CHAPTER 6: THE CGE MODEL AND ITS POLICY SIMULATION RESULTS

6.1 Introduction

In this chapter, calibration and policy simulation results of the CGE model for assessing the implication of shifting the energy mix of the Malawi economy from biomass and fossil fuels to hydroelectricity are presented. In particular, the distributional effects of an environmental policy regime that taxes high carbon fuels and subsidizes alternative low carbon substitutes are discussed. One proposition is that the impact of carbon taxes would be negative for capital intensive sectors but positive for labour intensive sectors because capital intensive sectors are also energy intensive. Also, it is expected that the positive impact of fiscal policy regimes that taxes high carbon fuels and subsidizes alternative low carbon substitutes on labour intensive sectors would offset the negative impact on capital intensive sectors resulting in a positive overall net economic impact (gains). Thus, within the limits of these two propositions, the viability of simultaneous environmental and welfare improvements (double dividend) from a fiscal policy regime that taxes high carbon fuels and subsidizes alternative low carbon substitutes would be assessed.

The model used in this chapter is heavily restricted by data availability. In particular, virtually all energy sectors are aggregated to a level that prevents use of fuel switching technologies to simulate emission reduction by production sectors. The implication is that policy simulations may overestimate the cost of emission reduction in the sense that output reductions are exaggerated to some extent (Jorgenson and Wilcoxen, 1993; Fullerton and Metcalf, 1997; Fischer, 2001). To reduce output loss due to emission taxes, other studies use output-rebated emission taxes to achieve revenue neutrality albeit with the understanding that for any given emission rate, output-based rebating induces less total emission reduction (Fischer, 2001). Alternatively, this chapter adopts the approach that assumes that emissions and resource extractions have a small but positive elasticity of substitution with output. This minimizes the inefficiency of the model in predicting general equilibrium impacts of environmental taxes.

The rest of the chapter is organized as follows. Calibration of the general equilibrium model is discussed in section 2 while section 3 presents the design of environmental policy simulations. Sections 4 and 5 discuss the results in terms of economic and environmental implications, respectively. Section 6 concludes the chapter.

6.2 Calibration of the general equilibrium model

The International Food Policy Research Institute (IFPRI) SAM for Malawi was used to calibrate the model. The IFPRI SAM is the most reliable database on which to calibrate CGE models for Malawi. A full documentation of the SAM is Chulu and Wobst (2001). Lofgren (2000; 2001) provide a full documentation of the standard CGE model for Malawi. Although this study has some similarities with Lofgren's specification of the model, there are subtle differences in the assumptions used to derive equilibrium. Also, unlike Lofgren (2001), a one-to-one correspondence is imposed between activities and commodities (Table 17) as it is assumed that the loss of information from aggregating large-scale and small-scale agricultural activities is negligible. The algebraic specification of the model is in the appendix.

To model substitution between fuels in the energy aggregate, and between energy and non-energy inputs, the data in the Malawi SAM should ideally be disaggregated to show energy flows among industries (intermediate demand for energy), energy flows between industries and final consumers (final demand for energy), primary factor demands by energy producing industries, taxes on energy and imports of energy products. With this structure, emission reduction can be achieved by imposing an energy sales tax to minimize the energy sector's footprint on the environment.

The Malawi SAM is not fully disaggregated by energy activities. Except for AOIL, all other energy producing activities have concurrent production of non-energy outputs. For instance, AMINE has coal and other mining products such as lime and quarry stone, AFORE has other forestry products apart from fuelwood while AELEC has water and hydroelectricity (Table 17). However, using fuel demand data from AES and carbon emission coefficients from IEA (2003), the Malawi SAM is extended to include disaggregated data on activity level carbon emissions from fossil fuels, as well as quantities of biomass and hydroelectricity demanded. The IEA macro-level data is also used to check consistency of AES data as it relates to energy intermediate use.

Table 17: Description of SAM accounts

	ACTIVITY	ACTIVITY DESCRIPTION	INDUSTRY
1	AMAIZ	Maize (only small-scale)	Agriculture
2	ATEA	Tea and coffee	Agriculture
3	ASUGA	Sugar growing (only large-scale)	Agriculture
4	ATOBA	Tobacco growing	Agriculture
5	AFISH	Fisheries	Agriculture
6	ALIVE	Livestock and poultry	Agriculture
7	AFORE	Forestry	Agriculture
8	AOTHA	Other crops	Agriculture
9	AMINE	Mining	Mining
10	AMEAT	Meat products	Manufacturing
11	ADAIR	Dairy products	Manufacturing
12	AGRAI	Grain milling	Manufacturing
13	ABAKE	Bakeries and confectioneries	Manufacturing
14	ASUGP	Sugar production	Manufacturing
15	ABEVE	Beverages and tobacco	Manufacturing
16	ATEXT	Textiles and wearing apparel	Manufacturing
17	AWOOD	Wood products and furniture	Manufacturing
18	APAPE	Paper and printing	Manufacturing
19	ACHEM	Chemicals	Manufacturing
20	ASOAP	Soaps, detergents and toiletries	Manufacturing
21	ARUBB	Rubber products	Manufacturing
22	ACEME	Non-metallic mineral products	Manufacturing
23	AMETA	Fabricated metal products	Manufacturing
24	AMACH	Plant and machinery	Manufacturing
25	AELEC	Electricity and water	Utilities
26	ACNST	Construction	Construction
27	AOILD	Oil distribution	Services
28	AAGRD	Agricultural distribution	Services
29	AOTHD	Other distribution	Services
30	AHOTE	Hotels, bars, and restaurants	Services
31	ATELE	Telecom and transportation	Services
32	ABANK	Banking and insurance	Services
33	ABUSI	Business services	Services
34	APUBS	Public services	Services
35	APERS	Personal and social services	Services

Source: Chulu and Wobst (2001)

Both the IEA (2003) and AES data consistently show that manufacturing emits most of the energy-related carbon, while agriculture contributes the lowest to energy emissions (Table 18). Some of the carbon emissions are from construction, mining, and services, although together these sectors contribute less than 8 percent of the emissions. Manufacturing also has the highest pressure on forests as it uses most of the fuelwood and is important for shifting energy demand by production activities as it uses most of the hydropower supplied to production activities. Agriculture, on the other hand, is also an important sector for biomass energy management as it uses a significant amount of fuelwood.

Table 18: Sectoral biomass use (%) and carbon emissions (%)

Sector	Hydroelectricity use (%)	Biomass use (%)	Carbon emission (%) from oil and coal
Agriculture	6.6	20.6	0.4
Mining	6.8		2.3
Manufacturing	79.0	79.4	92.1
Utilities			
Construction	1.5		2.9
Services	6.0		2.3
TOTAL	100	100	100

Source: 1998-2000 AES, NSO (2001)

The services sector was important for generating most income in the economy in 1998, followed by agriculture (Table 19). The share of labour in value added suggests that mining, services and agriculture spend relatively more on labour, respectively, than other sectors. Manufacturing, utilities and construction spend relatively more on capital than on labour. Thus, mining, services and agriculture are typically labour intensive, while manufacturing is capital intensive. For agricultural activities however, the value of land is almost twice the value of capital input reflecting the extent of land expansion by small-scale agriculture compared to capital investment by large-scale agriculture.

