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A General Equilibrium Analysis of Demand Side Management Programs under the Clean Development Mechanism of the Kyoto Protocol

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Abstract

This paper analyzes the economic and environmental consequences of a potential demand side management program in Thailand using a general equilibrium model. The program considers replacement of less efficient electrical appliances in the household sector with more efficient counterparts. The study further examines changes in the economic and environmental effects of the program if it is implemented under the clean development mechanism of the Kyoto Protocol, which provides carbon subsidies to the program. The study finds that the demand side management program would increase economic welfare if the ratio of unit cost of electricity savings to price of electricity is 0.4 or lower even in the absence of the clean development mechanism. If the program's ratio of unit cost of electricity savings to price of electricity is greater than 0.4, registration of the program under the clean development mechanism would be needed to achieve positive welfare impacts. The level of welfare impacts would, however, depend on the price of carbon credits the program generates. For a given level of welfare impacts, the registration of the demand side management program under the clean development mechanism would increase the volume of emission reductions.

This paper—a product of the Sustainable Rural and Urban Development Team, Development Research Group—is part of a larger effort in the department to study climate change and clean energy issues. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at gtimilsina@worldbank.org.

A General Equilibrium Analysis of Demand Side Management Programs under the Clean Development Mechanism of the Kyoto Protocol

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Keywords: *Demand side management, general equilibrium analysis, clean development mechanism*

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1. INTRODUCTION

The energy crises of the 1970s and high energy prices accompanied with high inflation and interest rates led to energy conservation or demand side management (DSM) programs all over the world (Gellings 2000). Electric utilities in the US and European countries launched DSM programs in the 1980s. In the United States, about US$23 billion was invested for DSM programs between 1989 and 1999 (Laughran and Kulick, 2004). Growing environmental concerns, particularly over the increasing emissions of air pollutants from energy production and consumption activities, further encouraged DSM programs (Wirl, 2000). In Asia, DSM programs were started in the early nineties. In Thailand, the Electricity Generating Authority of Thailand (EGAT) implemented a five-year DSM program during 1993-1998, which resulted in reductions of 468MW of peak demand, 2,194GWh of electricity generation and 1.64 million tons of CO_2 emission (EGAT, 2000).

There exists a large potential for reducing energy consumption as well as environmental emissions from various DSM programs, including energy efficient lighting, refrigeration and air-conditioning, and energy efficient motors and other electrical appliances in developing countries (DC) in Asia (See e.g., ALGAS, 1999b; Shrestha et al, 1998a,b). According to ALGAS, 1999b, implementation of DSM programs in eight Asian countries (i.e., China, Myanmar, Mongolia, Pakistan, Philippines, South Korea, Thailand and Vietnam) could reduce 17.4 billion tons of CO_2 emission during 2000-2020 period with net economic benefits in addition to the climate change benefits. In Thailand alone, DSM programs have the potential to mitigate 142 million tons of CO_2, during the 2000-2020 period with net economic benefits (ALGAS, 1999a). Despite the large potential of GHG mitigation and other environmental and economic benefits, DSM programs are not being implemented in many DCs due to the lack of financial resources.

Using partial equilibrium analysis[1], existing studies, such as Shrestha et al. (1998a, b), Schipper and Meyers (1991), Hsueh and Grener (1993), find DSM activities economically attractive[2]. On the other hand, studies, such as Dufournaud et al. (1994) and Rose and Lin (1995) argue that DSM options, which are economically attractive from a partial equilibrium approach, may not necessarily be attractive if they are examined using general equilibrium models[3]. A question may, however, arise: would all DSM options, no matter how economically attractive they are in a partial equilibrium setting, lead to negative welfare effects in a general equilibrium setting? Would DSM programs with highly attractive internal rate of returns (IRR) be still welfare regressive if their economy wide impacts are considered? This question is a crucial one for countries which are implementing DSM programs (e.g., Thailand). Moreover, even if DSM programs are found welfare regressive from a general equilibrium perspective; are there ways to offset these negative impacts? The clean development mechanism (CDM) of the Kyoto Protocol could be an instrument to resolve this issue because the CDM not only enhances the economic attractiveness of a DSM program, but also helps reduce financial barriers to DSM programs. By the end of December 2007, 52 energy efficiency projects have already been registered by the Executive Board of the CDM (CDMEB) and more than 250 similar projects are in pipeline (UNEP RISØ Centre, 2007; UNFCCC, 2007).

In this paper, we examine the welfare effects of a potential DSM program in Thailand, under which existing less efficient electrical appliances in the household sector are replaced with their efficient counterparts, by using a general equilibrium model. We first assess the welfare impacts if the DSM program is implemented in the absence of a CDM

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[1] A partial equilibrium analysis accounts for only direct costs and benefits of a project or a program in consideration, it does not account the indirect costs and benefits that would incur due to linkages between various agents of the economy (e.g., industry, household, government, international trade). Thus, it can not estimate the economy-wide impacts of the project or program (e.g., impacts on economic welfare, GDP, trade balance).

[2] Note also that economic analyses of DSM programs often neglect social benefits of reducing environmental pollutants (e.g., oxides of sulfur, oxides of nitrogen, suspended particulate matters, volatile organic compounds, etc.). If such benefits are quantified and accounted for, DSM programs would be further attractive.

[3] A general equilibrium model accounts for all direct and indirect impacts of an activity to an economy.

scheme. This will be followed by an analysis of the roles for CDM to improve the welfare effects of the DSM program. We show that not all DSM options are welfare regressive. It depends on three factors: (i) the ratio of unit cost of electricity savings to price of electricity (CPR), (ii) price of certified emission reductions (CERs), and (iii) rate of substitution of less efficient appliances with their efficient counterparts. We find that the DSM program would result in positive welfare impacts as long as the CPR is smaller than 0.4 (or IRR > 23%) even in the absence of CDM. Implementation of the DSM program under the CDM would result in positive welfare effects when CPR is higher than 0.4 (or IRR < 23%) depending on the price of CERs.

The paper is organized as follows: Section 2 briefly presents the general equilibrium model developed for the purpose of the study and the source of the data. Section 3 discusses results from model simulations (i.e., the economic welfare and environmental impacts of the DSM program), followed by sensitivity analyses of key parameters. Finally, the major conclusions of the paper are summarized.

2. A BRIEF DESCRIPTION OF THE CGE MODEL

A static general equilibrium model has been developed for the purpose of this study. In this section, we briefly present approaches to modeling various economic agents (e.g., producers, households, the government and the foreign sector)[4].

