Computable General Equilibrium Analysis of the Economic and Land-use Interfaces of Bio-energy Development

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Introduction

The recent years have witnessed the growing concern over the developing countries' stakes and contribution to the climate change problem. The gradual increase in global temperatures from the accumulation of carbon dioxide (CO_2) is expected to be spun in the future by their economic expansion (Sachs, et al, 1999) and is believed to impair the productivity of their major sector: agriculture (Sachs, et al, 1999) , (Rosenzweig, et al 1993). However, implementing conventional policies in developing countries to reduce CO_2 is an arduous task, given their increasing demand for energy, their financial constraints to develop cleaner energy alternatives and their vulnerability to energy or emission taxes. Of equal importance to CO_2 mitigation in developing countries as the energy sector, are the agriculture and forestry sectors. Agricultural soil and biomass from forest stocks are potent carbon sinks. Land-use conversion for industry and residential purposes, and the deforestation for agricultural use have turned the sectors into sources of CO_2 emissions.

A policy option that could address the CO_2 emissions from fossil fuel consumption and from land-use conversion is the development of a cleaner energy alternative from the products and residues of agriculture and forestry. Bio-fuels from agriculture and forest crops and residues can curtail the high levels of CO_2 from energy use and from deforestation by its diversion of energy use away from fossil fuels and its competition of land-use away from deforestation to biomass plantation. Currently, households, industries, and commercial enterprises in developing countries are the main users of bio-energy. Developing bio-energy as a carbon offset requires the extension of its use to modernized systems such as transport fuel and electricity generation. Such venture will involve however, a substantial reallocation of resources, both financial and physical to bio-energy production. Given its current non-marketability (Mc Carl and Schneider, 2002), the only way bio-energy can ease through its market diffusion is through the aid of government subsidy. Replenishing the government treasury with increases either in the existing tax rates or in the tax base to fund the additional expenditure, will certainly impinge upon the various components of the economy and therefore should be examined in conjunction with bio-energy subsidy's impact upon the economy, welfare, and the environment. The future supply of bio-energy is also expected to come from devoted plantations, which in turn will induce changes in the current land use system and thereby in the productive capacity and environmental services of agriculture and forestry. The analysis of bio-energy as a climate change policy will then require the assessment of its costs both in terms of the financial investment needed for its market penetration and in terms of the trade-offs its future supply will entail upon the land-use system. Hence, its analysis necessitates a representation of bio-energy as a productive activity; intertwined with the other sectors through the forward and backward linkages of the economy and through the various sectors' competition for resources of land, labour, and capital. This study aims to depict these intersectoral linkages of bioenergy and its dynamics with other land-uses. It employs a CGE with a land-use changes model to map the intersectoral and land-use interface of bio-energy, and to determine the bio-energy policy implications upon the direction of land-use change and the subsequent addition of the land transformation to CO_2 emissions. As the cost of developing bio-energy differs by the policy instrument applied, the study will also therefore, look at the repercussions of different combinations of policy instruments. The major policy examined is the imposition of a revenue-neutral carbon tax with proceeds directed towards the reduction in direct taxes and the finance of bio-energy subsidy.