Table 19: Sectoral generation of income in 1998 SAM for Malawi

Industry	Value added (VAD) (%)	Labour income in VAD (%)	Capital income in VAD (%)	Land income in VAD (%)	VAD in Gross output (%)
Agriculture	35.9	53.4	16.4	30.2	64.3
Mining	1.3	76.3	23.7		91.4
Manufacturing	14.8	34.1	65.9		25.6
Utilities	1.5	43.6	56.4		26.2
Construction	2.3	43.6	56.4		35.7
Services	44.2	64.9	35.1		72.0
Total	100.0	55.6	33.6	10.8	53.0

Source: 1998 IFPRI SAM for Malawi

The distribution of factor earnings to households shows that labour is the main source of income for all rural households, especially those with less than 2 hectares of landholdings (Table 20). However, rural agricultural households with between 2 and 5 hectares of land earn proportionately equal income from land and labour. On the other hand, urban agricultural households earn relatively more from labour than rural agricultural households with more than 5 hectares of landholdings possibly because they have alternative employment opportunities. For rural households, the proportion of earnings from capital tends to increase with a household's landholding. For urban non-agricultural households, capital is the main source of income and the proportion of earnings from capital increases with household's education level. Labour is the sole source of income for all rural non-agricultural households and urban non-agricultural households with no education.

The results above are further clarified by lumping together rural and urban households and then comparing the spatial distribution of factor incomes. This reveals that rural households get 72 percent of all the labour income while urban households get 93 percent of all the capital income. Rural households also get about 57 percent of the land rents with the remainder going to urban households. Thus, rural households are labour and land endowed while urban households are capital endowed.

Table 20: Household type and factor income sources (%)

Household type	Labour	Land	Capital	Total
Rural agriculture less than 0.5 ha landholding	97	2	1	100
Rural agriculture between 0.5 ha and 1.0 ha landholding	93	5	2	100
Rural agriculture between 1.0 ha and 2.0 ha landholding	91	7	2	100
Rural agriculture between 2.0 ha and 5.0 ha landholding	42	43	15	100
Rural agriculture more than 5.0 ha landholding	4	64	31	100
Rural non-agriculture no education	100			100
Rural non-agriculture low education	100			100
Rural non-agriculture medium education	100			100
Rural non-agriculture high education	100			100
Urban agriculture	33	44	23	100
Urban non-agriculture no education	100			100
Urban non-agriculture low education	8		92	100
Urban non-agriculture medium education	37	5	58	100
Urban non-agriculture high education	30	6	64	100

Source: 1998 IFPRI SAM for Malawi

Households also differ by the type of goods and services demanded. Grain is an important component of expenditure for all households but rural households spend relatively more on grain and other crops than urban households (Table 21). Public services are also a significant proportion of household expenditure for both rural and urban households while telecommunication and transportation services are important for urban agricultural households. Urban non-agricultural households also spend a significant proportion of their income on hotels, restaurants and bars, and on chemicals.

Table 21: Household consumption expenditure shares (%) for the CGE model

Commodity	Rural Agricultural	Rural Non-Agricultural	Urban Agricultural	Urban Non-Agricultural
Grain milling	25.4	23.2	16.7	14.0
Other crops other than maize, tea, tobacco and sugar	15.0	14.7	10.1	8.3
Fish	1.0	1.2	0.9	0.2
Meat products	6.5	6.2	7.1	4.4
Dairy products	0.5	0.9	1.9	2.6
Bakeries and confectioneries	1.0	1.8	2.4	2.2
Sugar	2.0	3.1	3.0	3.3
Beverages and tobacco	9.3	7.2	1.9	3.8
Textiles and wearing apparel	6.6	8.3	6.1	6.8
Wood products and furniture	2.5	2.7	3.0	6.0
Paper and printing	0.2	0.3	0.4	0.5
Chemicals	2.3	3.5	6.5	7.1
Soaps, detergents and toiletries	3.6	4.7	2.3	2.1
Rubber products	0.3	0.7	1.2	1.4
Non-metallic mineral products	0.8	0.9	1.0	0.8
Fabricated metal products	0.7	0.9	1.2	1.1
Electricity and water	0.4	0.6	0.7	2.9
Hotels, bars, and restaurants	3.0	3.4	6.3	10.2
Telecommunication and transportation	2.8	2.2	12.6	6.9
Banking and insurance	0.3	0.7		5.1
Business services	0.1		0.2	0.5
Public services	15.4	12.3	9.7	7.5
Personal and social services	0.9	1.2	4.8	5.0
Total	**100**	**100**	**100**	**100**

Source: 1998 IFPRI SAM for Malawi

Table 22 shows production cost shares for the CGE model. Utilities, construction, and manufacturing sectors have relative high cost shares (>59 percent) for intermediate goods while mining has the lowest cost share for intermediate inputs. Aggregate energy cost shares are generally low, ranging from 2-4 percent except in manufacturing where energy costs are 9 percent of production costs. Capital cost shares are fairly even across sectors except agriculture and utilities which have low capital cost shares, relatively. For agriculture, the cost shares for labour and intermediate inputs are equal while for services, and consistent with the distribution of value added in Table 19, labour costs almost twice as much as intermediate inputs.

Manufacturing, utilities and construction have capital-labour ratios of greater than 1 implying that they are relatively capital intensive while agriculture, mining and services have capital-labour ratios of less than 1 implying that they are labour intensive (Table 22). For agriculture, the capital-labour and the land-labour ratios are quite close, reflecting the structure of production among small-scale farmers who may be using land and capital as if they are substitutes. This is consistent with the observation by Wobst et al. (2004) that for small-scale agricultural activities the land-capital ratio is fixed so that capital shifts basically reflect land shifts. For all sectors, the capital-energy and labour-energy ratios are large mirroring the low energy cost shares.

