ROLE OF CO_2 GAS EMISSION TAX ON FOSSIL FUEL IN REDUCING ENVIRONMENTAL IMPACT "A PERSPECTIVE FOR INDONESIA" [1)]

by

Kemas Fachruddin [2)] **, Akhmad Fauzi** [3)]**, Ahmad Bey** [4)]**,** and **Surjono H.Surtjahjo**[5)]

ABSTRACT

In the year 2001, Indonesia was ranked 21st in producing CO_2 emissions. In 1990 the total emission of CO_2 from the burning of fossil fuel was estimated at 83.8 million tonnes and by the end of the year 2020 the total emissions are estimated to be 368.3 million tonnes. Currently, Indonesia has no specific regulation in place for controlling CO_2 emissions either in the form of an act or government regulation.

Some approaches in controlling such emissions are through "common and control" and or "market based instrument" (sometimes this term is called "economic instrument"). Based on experience from developed countries, economic instrument in the form of carbon tax or emission tax is preferred due to it's effectiveness compared with the common and control instrument.

This empirical study is intended to analyze the role of economic instrument in the form of a carbon or emission tax on the energy of fossil fuel through a modified DICE (Dynamic Integrated Model of Climate Change and the Economy). The DICE model is also called a "Three –Box Model" or "Two Folded Model"

By using some rate of social preference (R), the model outcome suggests that appropriate optimal taxes for petrol and coal are if model using R value of 5%. Value of carbon tax per ton in optimal condition for period of 1990-2019 is within the range $US3.90 – 40.35 or $US1.06 -11.00 USD CO_2 per ton. The price is equivalent to $US 0.002 – 0.024 per liter petrol and $US 1.95 -20.25 per ton coal.

Based on the model output it is indicated that carbon or emission tax with optimal scenario has no significant impact on income per capita relative to "Base Case". Should the government apply tax instruments with optimal scenario, revenue of emission taxes will fall between $US 457.6 – 2,362.8 million for period 1990-2019. The revenue consists of $US 376.1 – 1,585.6 million generated from petrol and $US 81.4 – 777.2 million from coal.

Key words: Carbon/emission tax, abatement cost and common & control.

[1)] *This paper is part of dissertation on Doctor Program of Natural Resources and Environmental at Institute Pertanian Bogor - IPB*

[2)] *Staff IRESS (Institute of Resources and Environmental Economics Studies) and student of Doctor Program of Natural Resources and Environmental at Institute Pertanian Bogor - IPB*

[3)] *Chairman of committee*

[4)] *Member of the advisory committee*

[5)] *Member of the advisory committee*

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 2, OCTOBER 2007 : 19 - 27

I. INTRODUCTION

Increase of population will lead to a rise of household consumption sector demand and also increasing domestic production. Production sectors require energy from fossil fuel such as petrol, diesel oil, fuel oil, natural gas and coal for production of goods. Consumption of fossil fuel is increasing 13,5% from 307 million boe in the year 2000 become 348.52 million ton boe in year 2003. Based on per sector consumption, in year 2000 transportation sector consumed 48.8%, industry 27.3%, resident 16.3% and the rest 7.6% by commercial sectors. In year 2003 there were changes in consumption where transportation consumed 46.7%, industry 27.3%, resident 15.6% and commercial 7.4%. Increasing fossil fuel consumption will lead to a rise in CO_2 gas emission.

In the year 2001 Indonesia was ranked 21st in producing CO_2 emission with 74 million metric ton where 59% of the emission was produced from liquid fossil fuel. Report of World Resources Institute (2005) indicated that Indonesia is the fifteenth largest country in producing green house gas with 503Mt CO^2 equivalent or 1.5% from world total green house gas. Base on year 1990 baseline, Indonesia CO_2 emission was 83.8 million ton and by year of 2003 this had increased to 198.1 million ton. If economic growth is projection 5% yearly and population growth is 1% every year, CO_2 emission in year 2010 is projected to be 254.8 million ton and at the end of year 2020 this is estimated to be in the region of 366 million ton. Increasing Indonesia CO_2 emission will contribute to the increase in global green house gas, particularly CO_2. This will automatically increase CO_2 concentration in the earth's atmosphere. There is strong evidence to suggest this will contribute to climate change, especially global warming.