2.1 The production sector

The study considers 21 production sectors (see Table 1), of which seven produce energy goods and services, and the rest material goods and services. The production behavior of each sector is represented through a four level nested structure (see Figure 1a and 1b). In each sector, gross output (XD) is a nested function of capital (K), labor (L), material (G_k), fossil fuel (G_f) and electricity (G_{EL}):

[4] Not all equations of the model are presented here. Please see Timilsina (2007) for more detailed descriptions of the model.

$$XD = \beta[\theta(K, L), \varphi\{\gamma(G_1, .., G_k), \nu(\phi(G_1, .., G_f), G_{EL})\}] \quad (1)$$

where θ is the constant elasticity of substitution (CES) composite of primary factors; φ is the CES composite of the material aggregate (γ) and the composite of the fuel aggregate (ϕ) and electricity (ν). ϕ is the CES aggregate of fossil fuels and γ is the Cobb-Douglas aggregate of materials. The CES functional form of XD can be written as follows:

$$XD = [\lambda_\theta^{1/\sigma}.\theta^{(\sigma-1)/\sigma} + \lambda_\varphi^{1/\sigma}.\varphi^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)} \quad (2)$$

where λ is the share parameter and σ is the elasticity of substitution between θ and φ. Similar functional forms could be written for θ, φ, γ, ν and ϕ. θ and φ are derived as follows:

$$xdp\frac{\partial XD}{\partial \theta} = p_\theta \quad \Rightarrow \quad \theta = \lambda_\theta . XD.(\frac{xdp}{p_\theta})^\sigma \quad (3)$$

$$xdp\frac{\partial XD}{\partial \varphi} = p_\varphi \quad \Rightarrow \quad \varphi = \lambda_\varphi . XD.(\frac{xdp}{p_\varphi})^\sigma \quad (4)$$

where xdp is the output price, and p_θ and p_φ are prices of θ and φ respectively. xdp is derived from a cost function, which is dual to the production function in Equation (2) and is given as:

$$xdp = [\lambda_\theta p_\theta^{(1-\sigma)} + \lambda_\varphi p_\varphi^{(1-\sigma)}]^{1/(1-\sigma)} \quad (5)$$

Table 1: Economics Sectors and Electricity Sub-sectors Considered in the Model

(a)Economic Sectors, Goods and Services

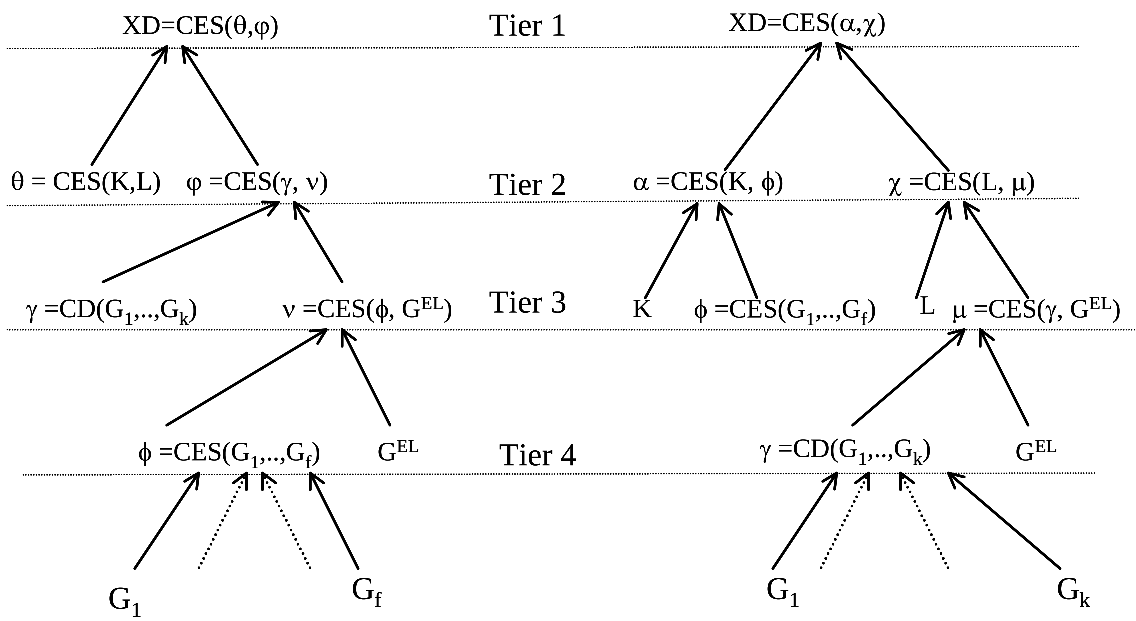
Non-Energy Sector and Good	Energy Sector and Good
1. Agriculture & Forestry	1. Fuel Wood
2. Construction	2. Coal
3. Mining (Except Energy)	3. Crude Oil
4. Food and Beverage	4. Petroleum Products
5. Textile and Apparel	5. Natural Gas
6. Pulp and Paper	6. Electricity
7.Chemicals & Fertilizers	
8.Non-Metallic Minerals	
9. Primary Metals	
10. Fabricated Metals	
11.Electrical Machinery	
12.Other Manufacturing	
13. Commercial Services	
14. Transportation Services	
15.Other Services	

(b) Electricity Sub-Sector or Technology

Primary Electricity	Secondary or Thermal Electricity		
Hydro	Steam Turbine	Combined Cycle & Gas Turbine	Internal Combustion Engine
	Coal Oil Natural Gas	Oil Natural Gas	Oil

All other demand variables, as indicated in Figure 1a, are determined in a similar manner to Equations (3) and (4), while the price variables are determined in a similar manner to Equation (5).

Figure 1: Nested Structure of the Production Sectors



(a) Sectors except electricity generation (b) Electricity generation sector

One of the key features of the model is that it treats the electrical sector in a different manner than most existing studies. First, the electricity sector is divided into seven sub-sectors based on technologies used for electricity generation (see Table 1b)[5]. This allows the substitution possibilities between various technologies used for electricity generation. Secondly the nested CES structure used for the electricity sector differs from those used in the rest of the sectors to allow direct substitution between capital and fuel in the electricity generation industries. It is very important to treat the electricity sector with special attention

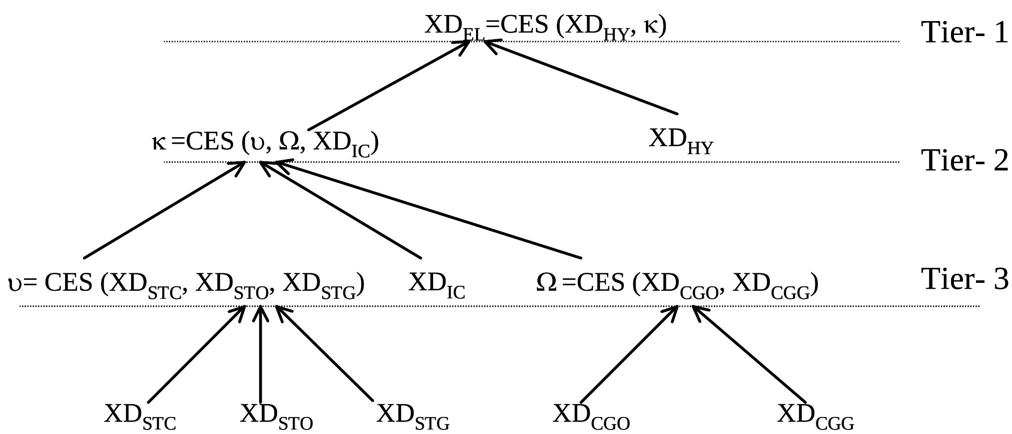
[5] Some studies such as Brown et al. (1999) also consider different technologies to generate electricity while modeling the electricity sector in GTEM model.

in GE models for environmental policy analysis in countries where electricity generation based on fossil fuels is one of the main sources of GHG emissions. The gross output of the electricity industry g is given as:

$$XD_g = \beta[\omega\{K_g, \phi(G_{g,1},..,G_{g,f})\}, \chi\{L, \mu(\gamma(G_{g,1},..,G_{g,k}), G_{g,EL})\}] \quad (6)$$

where ω is the composite of capital and the fuel aggregate used in electricity industry g and χ is the composite of labor and the material-electricity composite (μ). The demand and price variables in the case of the electricity industries are determined in a similar manner to the other sectors discussed above. Electricity generated with different types of technologies is aggregated as shown in Figure 2.