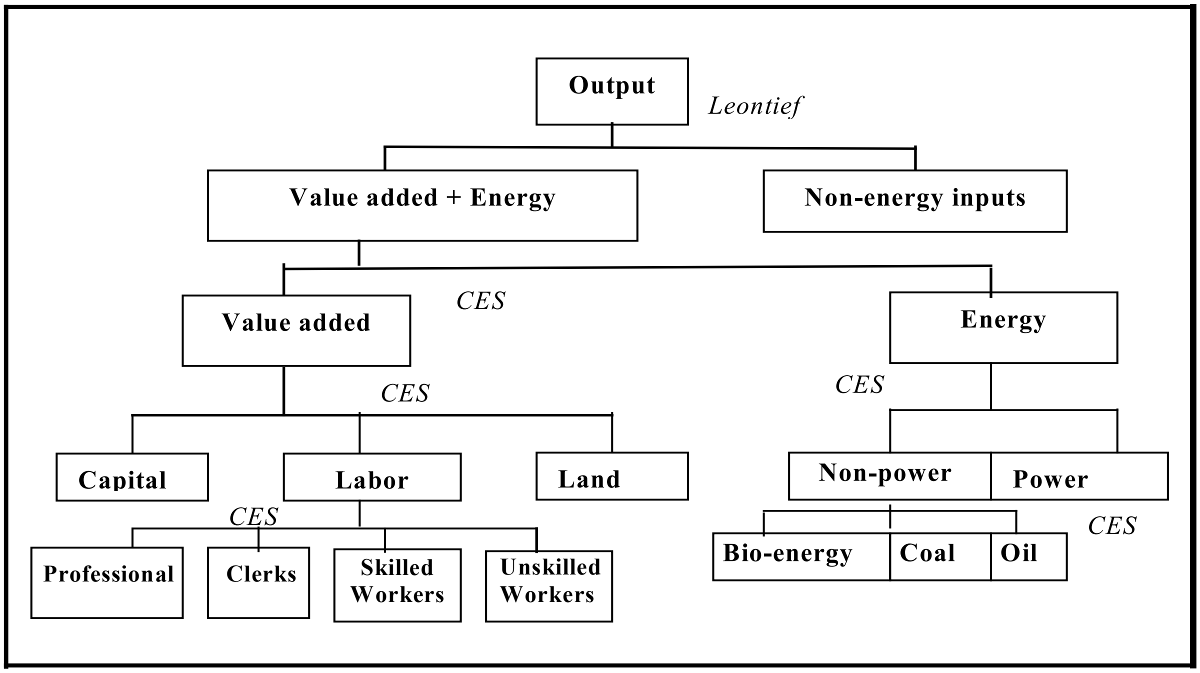
2 Methodology

The study employs a CGE model developed by International Food Policy Research Institute (IFPRI) modified for the inclusion of the environmental sector and policy, for functional specifications allowing for capital-labor-energy and inter-fuel substitution, and for a simple static land-use change model. The succeeding discussion only gives details regarding the modifications made by the author upon the IFPRI model, which consists of the production function specification, the environmental policy and the land-use changes. For a more detailed discussion of the IFPRI model, refer to (Lofgren, et al, 2002). The complete system of simultaneous equations is not included but is available upon request. In this study, the Philippine economy is represented by 14 activities and commodities: *crops, livestock, other agriculture, forest, biomass energy, coal, oil, power food manufacturing, heavy polluting industries, other industries, transport sector, sanitation and waste disposal, and other services.* These activities employ a combination of the following factors of production: *capital* and *professional, clerical, skilled* and *unskilled labor*. The production of crops, livestock, forest, and bio-energy also utilizes a mass of agricultural land, grazing land and forestland. The households, on the other hand are differentiated according to income (poor/nonpoor) and locality (rural/urban).

2.1 Production Structure

Each producer is assumed to maximize profits subject to a production technology structured as in figure 1.

Fig.1. Production Structure



At the topmost level, technology is specified by a leontief function of the quantities of composite capital-land-labor-energy, and of non-energy materials. To allow for different elasticities of substitutions across capital, labour and energy and within their subtypes, a nested constant elasticity of substitution (CES) is employed. The composite value-added and energy is disaggregated into combined value-added and aggregate energy with value-added corresponding to labor, capital, and land, while energy to coal, oil, bio-energy, and electricity. Different types of labor are also employed at varying margins of substitution.

2.2. Land market and Land-use changes

The description of the land market sets off with the decision of the producers of the total amount of land to employ together with labor and capital. This is specific to the following land-users: the crops, livestock, bioenergy and forestry sectors. The land-users after determining the total amount of land to use, then decides upon which sectors to source the land from. For a crop producer for example, its decision will involve using cropland intensively or to use forestland or pasture currently used by bio-energy and forestry sectors.