Based on experience from many countries, effective instrument for controlling rate of CO_2 emission is through economic instrument (*Market Based Instrument*) in the form of Tax Instrument

The objective of this research is to study the role of emission tax on CO_2 emissions from fossil fuel in reducing the environmental impact caused by such emissions. The specific objectives are: (1) determine optimal tax emission, (2) analysis of tax impact of CO_2 emission on national income and welfare, (3) determine total damage cost to abate CO_2 emission impact and (4) revenue generated from CO_2 emission tax.

II. METHODOLOGY

This research is adapted and based on the DICE model with aggregate level of top-down approach. Some equations in the model have been modified to suit Indonesia conditions. The model integrates between dynamic emission, impact of emission and economic cost to slow CO_2 gas emission growth rate. Model DICE is developed based on growth model of Ramsey. National output is production function of Cobb-Douglas which consists of capital (K), labor (L) and technology (A). Population growth and technology are exogenous variables.

Table 1
Change of CO_2 Emission Indonesia to OECD Countries and Non-OECD from 1990 – 2020 (Million ton CO_2)

Country	Data		Projection		
	1990	2003	2010	2015	2020
OECD	11.378	13.15	14.249	15.02	15.709
% World	53,61	52,55	46,93	44,61	42,74
Non OECD *	9.762	11.679	15.858	18.339	20.672
% World	45,99	46,67	52,22	54,47	56,25
Indonesia	83,788	198,104	254,796	303,646	366,018
% World	0,40	0,80	0,83	0,90	0,99
World	21.223	25.02	30.362	33.663	36.748

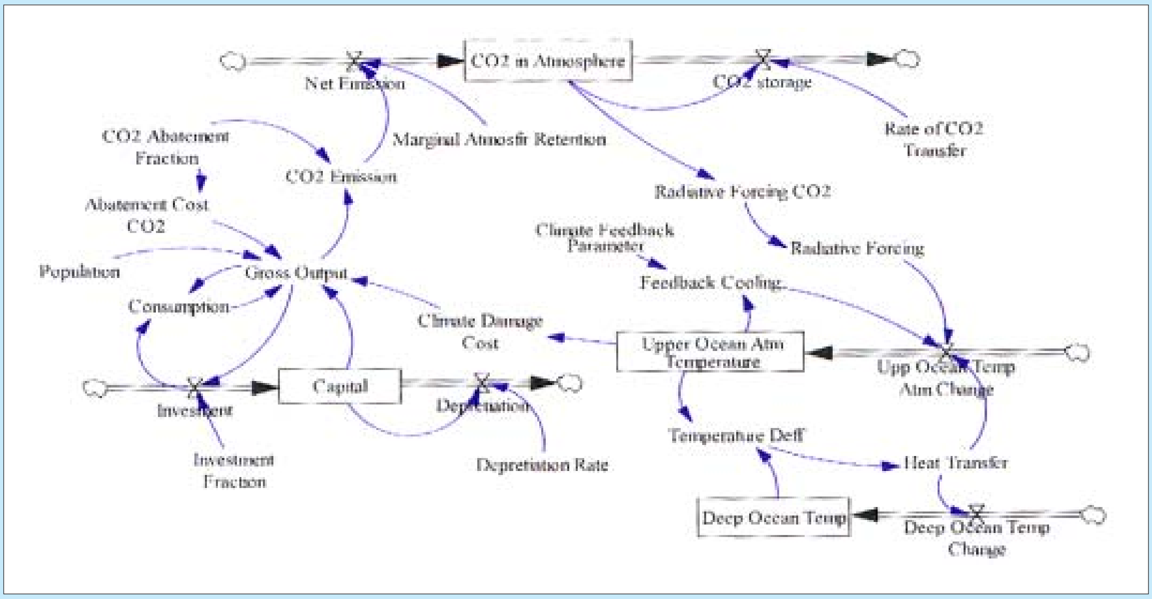

Figure 1
DICE model structure

The production equation in DICE model is:

$$Q(t) = ¿(t). A(t). K(t)^{ã}. L(t)^{1-ã},$$

where Q is national output or GDP and ¿ is the damage factor due to climate change to national output, it is a emission reduction rate and cost for reducing the emission. Total emission multiplied by value of emission tax added into national income will give equilibrium of national income. Model structure in DICE as indicated in Figure 1.