Figure 2: Aggregation of Electricity Outputs Produced by Different Electricity Generation Technologies



As can be seen from Figure 2, the total electricity output (XD_{EL}) can be expressed as:

$$XD_{EL} = \Lambda[\kappa\{\upsilon(XD_{STC}, XD_{STO,} XD_{STG}), \Omega(XD_{CGO}, XD_{CGG}), XD_{IC}\}, XD_{HY}] \quad (7)$$

where Λ is the CES composite of the outputs of the hydropower industry (XD_{HY}) and the thermal power industry (κ). κ is the CES aggregate of the outputs of the steam turbine electricity industry (υ), the combined cycle/gas turbine electricity industry (Ω) and the internal combustion electricity industry (XD_{IC}). υ is the CES aggregate of the outputs of the coal fired steam turbine electricity industry (XD_{STC}), the oil fired steam turbine electricity industry (XD_{STO}) and the gas fired steam turbine electricity industry (XD_{STG}), while Ω is the

CES composite of the outputs of the oil fired combined cycle/gas turbine electricity industry (XD_{CGO}) and the gas fired combined cycle/gas turbine electricity industry (XD_{CGG}).

The demand for electricity generated from various types of technologies as well as the demand for primary factors, energy, and material inputs are derived as discussed in other industries above. For example, demand for and price of thermal electricity are given as follows:

$$\kappa = \lambda_{\kappa} . XD_{EL} . (\frac{xdp_{EL}}{p_{\kappa}})^{\sigma^{HYTH}} \quad (8)$$

$$p_{\kappa} = [\lambda_{\upsilon} p_{\upsilon}^{(1-\sigma^{TH})} + \lambda_{\Omega} p_{\Omega}^{(1-\sigma^{TH})} + \lambda_{IC} xdp_{IC}^{(1-\sigma^{TH})}]^{1/(1-\sigma^{TH})} \quad (9)$$

where p_{κ} is the aggregate of unit costs of electricity generation from steam turbine (p_{υ}), combined cycle/gas turbine (p_{Ω}) and internal combustion technologies (xdp_{IC}). σ^{HYTH} is the elasticity of substitution between electricity generated from hydro and thermal power plants, and σ^{TH} is the elasticity of substitution between electricity generated from steam turbine, combined cycle/gas turbine and internal combustion technologies.

2.2. The household sector

2.2.1. Household demand

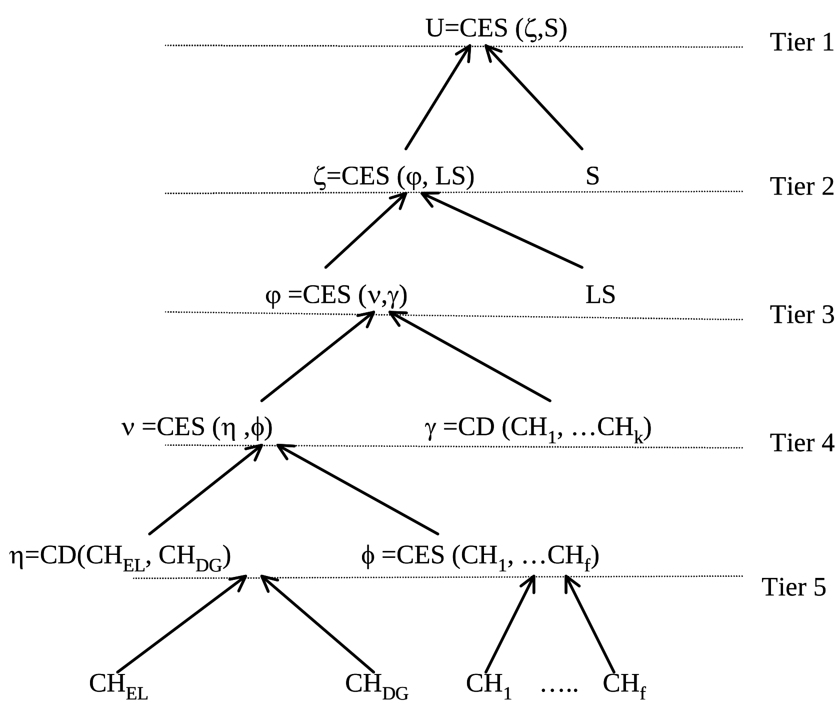
This study considers a representative household that follows a five-step hierarchical optimization process to maximize its utility as shown in Figure 3. At the left hand side of the bottom of the nested structure (i.e., Tier 5 in Figure 3), household consumption of electricity (CH_{EL}) and electrical appliances (CH_{DG}) are combined through a Cobb-Douglas function to get electrical services for the households (η)[6]. At the right hand side of the same tier, a fuel aggregate (ϕ) is obtained through a CES aggregation of different fuels, such as coal, oil, gas and fuelwood. The aggregate energy service (ν) in the household sector is derived through a CES combination of the electrical services and the aggregate fuel consumption (ϕ) (please

[6] A sensitivity analysis is also presented later (Section 5), considering an alternative functional form (i.e., CES) to combine consumption of electricity and electrical appliances in the household sector.

see left part of Tier 4). In the right hand part of Tier 4, a material aggregate (γ) is derived from the Cobb-Douglas aggregation of different materials. The energy-material composite (φ) is combined with leisure (LS) to give the present consumption (ζ) at the second tier of the nested structure. Finally, at the top most tier of the nested structure, households trade off between present consumption and savings (S) while maximizing their utility. The household utility function is expressed as follows[7]:

$$U = \psi[\varsigma\{\varphi(\nu(\eta(CH_{EL}, CH_{DG}), \phi(CH_1,..,CH_f)), \gamma(CH_1,..,CH_k)), LS\}, S] \qquad (10)$$

Figure 3: Nested Structure for the Household Sector to Model the DSM Option



The CES functional form for U is given as follows[8]:

[7] A similar approach has been used in a number of existing general equilibrium models (e.g., Jorgenson and Wilcoxen 1993; Bohringer and Rutherford 1997; Shoven and Whalley 1992 and Ballard et al. 1985).

[8] The difference in household utilities between the base and counterfactual simulations is used as the measure of the change in economic welfare in this study.

$$U = [\alpha_{\varsigma}^{1/\sigma^H} . \varsigma^{(\sigma^H - 1)/\sigma^H} + (1-\alpha_{\varsigma})^{1/\sigma^H} . S^{(\sigma^H - 1)/\sigma^H}]^{\sigma^H/(\sigma^H - 1)} \quad (11)$$

where α_ζ is the scaling factor and σ^H is the elasticity of substitution between present consumption and household savings. ζ and S are derived from the first order condition of maximizing utility under budget constraint, $I = \varsigma . p_{\varsigma} + S . p_S$, as follows:

$$\varsigma = \alpha_{\varsigma} . I \Big/ (p_{\varsigma}^{\sigma^H} . Z) \quad (12) \qquad \text{and} \qquad S = (1-\alpha_{\varsigma}) . I \Big/ (p_S^{\sigma^H} . Z) \quad (13)$$

with $Z = \alpha_{\varsigma} . p_{\varsigma}^{1-\sigma^H} + (1-\alpha_{\varsigma}) . p_S^{1-\sigma^H}$

where p_ζ and p_S are prices of present consumption and savings. I is the full income of households. In the same manner, other demand and price variables in the household model are derived through the different levels of the nested structure shown in Figure 3.

2.2.2. Incorporation of the DSM into the model

The DSM program is incorporated into the model while modeling household behavior. This is because the DSM program considered here refers to electrical appliances in the household sector. It is also possible to include electrical appliances in other sectors, such as manufacturing and service sectors. This could be a further expansion of the study because the end-use demand for electricity in the manufacturing sector differs significantly from the household sector[9].