The land-owners on the other hand determine the amount of land of each type that will be supplied in the market. The landowner uses his land where it gets the highest possible return to maximize his profit. This follows the GTAPE-L (Burniaux and Lee, 2003) methodology of incorporating land-use changes in CGE whereby a landowner decides whether to keep land in its status quo or to convert it to serve another purpose. In principle, this decision is best illustrated in a dynamic optimization where the landowners maximize the present discounted value of the stream of expected future returns from changing the status of a given land (Burniaux and Lee, 2003). The model adopted here also transposes this principle in a static framework. Each land type is in fixed supply and the landowner chooses the op timal land allocation mix across alternative uses such as to maximize his revenue, given the land transformability constraint of the land. The land-owner then maximizes his returns from the land allocation given the rental rate specific to the land and sectoral use, sub ject to a constant elasticity of land transformation. For an initial endowment of cropland, for instance, the land-owner may then decide either to maintain the status of his land or to convert it into forestry or bio-energy plantation.

Similarly, a fixed supply of forestland may either be maintained or converted for traditional or energy crops cultivation. In this study, the decision to convert pasture for animal rearing or for bioenergy plantation was also made possible. The technical and economic considerations underlying the decisions are reflected by the propensities to keep land in its current use or to change in another status, which in turn are derived from the land-use status observed over a given period. Moreover, to capture the rigidity in land-use conversion arising from differences in land quality, the transaction costs of land conversion and the biological constraints behind the physical transformation; the elasticity of transformation for the three land types is assumed inelastic. The returns from converting these lands are different across land types and activities. The profit from converting the land of type *flnd* will then be the sum of the values of the land converted to all its potential use; which is the sum of the amount of land shifted $QFf_{lnd,a}$ multiplied by its corresponding price $WFA_{flnd,a}$. For a landowner of land type *flnd*, its land allocation decision will be governed by the portfolio of land combinations that maximizes its profit, subject to the feasibility constraints of the land transformation. As indicated earlier this constraint is depicted by a CET function, characterized with rigidities in land transformation and technology shift parameter specific to land type. Equation 1 shows the maximization problem. In equilibrium any type of land use is set simultaneously by the decisions of the landowners and the land-users.

$$Max \sum_{f\ln d} WFA_{f\ln d,a} * QF_{f\ln d,a}$$

$$QFS_{f\ln d} = \alpha^{lu}_{f\ln d} \left(\sum_{a} \delta^{lu}_{f\ln d} * QF_{f\ln d,a}^{\;-\rho^{lu}_{f\ln d}} \right)^{\left(-\frac{1}{\rho^{lu}_{f\ln d}} \right)} \qquad (1)$$

where

$flnd$ = set of land types:cropland,pasture and forest

QFS_{flnd} = supply of land by land type *flnd*

QF_{flnd} = quantity of *flnd* land used by sector *a*

$\alpha^{lu}_{f\ln d}$ = shift parameter

$\delta^{lu}_{f\ln d}$ = share of flnd land to output of *a*

$\rho^{lu}_{f\ln d}$ = exponent for CET land transformation function

2.3 Carbon emissions and the carbon tax policy

The emissions of CO_2 come from processes in heavy polluting industry, from the consumption of oil and coal, and from land use changes. Emission coefficients were then assigned for each activity, energy consumption, and land-use change type. These coefficients are derived from the base emissions divided by the quantity of output for the process-based emissions, by the quantity of coal and oil consumed by households and the industry for combustion-based emissions, and by the land area converted for land-use change emissions. Given the data limitations, only the emissions from deforestation (forest-cropland) and the sequestration from afforestation (cropland-forest) are considered[1]. The emission for deforestation is affixed in the use of forestland by the crops sector, while the sequestration for afforestation is indicated by a negative coefficient for cropland use by the forestry sector. To internalize the externality from energy use and land-use changes, a carbon tax has been imposed first upon the energy sector and then upon all sources of CO_2 emissions. To maintain the budget balance, two cases of revenue recycling were considered: first to subsidize bioenergy and second to reduce direct taxes. In the policy simulation, the amount of carbon tax and the magnitude of complementary recycling policy that both meet a 10% CO_2 reduction and a balanced budget were determined.