Model consist of exogenous variable, endogenous variable and policy variable. Value of emission carbon tax or CO_2 emission will be determined through optimization of 14 equations in the model.

The Model consists of three main subsystems i.e., economy, carbon cycle and climate. This model is also known as the "three-box model". Capital structure with two loop feedback, capital accumulation through re-investment (R1) and depreciation (B1). Output will depend on capital and exogenous input of the population and the productivity factor, cost to abate emission and climate damage (loop B1). Emission accumulate in stock of carbon in the atmosphere and mixed-layer of the ocean through *radiative-forcing*. Radiative forcing warms the atmosphere and surface ocean. Some heat is reradiated (B1) and heat is slowly transferred to deep ocean (loop B2 and B3). Climate damages are a quadratic function of atmospheric temperature.

III. RESULT AND DISCUSSIONS

A. *Research phase*

The research phase is presented in Figure 2. Research and theory related to the economic-climate change model are evaluated and re-formulated. The DICE model is the basic theory of the model and all data were verified. Productivity variable in the model equation is calibrated before model equation is applied.

B. *Model Equations*

The Model is run based on 13 equations. Emission tax equation (equation 8) is made separately and will be run by GAMS (General Algebraic Modeling System) based on optimization.

1. Social walfare function:

$$\text{DICE}: \; W = \sum_{t}^{T} U\,[\, c(t), L(t) \,]\, R(t)$$

Where R(t) is *discount factor* $\prod_{v=0}^{t} [\, 1+\rho(v) \,]^{-t}$

And ñ is *pure rate of social preference.*

Utility equation is: $U[c(t)] = L(t) \{[c(t)]^{1-á}\}/(1-á)$; where á is rate of inequality aversion

DICE utility function is: $U[c(t)] = L(t) \{ \log[c(t)]\}$

2. Production function: DICE : $Q(t) = ¿(t) \{ A(t) K(t)^{ã} L(t)^{1-ã}$ $g_A(t)$ $_A(t) = g_A(t-1)(1-d_A)$, $g_{A\ (1990)}$ = 0,1 % per decade and $ä_A$ = 0,10 per decade. $g_A(t) = g_A(0) \exp(-ä_A t)$.
3. Output function: DICE : $Q(t) = C(t) + I(t)$.
4. Income per capita function; DICE: $c(t) = C(t)/L(t)$.
5. Equilibrium function *capital stock*

   DICE: $K(t) = (1-ä_k)K(t-1) + I(t-1)$; äk is 0,10 per year.
6. Population growth function:

   DICE: $g_{pop}(t) = g_{pop}(1-t)(1-ä_{pop})$, äpop = 1,2% per decade g pop = 1,2% per year ; $g_{pop}(t) = g_{pop}(0)\exp(-ä_{pop} t)$.
7. Scaling factor (Reduction function) as impact of emission.

   DICE 1992: $\Omega = (1-b_1 ì(t)^{b2})/[1+D(t)] = (1-b_1 ì(t)^{b2})/[1+0.013[T(t)/3]^2]$

   In this research: $\Omega = (1-b_1 ì(t)^{b2})/[1+D(t)] = (1-b_1 ì(t)^{b2})/[1+0.0035 T^2]$.
8. Emission tax function: DICE: $Q(t) + ô(t)[\Pi(t) - E(t)] = C(t) + I(t)$

   In this reasearch: $Q(t) + ô(t)[\Pi(t) - (E_{IND}(t) + E_{ROW}(t))] = C(t) + I(t)$.
9. Total cost of reducing green house emission as fraction of GDP

   DICE : $TC = 0{,}0686 ì(t)^{2,887}$
10. Damages function due to temperature increase

    DICE : $0{,}00144T(t)^2$; In this research : $D(t) = 0{,}0035 T^2$
11. Emission function : Use DICE : $E(t) = [1 - ì(t)] ó(t) Q(t)$

    Emission ratio per unit of output (ó) will use year 1990 as baseline. ó is emission intensity or CO_2/GDP. $g_ó(t) = (1+g_ó)ó(t-1)$.
12. Carbon cycle function (Concentration of emission of CO_2)

    DICE : $M(t) = \beta E(t) + (1-äm)M(t-1)$

    In this research: $M(t) = \beta [E_{IND}(t) + E_{ROW}(t)] + (1-ä m)M(t-1)$.