Modeling demand side options in a general equilibrium framework is often constrained by data limitations. For example, an analysis of the substitution of incandescent lamps by compact fluorescent lamps would require detailed information on the industries producing these appliances (e.g., labor, capital and material inputs). In other words, we need an input-output table (I/O table) that treats the lamp industry as a separate sector. However, in the existing I/O tables of Thailand, information is available only at an aggregated electrical appliances/machinery industry level. Because of this limitation, we incorporate the DSM

[9] While most of the electricity demand in the manufacturing sector is for motive power (i.e., electrical motors), household demands for electricity is for lighting, air-conditioning and refrigeration etc.

options in our model by assuming an aggregate end-use appliance instead of individual appliances.

This approach now looks more relevant as the CDM Executive Board has developed, in its 28th meeting, guidance on the registration of a program of activities as a single CDM project activity (CDM EB, Dec. 2006). According to the guidance, a number of GHG mitigation activities, such as efficient lighting, refrigeration, air-conditioning, energy efficient electric motors, etc., can be packaged and registered as a single CDM project. In other word, the DSM program such as the one considered in this study can now be registered as a single CDM project.

Efficient appliances have relatively higher capital costs than their inefficient counterparts. On the other hand, efficient appliances use less electricity than their inefficient counterparts, leading to savings in fuel costs. In the general equilibrium modeling context, this implies a substitution of electricity costs with the capital costs. The increased use of efficient electrical appliances reflects a situation where households allocate higher expenditure on appliances (i.e., purchase efficient appliances) and less expenditure on electricity. It is assumed that the use of efficient electrical appliances provides at least the same level of end use energy services (e.g., lighting) as before (i.e., prior to replacement of the inefficient appliances).

The incorporation of the DSM aspect in the CGE model can be described with the help of Figure 3. As illustrated in the figure (bottom tier in the left hand side of the nested structure), electricity (CH_{EL}) and electrical appliances (CH_{DG}) are combined through a Cobb-Douglas function to get electrical services (e.g., heat, air-conditioning, light), η, for the households. The household maximizes its utility from the use of the electrical services subject to the budget constraint:

$$\text{Max } \eta = CH_{EL}^{\alpha}.CH_{DG}^{1-\alpha} \qquad (14)$$

s.t.

$$DI - SAV - \sum_f CH_f .gp_f .(1+indt_f) + \sum_k CH_k .gp_k .(1+indt_k)$$
$$= CH_{EL} .gp_{EL} .(1+indt_{EL}) + CH_{DG} .gp_{DG} .(1+indt_{DG}) \quad (15)$$

In the case of the CES functional form, the utility function to maximize is expressed as:

$$\text{Max } \eta = [\alpha^{1/\sigma}.\text{CH}_{\text{EL}}^{(\sigma-1)/\sigma} + (1-\alpha)^{1/\sigma}.\text{CH}_{\text{DG}}^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)} \quad (16)$$

The constraint is the same as in Equation (15). Here, α is the share of electricity in the total expenditure on electrical services (i.e., sum of expenditure on electricity and electrical appliances). CH_f is the household consumption of other fuels (e.g., natural gas, fuel wood, petroleum products); CH_k is the household consumption of goods and services except electrical appliances (e.g., food and beverage, health care, education); gp_{EL}, gp_f, $gp_{DG,}$ and gp_k are the prices of electricity, other fuels, electrical appliances and other goods and services, respectively; $indt_{EL}$, $indt_f$, $indt_{DG,}$ and $indt_k$ are the corresponding indirect tax rates. DI is disposable income; it also includes revenue generated from exports of CERs.

As we mentioned earlier, an improvement in the end-use energy efficiency of electrical appliances implies that households derive at least the same level of electrical services as before, using smaller amount of electricity. This aspect of energy efficiency is incorporated into the model through the addition of the following constraint:

$$\eta = \eta^0 \quad (17)$$

where η^0 is the electrical services that the household is deriving in the base case (i.e., before implementation of the DSM program). Equation (17) implies:

$$CH_{EL}^{\alpha}.CH_{DG}^{(1-\alpha)} = CH^{0\alpha}_{EL}.CH^{0(1-\alpha)}_{DG} \quad (18)$$

where CH^0_{EL} and CH^0_{DG} are household consumption of electricity and electrical appliances in the base case. By rearranging Equation (18), we get:

$$\frac{CH_{DG}}{CH_{DG}^0} = \left(\frac{CH_{EL}^0}{CH_{EL}}\right)^{\frac{\alpha}{(1-\alpha)}} \quad (19)$$

$$\text{Let, } \frac{CH_{DG}}{CH_{DG}^0} = \theta \quad (20)$$

θ is the policy variable here and exogenous to the model. It represents the rate of replacement of inefficient appliances with their efficient counterparts. In the base run, θ has a value of 1. In policy simulation runs (counterfactual runs), θ is assigned to different values. For example, if θ is equal to 1.25, it can be interpreted as households spending 25% more to buy efficient appliances than in the base case. Increasing the consumption of electrical appliances would cause a reduction of electricity consumption for deriving the same level of electricity services. New electricity demand is then calculated as:

$$CH_{EL} = \frac{CH_{EL}^{0}}{\theta^{\frac{(1-\alpha)}{\alpha}}} \tag{21}$$

The rate of replacement also represents the level of emission reductions; a low rate of replacement would generate small amounts of emission reduction and vice versa.

Our model is a single year static model, but the DSM program generates costs and benefits for multiple years. In order to deal with this situation, we calculate annuity of the total investment over the economic life of the DSM program. The annuity is compared with the annual electricity savings in the absence of CDM, and with the sum of annual electricity savings and annual CDM revenue when the DSM program is considered under the CDM. Alternatively, we start with an exogenous unit cost of energy savings, which is equal to the total costs of the DSM program divided by electricity savings throughout the economic life of the program. We then divide the unit cost of electricity savings by an average electricity price to get a ratio of unit cost of energy savings to electricity price (CPR). If the CPR is smaller than 1, the DSM program will have net savings. The smaller the value of CPR, the higher will be IRR of the DSM program. Thus, the model fully accounts for the overall costs and benefits of the DSM program. The net savings of the DSM program (DSMSAV) is calculated as follows:

$$DSMSAV = (CH_{EL} - CH_{EL}^{0}).(1 - CPR) \tag{22}$$

The economics of a DSM project is sensitive to two factors: (i) cost of its implementation and (ii) price of electricity, which is used to estimate DSM benefits. Hence instead of assuming fixed values either on DSM cost or electricity price (i.e., DSM benefit), we used a ratio letting both DSM cost and electricity price to vary. Moreover, the use of the ratio ensures the results of study are not-sensitive to approaches (i.e., economic or financial) used in the partial equilibrium analysis. This is because, if the DSM cost (i.e., the numerator used for the calculation of the ratio) is a commercial or financial cost, electricity tariff is used in the denominator. On other hand, if the DSM cost is an economic cost, the electricity tariff is replaced with the economic cost of electricity supply. Use of ratio helps the study to have generic results otherwise the results are subject to assumptions on DSM costs and electricity prices.