6.3 Design of environmental policy simulations

To induce a shift in the energy mix from biomass and carbon-intensive fuels to hydroelectricity, the study simulates Pigouvian taxes on carbon emissions. Also, following Bruvoll and Ibenholt (1998), a material throughput tax on fuelwood is implemented to reduce the quantity of fuelwood input used by production activities. Consistent with Burniaux et al (1992), the material throughput tax is an excise tax levied on each ton of fuelwood. The resulting tax rate is levied specific to fuelwood using sectors and it varies with fuelwood use intensities. This is simultaneously implemented with an *ad valorem* subsidy on hydroelectricity to offset a rise in energy cost associated with taxes on fossil fuels and fuelwood. Specifically, the simulations are designed as follows:

Simulation 1:

Let the regulator set targets for carbon emissions from fossil fuels (coal and oil). Since Malawi has zero Kyoto Protocol targets, the targeted reductions of the benchmark total emissions ranges from 6 percent to 12percent. In simulation 1, the targeted reduction in emissions coincides with half of the average rate of increase in cumulative emissions from sub-Saharan African countries from 1990 to 1998 (i.e., 6percent). This is rather conservative considering that Malawi's own emissions grew by an annual average of 17 percent during the 1990-1998 period, and by about 42 percent annually up to year 2005 (World Resources Institute, 2008).

Hydroelectricity is a produced commodity and is represented in the SAM based on monetary valuation of factors, goods and services flows in the economy. However as shown in chapter 1 and 2, effective demand for hydroelectricity is less than 50 percent of generated output. This therefore allows the environmental regulator, who is also the sole generator and distributor of hydroelectricity to arbitrarily set targets for increased demand by production activities. This is implemented in the form of a subsidy on hydroelectricity since partial equilibrium results revealed substitution possibilities between hydroelectricity and oil and coal, respectively. Since the projected increase in demand as a result of subsidies is consistent with installed generation capacity of hydroelectric *vis a vis* effective demand, the proposed subsidy rate coincides with half the subsidy value envisaged under the rural electrification project.

Similarly, fuelwood in the Malawi SAM is a produced commodity by Forestry activity. However, by introducing physical quantities of fuelwood demanded by production activities in the extended SAM, we can simulate the impact of reducing physical demand of fuelwood by production activities. This is implemented in the form of a unit excise tax on a ton of fuelwood demanded. The unit excise tax rate on fuelwood is premised on the need to manage deforestation risk. In this regard, the rates of loss of forest cover between 1990 and 2005, and of primary cover between 2000 and 2005 are assumed as the lower and upper bounds for taxes to reduce fuelwood use by production activities. According to Butler (2006), the loss of forest cover between 1990 and 2005 was 13percent, and between 2000 and 2005, the country lost about 35 percent of primary forest cover. However, since some of the deforestation is caused by household use of fuelwood, the upper bound is set at 24percent, which is the average between the assumed values for low (13percent) and high deforestation rates[9]. It is therefore assumed that the excise tax levied on fuelwood is MKW 0.13 per kg or MKW130 per ton of fuelwood.

Simulation 2:

Cut carbon emissions by 12 percent and raise fuelwood excise tax to MKW 0.24 per kg or MK240 per ton while simultaneously implementing a 12.5 percent subsidy on hydroelectricity as a cost offsetting strategy. As indicated above, 12 percent reduction in carbon emissions is consistent with the average annual growth rate in cumulative emissions from sub-Saharan Africa from 1990 to 1998. The other figures for subsidy on hydroelectricity and excise tax on fuelwood are based, as above, on proposed rates of subsidy for rural electrification and on estimated loss of forest cover, respectively. Simulation 2 is the most stringent environmental policy stance as both carbon emissions and fuelwood demand are heavily constrained.

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[9] Although there is no linear correspondence between fuelwood use and observed deforestation rates, it is important for policy purposes to target objective and measurable variables that impact on deforestation rates. In this case, fuelwood use intensities and physical fuelwood demands per sector are key factors.

Simulation 3:

Carbon emissions are allowed to increase by up to 1.5 percent above the benchmark. This is implemented simultaneously with a MKW 0.24 per kg excise tax on fuelwood while simultaneously subsidizing hydroelectricity by 12.5percent. In addition, the virtual price of carbon emission permit is set at minimum of zero but flexible upward to ensure that there is no pecuniary cost on government for relaxing the carbon constraint on producers. This simulation is arbitrary and is used to demonstrate that other policies except direct taxes on carbon emissions could be used to control energy-related carbon emissions in developing countries.

6.4 Economic implications of environmental policy

The environmental policy simulations described above have implications for not just the environment but also the economy. The economic impacts are evaluated in terms of relative changes in output, household welfare (utility), government revenue and current consumption, and national savings and investment. In all cases, the changes are evaluated as a percent change with respect to benchmark values. All the CGE simulation results are in the appendix.

6.4.1 Household welfare

Aggregate household welfare measured by utility of a representative household marginally decline when environmental revenues are pooled with other government revenues with the only exception when the carbon constraint is nonbinding. On the other hand, recycling of environmental revenues improves welfare of the representative individual (Table B1). While a non revenue-neutral environmental policy is damaging for almost all urban agricultural households and rural households with large landholdings, the greatest welfare gain (loss) for disaggregated households is when environmental policy is stringent and revenues are (not) redistributed to households (simulations 2). A nonbinding carbon constraint is welfare improving in both revenue-neutral and non-neutral cases and would generally benefit non-agricultural households (simulation 3). Hence, not all households are equally affected by tax and subsidy policy on carbon emissions, fuelwood and hydroelectricity.

Simulations 1 and 2 lead to welfare losses for all households except rural households with large landholdings and for one urban agricultural household category when environmental revenues are pooled with other government funds. In contrast, recycling of additional environmental tax revenues to households improves welfare of virtually all agricultural households except those with large landholdings. However, recycling of revenue to households may not benefit urban non-agricultural households as they suffer marginal welfare losses.

These results can be explained by the fact that the main sources of income for rural households (i.e., the various labour categories) marginally gain value regardless of how additional environmental tax revenues are utilized while prices of some main consumption commodities (beverages and tobacco, and soaps and detergents) rise by between 4 and 30 percent(Tables B2 and B9). Similarly, urban non-agricultural households with low or medium education attainment get most of their income from either labour or non-agricultural capital whose values either declined or slightly increased, respectively, while prices of main consumption commodities such as meat, beverages and tobacco, and hotels, bars and restaurant services have gone up.

With recycling of environmental tax revenues, all rural agricultural households are welfare gainers, with the greatest gain of 7.25 percent by households with between 2 and 5 hectares of landholding (Table B1). Although large-scale land values do not increase by much, rural households with between 2 and 5 hectares of landholding have more diverse sources of income including medium education labour (both agricultural and non-agricultural), land and capital. Increased productions of cash crops such as tobacco, tea and coffee which are typically produced by households with large landholdings also have positive impact on incomes and welfare of these households (Tables B1 and B4).

All agricultural households are welfare winners when the regulator recycles environmental revenue to reduce the burden of direct taxes on households. The decision to recycle revenues to reduce direct tax obligations favours low income agricultural households because factor incomes to small-scale land owners consistently and significantly rise (Table B5). However, it is households with landholdings of between 2 and 5 hectares that have the highest welfare improvement as explained above (Tables B1 and B4). This suggests that smallholder farmers who are not land constrained would benefit as they could diversify production since increases in factor earnings are also accompanied by increases in production of cash crops such as tea, coffee and tobacco. Although the extra production of cash crops leads to a fall in relative prices of most agricultural commodities (Table B9), the change is so insignificant as to inflict welfare losses on farming households.