    E_{ROW} is rest of world emission and E_{IND} is Indonesia emission.
13. Climate change function

    DICE : $T_1(t) = T_1(t-1) + á_1 \{F(t) - á_2 T_1(t-1) - á_3 [T_1(t-1) - T_2(t-1)]\}$

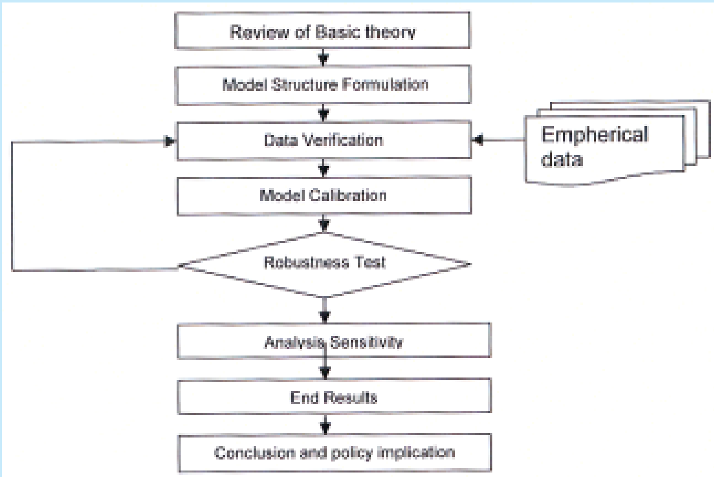

Figure 2
Research phase

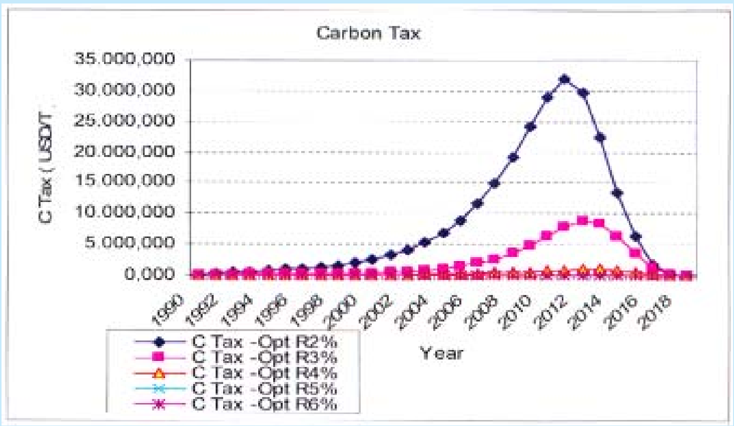

Figure 3
Optimal carbon tax using value of R2%-6%

Tabel 1
Value of A from calibration

Y (Tln IDR)	L (Million)	K (Tln IDR)	γ	1- γ	1 -ABCOST	1- TECOST	A'	Y'
263.262	179.400	59.758	0,25	0,75	-	-	1.931	263.262
263.262	179.400	59.758	0,25	0,75	0,9314	0,986945	2.101	263.262

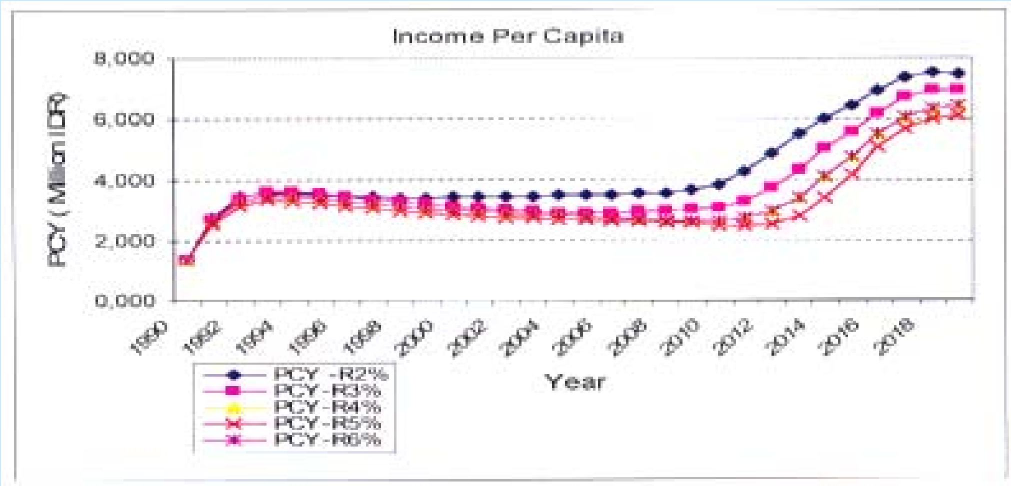

Figure 4
Change in per capita income because of different value of R

$T_2(t)=T_2(t-1) +$ á$_4$ $[T_1(t-1) - T_2(t-1)]$.