2.2.3. Household income

Total household income (THI) consists of capital income, labor income, and net transfer from the rest of the world. Capital income also includes depreciation. Labor income consists of not only salary and wages but also social security benefits to households. Total household income is then expressed as:

$$THI = \sum_i [K_i.kp_i.(1+\tau^K) + L_i.wr.(1+\tau^L)] + NTRH + DSMSAV + CDMREV \qquad (23)$$

where wr and kp_i are the gross tax prices of labor and capital, respectively. NTRH is the net transfer from the rest of the world to households and is expressed as a constant fraction of total exports. DSMSAV is net household savings due to the DSM program and CDMREV is revenue generated from the sales of GHG mitigation as certified emissions reduction (CER) units (hereafter the 'CDM revenue') and Equation 22 is modified as:

The CDM revenue (CDMREV) is calculated as follows:

$$\mathrm{CDMREV} = \mathrm{adf} \times \mathrm{cerp} \times (\mathrm{TPOL}^0_{\mathrm{CO2}} - \mathrm{TPOL}_{\mathrm{CO2}}) \qquad (24)$$

where adf is the fraction of total CDM revenue that is required to cover administrative costs and adaptation fees[10]. The price of CER is represented by 'cerp', and $\mathrm{TPOL}^0_{\mathrm{CO2}}$ and $\mathrm{TPOL}_{\mathrm{CO2}}$ are emissions of carbon dioxide (measured in tons of carbon) in the base and policy simulation cases, respectively.

[10] Article 12.8 of the Kyoto Protocol states that a share of the proceeds from certified project activities is used to cover administrative expenses as well as to assist developing countries that are particularly vulnerable to the adverse effects of climate change, to meet their costs of adaptation (UNFCCC, 1998).

Considering the wide range of transaction activities under the CDM project cycle (e.g., project validation, registration and monitoring; and credit verification and certification), 25% of the total CER revenue derived from the DSM program is allocated to cover transaction costs. Besides, we also carry out sensitivity analyses later, at various levels of transaction costs (e.g., 10%, 20% and 30% of the total CER revenue). The price of carbon credits is another key factor in determining the economic impacts of a CDM project activity. In 2006, CERs were traded in the secondary markets at a price range between US\$14/tCO_2 and US\$20/tCO_2 (Capoor and Ambrosi, 2007). Instead of setting a price for CERs, our model simulates the DSM program for a price range from zero to US\$50/tCO_2.

Total income tax paid by the household (ITAX) is given by:

$$\mathrm{ITAX} = \sum_i (K_i . kp_i . \tau^K + L_i . wr . \tau^L) \tag{25}$$

We assume here that households do not pay tax on income generated from net transfer from rest of world to households and CDM revenue. Total household income (I) corresponds to disposable income and the imputed value of leisure, and is given as:

$$I = \mathrm{THI} - \mathrm{ITAX} + \mathrm{LS}.wr \tag{26}$$

2.3. The government sector

Total government revenue (GI) consists of indirect taxes paid by firms, direct taxes paid by households, import duties, and net transfers from the rest of the world (NTRG). GI is allocated to government expenditure (GCE) and government savings (SAVG).

$$\mathrm{GI} = \sum_i G_i . gp_i . indt_i + M_i . mp_i . impt_i + \mathrm{ITAX} + \mathrm{NTRG} \tag{27}$$

$$\mathrm{SAVG} = \mathrm{GI} - \sum_i CG_i * gp_i * (1 + indt_i) \tag{28}$$

where G_i and M_i are demand for the composite good and imported good respectively, and gp_i and mp_i are the corresponding prices; $indt_i$ and $impt_i$ are indirect tax and import duty rates, respectively. Government consumption of good i (CG_i) is kept constant at the same level as in the base case[11].

2.4. The foreign sector

2.4.1. Import demand

Following Armington (1969), we assume domestically produced and imported goods to be imperfect substitutes. The total domestic demand for a good or a service (G) is assumed to be a CES composite of domestically produced (G^D) and imported components (G^M). It can be expressed as:

$$G_i = [\alpha_{D_i}^{1/\sigma_i^{DM}} G_i^{D(\sigma_i^{DM}-1)/\sigma_i^{DM}} + \alpha_{M_i}^{1/\sigma_i^{DM}} G_i^{M(\sigma_i^{DM}-1)/\sigma_i^{DM}}]^{\sigma_i^{DM}/(\sigma_i^{DM}-1)} \tag{29}$$

where α_{Di} and α_{Mi} are scaling factors of $G^D{}_i$ and $G^M{}_i$ respectively, and $\sigma_i{}^{DM}$ is the elasticity of substitution between $G^D{}_i$ and $G^M{}_i$. The dual function of Equation (22) is used to derive gp_i:

$$gp_i = [\alpha_{D_i} xdp_i^{(1-\sigma_i^{DM})} + \alpha_{M_i} \{gpw_i.ER.(1+impt_i)\}^{(1-\sigma_i^{DM})}]^{1/(1-\sigma_i^{DM})} \tag{30}$$

where gpw_i is the world price of good i, and ER is the exchange rate. Both of them are exogenous to the model.

2.4.2. Export demand

The model calculates export demand as follows:

$$EX_i = \alpha_i^{EX} (\frac{gpw_i.ER}{xdp_i})^{\varepsilon_i} \tag{31}$$

where $\alpha_i{}^{EX}$ is the share of good i in total export demand and ε_i is the price elasticity of exported good i with respect to the world price of the same good[12]. Similar to a number of existing general equilibrium models such as Dervis et al (1982) and Benjamin (1994) the nominal exchange rate is kept fixed; domestic prices fluctuate against the fixed foreign price level, which serves as the price numéraire in the model.

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[11] Similar approach also adopted in most existing general equilibrium models (e.g., Xie 1996 and Zhang 1997).

[12] Similar approach is followed by a number of existing studies such as Dervis et al. (1982), Proost and van Rogermorter (1992) and Naqvi (1999) to model export demand.

2.4.3. Current balance

The current balance (TBAL) refers to the difference between total value outflow (e.g., imports of goods and services) from the country to the total value inflow (e.g., exports and transfers from the rest of the world) to the country.

$$TBAL = [\sum_j M_j . mp_j - EX_j . ep_j] - NTRH - NTRG \qquad (32)$$

2.5. Investment demand

The model assumes that the total current investment in an economy is equal to the total capital goods delivered to the economy in the previous year (Capros et al. 1997). Current investment in the sector i (INV_i) is given as follows:

$$INV_i = K_i . [(\frac{kp_i . (1+\tau^K)}{invp_i . (ir + dpr)})^{\sigma_i} . (1+gr) - (1-dpr)] \qquad (33)$$

where, $invp_i$ is price of investment in sector i; ‘ir’, ‘dpr’ and ‘gr’ are interest rate, depreciation rate and growth rate of sectoral production, respectively. Although the rate of depreciation and production growth rates can vary across the sectors, the model assumes them the same for all the sectors. Delivery of investment good i ($INVD_i$) is assumed to be a fixed share of total investment goods delivered to the economy.

$$INVD_i = a_i^{INV} . \sum_i INV_i \qquad (34)$$

where, a_i^{INV} is the share of investment demanded by sector i in total investment demand.

2.6. Market clearing

Total production of good i is the sum of the domestic consumption of domestically produced good and exported good.

$$XD_i = G_i^D + EX_i \qquad (35)$$

Total domestic demand (G) consists of intermediate (ZA) and final demand (i.e., household consumption CH, government consumption CG, capital goods INVD, and inventory goods STK).

$$G_i = ZA_i + CH_i + CG_i + INVD_i + STK_i \quad (36)$$

Inventory demand for good i (STK_i) is maintained as a fixed fraction of output from sector i before and after the carbon tax.

It is assumed that the total time endowment (i.e., the active population) in the economy does not change due a policy change. This assumption implies that the total labor supply to the economy depends on the wage rate and labor supply elasticity. Following the Walrasian approach it is assumed that the total labor supply (TLS) in the economy is equal to the total demand of labor in the economy. This gives us the following relationship:

$$TLS = \frac{TTE}{\xi} = \sum_j L_j \quad (37)$$

where TTE is the total time endowment, ξ is the ratio of total hours to working hours, either on a daily basis or a weekly basis. The model allows capital mobility across the production sectors. However, the total capital stock in the economy (TK) is assumed to be unchanged as a result of a policy change.