Rural non-agricultural households with high education also benefit from recycling environmental tax revenues since the earnings to high education non-agricultural labour rises especially in simulation 2 (Table B5). Although these results are short-run responses, the change in relative price of land and of cash crops compared to staple crop, maize, could have negative consequences on food security of land constrained households in the long-run as households may be tempted to shift production to cash crops on their small landholdings (Tables B2 and B9).

Compared to simulations 1 and 2 when revenues are recycled, relaxation of the carbon constraint (simulation 3) actually unifies the distribution of welfare gains within rural and urban household categories, except that rural agricultural households with landholdings between 2 to 5 hectares still fair better than the rest. Also, a nonbinding carbon constraint is unfavourable to urban non-agricultural households with high education as these households have no way of diversifying their income sources to take advantage of the relaxed policy stance on carbon emissions (Table B1).

6.4.2 Real gross domestic product

Although some relatively capital intensive sectors such as construction and manufacturing would, as expected, reduce output, environmental tax and subsidy policies on fuelwood and fossil fuels lead to slight real GDP increases of between 0.2 percent when revenue neutrality constraint is nonbinding and 0.45 percent when environmental tax revenue is recycled and carbon constraint is relaxed (Table B6). Total domestic production falls consistently regardless of how the additional tax revenue is utilized by the regulator. However, output reductions are worse for most sectors when environmental policy is stringent and environmental revenues are recycled to reduce direct tax burdens on households (simulation 2, Table B4).

Agriculture, utilities (electricity and water) and manufacturing sectors have output gains regardless of how environmental revenues are utilized. Services sectors however benefit only in simulation 2 when environmental policy on carbon emissions and fuelwood is stringent

(Table B6). These results support expectations that environmental taxes on fuelwood and fossil fuels would benefit labour intensive sectors, particularly those that hire labour with low to medium education levels. The gains in agriculture and manufacturing sectors are slightly improved when environmental revenues are distributed to households because households spend some on the transfers on products from these sectors. This is particularly evident for tea and coffee, tobacco, forestry, fisheries, meat and dairy products for agriculture and for services, banking and insurance, and distribution services for agriculture and other (unclassified) distribution services. Relaxation of the carbon constraint (simulation 3) is also particularly beneficial to most sectors, although the distribution of output gains or losses across all sectors is virtually similar with or without revenue neutrality (Table B4).

6.4.3 Government revenue

Government revenue is at its peak when a stringent environmental policy is implemented (simulation 2) and in particular when no revenue-neutral constraint is imposed on the fiscal system (Table B7). Simulation 2 also yields the highest net environmental tax revenue made up of tax revenue on fuelwood and carbon emissions, and subsidy on hydropower. Government revenue generally increases as environmental tax rates are increased because other taxable components are also increasing with the implementation of environmental policy. In particular, increases in factor income, exports and domestic output of some key taxable sectors bolster tax revenue (Tables B7 and B8).

When total non-environmental tax revenues are endogenously determined while additional environmental revenues are distributed to households, yield from pre-existing taxes would increase by at most 3.2percent. In simulations 1 and 2, environmental tax yields are consistently higher at higher tax rates since some distortions caused by pre-existing taxes are reduced by redistributing revenues to households (Tables B7 and B8). Hence, placing a ceiling on pre-existing tax revenues while environmental taxes are being recycled would be inefficient from both the revenue point of view and economic considerations. In particular, the results show that GDP is slightly higher when pre-existing tax yields are flexible, implying that the efficiency losses from the interaction between environmental taxes and pre-existing taxes could be significant when a ceiling is placed on pre-existing taxes. This assertion was verified by introducing an absolute revenue ceiling on pre-existing taxes. The result, not included in the appendix, was a total reduction in domestic output of at most 1.5 percent which is comparable to the loss in revenue when the carbon constraint is relaxed.

6.4.4 Savings and investment

Total household savings generally fall in all simulations regardless of how additional environmental policy revenues are utilized (Table B3). The impact of specific households however depends on the impact of policies on factor incomes and on prices of consumer goods. When environmental tax revenues are not recycled, all households except rural agricultural households with large land holdings, rural non-agricultural households with high education, and all other non-agricultural households with low and medium education would have higher factor incomes. Among these, households that had positive savings in benchmark scenario would correspondingly increase or reduce savings, with the greatest reduction in saving incurred by urban non-agricultural households with high education (Tables B2, B3 and B5). When revenue-neutral measures are introduced, the positive increase in savings of rural households is more pronounced while urban households would have zero or negative increase in saving. However, urban agricultural households would benefit from recycled environmental revenues as savings increase by up to 1.5percent. The presence of a nonbinding carbon emission constraint leads to marginal increase in saving for all household categories. However, there is no conclusive evidence to suggest that savings improve when the carbon constraint is relaxed conjointly with revenue-neutral considerations.

In all simulations, foreign saving is held constant while the exchange rate, and foreign aid flows are allowed to vary to bring about equilibrium of balance of payments. Savings by government decline in all simulations particularly with revenue neutrality (Table B3). Since net national saving falls in all simulations regardless of whether environmental taxes are recycled or not, investment demand also declines. However, the change in investment demand is significantly higher under revenue-neutral regimes, reflecting that a significant portion of investment in the economy is by government. Hence, if the additional revenue was to support investment in environmental protection, it would be in the interest of the regulator to allocate the additional environmental revenue to the pool of government resources.

6.4.5 Capital-intensive versus labour-intensive sectors

For simplicity, labour intensive (capital intensive) sector is defined to mean a sector whose main value added component is labour (capital). To assess the impact of environmental policy on labour intensive and capital intensive sectors, we compare the change in output averaged over simulations 1 and 2 for revenue-neutral and non-neutral scenarios, respectively.

In benchmark scenario, labour intensive sectors contribute MKW 50, 448.1 million (53percent) to domestic output while capital intensive sectors produce MKW 43, 906.6 million (47percent) (Table B18). The entire economy has overall output gain when environmental policy is imposed. Although there are gains and losses for both labour intensive and capital intensive sectors, on aggregate, it is capital intensive sectors that have output gains while labour intensive sectors lose out. Hence, environmental policy is favourable to capital intensive sectors in that gains in capital intensive sectors more than offset the loss in labour intensive sectors, resulting in overall output improvement for the entire economy. However, the loss in output from labour intensive sectors is very low compared to both benchmark and policy induced levels of output suggesting that any damage to employment would be very low.