14. Radiative forcing function

DICE : $F(t) = 4.1 \log[M(t)/590] / \log(2) + O(t)$.

C. *Initial Value of Model*

Initial value of parameters in model are as follows:

ã = 0,30 ; ñ = 3% per year or 0,03 per year b_1 = 0,0686 ; b_2 = 2,877

ó $_{(1990)\ world}$ = 0,519 in billion tons CO_2 equivalent per trillion USD

ä$_6$ = 0,1168 per decade ; ä$_A$ = 0,1 per decade ; g_A = 0,001 per decade

ó $_{(1990)\ IND}$ = 0,32 ton CO_2 per trillion rupiah (1993 prices) ;

g $_{pop\ (1990)}$ = 1,2% or 0,012 per year for 30 years ; ä$_{pop}$ = 0,012 per decade ; ä$_{k\ (1990)}$ = 0,1 per year ; äm $_{world}$ = 0,0833 per decade ;β $_{world}$ = 0,64 ; á$_2$ = ë $_{world}$ = 1,41 °C/W-m2 ; K $_{(1990)}$ = 59,758 triliun Rupiah (1983 prices) ;

Q $_{(1990)}$ = 263,262 trillion rupiah (1993 prices) ; $T_{1\ (1990)\ world}$ = 0,2 °C ; $T_{2\ (1990)\ world}$ = 0,1 °C ;$p_{1\ (1990)}$ = 1 ; á$_1$ = 1/$R_{1\ world}$ = 0,226 °C-m^2/Watt—year ; á$_3$ = R_2/ô$_{12\ world}$ = 0,44 Watt/ °C-m^2 ; á$_4$ = 1/ô$_{12}$ = 1/500 = 0,002

$L_{(1990)}$ = 179,4 million population ; $M_{(1990)}$ = 787 billion ton CO_2 equivalent, carbon weight

D. *Model Calibration*

Initial level of total factor productivity value (A) use in this model is 1,9. The value is result of model calibration. Abatement cost value (ABCOPT) and damages cost (TECOST) were not included in calibrating process because both values were close to 1(one). Result of calibration is showed in Table 1.

E. *Scenario*

The Model uses scenarios such as *"optimal"*, *"base"* and *"reduction"*. Scenario reduction is scenario for policy maker to control emission through a

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 2, OCTOBER 2007 : 19 - 27

variable, this is the control variable in this model. Base scenario is a scenario that have no abatement cost because no abatement occurred. This is representative of BAU (Business-As –Usual). In optimal scenario, value of abatement rate is calculated and optimal point occurred when marginal cost is the same as marginal temperature cost.

F. *Sensitivity Analysis*

Based on sensitivity analysis, value of *social time preference rate* (R) 5% will give higher per capita income compare to value of R6%. There is a trade off between R-value and carbon tax value. Both values are shown in Figure 3 and 4. Value of R will depend on our appreciation towards inter-generation, whether we use and consume all existing natural resources and leave nothing for future generation or vice versa. Value of R will have implication to the value of average surface temperature, see Figure 5.

G. *Outcome of Model Simulation*

The outcome of the model simulation suggests that for R5%, carbon tax in optimal condition has a range of USD 3.90 – USD 40.00 per ton or equivalent to USD 1.06 –USD 11.00 per ton CO_2 (see Figure 3 for price change). If the model is run using R5%, in optimal condition the value of emission control rate (MIU) will be in the range of 20-80% for the period of 1990 -2019 as indicated in figure 6. The value of carbon tax for certain scenarios using R5% and R6% is shown in Figure 7. Income per capita for thirty year period (1990-2019) is in range Rp 4.000.000,- – Rp 8.000.000,- (see Figure 8)