2.7 Emission estimation

Emissions of a pollutant p from sector n ($POL_{n,p}$) (p = CO_2, SO_2 and NO_x) can be estimated as follows:

$$POL_{n,p} = \sum_f FF_{f,n} . c_f . ef_{f,p} \quad (38)$$

where n represents 20 industrial sectors (except the electricity sector), the household sector and the government sector; $FF_{f,n}$ refers to use of fossil fuel f (in monetary unit) in sector n; $c_{f,}$ converts FF_f to energy unit (e.g., Giga Joule, GJ) and can be expressed as GJ/Baht; and $ef_{f,p}$ is the emission factor of pollutant p for fuel f, expressed in kg of pollutant per GJ unit fuel consumption. Emissions from the electricity sub-sectors are also calculated in a similar manner.

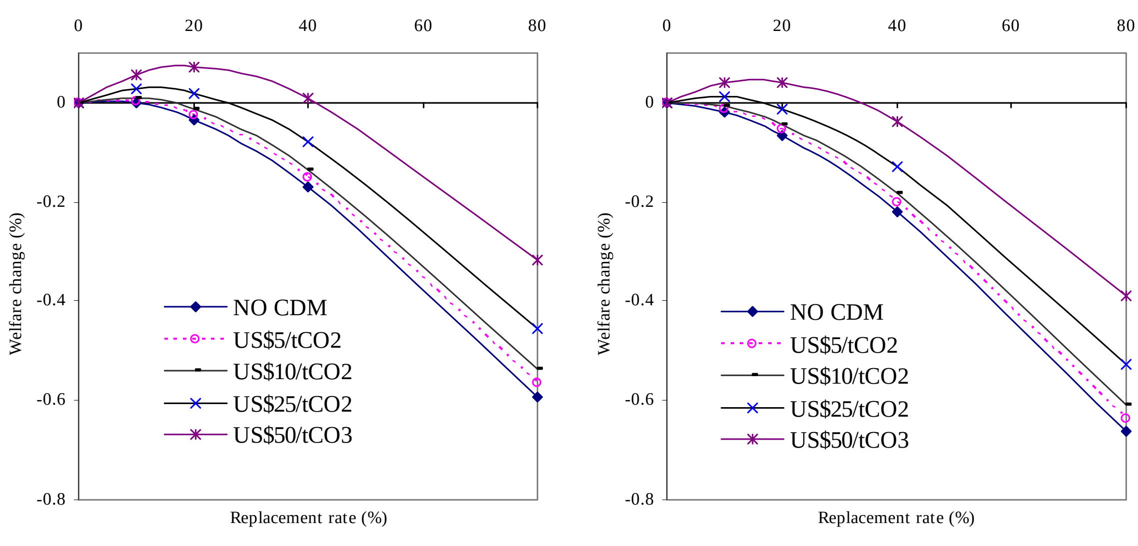
The main data needed for the study includes a social accounting matrix (SAM) of Thailand and elasticity parameters as implied by Figure 1 to Figure 3. The SAM was taken from Timilsina and Shrestha (2002) and elasticity values were taken from Timilsina and Shrestha (2006).

3. RESULTS FROM MODEL SIMULATIONS

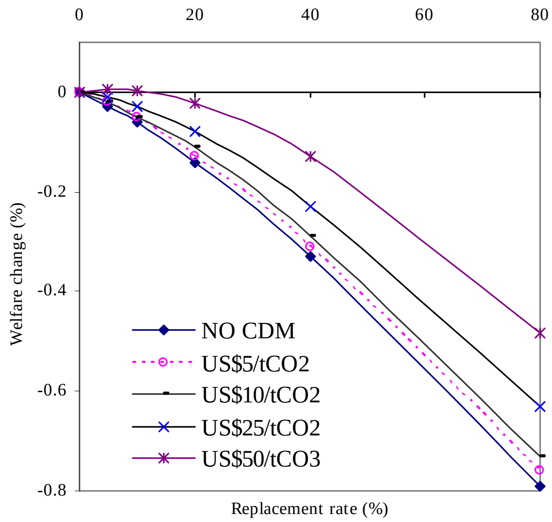
3.1. Impacts on economic welfare

Welfare impacts of the DSM program are presented in Figures 4(a) to 4(c). In each figure, the curve designated by "No CDM" represents welfare effects of the DSM program in the absence of the CDM, whereas the other curves represent the welfare effects of the DSM program under the CDM with varying CER prices. Figure 4(a) assumes that the unit cost of electricity savings is 40% of the price of electricity (i.e., CPR =0.4). Figure 4(b) and 4(c) assume CPR to be equal to 0.6 and 1.0, respectively.

Figure 4: Welfare Effects of the DSM Option



(a) η = 0.4 (b) η = 0.6



(c) η = 1.0

The figures illustrate quantitatively how the welfare impacts of the DSM program change with: (i) the rate of substitution of less efficient appliances with their more efficient counterparts, (ii) the ratio of unit cost of electricity savings to electricity price and (iii) the price of CERs. For a given value of CPR and CER price, the welfare impacts decrease with the rate of substitution as the marginal cost of energy efficiency improvements is increasing. If CPR equals 0.4, the welfare impacts of the DSM program would be slightly positive when the rate of substitution is 10% even if the DSM program is implemented in the absence of CDM. A 10% substitution of inefficient electrical appliances in the household sector results in approximately 0.91% reductions of national CO_2 emissions per year. If the rate of substitution is increased to 20%, the DSM program would reduce approximately 1.63% of national CO_2 emissions per year. This would, however, cause a welfare loss, even if CPR equals 0.4, unless the DSM program is implemented under the CDM and CERs are sold at a price greater than US$10/t$CO_2$. Similarly, if CPR increases to 0.6, CDM revenues would be required to have a positive welfare effect even at 10% substitution rate. This result implies that the ratio of unit cost of electricity savings to price of electricity is highly critical to economy wide effects of a DSM program.

The study finally demonstrates how the welfare impacts of a DSM program improve if the DSM program is implemented under the CDM. For example, for 0.4 CPR and 20% rate of substitution, the welfare impact of the DSM program would be -.036% in the absence of the CDM; it would increase to 0.018% if the program is implemented under the CDM and CER price is 25/tCO_2 (see Figure 4a). This is because an implementation of the DSM program significantly enhances its profitability. We find that the IRR of the DSM program increases from 13% to 26% if CER price increases from zero to US$50/t$CO_2$ when CPR is 0.6. At a lower value of CPR (0.4), the IRR increases from 24% to 41% when CER price increases from zero to US$50/t$CO_2$. Even if CPR equals 1 (i.e., net savings from the DSM program is zero), a CER price of US40/tCO_2 could cause positive welfare impacts as long as the rate of substitution is below 10%. Thus, CDM could play an instrumental role in enhancing the attractiveness of DSM programs in Thailand as it helps improve the welfare impacts of the programs. Moreover, CDM would not only improve economic attractiveness of a DSM program, it could also help reduce deliverable barriers to DSM programs (e.g., financial barriers). Dealing with deliverable barriers is crucial in Thailand because only a limited number of DSM projects have been implemented in the country despite being highly attractive economically (IRR > 25%) (du Pont, 2005).