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[1] The contributions of the growth in forestry stock and of the land-use changes to energy plantation were not considered.

4 Simulation and Results

In the succeeding discussion, the following issues concerning the climate policy of bio-energy will be addressed: (a) the repercussions o f carbon taxation as a major policy for bio-energy development; (b) the implications of bio-energy subsidy as an accompanying instrument to carbon tax; and (c) the consequences of bio-energy development upon the trend of land-use changes and upon the CO2 levels.

4.1. Energy mix change

The magnitudes of the policy instruments required to attain the targets are indicated in Table 2, together with the changes in the energy mix. All the items in the table are expressed in percentage changes. The values in the parenthesis represent the results of the carbon tax imposed upon all the sources of emissions, while the rest corresponds to carbon tax on energy consumption of coal and oil only. From the table, it can be noted that the synergistic impact of carbon tax and bio-energy subsidy upon the contraction of coal and oil substantially has lowered the amount of carbon tax needed to reach the 10% reduction target. Applying a carbon tax alone requires an amount of 13$ per ton of carbon compared to a tax of 3$ per ton of carbon levied to fund bio-energy subsidy. Aside from offering a lower cost of mitigation, the carbon tax policy supplemented by a bio-energy subsidy has also gained the farthest success in altering the pattern of energy mix in the economy. This result has far-reaching implications upon the future trend of the energy system and thus upon the future levels of CO2. The degree to which a policy induces the development of an alternative cleaner energy substitute is a crucial criterion in the climate policy choice as securing a sustainable energy system is tantamount to ensuring an irreversible path of mitigation. Under the grounds of sustainable CO_2 mitigation, revenue recycling to finance bio-energy subsidy seems to be the rational policy choice.

Table 2. Energy mix from achieving 10% CO_2 reduction, (% change from the base, which is in Million Peso)

	BASE	C tax on energy (all) sources recycled to			
		Bioenergy subsidy		Direct tax cut	
Composite supply					
Bioenergy	27.5	26.5	(28.6)	-1.2	(12.3)
Coal	5.8	-3.8	(-2.5)	-12.2	(-5.8)
Oil	162.9	-3.4	(-2.5)	-6.3	(-7.9)
Power	84.8	-1.8	(-1.2)	-6.4	(-3.2)
Industry consumption					
Bioenergy	4.7	0.7	(11.3)	-1.1	(10.6)
Coal	5.5	-11.7	(-5.6)	-12.6	(-5.9)
Oil	130.1	-13.3	(-7.5)	-14.2	(-7.7)
Power	41.7	-5.9	(-3.0)	-6.5	(-3.2)
Household consumption					
Bioenergy					
Urban poor	4.1	23.4	(25.6)	-2.0	(11.2)
Urban nonpoor	1.0	18.2	(19.9)	2.3	(12.3)
Rural poor	12.4	30.5	(32.8)	-2.1	(12.8)
Rural nonpoor	5.3	23.0	(24.8)	0.6	(11.8)
Oil					
Urban poor	2.2	-1.8	(-1.3)	-6.4	(-3.6)
Urban nonpoor	19.9	-2.8	(-2.3)	-3.0	(-1.1)
Rural poor	2.9	1.2	(1.6)	-7.7	(-3.9)
Rural nonpoor	6.3	-1.4	(-1.2)	-5.1	(-3.2)
Power					
Urban poor	15.0	-1.6	(-1.0)	-6.8	(-3.4)
Urban nonpoor	18.1	-2.6	(-2.0)	-2.9	(-0.4)
Rural poor	3.2	1.6	(2.1)	-7.6	(-3.4)
Rural nonpoor	6.8	-1.1	(-0.8)	-4.8	(-2.6)
Policy instrument					
Carbon tax		3.1 $/t C	2 $/t C	13.1 $/t C	6.2 $/ t C
Bioenergy subsidy (%)		24%	22%	All households	*-50.2 (-36.8)*
% change in direct tax					

