}^g - W_1^e].dN_{41} - (W_1^e + \theta_{42}.\zeta.W_{42}^g).dN_{42} + \sum_{j \in \beta,\gamma} T_{2j}.W_{2j}^g.dN_{2j} \\
& + \sum_{i \in T} X_{i1}^6.dP_{i1} - \sum_i X_{i2}.dP_{i2} + \sum_i T_i^x.P_{i1}.dX_{i1} + \sum_i \sum_j T_i^m.P_{i2}.dX_{i2j}^1 \\
& + \sum_{i \in \tilde{x}} T_{i1}^c.P_{i1}.dX_{i1}^2 + \sum_{i \in \tilde{x}} (T_i^m + T_{i2}^c + T_i^m.T_{i2}^c).P_{i2}.dX_{i2}^2 - dQ + dF
\end{aligned}
\tag{11.7}
$$

Despite the repatriation of capital being exogenous to the model it is left in (11.6) and (11.7) in case we want to perform a simulation where the status of the current account changes. We include the change in foreign grants which is also exogenous in the usual closure because it allows us to calculate the compensating variation or equivalent variation measure of the change in welfare. On its own the change in welfare measures of (11.5)–(11.7) cannot be used as they are path dependent and so not well defined (the welfare measure will not necessarily be unique).[19] In welfare economics the well defined and accepted measures of change in welfare are the compensating variation and the equivalent variation. Both these give unique path independent measures.[20] The compensating variation measure of the change in welfare is easily obtained by adjusting the closure so that welfare is constant (*dV=0* in equation (11.5)) and foreign grants adjust endogenously to enable welfare to remain constant. The change in foreign grants will then simply be the compensating variation, or more explicitly, the amount that the nation will need to be compensated with in foreign grants in order for the level of welfare to remain unchanged at the initial level.

The equivalent variation is defined as the amount of increase in foreign grants in the original economic environment necessary to give a welfare level equivalent to that arrived at *after* the simulation. To obtain the equivalent variation is a less straightforward process. Let us denote the first base economic situation as 'F' and that after the simulation of a shock to an exogenous variable as 'U'. We denote this as 'U' because it is the new uncompensated situation, so foreign grants are exogenous in the simulation and welfare is allowed to adjust endogenously. The equivalent variation measure of the change in welfare is the amount of foreign grants that the nation would need to be compensated with at the initial situation 'F' to enable the level of welfare to reach that of situation 'U'. To obtain the equivalent variation measure, we perform a simulation from the base situation 'F' where welfare is set exogenous and increased to the level of welfare achieved at situation 'U'. Foreign grants are made endogenous and so allowed to adjust to enable welfare to reach the new level, and the amount of the adjustment is the equivalent variation. The new modified economic situation realised by this simulation we denote by 'N'. At Figure 1 we give a diagram to help clarify our description of the simulations from 'F' to 'U' and from 'F' to 'N'.

Figure 1 **Explanation of situations F, U and N**



F = initial economic situation

U = situation after the shock to the exogenous variable

N = initial economic situation but with foreign grants allowed to increase to bring welfare to the same level as U

Unfortunately the above method of deriving the equivalent variation does not allow the ability to derive the components given at Table 3. This is the case because the equivalent variation is determined in the movement from situation 'F' to situation 'N' in Figure 1, and so bypasses the effects of the exogenous shock on the various economic variables. It is therefore only a useful procedure to check for the robustness of the results. To obtain interesting disaggregated results, rather than go directly from 'F' to 'N', an extra step is required so as to move from 'F' to 'U' and then back to 'N'. To take the second step from 'U' to 'N', the exogenous shock performed in moving from 'F' to 'U' is reversed only this time adjusting the closure so that welfare is constant and foreign grants endogenous. Situation 'N' is reached because we return the exogenously shocked variable to its original level, but enable welfare to remain at the new level. Again, the movement from 'U' to 'N' is described in Figure 1. The change in foreign grants in moving from 'U' to 'N' will be that which enables welfare to remain at the new level, and so again it will represent the equivalent variation. In essence, and as is obvious at Figure 1, this is a roundabout way of arriving at the same result, but this time we will be able to obtain the various components because the result is arrived at by reversing the original shock.

Notes

[1] Cited in Dixon et al. 1982:5.
[2] This methodology refers to that developed by Johansen (1960). For an overview of the Johansen approach, refer Chapter 3 of Dixon et al. 1992.
[3] This information is in the database which is available and was written in Excel 5.0.
[4] Or commodities transferred abroad for which no payment is received.
[5] Refer Levantis(1997 for the steps in this derivation.
[6] For example, X_1 is output in absolute terms and x_1 is the percentage change of this output so that $x_1 = \frac{dX_1}{X_1}$.
[7] As we see in Section 6.2, labour demand is proportional to output supplied for these industries.
[8] Refer to Powell 197), or Dixon et al. 1982.
[9] The sources include Finlayson et al. 1991, Gibson 1995, and the original CGE model for Papua New Guinea developed by Vincent et al. 1991 where estimates for Indonesia are used.
[10] The value for the Frisch parameter used by Vincent et al. (1991) was 6. This value gave unrealistically low estimates for the price elasticities and we set it at 2. This approximates that used in the ORANI model of Dixon et al. (1982:194) and gives us price elasticity estimates for food commodities that resemble that estimated for Papua New Guinea by Gibson 1995.
[11] This is derived in Levantis 1997.
[12] The derivation of this is explained in Levantis 1997.
[13] Due to the tax free threshold of 3000 kina per annum there is no income tax applicable to unskilled labour of plantation and urban industries.
[14] This is evident, for example, from the early needs-based Minimum Wages Board determinations where the urban wage was set significantly higher than the rural wage.
[15] Where effective units of labour is that actually used by the employers of labour.
[16] Roy's Identity is $X_i(P, \tilde{C}) = -\frac{\partial U}{\partial P_i} \Big/ \frac{\partial U}{\partial \tilde{C}}$. Refer, for example, to Kreps (1991:56).
[17] This derivation is similar in process to that of Broadway and Bruce (1989), pp 197–8.
[18] Note that the welfare functions we derive will be ill-defined if we assume risk aversion in the behaviour of participants in the urban labour market at Section 7.2. This is the case because the welfare functions will be derived based on the assumption of a utilitarian welfare function and this contradicts the assumption of risk aversion.
[19] A discussion of this path dependency problem in context of the change in welfare measure is given by Broadway and Bruce (1989:198–200).
[20] Refer Broadway and Bruce (1989:203–6).

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