For agricultural sectors, fisheries and other crops are the major sources of growth but most of the growth in output in the economy is from services sectors. In particular, environmental policy is favourable for telecommunications and transport, oil distribution, and banking and insurance. The only labour intensive manufacturing sector that benefits from environmental policy is the activity of manufacturing non-metallic mineral products.

For capital intensive sectors, manufacturing of plant and machinery almost doubles its output when environmental policy is implemented. Manufacturing of rubber products, and textiles and wearing apparel are other capital intensive beneficiaries of environmental policy (Table B 18). Construction, large-scale sugar growing, and manufacturing of soaps, detergents and toiletries, beverages and tobacco, and paper and printing are capital intensive sectors that lose out when environmental policy raises production costs for carbon-intensive energy users regardless of how additional revenues are distributed in the economy.

6.4.6 International trade and competitiveness

Under a flexible exchange rate regime and fixed foreign savings, recycling of environmental revenues leads to a fall in foreign aid flows as the Malawi Kwacha appreciates in value. All other things being equal, the overall demand for exports is likely to increase. This is attained in the main agricultural export sectors of tobacco, tea and sugar production. Total exports rise by between 0.6 percent and 2 percent in simulations 1 and 2, regardless of how additional environmental revenues are utilized (Table B19). Most of the gains in exports are in non-traditional sectors of manufacturing of plant and machinery, wood products, chemicals, fabricated metal products, textiles and wearing apparel, and business services. Except for fabricated metal products, these sectors are generally less carbon-intensive, and therefore do not face environmental policy constraints in production. Carbon-intensive sectors such as manufacturing of soaps, detergents and toiletries, and of beverages and tobacco face the highest reduction in exports in all simulations, regardless of how additional environmental revenues are utilized.

The increase in benchmark trade deficit from carbon-intensive sectors is significant considering that some imports increase by more than 100percent. Nevertheless, environmental policy generally improves international competitiveness as the major importing sectors such as manufactures of chemicals, plant and machinery, and services of telecommunication and transport consistently reduce imports. This is particularly significant for chemicals and plant and machinery which experience a surge in demand for its exports. Overall, trade deficits increase for carbon-intensive sectors but as indicated above, gains are significant in traditional and non-traditional export sectors. Relaxing the carbon constraint is also particularly beneficial to exporting sectors in both revenue-neutral and non revenue-neutral scenarios.

6.5 Environmental implications of the policy scenarios

6.5.1 The first and second dividends of environmental policy

The environmental policy is implemented to reduce carbon emission from fossil fuels and to reduce pressure on forests from fuelwood use by production activities. The exogenous reductions in carbon emissions from fossil fuels (oil and coal) and total use of fuelwood by production activities are the first and second dividends of the policy. There is an induced reduction of carbon emissions by 6 percent and 12 percent in simulations 1 and 2, respectively. There is also reduced fuelwood demand by between 1.3 percent and 1.9 percent with revenue neutrality and between 1.6 percent and 2.2 percent with non revenue-neutral policy stance in simulations 1 and 2, respectively (Table B10).

Tax revenues from fuelwood range from 6.8 to 12.6 million Kwacha when environmental revenues are not recycled to reduce distortions in the fiscal system. Under non-neutral revenue conditions, taxes on emissions from oil and coal yield between 555.7 and 649.3 million Kwacha when the carbon constraint is in place and nothing when the carbon constraint is nonbinding. In contrast, increasing hydropower demand would require subsidies ranging from 265.6 to 271.5 million Kwacha. In particular, a 12.5 percent subsidy on hydroelectricity has the effect of increasing demand for hydroelectricity by 4.9 percent to 7.6 percent depending on other environmental taxes and whether environmental revenues are distributed to households or not (Tables B8 and B10).

Imposing revenue-neutral conditions slightly raises tax revenues from fuelwood and carbon emissions. Similarly, total subsidies for increasing hydropower demand also decline since inefficiencies associated with tax interactions when revenues are not recycled are reduced. This in turn increases total environmental revenues from 293.6 million Kwacha in simulation 1 with no revenue-neutral constraint to a maximum of 408 million Kwacha when a revenue-neutral constraint is in place in simulation 2 (Table B10). In addition to lowering tax interactions when additional environmental revenues are distributed to households, total environmental tax revenue increases because marginal costs for abating carbon emissions are strictly increasing as abatement targets are increased. This is consistent with expectations that as environmental policy becomes stringent, the adjustment costs for different sectors of the economy must increase proportionate to levels of energy demand.

Sectoral responses to changes in marginal tax rates on fuelwood and marginal abatement cost (MAC) of carbon are not radically altered by recycling environmental revenue. However, carbon-intensive manufacturing activities have the largest reduction of carbon emission relative to benchmark emissions and the proportions are not altered by recycling of environmental revenues while for construction, recycling of revenues significantly increases rate of reduction in emissions (Table B12). In manufacturing, the activity of manufacturing of soap, detergents and toiletries has the highest single reduction in carbon emissions followed by distilling of spirits and manufacturing of malt liquor and soft drinks.

Although some manufacturing activities such as plant and machinery, and rubber products considerably increase emissions in all simulations, these sectors are insignificant since they contribute about 2.8 percent to total emissions in the benchmark scenario. In contrast, two manufacturing sectors (manufacturing of soap, detergents and toiletries, and manufacturing of distilled spirits, malt liquor and soft drinks) that contribute 77 percent of total emissions have a substantial reduction of emissions averaging 1.85 to 19.9 percent in simulations 1 and 2, respectively (Table B13). Thus, overall, marginal increases in emissions from small sectors are offset by large reductions in emissions by sectors that are carbon-intensive in their energy demands.

Regardless of whether revenues are recycled or not, the manufacturing sector also has the largest reduction of fuelwood use relative to benchmark demand (Table B14). In particular, processing of sugar, manufacturing of soap, detergents and toiletries and activity of distilling of spirits and manufacturing of malt liquor and soft drinks are important sectors as they have the greatest response in reducing fuelwood use. These sectors together account for 72.4 percent of fuelwood demanded in the benchmark scenario. However, growing of tobacco and tea, and activity of fabricating metal products would have a negative impact as these activities slightly increase fuelwood demand considering that together they account for 20 percent of fuelwood demand in benchmark scenario.

Tobacco growing which accounts for 14 percent of demand for fuelwood in benchmark case would increase fuelwood demand by about 0.2 percent in simulations 1 and 2. Tea growing which in benchmark accounts for 5.8 percent of fuelwood demand increases fuelwood demand by 0.4 percent in simulations 1 and 2 (Table B16). This result is consistent with findings in chapter 5 that fuelwood has limited substitution options with other fuels in the energy aggregate when carbon-intensive fuels are also taxed. In particular, tobacco and sugar growing (0.91) and tea, coffee and macadamia growing (1.25) would substitute fuelwood for hydroelectricity at a sluggish rate (chapter 5, Table 13). With taxes, total demand for fuelwood falls by between 1.3 percent and 2.2 percent since proportional increase in fuelwood demand is less than cumulative reductions in demand in the entire economy (Table B16).