Recycling carbon tax profits to reduce income tax rate has triggered a shift in the energy consumption in the economy, but in a less dramatic extent. The burden of the tax has taken its toll upon the production of most industries and upon the incomes of most of the households, and despite the compensation through direct tax reductions still has adversely affected the overall consumption. The disposable incomes received by the poor households were not sufficient to buttress their consumption, of which bio-energy comprises a big component. Bio-energy supply then did not grow in absolute terms. The cost of meeting the same 10% reduction target declines by 35-50%, when the scope of taxation is extended to the rest of the sources. Accordingly, the lower amount of carbon tax has allowed lower levels of bio-energy subsidy and direct tax reductions and has moderated the shortfall in the fossil fuel supply. The supply of bio-energy on the other hand has disproportionately expanded, due primarily to the positive influence of land conversion tax upon forestry production and forestry input into the bio-energy activity, on the production side. On the consumption side, it is influenced by the increased demand of households and industries, which was allowed for by their overall improved position from a lower carbon tax.

4.2 Overall growth, structural changes and household welfare

The carbon tax on energy operated to discourage the production in the CO_2 intensive sectors of coal, oil, transport, and heavy polluting industry, which in turn triggered the contraction of the real gross domestic product (GDP). Activities which are heavily dependent upon fossil fuels and transportation such as power generation and waste disposal and sanitary services have also suffered production losses from reduced material consumption. The trend in the production of agriculture, bio-energy, forestry, food and other industries, and other services; on the other hand is dependent upon the influence of the auxiliary policies to the movement of the factors of production. The bioenergy subsidy for instance, tends to reallocate resources to bio-energy sector and to other sectors relevant to it such as crops, forestry, food and other industry. The uniform direct tax reduction diverts inputs into the production of industrial goods, transportation, and other services, which are consumed mostly by the urban non-poor households. These findings are explicated further in the succeeding discussions.

The lower cost of mitigation under carbon tax recycling to bio-energy subsidy translated into a more modest economic decline that can be observed in Table 3. With respect to the sectoral pattern of growth, the subsidy has provided the impetus for the progress of the forward and backward linkages of the bio-energy sector. In particular, it has increased the demand for its inputs of forest products and crops and has raised its energy supply in food, other industry, and other services. As the activities in crops and forestry also compete for these resources, the net effect of bio-energy subsidy upon their production will then depend upon their relative contribution to bioenergy's material use and upon their relative complementarities or substitutabilities to bio-energy production. For the crops sector, the impact of the subsidy is twofold; on the one end , it increases crop output by raising the demand for crop residues; and on the other end, it encumbers crop output by relocating land resources, fertilizer, labor, and capital away from crop cultivation. Given the relatively lower share of crop residues and the relative importance of land and forest products to total inputs of bio-energy production, the net effect of the subsidy is negative upon agriculture and positive upon the forestry sector. The greater demand for forest production to meet the induced growth in bio-energy output therefore moderated the competition for inputs between forestry and bio-energy. The capital, land, labor, and materials prerequisite to bio-energy production were then displaced from crops and livestock activities.

The growth in the agricultural sector under the direct tax reduction on the other hand compensated for the relatively lower increase in the bio-energy output compared to the subsidy case; giving rise to fairly the same level of GDP decline. Moreover, as carbon tax indirectly penalizes the forestry production through its lower inputs to wood and paper manufacturing, substantial amount of resources transferred from forestry and bio-energy to crops and livestock sectors. Given the low household consumption of bio-energy, the forest production precipitated as well.

The inclusion of the land-use changes and industrial processes in the carbon tax base has worked to penalize the conversion of land from forestry to agricultural land as well as the processes in heavy industry. Considering the strong production link between bio-energy and forestry, the implicit deforestation tax has spurred the expansion in the forestry and bio-energy sectors and has exacerbated their competition vis-à-vis crop cultivation. Moreover, the increased inputs from forestry by wood and paper manufacturing industries have moderated the production constraint imposed by the carbon tax upon the industries processes and use of fossil fuels. The incomes received by all households have been severely affected by the carbon tax on energy, except when coupled by bio-energy subsidy, which worked to raise the incomes and real consumption of the rural households. As discussed earlier, the bio-energy subsidy has generated additional employment of low-skilled labor in other agriculture, bio-energy, and forestry. Consequently, this increased employment has improved the incomes of the low-skilled workers, and therefore of the rural poor households.