Unless the ratio of unit cost of electricity savings to the price of electricity is sufficiently low (or IRR of the DSM programs is sufficiently high, greater than 23% in the case of Thailand), the DSM program might lead to negative welfare impacts from a general equilibrium perspective. This is because the replacement of inefficient appliances with efficient appliances would cause an increased demand for electrical appliances services and reduce the demand for electricity. To meet the increased demand for appliances, their production (i.e., gross output) and imports would increase. The increase in the production of electrical appliances would mean an increase in the production and imports of those goods used in the electrical appliances industry. On the other hand, as demand for electricity decreases, electricity generation together with demand for fuels and materials used for electricity generation also decrease. Since the increase in sectoral outputs of the electrical appliance industry and of those industries supplying goods to the electrical appliance industry is higher than the reduction in sectoral outputs of the electricity and fuel sectors, there would be a net increase in total gross output of the economy. The increase in the total gross output is also accompanied by higher labor demand as well as higher labor supply in equilibrium. An increase in labor supply implies a decrease in leisure as a household's total time endowment is fixed. There would also be reductions in factor prices in equilibrium. The reductions in factor prices and leisure would result in the reduction in full income of households, which in turn causes a reduction in welfare. For lower values of CPR and higher CER prices, the positive feedback impacts from fuel savings and CDM revenue would be greater than the negative feedback impacts of the DSM program, thereby resulting in positive welfare impacts.

3.2. Environmental impacts

Table 2 presents the impacts of the DSM program on emissions of CO_2, SO_2 and NO_x. As can be seen from the table, percentage reductions in emissions would increase with the rate of replacement of inefficient electrical appliances with efficient ones. On the other hand, the price of CER and the ratio of unit cost of electricity savings to electricity price do not have noticeable impacts on emission reductions.

One interesting finding is that the DSM program would reduce SO_2 emissions at a higher proportion than CO_2 emissions. If the value of local air pollutants are also accounted for, the welfare impacts of the DSM program would be higher than that we report in this study.

Combining the welfare and environmental impacts yields some interesting insights. The household sector DSM program considered here would result in positive welfare impacts even in the absence of CDM while reducing national level CO_2, SO_2 and NO_x annual emissions by 0.91% 1.31% and 0.64%, respectively, as long as the unit cost of electricity savings to electricity price is smaller than 0.4 (i.e., IRR > 23%). At 0.4 CPR, a CDM scheme with a CER price greater than US$10/t$CO_2$ would increase CO_2, SO_2 and NO_x reductions to 1.6%, 2.4% and 1.2% while maintaining the positive welfare effects; if the price of CER is greater than US$25/t$CO_2$, the corresponding emissions reductions would be 2.8% 3.9% and

2.0%. The CDM registration would be more instrumental when the DSM program is not economically attractive otherwise. If the DSM program has a CPR greater than 0.6 (IRR < 12%) and is implemented in the absence of the CDM, it would reduce economic welfare by 0.02% to achieve the same level of emission reductions when CPR was 0.4. The welfare loss would be offset if the DSM program is implemented under the CDM and CERs are sold at a price slightly greater than US$10/t$CO_2$; welfare improvement would be 0.01% if CERs are sold at US$25/t$CO_2$. The CDM with CER price US$25/t$CO_2$ would reduce CO_2, SO_2 and NO_x emissions by 1.6%, 2.4% and 1.2% without reducing welfare even if the DSM program has CPR 0.6.

Table 2: Impacts of DSM Program on Total CO_2, SO_2 and NO_x Emissions

(% change from the base case)

	Rate of replacement of inefficient appliances with efficient counterparts							
	CPR = 0.4				CPR = 0.6			
	10%	20%	40%	80%	10%	20%	40%	80%
CO_2 Emission								
NO CDM	-0.90	-1.63	-2.75	-4.18	-0.90	-1.63	-2.74	-4.17
US$5/tCO2	-0.90	-1.63	-2.75	-4.18	-0.90	-1.63	-2.74	-4.17
US$10/tCO2	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90
US$25/tCO2	-0.91	-1.64	-2.76	-4.20	-0.90	-1.64	-2.75	-4.19
US$50/tCO2	-0.91	-1.65	-2.77	-4.22	-0.91	-1.64	-2.77	-4.21
SO_2 Emission								
NO CDM	-1.31	-2.34	-3.87	-5.72	-1.30	-2.33	-3.86	-5.70
US$5/tCO2	-1.31	-2.34	-3.88	-5.72	-1.30	-2.34	-3.86	-5.71
US$10/tCO2	-1.31	-1.31	-1.31	-1.31	-1.30	-1.30	-1.30	-1.30
US$25/tCO2	-1.31	-2.36	-3.90	-5.75	-1.31	-2.35	-3.88	-5.73
US$50/tCO2	-1.32	-2.37	-3.92	-5.79	-1.32	-2.36	-3.91	-5.77
NO_x Emission								
NO CDM	-0.64	-1.17	-2.01	-3.17	-0.64	-1.16	-2.00	-3.16
US$5/tCO2	-0.64	-1.17	-2.01	-3.17	-0.64	-1.17	-2.01	-3.17
US$10/tCO2	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64
US$25/tCO2	-0.64	-1.17	-2.02	-3.18	-0.64	-1.17	-2.01	-3.18
US$50/tCO2	-0.64	-1.18	-2.02	-3.20	-0.64	-1.17	-2.02	-3.19

Although reductions of SO_2 and NOx have been calculated in the analysis, the monetary values of these pollutants have not been incorporated in welfare impacts. If included, the economic welfare of the DSM programs would be higher than those reported here. Moreover, impacts of the DSM program on fine particulate matters (e.g., PM_{10}, $PM_{2.5}$) have not included in the study. Reduction of the fine particulate matters can be perceived as an important side benefit of a DSM program particularly in country like Thailand, where lignite (i.e., brown coal) is one of the primary sources of electricity generation. If the benefits of fine particulate reduction are also accounted for, the welfare of DSM program would be further higher. Further analysis including monetary benefits of SO_x, NO_x and PM_{10} could be an interesting future extension of the study.

3.3 Sensitivity analysis

The sensitivity analyses focus on the elasticity of substitution parameters for the household sector as the demand side CDM option considered here corresponds to the household sector. Moreover, we also carry out the sensitivity analysis using an alternative functional form (i.e., CES) to combine electricity and electrical appliances, to derive household electrical services. The sensitivity analyses on parameter values under the demand side CDM option focus on the following elasticities of substitution in the household sector:

(i) present consumption and savings (σ^{FCS})

(ii) the composite of the aggregate fuel and the electrical service, and the aggregate material goods (σ^{HDEM})[13]

(iii) the fuel aggregate and electricity service (σ^{HDFEL}).

The changes in emission mitigation and welfare loss due to the changes in elasticity of substitutions are found to be very small

In the main analysis, we represent the households' trade off between electricity and electrical appliances by using a Cobb-Douglas functional form (see Equation 14). We now replace the Cobb-Douglas functional form by a CES functional form (See Equation 16). We consider different values of elasticity of substitution between electricity and electrical

[13] Electrical service here represents composite of electricity and electrical appliances, while aggregate material represents the composite of all material goods used in the households except electrical appliances.

appliances. These values are smaller than 1 (i.e., considered in the main analysis under the Cobb-Douglas specification). As expected, for all levels of CER prices considered (i.e., from 0 to US$50/t$CO_2$) and at each rate of substitution of inefficient electrical appliances by their efficient counterparts (i.e., from 10% to 80%), the welfare cost of the DSM program is found to increase as the value of the elasticity of substitution between electricity and electrical appliances is decreased. However, the changes in welfare impacts as well emission reductions are not significant unless the values of elasticity of substitution are lowered by 50%.