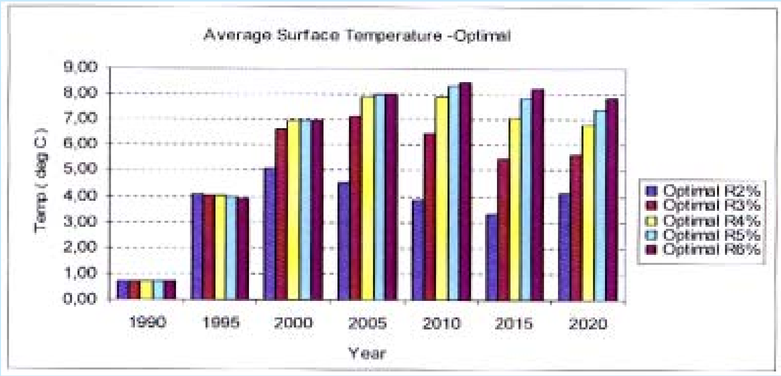

Figure 5
Average surface temperature if Indonesia using optimal scenario with R2%-R6%

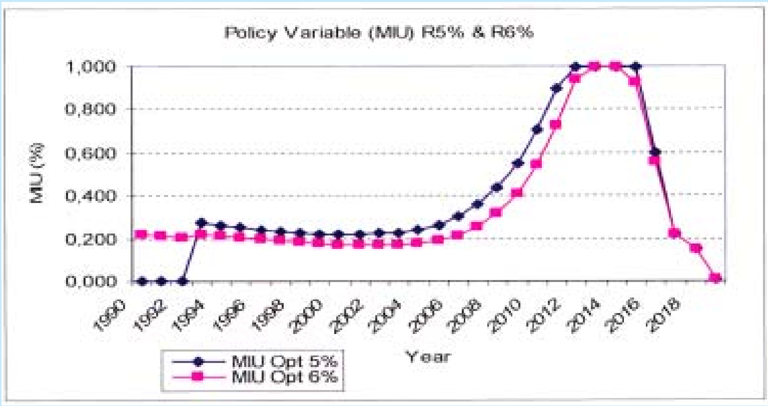

Figure 6
Value of MU in optimal condition with R5% and R6%

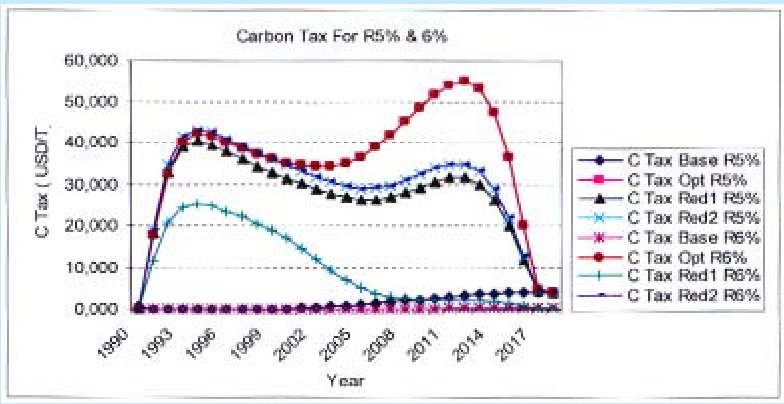

Figure 7
Value of carbon tax for some scenario

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 2, OCTOBER 2007 : 19 - 27

If the conversion factor for one liter of petrol is 0.0022tCO_2/liter, one ton of CO_2 is equivalent to 450.45 liter petrol (450 liters), this indicates that with optimal scenario CO_2 tax per liters of petrol for thethirty year period (1990 -2019) has a range USD 0.002 – USD 0.024 and for coal USD 1.959 – USD 20.251 per ton. Figure 9 and 10 show the trend of fuel and coal tax USD 457.6 – USD 2,362.2 for the period 1990 – 2019. The value of the emission tax is subject to change and it will depend on the control rate desired. If the level of control is not in optimal condition, e.g. scenario reduction-1 (reduction in 10% from current condition), it will change carbon tax to USD 3.9 – USD 40.3 per ton or CO_2 emission tax USD 1.06 – USD 11.00 per ton.