Table 3. Output growth and sectoral changes, (% change from the base)

	Base	**C tax on energy (all sources) recycled to**			
		Bioenergy subsidy		**Uniform direct tax cut**	
	Million peso				
Output					
Crops	357	-0.05	(-0.5)	1.3	(-0.6)
Livestock	195	-0.2	(-0.2)	1.0	(0.8)
Other agri	159	0.4	(0.4)	1.0	(0.8)
Bioenergy	33	22.4	(24.3)	-1.1	(10.6)
Forest	9	17.4	(18.9)	-2.9	(6.9)
Coal	5	-4.0	(-2.6)	-12.6	(-5.9)
Food	251	0.3	(0.2)	1.8	(1.0)
Other industry	183	2.9	(2.9)	9.4	(8.2)
Heavy industry	208	-3.7	(-4.0)	-11.4	(-9.8)
Oil industry	103	-4.2	(-3.0)	-14.2	(-7.7)
Transport	197	-3.9	(-2.6)	-11.3	(-5.6)
Power	86	-1.8	(-1.2)	-6.5	(-3.2)
Other services	552	-0.1	(0.1)	0.3	(0.6)
Waste	2	-0.4	(-0.3)	-0.5	(-0.0)
Real GDP	1403	-0.1	(-0.1)	-0.4	(-0.2)

Despite the overall reduction in household incomes, the reduction in the direct tax rates has substantially relieved some of the households from real consumption losses. This in turn may have been generated by the households' higher disposable income and by the price cuts in their favored commodities. Under the direct tax reduction, all households experienced the same percentage reduction of 50% in income taxes. The margin in the disposable income in turn was enough for the urban rich and middle- income households to enjoy a 0.6% increase in their real consumption.

4.3. Pattern of land-use changes

The pattern of land-use under the two policy shocks can be observed from Table 3. To map the direction of land-use conversion from one land-use type to another, the different land categories were disaggregated according to their sectoral distribution. An increase in the use of cropland by the forestry sector indicates afforestation, the conversion of cropland to forestry. Likewise, an increase in cropland used by the bio-energy sector indicates the change in its use from the cultivation of traditional agricultural crops to bio-energy plantations. Finally, the deforestation in the study pertains to the use of forestland by the agricultural sector.

From table 4, it can be observed that redirecting the carbon tax on energy proceeds to bioenergy support stimulated the expansion of land for forest and bio-energy activities and thus the reduction of land resources for crops and livestock production. The increase in the land supply required for bio-energy plantation has been supplied mainly by pasture and cropland; leaving land for livestock grazing and for traditional crop cultivation to decline by more or less than 1%. The bio-energy subsidy of 25% turned out to be not sizeable enough to spur a massive conversion of agricultural and pasture lands. Although there has been an induced conversion of forestlands to bio-energy plantation, this change has transpired at the expense of potential deforestation, as the status quo use of forestlands has simultaneously expanded. Moreover, the bio-energy subsidy has served as a catalyst in instigating afforestation. As shown in table 4, the land requirement of the forestry sector has come primarily from agricultural land conversion. Bio-energy subsidy has therefore promoted not only the land-use change towards bio-energy plantation, but also towards afforestation, without engendering radical transformations in the land-use system.

In the absence of bio-energy subsidy, the CO_2 tax has generated sufficient incentives for the production of the entire agricultural sector; increasing the demand for its factors of production, including land, which in turn has to be dislocated from pasture or forest lands. The country's reliance upon intensive agricultural production however necessitated only a sub-marginal amount of land to enhance its production. Forestland conversion for crop cultivation has then expanded only by 1.5% under the direct tax reductions, while the amount of agricultural land that has been set aside for afforestation only diminished by 3.2%. Given the hampered growth of bio-energy output in the absence of bio-energy, bio-energy plantation in cropland, pasture, and forestlands has therefore been discouraged. Without bio-energy subsidy therefore, the carbon tax works to favor crop cultivation over afforestation and bio-energy plantation.