Comparing simulation 3 when the carbon constraint is relaxed with a modest carbon constraint of 6 percent reduction in emissions (simulation 1), it is noted that for similar subsidy rates on hydroelectricity, an additional 3.7 megatons of carbon would be emitted over and above the benchmark total when environmental tax revenues are pooled with other government resources while 0.4 megatons of carbon would be abated by introducing revenue neutrality in the fiscal system. These additional emissions represent 18 percent of carbon abated when environmental revenues are pooled with other tax revenues or 16 percent of the carbon abated when additional tax revenues are distributed to households (Table B11). Simulation 3 also shows that emissions can increase at zero cost to producers if other environmental revenues are pooled with government resources or with a 0.36 million Kwacha tax per megaton of carbon if environmental tax revenues are distributed to households.

Doubling the carbon constraint (simulation 2) also doubles the difference between tolerable emissions when the carbon constraint is nonbinding and what can be abated when the carbon constraint is in place. However, there are sectoral differences in emission reductions, with a few key emitters reducing their benchmark emissions by more than the carbon constraint (Table B13). This suggests that it would be possible to reduce energy-related emissions without imposing a strict constraint on initial emissions. This is obviously the case for activities of growing sugar, paper manufacturing and printing, and construction, as these sectors actually reduce their benchmark emissions by an average of 2.9 percent when the carbon constraint is nonbinding. Similarly, the activity of manufacturing of soap, detergents and toiletries also reduces emissions by more than the carbon constraint in simulations 1 and 2.

These results are significant since the sectors that reduce carbon emissions when a carbon constraint is nonbinding collectively account for 43.2 percent of total emissions in benchmark scenario. Thus, it is not absolutely necessary to tax fuelwood and carbon emissions for environmental policy to effectively reduce carbon emissions and deforestation in the economy. This is important for Malawi because oil is a heavily taxed imported commodity that has knock-on effects on prices of many other commodities.

The environmental policy simulations also show that there would be direct emission reductions (or increments) and indirect emission reductions calculated from forgone combustion of biomass. The highest net emission reduction is 44.4 megatons of carbon when a stringent environmental policy is in place while the lowest net emission reduction is achieved when a modest direct reduction of carbon emission from oil and coal is implemented (Table B11). Further carbon abatement would be possible if biomass not used as fuel could be maintained in standing forest which in turn sequestrates atmospheric carbon. However, carbon sequestration gains in environmental quality are not captured by this study[10].

6.5.2 The third dividend of environmental policy

The third dividend is obtained when introduction of environmental taxes result in real GDP at least equal to benchmark value. This was achieved even when environmental tax revenues are not recycled to reduce direct taxes on households (Table B6). Also, a revenue-neutral environmental policy leads to additional gain to the economy in that aggregate household welfare improves. Further, the resulting welfare distribution among households is pro-poor since all rural agricultural households are welfare winners (Table B1).

6.5.3 The optimal energy mix

The optimal energy mix for Malawi is that set of fuels that yields maximum reduction in net carbon emissions from fossil fuels and minimizes total fuelwood demand by production activities at low cost to the economy. At equilibrium, the economy would use 2 percent less fuelwood costing 12.6 million Kwacha in excise taxes while carbon emissions would be reduced by 12 percent after imposing 2.18 million Kwacha tax per megaton of carbon emitted (Tables B8 and B10). This would be optimal if the environmental revenues are recycled to households and hydropower is subsidized by 12.5 percent, leading to a total subsidy expenditure of 264.2 million Kwacha and a 5.5 percent increase in hydropower demand[11].

Apart from abating a total of 44.4 megatons of carbon, the optimal energy mix would result in a direct reduction of fuelwood demand by 6.4 megatons, and net environmental revenue of 408 million Kwacha (0.8 percent of benchmark GDP) (Tables B8, B11 and B16). Excluding the subsidy on hydroelectricity, taxes on fuelwood and carbon emissions from fossil fuels are

[10] The sequestration rate used in Ecological Footprint calculations of the Living Planet Report of 2004 is based on an estimate of how much human-induced carbon emissions the world's forests can currently remove from the atmosphere and retain. It is estimated for instance that one global hectare can absorb the CO_2 released from consuming 1,450 litres of gasoline per year (Loh and Wackernagel, 2004).

[11] The Btu equivalent of hydroelectricity net demand is estimated by a flexible Cobb-Douglas structure specified in chapter 4. The same applies to fuelwood demand and net carbon emissions by production activities.

equivalent to 1.3 percent of benchmark GDP. This is significantly close to the annual growth rate of the economy's energy intensity per dollar GDP of 2.5 percent (IEA, 2003). As discussed above, recycling of environmental revenues only ensures that household welfare is at least equal to benchmark welfare and thus improves gains in other aspects of the economy.

6.6 Summary and conclusions

The impacts of tax and subsidy induced shifts from fuelwood and fossil fuels to hydroelectricity were analysed in terms of economic and environmental outcomes. In general, unit taxes on fuelwood and carbon emissions from oil and coal will improve the environment by directly reducing energy-related GHG emissions and relieving pressure on forests. The results also highlight the fact that taxes or subsidies are not the only solution to the twin problem of energy-related emission of greenhouse gases and deforestation in developing countries. In particular, Malawi could increase emissions from coal and oil as long as net carbon emissions are reduced by implementing an offsetting clean energy strategy such as increasing demand of hydroelectricity by production activities as well as maintaining standing biomass in forests to sequestrate carbon.

The direct cutback of emissions and industrial fuelwood use were counted as two dividends of environmental policy. Overtime, these could translate into a cleaner environment and less deforestation linked to energy use by production activities. Maintaining or improving benchmark value of gross domestic product was counted as a third dividend. The third dividend was obtained even without imposing revenue-neutral constraints on environmental policy. Thus, for Malawi, environmental taxes need not be revenue-neutral for a triple dividend to be obtained. However, revenue-neutral conditions are important when household welfare and distribution impacts are taken into account.

Although the general equilibrium results in this chapter represent short-run responses only, a number of medium to long-term inferences can be drawn. The long-run impact of environmental policy would depend on environmental and economic outcomes. First, capital intensive sectors such as manufacturing are expected to invest in more energy-efficient capital in order to counteract the cost of energy taxes. The short-run response indicates that labour intensive sectors such as services are going to lose from implementation of the energy tax. However, since the aggregate output loss by labour intensive sectors is insignificant relative to aggregate contribution to benchmark output by labour intensive and capital intensive sectors, respectively, it is likely that in the long-run any losses in employment would be minimal while energy-efficient capitalisation takes hold. This is consistent with conclusion of the previous chapter on long-run employment impacts of environmental taxes.