IV. CONCLUSION AND POLICY IMPLICATIONS

A. *Conclusion*

1. Carbon tax or emission tax for Indonesia can be explained through modified DICE model (Dynamic Integrated Model of Climate and the Economy). The result of model simulation using GAMS program (General Algebraic Modeling System). indicates that in optimal scenario with *rate social time preference* 5% and 6%, per capita income is still higher than “Base Case” scenario level.
2. Policy variable MU (ì) for optimal scenario have range 0.2 – 0.8 (20% -80%). This indicate that emission reduction will be at range from 20% up to 80 % for the period 1990 -2019. Abatement cost is in range of 0.1 – 6.7% of GDP. As the result of model output, optimal

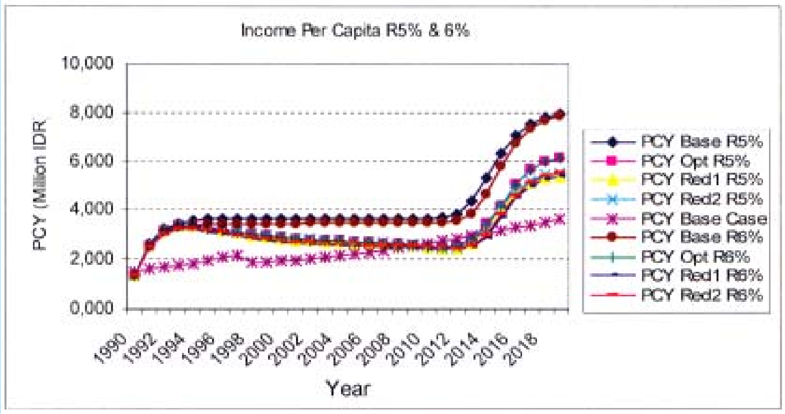

Figure 8
Income per capita for some scenario to base case

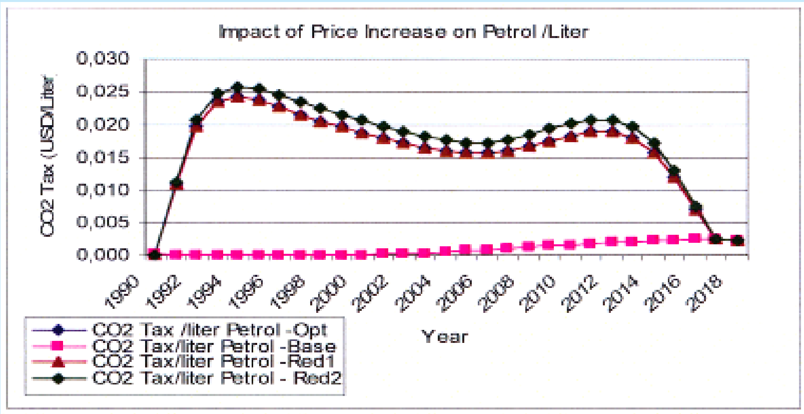

Figure 9
Price increase of petrol per liter in optimal condition

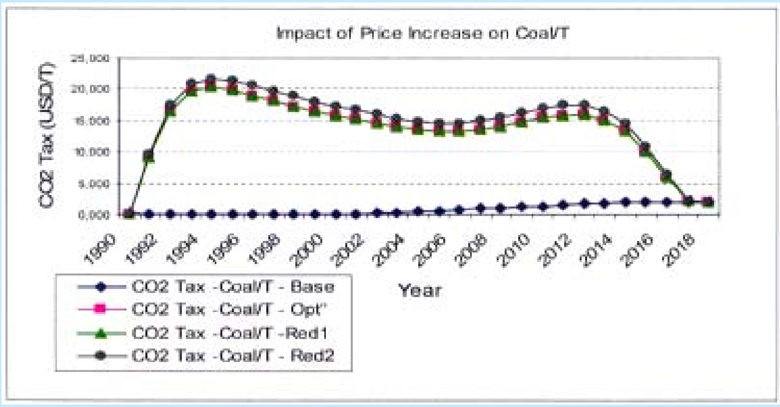

Figure 10
Price increase per ton of coal in optimal condition

carbon tax will fall within a range of USD 3.90 – USD 40.35 /ton carbon or USD 1.06 – USD11.00/ ton of CO_2. Value of the CO_2 tax per ton is equivalent to USD 0.002 – USD 0.024 per liter petrol for period of 1990 -2019 and coal in range USD 1,959 – USD 20,251 per ton. Based on Indonesia estimated trend of CO_2 emission for the thirty year period (1990 -2019), the revenue generated from petrol carbon tax would be in range of USD 376.1 – USD 1.585,6 million per year and revenue from coal CO_2 emission tax would be in the range USD 81.4 – USD 777.219 million for the same period. Estimated total revenue from emission tax of petrol and coal is USD 457.6 – USD 2,362.8 million for the thirty year period (1990 -2019).