Table 4. Pattern of land-use change from reducing CO_2 by 10% (% change from the base)

		C tax on energy (all sources) recycled to			
	Base In 10^4 ha	**Bioenergy subsidy**		**Direct tax cut**	
Total land					
Crops	84.6	-1.2	(-1.4)	0.1	(-0.6)
Livestock	36.4	-0.4	(-0.5)	0.0	(-0.2)
Bioenergy	4.5	14.5	(15.8)	-1.4	(7.4)
Forest	3.9	8.7	(9.5)	-2.0	(3.9)
Cropland					
Crops	*79.8*	-0.6	(-0.6)	0.1	(-0.3)
Bioenergy	*1.6*	20.8	(22.9)	-2.1	(10.3)
Forest	*0.5*	18.6	(20.5)	-3.2	(8.2)
Pasture					
Livestock	*36.4*	-0.4	(-0.5)	0.0	(-0.2)
Bioenergy	*0.6*	20.8	(22.5)	-1.9	(9.1)
Forestland					
Crops	*4.8*	-10.0	(-10.9)	1.5	(-4.8)
Bioenergy	*2.3*	9.4	(10.2)	-0.7	(5.2)
Forest	*3.5*	7.4	(8.1)	-1.8	(3.2)

With the carbon tax on land-use changes, the pattern of induced afforestation and bioenergy plantation observed when the proceeds are recycled to bio-energy subsidy becomes evident as well under pure carbon taxation case. The transformation in the land-use system is benign to agriculture and therefore represents no impending threats to future food security as opposed to what is claimed

(Azar, 2004). More importantly, this result has illuminated the other mechanism by which synergy between developing carbon offset and sink can be achieved: through an implicit land conversion tax.

6. Conclusion

The importance of biomass energy in developing countries encompasses its potential contribution to future sustainable energy system and sustainable development. As residues and by-products of agro-forestry are renewable, carbon offsets from bio-energy can be continuously supplied. Given the non-marketability of bio-energy, public investment is necessary to aid it through its nascent stage of diffusion. Its strain upon the fiscal balance however requires a source of finance that considers the other important objectives of achieving efficiency and equity. Carbon taxation meets this restrictive requirement, as it narrows the deadweight loss from the alternative use of other indirect taxes and limits the real consumption losses to CO_2 intensive goods, which are meagrely consumed by the poor households. Moreover, the carbon tax creates synergies with bio-energy subsidy in discouraging the consumption of fossil fuels. The reinforcement between the more stringent competition with bio-energy introduced by the subsidy, and the burden of taxation imposed by the carbon tax renders a more affordable cost of mitigation and therefore a more confined production and welfare losses. The combination of carbon tax and bio-energy subsidy has offered as well the secondary benefits of reducing imports of coal and oil, building domestic capacity for energy sourcing and of improving the rural livelihood. More fundamentally, the policy mix has induced the land conversion towards bio-energy plantation and afforestation, and thereby has restored the land-use changes' contribution to CO_2 mitigation. The observed complementarities between forestry and bio-energy activities were grounded in the greater importance of forest inputs in bio-energy production. Although these benefits worked at the expense of the agriculture, the threat to future food security is not strongly supported.

On a methodological note, the endogenous treatment of land-use conversion decision has enabled not only the analysis of policy impacts upon land-use changes and its consequent contribution to CO_2

levels, but more essentially, it allowed a more conclusive assessment of the bio-energy policy. Incorporating bio-energy's interface with other land-uses can demonstrate the various trade-offs involved in the issue, such as achieving growth, food security and CO_2 mitigation by carbon sequestration. It has also permitted the analysis of a wider-range of policies, such as implicit land conversion tax. Widening the coverage of carbon tax to land use changes emissions significantly reduces the cost of mitigation and therefore confines the welfare and productivity losses from the heavy intervention in the energy sector. This demonstrates as well the other course by which the goals of mitigating CO_2 emissions through developing carbon offset and carbon sink can be reconciled.

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