Second, the direct cost of energy demand on the environment as measured by the social cost of carbon emissions and fuelwood use by production activities was not significantly different from the moderate estimate of social cost of deforestation quoted in chapter 5. These general equilibrium results are important since in the absence of estimates of damages of secondary impacts of carbon emissions and deforestation, the optimal energy tax corresponds to the annual growth in economy's energy intensity. Thus, if short to medium term impacts are important as is the case in Malawi where data on secondary damages are unavailable, it would be more efficient to target growth in intensities of use of certain fuels that are contributing to the economy's burden on the environment.

Third, sectors that are heavily affected by the tax on fuelwood such as growing of sugar, manufacturing of soap, detergents and toiletries and beverages and tobacco could benefit from a policy that offers tax rebates on fuelwood sourced from own forest reserves. This would complement the existing but largely ineffective policy that requires agricultural estates to devote 10 percent of their land to tree crops (Hyde and Seve, 1993). Similarly, forests owned and managed by production activities could be used to assess carbon rebates a sector should be entitled to and the rebates could be assigned according to carbon sequestration potentials per hectare of forests owned.

CHAPTER 7: SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

7.1 Summary

This study evaluates the implications of voluntary reduction in energy-related emissions for the environment and economic welfare in Malawi. It identifies an energy base consisting mainly biomass (fuelwood and charcoal) and fossil fuels as a threat to sustainable development because of its related environmental pressures. Although Malawi's total GHG emissions are negligible even by sub-Saharan Africa averages, the problems of deforestation and loss of forest cover due to industrial fuelwood use are quite significant. This study is unique in that it suggests solutions to greenhouse gas emissions within the economic development agenda for Malawi. The results prove that developing countries such as Malawi could achieve better economic and environmental outcomes by implementing policies that address not just efficiency problems in the energy sector but also environmental concerns.

This is the first study to analyse the economywide impacts of shifting the energy mix from biomass to modern fuel sources in Malawi. The study has policy relevance for GHG mitigation, forestry management and for efficiency of the energy sector. In terms of methodological contribution, the study complements partial equilibrium results with conclusions drawn from a CGE framework. In particular, an energy sector model consisting interfuel substitution model and an aggregate energy and non-energy input demand system that incorporates short-run and long-run structural adjustment parameters is specified. The energy sector results are used in simulations to assess partial equilibrium impacts of fiscal policy regimes that taxes biomass and carbon-intensive fuels while subsidizing hydroelectricity. The study also evaluates general equilibrium impacts of reducing fossil and biomass fuel use by production activities while investing in more hydropower. The general equilibrium results are specifically used to determine the optimal fiscal policy regime and thereby the optimal energy mix for the economy. This study is therefore a direct contribution to the literature on environmental CGEs in sub-Saharan Africa.

The main result of this study is that carbon emissions and forest resource depletion due to energy use, respectively, can be reduced by imposing environmental taxes aimed at inducing a shift from biomass and fossil fuels to hydroelectricity. More significantly, there are at least three dividends from inducing a shift in the energy mix of the economy in that the economy can attain GDP at least equal to the value before imposition of the environmental taxes besides reducing carbon emissions and deforestation. Further, redistributing the environmental revenues to reduce direct taxes on households could lead to better income distribution since low income (agricultural) households benefit more than high income (non-agricultural) households. Thus, depending on how the additional revenues are utilized by government, environmental taxes could complement poverty reduction goals.

The general equilibrium conclusions are consistent with partial equilibrium estimation results and simulations. Since the energy sector model reveals strong substitution possibilities among fuels in the energy aggregate and between energy and non-energy aggregate inputs, economic incentives could be used to induce firms to shift from fossil fuels and fuelwood to environmentally friendly energy sources such as hydroelectricity. In particular, the partial equilibrium policy simulations show that forest resource conservation could be enhanced by levying a positive tax on coal, zero tax on fuelwood and subsidizing hydroelectricity while the greatest reduction in carbon emissions could be achieved by positively taxing both fuelwood and coal. In addition, the aggregate energy and non-energy input demand system reveals that energy saving policies that favour capital intensive over labour intensive production could lead to lower energy use per unit of output since firms in Malawi adjust energy-capital input ratios faster than labour-energy ratios by about 10 percentage points.

Policy inferences from the energy sector model simulations are, however deemed inconclusive as they entail negative environmental and economic tradeoffs. Specifically, existence of substitution possibilities among fuels in the energy aggregate imply that tax induced differences in relative prices of fossil fuels and fuelwood could trigger either more use of fuelwood and hence deforestation or more use of fossil fuels and hence increased carbon emissions. Employment effects from energy conservation could also be significant in the long-run because of the slow rate at which firms adjust labour-energy input ratio compared to capital-energy input ratio. Hence, a policy that induces energy-efficient capitalisation by production activities could eventually impact negatively on labour employment although environmental benefits such as lower carbon emissions and deforestation per unit of output could be considerable.

Taking into consideration the inconclusive policy implications from the energy sector model, general equilibrium analysis was used to evaluate distributional costs and benefits of a policy that taxes fossil and biomass fuels while subsidizing hydropower. The CGE model establishes that taxes on fossil and biomass fuels would not impose undue costs to the economy, and that employment losses could be minimal regardless of how additional environmental revenues are utilized by the government. Ultimately, it is the distributional effect on factor incomes that matter since welfare for the representative individual improves in revenue-neutral scenarios. Thus, apart from improving the environment, environmental taxes would not reduce the economy's output (GDP) and could be welfare augmenting if the environmental tax revenues are redistributed to reduce direct taxes on households.

The study also finds credible support for key partial equilibrium analysis based conclusions. For instance, the partial equilibrium implication that capital intensive sectors could contribute to lowering energy intensities in production is confirmed by general equilibrium output responses of capital intensive sectors. Capital intensive sectors reduce demand for some fuels to minimize costs of producing a given level of output or reduce output when adjusting to extra energy costs associated with taxes on carbon emissions and fuelwood. However, a carbon tax policy might be a knife-edge since a lenient policy stance on emissions could result in reversal of output gains in capital intensive sectors since the tax leads to higher factor prices arising from excess demand for inputs in other sectors of the economy. Thus, only when carbon emission reduction targets are large would taxes on fossil fuels and fuelwood and subsidies on hydroelectricity have positive impacts on capital intensive sectors sufficient to offset negative impacts on labour intensive sectors.

The study also highlights the fact that environmental policy may be beneficial for both traditional and non-traditional exporting sectors. In particular, there are clear gains in all major export crops, although on aggregate for the whole economy's trade balance deteriorates with imposition of strict environmental policy. On the other hand, relaxation of the carbon constraint leads to improvement in competitiveness as the trade deficit narrows. This result is particularly important in that in the absence of policy coordination, domestic sectors may be overly disadvantaged by environmental policy while dirty consumer and producer goods are imported at zero environmental surcharges.