B. *Policy Implication*

1. To reduce rate of Green House Gas emission particularly CO_2 emission, Indonesia shall work together with other countries through Protokol Kyoto mechanism. While reducing CO_2 emission for Indonesia is not mandatory the Kyoto Protocol has been ratified by Indonesia;, indirectly Indonesia shall show commitment and willingness to reduce green house gas, and take benefit from the ratification through Clean Development Mechanism (CDM).
2. Policy maker is suggested to consider using economics instrument in form of carbon or emission tax as complement of current *common and control* (C&C) because C&C in most cases are not appropriate for application of reducing gas emission.
3. Tax will cause deleting subsidies and also will cause an increase in the price of goods. Price increases in most cases will impact the lower income household, therefore revenue from environmental tax shall be managed in certain mechanism to minimize impact to lower income household; it shall not be treated as current fiscal policy. Policy maker is required to set up a strategy for tax recycle that avoids double taxation for the tax payer but which directs the taxes for the greater benefit of the environment.

REFERENCES

1. Ackerman,Frank and Finlayson.,2005, *The Economic of Inaction on Climate Change*: *A Critique. Global Development and Environment Institute,Tufts University.*
2. Baumert,A.Kevin,et.all.,2005, *Navigating the Numbers.Greenhouse Gas data and International Climate Policy.* World Resources Institute.
3. Behavioral Responses to Environmentally-Related Taxes.,2000. Environment Directorate. OECD. COM/ENV/EPOC/DAFFE/CFA(99) 111/FINAL.
4. Babiker,Mustafa, *et al*.,1999, *The Kyoto Protocol and Developing Countries*.MIT Joint Program on the Science and Policy of Global Change. Science Policy.
5. Beyond Kyoto.,2002, *Energy Dynamics and Climate Stabilization*. International Energy Agency.OECD/EIA.
6. Blades,Derek and Meyer,Jeroen.,1998, *How to Represent Capital in International Comparison of Total Factor Productivity*. OECD.Statistics Directorate. Second Meeting of the Canberra Group On Capital Stock Statistics.
7. Connor,David.,1996, OECD Development Centre (Paris French). *Applying Economic Instruments in Developing Countries*; From Theory to Implementation.Special Report.
8. Fiddaman,Thomas.,1997, *A System Dynamic Perspective On an Influential Climate/Economiy Model*. MIT Sloan School of Management.
9. Nordhaus,William and Boyer,Joseph.,1999, *Economics Models of Global Warming. DICE and RICE Model*. Internet edition.
10. Nordhaus,William.,1992, Rolling the "DICE" : *An optimal transition path for controlling greenhaouse gases*. Resources and Energy Economics 15.,1993 27-50.North Holland.
11. Nordhaus,William and Boyer,G.Joseph.,1999, Requiem for Kyoto: *An Economic Analysis of the Kyoto Protocol*. KYOTO ECON 020299.DOC.
12. Nordhaus,William.,2001, *Global Warming Economics. Science Compass*, Vol 294.Policy Forum:Cliamte Change.

LEMIGAS SCIENTIFIC CONTRIBUTIONS
VOL. 30. NO. 2, OCTOBER 2007 : 19 - 27

13. OXERA report.,2002, *A Social Time Preference Rate for Use in Long-Term Discounting*. OXERA Consulting Ltd.Oxford OX1 4EH,UK.
14. Thomas.Charles., Tennant.Tessa and Rolls Jon.,2000, *The GHG Indicator: UNEP Guidelines for Calculating Greenhouse Gas Emissions for Business and Non Commercial Organizations.*
15. Petroleum Report Indonesia. American Embassy –Jakarta., 2003.
16. Petroleum Report Indonesia. American Embassy –Jakarta.,2006.
17. The Green Book (printed 2004).Discount Rate, Annex 6. http://greenbook.treasury.gov.uk/annex06.htm.
18. Marland,Gregg,et.al. Oak Ridge National Laboratory.University of North Dakota. Website: http://cdiac.esd.ornl.gov/trends/emis/top2000.tot. printed 11/8/2004.ˇ