4. CONCLUSIONS

We examine, using a CGE model, the welfare effects of a potential DSM program that can replace inefficient electrical appliances with their efficient counterparts in the household sector in Thailand. Our study shows empirically that the welfare impact of a DSM program depends on three key factors: (i) the ratio of unit cost of electricity savings to electricity price, (ii) CER price and (iii) the rate of substitution of less efficient appliances with their efficient counterparts (or volume of emission reductions). Although the existing literature, such as Dufournaud et al. (1994) and Rose and Lin (1995), argue that a DSM program would lead to negative welfare implications, we find that not all DSM programs cause a welfare loss. In this study, we find that the DSM program would increase economic welfare if the ratio of unit cost of electricity savings to price of electricity (CPR) is 0.4 or lower even in the absence of CDM. If the DSM programs are implemented under the CDM, welfare effects would improve further. The CDM registration of DSM projects would also increase the volume of GHG mitigation along with price of CERs while achieving a given level of welfare impacts. The welfare function considered in the study does not account for benefits of local air pollution reductions; if these benefits are included, welfare impacts would be higher than that found in this study.

References

Armington, P., 1969, A Theory of Demand for Products Distinguished by Place of Production, IMF Staff Papers, 16, 159-178.

Asia Least-cost Greenhouse Gas Abatement Strategy (ALGAS), 1999a, Country Report of Thailand, Asian Development Bank (ADB), Manila, Philippines, 1999

Asia Least-cost Greenhouse Gas Abatement Strategy (ALGAS), 1999b, Summary Report, Asian Development Bank (ADB), Manila, Philippines, 1999

Ballard, C.L. D. Fullerton, J.B. Shoven and J. Whalley, 1985, General Equilibrium Model for Tax Policy Evaluation, University of Chicago Press.

Benjamin N. (1994), "Investment, Expectations, and Dutch Disease: A Comparative Study (Bolivia, Cameroon, Indonesia)", in Applied General Equilibrium and Economic Development (J. Mercenier, and T.N., Srinivasan eds.) The University of Michigan Press, pp. 235-251.

Böhringer, C. and T.F. Rutherford, 1997, Carbon Taxes with Exemptions in an Open Economy: A General Equilibrium Analysis of the German Tax Initiative, Journal of Environmental Economics and Management, 32, 189-203.

Brown S., Kennedy, D., Polidano, C., Woffenden, K., Jakeman, G., Graham, B. Jotzo, F. and Fisher, B.S., 1999. Economic Impacts of the Kyoto Protocol: Accounting for the Three Major Greenhouse Gases, ABARE Research Report 99.6, Australian Bureau of Agricultural and Resource Economics, Canberra.

Capoor, K. and P. Ambrosi, 2007, State and Trends of the Carbon Market 2007, the World Bank, Washington D.C.

Clean Development Mechanism Executive Board (CDMEB), 2007, Report of the 32nd Meeting of the CDMEB, http://cdm.unfccc.int/EB/032/eb32rep.pdf

Dervis, K, J. De Melo and S. Robinson, 1982, General Equilibrium Models for Development Policy, Cambridge University Press.

Dufournaud, C.M, J.T. Quinn and J.J. Harrington, 1994, An Applied General Equilibrium (AGE) Analysis of a Policy Designed to Reduce the Household Consumption of Wood Use in the Sudan, Resource and Energy Economics, 16 (1), 67-90.

du Pont, P. (2005). Nam Theun 2 Hydropower Project (NT2) Impact of Energy Conservation, DSM, and Renewable Energy Generation on EGAT's Power Development Plan. World Bank. http://siteresources.worldbank.org/INTLAOPRD/Resources/DSMmarch2005.pdf

Electricity Generating Authority of Thailand (EGAT) 2000. Demand Side Management in Thailand 1993-1998. EGAT, Thailand.

Gellings, C.W., 2000, Before Demand Side Management is Discarded, Lets see What Pieces Should be Kept, OPEC Review, March 2000, pp. 61-72.

Goulder L.H., I.W.H. Parry, R.C. Williams III and D. Burtraw (1999), "The Cost-effectiveness of Alternative Instruments for Environmental protection in a Second-best Setting", Journal of Public Economics 72: 329-360.

Hsueh, L. and J.L. Gerner, 1993, Effect of Thermal Improvements in Housing on Residential Energy Demand, Journal of Consumer Affairs, 27 (1), 87-105.

Jorgenson, D.W. and P.J. Wilcoxen, 1993, Reducing US Carbon Emissions: An Econometric General Equilibrium Assessment, Resource and Energy Economics, 15, 7-25.

Laughran, D.S. and J. Kulick, 2004, Demand Side Management and Energy Efficiency in the United States, The Energy Journal, 25 (1), 19-43.

Naqvi, F., 1999, A Computable General Equilibrium Model of Energy and Equity Interactions in Pakistan, Energy Economics, 20, 347-373.

Parry, I.W.H., R.C. Williams III and L.H. Goulder, 1999, When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets, Journal of Environmental Economics and Management, 37, 52-84.

Proost, S. and D.Van Rogemorter, 1992, Economic Effects of a Carbon Tax with a General Equilibrium Illustration for Belgium, Energy Economics, 13, 136-149.

Rose A. and S. M. Lin, 1995, Regrets or No-Regrets-that is the Question: Is Conservation a Costless CO_2 Mitigation Strategy'? The Energy Journal, 16 (3), 67-87.

Schipper, L. and Meyers, S., 1991, Improving Appliance Efficiency in Indonesia, Energy Policy, 19, 578-588.

Shoven, J.B. and J. Whalley, 1992, Applying General Equilibrium, Cambridge University Press.

Shrestha R.M., G. R. Timilsina, P. Khummongkol, W.K. Biswas and S. Sinbanchongjit, 1998a, CO_2 Mitigation Potential of Efficient Demand-Side Technologies: A Case of Thailand, Energy Sources, 20 (3), 301-316.

Shrestha R.M., B. Natarajan, K.K. Chakaravarti and R. Shrestha, 1998b, Environmental and power generation implications of efficient electrical appliances for India, Energy the International Journal, 23, 1065-1072.

Timilsina, G.R. (2007), The Role of Revenue Recycling Scheme in Environmental Tax Selection: A general Equilibrium Analysis, Policy Research Working Paper, No. 4388, The World Bank, Washington DC.

Timilsina, G.R. and R.M. Shrestha (2002), A General Equilibrium Analysis of Economic and Environmental Effects of Carbon Tax in a Developing Country: Case of Thailand, Environmental Economics and Policy Studies, 5 (3), 179-211.

Timilsina, G.R. and R.M. Shrestha (2006), General Equilibrium Effects of a Supply Side GHG Mitigation Option under the Clean Development Mechanism, Journal of Environmental Management, 80, 327-341.

Timilsina, G.R. and R.M. Shrestha (2007), Demand Side Management Options under the Clean Development Mechanism of the Kyoto Protocol: A General Equilibrium Analysis, IAEE International Conference, Wellington, New Zealand, February 18-21.

UNEP RISØ Centre, 2007. CDM/JI Pipeline Analysis and Database, http://cdmpipeline.org/

United Nations Framework Convention on Climate Change (UNFCCC), 2007, CDM Website, http://cdm.unfccc.int/Projects/registered.html

United Nations Framework Convention on Climate Change (UNFCCC), 1998, Kyoto Protocol to the United Nations Framework Convention on Climate Change, Climate Change Secretariat, Bonn.

Wirl, F., 2000, Lessons from utility conservation program, The Energy Journal, 21, 87-108.

Xie, J.,1996, Environmental Policy Analysis: A General Equilibrium Approach, Ashgate Publishing Company, England.

Zhang Z.X., 1997, The Economics of Energy Policy in China: Implications for Global Climate Change, Cheltenham, Edward Elgar.