The general equilibrium model also highlights policy alternatives to taxation that can be pursued to achieve the dual goal of reducing deforestation and carbon emissions associated with energy use. One alternative is a carbon rebate system based on biomass left in standing forests. Currently, large agricultural estates in Malawi are required by law to devote 10 percent of their land to tree crops. However, the system does not reward farmers who devote substantially more land to tree crops nor does it effectively sanction those that fail to adhere to the law. This study suggests that the law should evolve into a rebate system whereby production activities can exchange their carbon emissions from fossil fuels with carbon that can be sequestrated by biomass in standing forests owned or maintained by the producers. In addition, a tradable permit system can be developed based on the rebate system to encourage those that have excess land to plant more trees and increase their emission rights.

7.2 Conclusion and policy implications

There are persuasive economic conditions for Malawi to introduce environmental taxes on fuelwood and carbon-intensive fossil fuels. This would not only reduce environmental pressures, but would also improve efficiency in other energy sub-sectors such as hydroelectricity. This is crucial because with economic growth and rising energy demands, cumulative GHG emissions from developing countries will continue rising faster than those from industrialized countries implying that convergence with developed regions in terms of cumulative contributions to GHGs may not be far off. Thus, Malawi must strategically position itself in international agreements for reducing environmental pressures while pursuing higher goals of economic growth and poverty reduction.[12]

Most developing countries consider environmental taxes as undesirable for compromising economic growth and other social goals. However, as shown in this study, environmental

[12] The climate change negotiations in Copenhagen, Denmark in December 2009 (COP 15) revealed strong considerations by some influential developed countries for tangible commitments from developing countries. It is thus envisaged that the next round of negotiations in Canada in December 2010 may focus on what developing countries can realistically do in order to have a global climate change agreement after Kyoto. This may include adaptation of emission targets for larger and fast growing developing countries like China and India, and financing arrangements for climate change adaptation and mitigation for other developing countries, including Malawi.

taxes can be welfare improving depending on initial conditions including efficiency of existing taxes, size of inefficiency the new tax is correcting and how government utilizes the additional tax revenue. The direct environmental benefits estimated by this study are only a small proportion of total benefits since reduced deforestation has significant positive impacts on ecosystem system functions such as conserving biodiversity, watershed protection, and soil conservation. Forests are also important in the global context of absorbing carbon from the atmosphere and mitigating the impact of climate change. Malawi should therefore develop its forestry to rip benefits from carbon trading schemes that may come with future global agreements on climate change. The economy therefore stands to benefit substantially more from a policy that induces a shift from biomass fuels to avert deforestation in several ways.

In general, it is expected that over time, biomass energy use and greenhouse gas emissions will be influenced by costs imposed on producers and on consumers by environmental policy. The direct environmental benefits to the economy will depend on short-run and long-run elasticities of demand for taxable intermediate inputs especially fuelwood and fossil fuel. For primary resource extractions, the impact of an environmental tax will depend on the scale of production that drives resource use. In addition, the impact of environmental taxes on households will be felt through prices of taxed commodities and through income effects arising from energy and non-energy input substitution in production.

The estimate of direct environmental cost associated with the use of fuelwood and fossil fuels is not significantly different from the moderate estimate of social cost of deforestation in the Malawi NEAP. This is significant because in the absence of estimates of damages of secondary impacts of both carbon emissions and deforestation, the optimal energy tax as inferred from the general equilibrium model corresponds to the annual growth rate in economy’s energy intensity. Since short-run to medium term environmental impacts are critical in the case of Malawi where data on secondary damages are unavailable, it would be prudent to target growth in intensities of use of fuels that contribute to the economy’s footprint on the environment.

Countries like Malawi where domestic production is low compared to domestic absorption face both financial problems from balance of payments, and environmental costs of disposal of materials from traded goods. Where there are negative externalities in consumption but production takes place under conditions of perfect competition, importing countries are expected in theory to develop strategic trade policies that address the externality within their jurisdiction. If the small country assumption is valid, there are a few significant process instances per industry, i.e., production stages with intense environmental interventions, thereby allowing time and location dependent assessment of environmental impacts in relation to the entire sector or economic system. In particular, the manufacturing of soaps, toiletries and detergents, and the activity of distilling malt liquor and manufacturing of soft drinks are key sectors for both industrial fuelwood use linked to deforestation and carbon emissions from fossil fuels. It is therefore feasible for the environmental regulator to collect pollution and biomass fuel use information on each firm, and apply appropriate environmental policy instrument especially on firms that produce tradable output.

7.3 Study limitations and recommendations for further study

The limitations of this study are endemic to most if not all static environmental CGE models. The first major limitation is that in the calibration of the model, elasticities for all inputs are calculated from equilibrium values in the SAM. As a result, our simulations only give an indication of the direction and size of the effects of policy changes. However, the results are fairly robust to changes in the range of values for the proposed change in environmental taxes. The second limitation is that environmental feedbacks are not explicitly modelled in production and utility functions and so dynamic effects are ignored.

The implication of the second limitation is that the model may have overestimated the cost of environmental policy to the economy or equivalently underestimated environmental benefits because technology improvements or changes in consumer tastes were not considered over the simulation period. This is also compounded by the fact that data limitations does not permit the CGE model to adequately represent substitution possibilities among fuels in the energy aggregate, and between energy and non-energy aggregates in production. The efficiency loss of the model in terms of accuracy and reliability of results is however mitigated by the assumption that the estimated environmental externalities have a small positive elasticity of substitution with output. Hence, pure output losses due to model specification error are minimized, and thus the results are much closer to reality.

Since energy driven environmental interventions are important, this study could be improved by modelling at the highest level of detail all energy products in the CGE. This would require disaggregated SAM data for all energy products (fuelwood, oil, coal and hydroelectricity) to improve validity of results since as Thompson (2006) argued, substitution involving an aggregate is not necessarily a weighted or other average of the disaggregated inputs. In particular, to measure the overall economic impacts of changes in the energy sector, the impacts are heavily dependent on interfuel substitution as well as the rate at which firms adjust their non-energy and energy input ratios with respect to labour and capital. These aspects could be modelled more vividly with additional data.

Dynamic elements of the partial equilibrium model suggest that the static CGE is only an approximation of how firms and households may react to environmental policy. The dynamic adjustment processes by labour intensive and capital intensive sectors are crucial and must be observed over a period long enough for firms to vary capital-labour ratios in the simulation. This requires more data, additional modelling (subroutines for dynamic elements), and more precision in assumptions of structure and calibration parameters. The dynamic CGE approach would also be more appropriate for analysing the implications of international agreements on GHG emissions to which Malawi is a party. In particular, it would be valuable to test the results of this study within the context of a new global climate change agreement (post Kyoto and Copenhagen) which may include emission targets for developing countries as well as financial arrangements for climate change adaptation and mitigation.